ARISE: American Renaissance in Science Education

Instructional Materials Guide

Part 2 – Chemistry

May 2004

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Funded by
an anonymous donor through the U.S. Trust

Additional support from the U.S. Department of Energy

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ARISE - CHEMISTRY

Forward: by Leon Lederman

This is the second volume of a three-volume "cut and paste" guide to the "Physics First" curriculum. Each volume, Physics, Chemistry, and Biology, is tasked to supply guides to the best materials available for instruction in each of the traditional disciplines. However, the emphasis in a coherent three-year curriculum is to ease access to the connections between disciplines, to seek the most useful materials in physics, which will facilitate the understanding of the chemistry topic under discussion and to indicate those components of chemistry that will be most useful for molecular biology. We also provide a guide to storytelling, to history of who did what, and how.

The study of chemistry includes essentially all aspects of the behavior of atoms and molecules (a.k.a. elements and compounds). The structure of atoms is fundamental to chemical behavior and to the process by which atoms combine to form simple molecules such as H_2 all the way to the complex molecules of life. Applications of chemistry dominate the societal impact of science from the essential applications to life sciences, to energy sources, to nuclear chemistry and to the development of drugs. Chemistry, the central discipline, has a pivotal role in the three-year sequence that is designed to erase disciplinary boundaries, but to preserve disciplinary integrity.

Please send your comments and questions to me at lederman@fnal.gov.

Credits:

Three teachers contributed the chemistry resources:
Frank Cardulla, Niles North High School, Skokie, IL, (retired) editor of *ChemMatters,* indexed *ChemMatters.*
Bill Grosser, Glenbard South High School, Glen Ellyn, IL provided ideas and examples of cooperative learning and use of technology in the classroom.
Lee Marek, University of Illinois, Chicago, indexed Flinn ChemTopic Laboratory Manuals and provided ideas and examples.

Users Guide

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A. CURRICULUM TOPICS

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B. SOURCE MATERIALS

Chemistry Textbooks

Textbooks are important in spite of the Internet. They affect both the student and teacher alike. Teachers rely upon textbooks; they serve as ready-made courses and define the material that students will learn from lesson plans, homework assignments and tests. Selection of a textbook is important because you will probably be using it for at least five years.

The American Chemical Society web site lists many textbooks available for high school chemistry: <http://www.umsl.edu/~chemist/cgi-test/mybooks.pl?category=16>

The following list of chemistry textbooks (some of them from the ACS list) gives the web links to their publisher. The order here has no particular significance. If your favorite book is not on this list, let us know. As you will see from the *The Textbook Letter* (in the following section), textbook selection is never easy and in some states rather "interesting."

Addison-Wesley Chemistry
6th Edition 2002 881 pp. 0-130-54384-5 (student edition); 0-130-58056-2 (student edition with CD-ROM); 0-130-54847-2 (teacher edition with resource CD-ROM)
Wilbraham, Antony C., Dennis D. Staley, Michael S. Matta, and Edward L. Waterman
<http://www.phschool.com/atschool/chemistry/index.html>
$69.95 (student edition); $76.21 (student edition with CD-ROM); $118.71 (teacher edition with resource CD-ROM)
4th edition reviewed in The Textbook Letter July-August 1997

Chemistry in the Community (ChemCom)
4th Edition 2001 ACS 0-7167-3551-2 (full version); 0-7167-3890-2 (minibook)
American Chemical Society
<http://www.whfreeman.com/highschool/book.asp?disc=CHEM&id_product=1124001763&@id_course=1058000061&disc_name=Chemistry&cd_booktype=CRTX>
$70.00
Reviewed in *The Textbook Letter,* July-August 1997

Chemistry: Matter and Change
The McGraw-Hill Companies (Glencoe/McGraw-Hill), Columbus, OH, ISBN 0-02-828378-3
Dingrando, Gregg, Hainen & Wistrom
<http://www.glencoe.com/sec/science/index.html>

Prentice Hall Chemistry - Chemistry: Connections to Our Changing World
2nd Edition 2000 960 pp. Prentice Hall 0-13-434776-5 (student edition); 0-13-434777-3 (teacher edition)
LeMay, H. Eugene, Herbert Beall, Karen M. Robblee, Douglas C. Brower
<http://www.phschool.com/atschool/chemistry/index.html>
Price unavailable
Previous edition reviewed in The Textbook Letter January-February 1995

Holt Chemistry: Visualizing Matter
"Technology Edition" 2000 864 pp. Holt, Reinhart and Wilson 0-03-052002-9 (student edition); 0- 03-053837-8 (teacher edition)
Myers, R. Thomas, Keith Oldham, and Salvatore Tocci
<http://www.hrw.com/science/hc/index.htm>
$52.95 (student edition); $70.50 (teacher edition)
Previous edition reviewed in The Textbook Letter November-December, 1996

Chemistry: Concepts and Applications
2nd Edition 2000, Glencoe 0-02-828209-4 (student edition); 0-02-828210-8 (teacher edition)
Phillips, John, Victor Strozak, Cheryl Wistrom wrote the previous edition; the publisher lists no author for this one.
<http://www.glencoe.com/sec/catalog/cgi-bin/secDisplay.cgi?function=display&area=science&category=productinfo&nameid=9>
$66.00
Previous edition reviewed in The Textbook Letter July-August, 1998

Modern Chemistry
19th Edition 1999 Holt, Reinhart and Wilson 0-03-051122-4 (student edition); 0-03-051389-8 (teacher edition)
Davis, Raymond E., H. Clark Metcalfe, John E. Williams, and Joseph F. Castka
<http://www.hrw.com/science/mc/index.htm>
$52.95 (student edition); 70.50 (teacher edition)
Reviewed in The Textbook Letter January-February 1998

The Real World of Chemistry
3rd Edition Kendall Hunt (I can no longer find it on the Kendall Hunt webpage). 1998 320 pp.
0-7872-4190-3
Fruen, Lois
$39.95 (wire coil)

Merrill Chemistry
7th Edition 1998 910 pp. Glencoe 0-02-825526-7 (student edition); 0-02-825527-5 (teacher edition)
Smoot, Robert, Richard G. Smith, and Jack Price
<http://www.glencoe.com/sec/catalog/cgi-bin/secDisplay.cgi?function=display&area=science&category=productinfo&nameid=10>
$44.98 (student edition); $59.99 (teacher edition)
Reviewed in *The Textbook Letter,* November-December, 1998

Active Chemistry
1st Edition, It's About Time 1-58591-113-5 (student edition); 1-58591-114-3 (teacher edition)
Anonymous
<http://www.its-about-time.com/htmls/ac/ac.html>
$23.95 (Student edition); $49.95 (Teacher edition)

World of Chemistry
McDougal Littell - A Houghton Mifflin Co., Evanston, IL, ISBN 0-618-13496-4
Steven Zumdahl, Susan A. Zumdahl, and Donald DeCoste
<http://college.hmco.com/chemistry/general/zumdahl/world_of_chem/1e/students/>
<http://college.hmco.com/chemistry/general/zumdahl/world_of_chem/1e/instructors/index.html>

Conceptual Chemistry: Understanding Our World of Atoms and Molecules
2nd Edition, 2004 ISBN: 0-8053-3228-6 John Suchocki
<http://www.aw-bc.com/catalog/academic/product/0,4096,0805332286,00.html>
Publisher: Benjamin Cummings
Format: Cloth Bound w/CD-ROM; 647 pp
$84.60

Chemistry in Your Life
2003, 600pp, Bedford, Freeman and Worth
Colin Baird, University of Western Ontario, Wendy Gloffke, Science Writer and Educational Consultant
Go to: <http://www.bfwpub.com/book.asp?2001002476> to access table of contents etc.

CHEMISTRY: Connections That Matter
W. H. Freeman and Company 2003
Joseph Krajcik, Brian Coppola, Alan Kiste
<www.whfreeman.com/highschool/book.asp?2001002486>

Meeting Tomorrow's Science Needs Today
<www.whfreeman.com/stw/>

ChemCom
Chemistry In The Community, Student Text; ISBN 0-7167-3551-2, $62.90
Wraparound Teacher's Edition, 0-7167-3918-6, $69.90
<http://www.acs.org/education/curriculum/chemcom.html>
For the Student:
Website: <http://www.whfreeman.com/chemcom/>

Textbook League

By Lee Marek

The Textbook League, which publishes The Textbook Letter (TTL), is an interesting group. I have been reading the letter for a number of years and really like the reviews and find them honest and refreshing compared to most, but go to their website and judge for yourself. <http://www.textbookleague.org/>. You will find that new material is added frequently to the web site and The Textbook Letter could help you in the choice of a suitable textbook for your course.

The textbook selection process can be really important. For one thing the teacher is liable to be "stuck with it" for five or more years. Textbooks affect not only the students but also the teacher. They "tell" the teacher "what is important and how it should be taught." As the Textbook League webpage says, "In many instances the books serve as ready-made courses, since many teachers depend on them to define a curriculum, to prescribe the material that students will learn, and to dictate how the material will be presented. This effect is all the greater because teachers often rely upon textbook publishers to provide ready-made lesson plans, ready-made homework assignments for students to execute, and ready-made tests for students to take — all keyed to the textbooks that the teachers have chosen." The following is culled from Textbook League's website, except for a few of my comments in parentheses. There are two sample reviews included.

> One might expect, then, that textbooks would undergo considerable scrutiny before they get into schools. Indeed, one might expect that the American education community would sponsor formal textbook-review proceedings, and would disseminate the results of such proceedings to teachers throughout the country, so that the teachers would be made aware of good books and would be warned away from poor ones.
>
> In fact, however, no national textbook evaluation processes exist, and the "evaluations" conducted by state departments of education or by local school districts are rarely anything more than bureaucratic shams—bogus proceedings where textbooks are judged by those who have no discernible qualifications for such work. In typical cases, the state education agencies and local districts approve textbooks without soliciting appraisals from persons who have expert knowledge of the relevant subject matter. As a result, classroom teachers can be stuck with biology books that have never been reviewed by any biologist, history books that have never been seen by any historian, geography books that have never been evaluated by any geographer, or health-education books that have never been reviewed by any physician. (Indeed I have seen such in my own district—tops in the world on the TIMMS test. We had a committee that I foolishly said I would be on for junior high textbook selection. We met off and on for over a year, then an administrator picked the textbook series for us because they got a good deal from the publisher!)

> In 1989 a group of Californians undertook to do something about this situation by founding an organization and a periodical devoted to providing the knowledgeable reviews that educators need. The organization is The Textbook League. The periodical is *The Textbook Letter*, which the League mails to subscribers throughout the United States. The subscribers include classroom teachers, officers of local school districts, officers of state or county education agencies, and private citizens who take a serious interest in the content and quality of the instruction offered in the public schools.
>
> Each issue of *The Textbook Letter* is built around reviews of schoolbooks, with emphasis on middle school and high school books in history, geography, social studies, health education, and the various branches of natural science. Reviews are augmented by articles on topics that are important to educators, who must choose and use instructional materials.
>
> A typical review in *The Textbook Letter* is contributed by a person who has professional credentials in the pertinent discipline. A physics textbook is reviewed by a professional physicist; a chemistry text is reviewed by a professional chemist; a health education text is reviewed by a practicing physician; an earth science text is reviewed by a geologist or a paleontologist; and so forth.
>
> Each review focuses strongly on the factual and conceptual content of the book in question. The reviewer's principal aim is to judge whether the book's factual information is solid, whether the book's conceptual syntheses and interpretations are up to date, and whether the material that the book presents will be meaningful to the intended audience.
>
> When the editors of *The Textbook Letter* send a book to a reviewer, they deliberately do not furnish any list of evaluation criteria for the reviewer to use. The editors' precept is that a textbook is (or should be) a tool for promoting intellectual development, and that intellectual matters cannot be reduced to checklists or catalogues of buzzwords. Their approach is to engage an expert, then let the expert use his own judgment in deciding which features of the book deserve to be described and analyzed in a review.

The website of The Textbook League is a resource for middle-school and high-school educators. It provides commentaries on some 200 items, including textbooks, curriculum manuals, videos and reference books. The Textbook League, P.O. Box 51, Sausalito, California 94966
<http://www.textbookleague.org/>

The following from the website describes the process of State Textbook adoption. I have only put part of it here. If you go to the website, you can read more. If you teach science, this can really scare you! The following webpage Annals of Corruption: Part 1 is about Richard Feynamn's "Judging Books by Their Covers" and proves to be an interesting read. I have included but a small part here. <http://www.textbookleague.org/103feyn.htm>

> In 1964 the eminent physicist Richard Feynman served on the State of California's Curriculum Commission and saw how the Commission chose math textbooks for use in California's public schools. In his acerbic memoir of that experience, titled "Judging

Books by Their Covers," Feynman analyzed the Commission's idiotic method of evaluating books, and he described some of the tactics employed by schoolbook salesmen who wanted the Commission to adopt their shoddy products. "Judging Books by Their Covers" appeared as a chapter in "Surely You're Joking, Mr. Feynman!"—Feynman's autobiographical book that was published in 1985 by W.W. Norton & Company.

To introduce a series of articles about corruption in schoolbook-adoption proceedings, we present here (with permission from W. W. Norton & Company) an extended excerpt from Feynman's narrative. Readers will see that Feynman's account is as timely now as it was when he wrote it. State adoption proceedings still are pervaded by sham, malfeasance and ludicrous incompetence, and they still reflect cozy connections between state agencies and schoolbook companies.

Some Nasty Performances in Oklahoma: <http://www.textbookleague.org/106okla.htm>
By William J. Bennetta

Oklahoma is an "adoption state." It is one of 22 states, most of them in the South or the West, in which state agencies control the evaluation, selection and adoption of the textbooks that will be used in public schools. In Oklahoma, the agency that performs the evaluating and selecting and adopting is the Oklahoma State Textbook Committee.

Oklahoma law says that the State Textbook Committee shall comprise thirteen persons, all appointed by the governor. Twelve members must be employees of public schools, and a majority of those twelve must be classroom teachers. The thirteenth member must be a layman "having at least one child in the public schools of Oklahoma." The declared function of the Committee is to "select textbooks or series of textbooks for each subject, which are in its judgment satisfactory." The Committee must carry out "careful consideration of all the books presented (by publishers)" and must select for adoption "those which, in the opinion of the Committee, are best suited for the public schools in this state." The Committee may engage consultants, but the consultants must be "regular classroom teachers."

These prescriptions constitute a recipe for farce. Though the Committee is supposed to judge books in history, mathematics, biology, chemistry and many other subjects, there is little chance that the Committee ever will have a member (or will be able to engage a consultant) who possesses professional knowledge of any of those subjects. Hence there is little chance that the Committee ever will have a member (or will be able to engage a consultant) who is qualified to evaluate the treatment that is accorded to any of those subjects in a schoolbook.

In practice, Oklahoma adoptions are indeed farcical. The State Textbook Committee's proceedings serve chiefly to celebrate the invention of the rubber stamp, and the Committee commonly approves textbooks that any competent agency would immediately consign to the trash heap. . . .

A sample review of a physical-science book for grade 8 or 9:

Introductory Physical Science
Seventh edition, 1999. 268 pages. ISBN: 1-882057-18-X
Science Curriculum Inc., 24 Stone Road, Belmont, Massachusetts 02478
This Book Is the Best, by a Wide Margin
By Lawrence S. Lerner

About four years ago I had the pleasure of reviewing the sixth edition of Science Curriculum Inc.'s Introductory Physical Science. "This is an outstanding book," I reported in TTL, "written by authors who know what science is about, know their subject matter, and know how to teach it to 8th-graders and 9th-graders."

[Editor's note: Lawrence S. Lerner's review of the sixth edition appeared in TTL for November-December 1995, with this headline: "The Authors Are Knowledgeable, and the Book Is a Delight."]

That statement applies to the seventh edition, too, and the word "authors" is significant. The persons named on the title page of Introductory Physical Science are truly the book's authors, and they have maintained full control of its contents. Readers who are familiar with the schoolbook industry, and with the habits of the major schoolbook companies, will recognize that this is an atypical circumstance. In most schoolbooks, the lists of so-called authors are fictitious and have been devised to serve as sales-promotion features.

Introductory Physical Science has only 268 pages, so it is less than half as long as the other physical-science books I have reviewed—yet it offers far better content. Unlike those other texts, Introductory Physical Science is not bloated with gratuitous factoids, empty mentionings, environmental pieties and irrelevant sidebars.

The authors of Introductory Physical Science show the student how science is done, and they teach the student to think like a scientist. Their strategy, as I noted in my review of the sixth edition, is to take the student through a series of experiments and analyses that amount to an abridged account of the development of chemistry and physics from the mid-1700s to 1900 or so.

Comparing the Editions

A striking experiment in the earlier edition allowed the student to make a direct estimate of the size and mass of a molecule of oleic acid. These quantities were inferred after the student measured the area of a film of oleic acid that was floating on water. In the seventh edition, the procedure has been dramatically improved: Instead of using pure oleic, the student uses a dilute solution of oleic acid in alcohol. This enables the student to obtain better results (and all the satisfaction that goes with them). In keeping with this refinement, oleic acid's density—which the student must use in a calculation—is now given as 0.87 g/cm3 instead of 1 g/cm3.

On the other hand, a beautiful sequence of experiments that I admired in the sixth edition has been modified in a disappointing way. Let me describe this case in some detail:

Most textbooks treat the difference between a chemical element and a compound simply by asserting that every compound consists of more than one element, but the authors of Introductory Physical Science prefer a scientific approach to this topic. In the sixth edition, the authors used a number of experiments and comparisons to show the student that certain solid substances, when they participate in chemical reactions, invariably yield solid products that have greater mass. The student then was led to understand—indeed, to define—such substances as elements. Likewise, the student found out that other solid substances, when they participate in reactions, may yield products that have greater mass or products that have lesser mass. The student then came to comprehend that any substance which gives such variable results must be a compound. The supporting evidence came from several sources, including an experiment in which the student observed the thermal decomposition of baking soda, then a narrative account of the thermal decomposition of mercuric oxide, and later an experiment in which the student watched the thermal decomposition of sodium chlorate and measured the difference between the initial mass and the final mass of the solid in the test container.

Looking at the seventh edition, I find that the experiment with sodium chlorate has been excised, presumably in the interests of safety. (The decomposition of sodium chlorate sometimes proceeds very vigorously.) Now the authors simply remind the student about the example of mercuric oxide and about the earlier experiment with baking soda. The excision of the sodium-chlorate experiment has not diminished the general argument, but the argument has lost some of its punch—especially because the case involving mercuric oxide still appears only in a narrative, not in an experiment that is actually performed by the student.

The sixth edition didn't contain many errors, and in the seventh edition most of them have been corrected—but not all:

- Page 110: The student again is asked to write an essay about the "sludge test." But there is still no indication of what is meant by this term.
- Page 115: The "tiny bubble" mentioned in the caption for figure 6.2(b) is not visible.
- Page 119: Problem 12 should come before problem 11.
- On page 132, figure 6.9 still shows an aluminum cell in which molten aluminum is siphoned from a lower to a higher level.
- Page 166: Here a radioactive atom is said to emit a particle "which affects a counter . . . ." But this is true only if the particle happens to be headed in the direction of the counter. It would be better to say that the particle "can affect" a counter.
- Page 204: In a passage about the production of hydrogen in two electrolysis cells, it is still unclear that the authors are referring to the rate of production in each cell, not in both cells together.
- Pages 231 through 234: The description of the operation of a dry cell is still vague, and the function of sacrificial electrodes is still not explained clearly.

In the sixth edition, some of the photographs weren't clear, and some of the graphs were too crude. Many of these have been replaced, usually for the better, but a few of the photos in the seventh edition demand further improvement. Alternatively, it may be profitable to replace them with line drawings. Figure 1.1 can serve as a case in point: In the sixth edition, it was an indistinct photograph of a pneumatic trough, and it failed to show the water level inside the collection bottle. The seventh edition has a new photo that is much clearer overall, but the crucial water level still can't be discerned. The same difficulty occurs in figure 1.4—and here the new photo is less clear overall than the older one was.

These, however, are but minor matters. Taken as a whole, Introductory Physical Science is an excellent book.

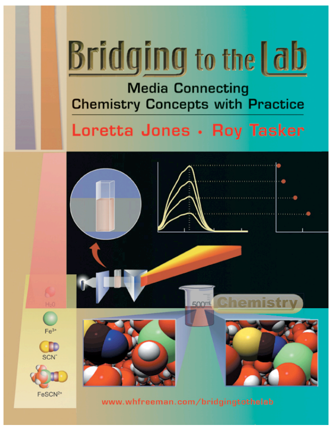
The thorough, clearly written Teacher's Guide and Resource Book for the seventh edition is largely a laboratory manual, designed to lead the teacher through the experiments that appear in the student's text. This Teacher's Guide is much like the guidebook that came with the sixth edition, but the "Introduction" has now been expanded by the addition of new pedagogic information and suggestions. The teacher, whether experienced or inexperienced, will find the Guide to be a trusty and valuable companion during the planning of a course based on Introductory Physical Science.

Students who work through Introductory Physical Science and do the experiments will be well rewarded, for they will acquire a good understanding not only of the subject matter but also of the way in which science is done. I recommend this book strongly. It is the best, by a wide margin.

Lawrence S. Lerner is a professor emeritus in the College of Natural Sciences and Mathematics at California State University, Long Beach. His specialties are condensed-matter physics, the history of science, and science education. His university text Physics for Scientists and Engineers was issued in 1996 by Jones and Bartlett Publishers, Inc. (Sudbury, Massachusetts). His report State Science Standards: An Appraisal of Science Standards in 36 States was issued in March 1998 by the Thomas B. Fordham Foundation (Washington, D.C.).

Virtual Labs

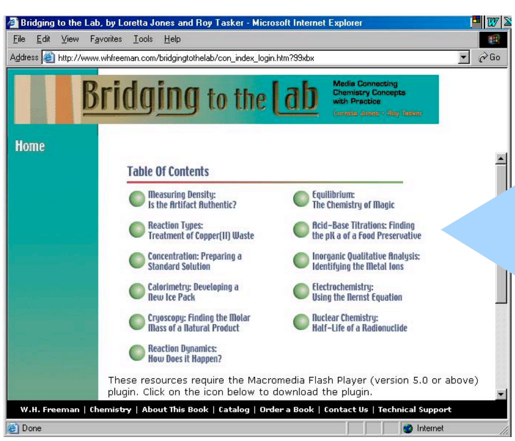
Virtual labs: the way of the future? Here are 11 interactive lab modules with real-life chemistry virtual environment for only $15.00. You be the judge and see if these will be of use to your students. There is a website where you can try some of these labs online.

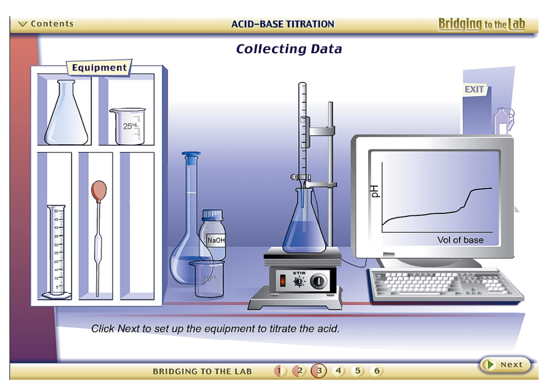


To view a free sample go to:
<http://bcs.whfreeman.com/bridgingtothelab//>

Designed to connect the laboratory and lecture experience, Bridging to the Lab is intended for use in Introductory and General Chemistry courses.
Features include:

- Activities based on solving real-world problems by using critical thinking and decision making.
- Specific feedback tied to student choices.
- Built-in accountability that records student progress and requires lesson completion while still allowing freedom of movement.
- An emphasis on experimental design, the accurate and precise reporting of results, the interpretation of data, and the conceptual basis for the experiment.
- Visualizations of structures and processes at the molecular level and videos and photos of laboratory procedures.





NSTA SciLinks

SciLinks® is an interactive, web-based service that connects your lesson and/or course materials (textbooks, supplemental titles, and journal articles) with online content chosen just for your selected topics. Simply type in your keyword or phrase, and you will receive a list of teacher-approved Internet resources. Best of all, SciLinks saves you and your students time when searching the Web for learning extensions. The next time you're reading your NSTA journal or an NSTA Press® publication, watch for the SciLinks® logo in the margins. It will point you to an Internet link that will help you find more information on the topic you're reading about.
SciLinks tour at: <http://www.scilinks.org/tour/default.asp>

If Lee Marek Had One Piece of Software, It Would Be This!

General Chemistry Interactive CD-ROM (Stand Alone), 3rd Saunders College Publ.,
by William J. Vining, John C. Kotz, Patrick Harman, William Vining, Angus McDonald, Jeffrey Ward $33.95 (amazon.com) ISBN: 003035319X

This is a two-disk CD-ROM set and a student workbook. It is designed to accompany the textbook Chemistry & Chemical Reactivity, 5th ed., by John C. Kotz and Paul Treichel, Jr. The CD-ROM is based on the Kotz and Treichel textbook material that forms the core of most college and high school general chemistry courses. Most of these are also part of the 22 ARISE Chemistry Topics. The CD-ROM can be run on either a Macintosh or a Windows computer.

The way I use this interactive CD-ROM is to enliven a lecture presentation through the excellent narrated QuickTime videos of chemical processes, demonstrations, animations of the molecular process, and brief lectures by notable scientists. There are also environmental lessons and materials that relate chemistry to real life. The sample problems can be exposed step by step to get to the solution. This is an excellent way to model problem solving; to think and explore through interactive computer-based exercises. Many of these exercises have "narrated problem-solving hints and suggestions that are provided to facilitate student mastery of problem-solving skills." There are interactive "tools" that allow one to do experiments and see how the variables change. This is a good use of computer technology and presents most of the main points and concepts in chemistry in an engaging way.

A nice way to use the CD-ROM is to do a live demonstration, the phenomenological approach to teaching, and then show the video of that or a similar reaction or process and use one of the QuickTime animations that show things happening at the molecular (submicroscopic) level. This can be followed by a discussion of the chemistry at the molecular level and then a description in terms of the symbolism chemists use to convey the concept in written language. This reinforces the three levels at which chemical phenomena are represented: the macroscopic, the symbolic, and the submicroscopic level. The use with hydrogen bonding, van de Waals forces, vapor pressure, colligative properties, etc. pulls these three level together like I have never been able to do before.

A tools icon allows access to an interactive periodic table and calculation tools. You can show a number of three-dimensional molecular models of chemical compounds, rotating, sizing, translating, and making ball and stick, wire frame or space filling versions of the models. You can copy these and put them into Word docs to use on labs, tests, etc. There is a nice plotting tool that comes with the CD-ROM also. There is a molar mass calculator and a molarity calculator. For the latter all you do is type the formula and the volume needed, and it calculates the mass needed to make up the solution.

Vining has said of his own CD-ROM, and I agree: "We have the ability to show students things they couldn't see before. They're actively learning in the best way. They actually have to figure everything out themselves. Whether you're standing in front of a class or writing a program, the idea is not to give students the answer. The idea is to just give information and a few hints, and enable students to arrive at the answer independently."

C. INDICES

ChemMatters Index of articles for student use

1. Matter and Change

Element X: Dec. 1987, pp. 8-9.
Matches. Striking Chemistry at Your Fingertips: *ChemMatters*, Dec. 2002, pp. 14-16.
Polywater: Dec. 1987, pp. 10-13.
Robert Bunsen—more than a burner designer: Oct. 1984, pp. 14-15.
Tapping Saltwater for a Thirsty World: Oct. 2002, pp. 4-7.

2. Measurement

Biosphere II: Feb. 1995, pp. 8-11.
Cartesian Divers: Squeeze Play: Feb. 2001, pp. 4-6.
How Dense is it? Feb. 2002, p. 10.
Murder She Floats: Dec. 2002, pp. 17-19.
Nanotechnology, The world of the super small: Dec. 2002, pp. 9-13.
Swimming Pools: April 1994, pp. 10-12.
Weighty Matter of the Kilogram Standard: Oct. 1999, pp. 14-15.

3. Problem Solving

Archimedes: Oct. 1987, p. 17.
The Crash of Flight 143: Oct. 1996, pp. 12-15.
Global Warming: Hot Topic Getting Hotter: Sep. 2001, pp. 14-15.
Homeopathy: Dec. 1991, pp. 8-11.
Murder She Floats: Dec. 2002, pp. 17-19.
Swimming Pools: April 1994, pp. 10-12.

4. Atomic Structure

An Atomic Tour: Oct. 1983, pp. 4-7.
The Birth of the Elements: Oct. 2000, pp. 4-5.
Bringing Helium Down to Earth: Oct. 1985, pp. 14-15.
Chemiluminescence: Oct. 1995, pp. 12-15.
CO Control: On the Street, In the House, Where You Live: Oct. 1997, pp. 10-12.
The Color of Gems: Dec. 1988, pp. 7-9.
Colors Bursting in Air: Oct. 1998, pp. 7-9.
Lasers: April 2003, pp. 2-3.
A Light of a Different Color: April 1999, pp. 4-7.
Light Your Candy: Oct. 1990, pp. 10-12.
Luminol. Casting a Revealing Light on Crime: Dec. 2001, pp. 12-13.
Memory Metal: Oct. 1993, pp. 4-7.
Nanotechnology, The world of the super small: Dec. 2002, pp. 9-13.
Radioactivity: It’s a Natural: April 2000, pp. 6-9.
The Radium Girls. Dialing up Trouble: Oct. 1998, pp. 13-15.

Spectroscopy: Sensing the Unseen: Sep. 2001, pp. 4-6.
Superconductivity: Oct. 1987, pp. 18-21.

5. **Radioactivity, Fusion, Fission**
The Birth of the Elements: Oct. 2000, pp. 4-5.
Bringing Helium Down to Earth: Oct. 1985, pp. 14-15.
Carbon-14 Dating: Feb. 1989, pp. 12-15.
Happy Birthday Helium: Dec. 1995, p. 12.
Hydrogen and Helium: Oct. 1985, pp. 4-7.
Positron Emission Tomography Scan: Feb. 1994, pp. 12-15.
Radioactivity: It's a Natural: April 2000, pp. 6-9.
Should Food be irradiated? April 1999, p. 16.
Volcanoes-Forecasting the Fury: Dec. 1999, pp. 12-13.

6. **Chemical Names and Formulas/Compounds and Elements**
An Atomic Tour: Oct. 1983, pp. 4-7.
Are Living and Nonliving Things Composed of Entirely Different Substances? Dec. 1999, p. 16.
Breakfast of Crystals: Oct. 1983, pp. 8-12.
Buckyballs: Dec. 1992, pp. 7-11.
Burning Diamonds and Squeezing Peanuts: April 1990, pp. 14-15.
Carbon Dioxide: A Pourable Greenhouse Gas: Sep. 2001, pp. 10-11.
Detergents: April 1985, pp. 4-6.
Dinosaurs and Iridium, Traces of an Impact: Feb. 2001, pp. 12-13.
The Explosive History of Nitrogen: Feb. 2003, pp. 8-10,
Global Warming: Hot Topic Getting Hotter: Sep. 2001, pp. 14-15.
Happy Birthday Helium: Dec. 1995, p. 12.
Hydrogen Fuel Cells for Future Cars: Dec. 2000, pp. 4-6.
Iron for Breakfast: Oct. 1994, pp. 13-15.
Making Ice Cream: Dec. 1995, pp. 4-7.
Matches. Striking Chemistry at Your Fingertips: Dec. 2002, pp. 14-16.
The New Gold Rush: Oct. 1989, pp. 4-4-8.
Nitrous Oxide: By no Means a Laughing Matter: Feb. 1986, pp. 17-19.
Ozone: Molecule with a Split Personality: Sep. 2001, pp. 7-9.
Real Leather: April 1990, pp. 4-6.
Salt: Dec. 1992, pp. 4-6.

7. **Moles**
Bringing Helium Down to Earth: Oct. 1985, pp. 14-15.
Homeopathy: Dec. 1991, pp. 8-11.

8. **Chemical Reactions**
Airbags: Chemical Reaction Saves Lives: Feb. 1997, pp. 4-5.
Apollo 13's Fight for Survival: Feb. 1994, pp. 5-8.
Automatic Sunglasses: Dec. 1989, pp. 4-6.
Biosphere II: Feb. 1995, pp. 8-11.

A Calorie-free Fat? April 1999, pp. 9-11.
Carbon Dioxide: A Pourable Greenhouse Gas: Sep. 2001, pp. 10-11.
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Colors Bursting in Air: Oct. 1998, pp. 7-9.
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Dissolving Plastic: Oct. 1987, pp. 12-15.
Distance Running: Feb. 1989, pp. 4-7.
The Exploding Tire: April 1988, pp. 12-14.
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Fats: Fitting them into a Healthy Diet: Oct. 2000, pp. 6-8.
Fire in the Hold: April 1997, pp. 11-13.
Fireside Dreams: Dec. 1988, pp. 13-15.
Friedrich Wohler's Lost Aluminum: Oct. 1990, pp. 14-15.
Going Against the Flow: The Isolation of Fluorine: Dec. 1986, pp. 13-15.
Hot and Cold Packs: Feb. 1987, pp. 7-11.
Hydrogen Fuel Cells for Future Cars: Dec. 2000, pp. 4-6.
Insect Arsenals: Oct. 1993, pp. 8-10.
The Interrupted Party: Oct. 1984, pp. 4-5.
Iron for Breakfast: Oct. 1994, pp. 13-15.
Is Water the Best Fire Extinguisher in the Kitchen? April 2001, p. 2.
Leavening: How Great Cooks Loaf: April 1996, pp. 4-5.
Luminol. Casting a Revealing Light on Crime: Dec. 2001, pp. 12-13.
Matches. Striking Chemistry at Your Fingertips: Dec. 2002, pp. 14-16.
Mighty Thermite: Feb. 2002, pp. 14-15.
Ozone—Out of Bounds: 1998, pp. 12-14.
Polymers: April 1986, pp. 4-7.
Rockets: Chemistry Model for Liftoff: April 2001.
The New Gold Rush: Oct. 1989, pp. 4-4-8.
Nitrous Oxide: By no Means a Laughing Matter: Feb. 1986, pp. 17-19.
Nylon: Dec. 1990, pp. 4-6.
Ozone: Molecule with a Split Personality: Sep. 2001, pp. 7-9.
Permanent Waves: April 1993, pp. 8-11.
Real Leather: April 1990, pp. 4-6.
Saint's Blood: Feb. 1993, pp. 12-15.
Silver Lightning: Dec. 1996, pp. 4-5.
Skunk Non-scents: Oct. 1996, pp. 7-9.
Soap: Feb. 1985, pp. 4-7, p. 12.
Treasure: April 1987, pp. 4-9.
Volcanoes-Forecasting the Fury: Dec. 1999, pp. 12-13.
Wastewater: April 1992, pp. 12-15.
When Good Ideas Gel: Dec. 1992, pp. 14-15.

9. Stoichiometry

The Exploding Tire: April 1988, pp. 12-14.
Rockets: Chemistry Model for Liftoff: April 2001.

10. Phases, Solids, Liquids and Gases (States of Matter)

Artificial Snow: Powder for the Slopes: Dec. 2000, pp. 10-11.
An Atomic Tour: Oct. 1983, pp. 4-7.
Breakfast of Crystals: Oct. 1983, pp. 8-12.
The Case of the Missing Caffeine: April 1999, pp. 12-13.
Cooking with Steam: Feb. 1987, pp. 17-19.
How Dense is It? Feb. 2002, p. 10.
The Fizz-Keeper: Does it Really Keep the Fizz? Feb. 2002, pp. 11-13.
Hot and Cold Packs: Feb. 1987, pp. 7-11.
Making Ice Cream: Dec. 1995, pp. 4-7.
Maple Syrup. Sweet Sap Boils Down to This: Feb. 2002, pp. 8-9.
Matches. Striking Chemistry at Your Fingertips: *ChemMatters*, Dec. 2002, pp. 14-16.
Memory Metal: Oct. 1993, pp. 4-7.
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Saint's Blood: Feb. 1993, pp. 12-15.
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A Supercritical Clean Machine: April 2000, pp. 14-15.

11. Thermochemistry

Burning Diamonds and Squeezing Peanuts: April 1990, pp. 14-15.
Colors Bursting in Air: Oct. 1998, pp. 7-9.
The Explosive History of Nitrogen: Feb. 2003, pp. 8-10.
Fire in the Hold: April 1997, pp. 11-13.
Fireside Dreams: Dec. 1988, pp. 13-15.
Hot and Cold Packs: Feb. 1987, pp. 7-11.
Matches. Striking Chemistry at Your Fingertips: *ChemMatters*, Dec. 2002, pp. 14-16.
Mighty Thermite: Feb. 2002, pp. 14-15.
Non-Safety Glass: Oct. 1987, pp. 10-11.
Rockets: Chemistry Model for Liftoff: April 2001.

12. Gases/Gas Laws/Kinetic Theory

Airbags: Chemical Reaction Saves Lives: Feb. 1997, pp. 4-5.
An Atomic Tour: Oct. 1983, pp. 4-7.
Carbon Dioxide: A Pourable Greenhouse Gas: Sep. 2001, pp. 10-11.
Cartesian Divers: Squeeze Play: Feb. 2001, pp. 4-6.
Do Ducks Get Cold Feet? Dec. 2001, p. 2.
The Exploding Tire: April 1988, pp. 12-14.
Hot Air Balloons, Gas and Go: April 2002, pp. 4-5.
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The Lake Nyos Disaster: Feb. 1996, pp. 13-15.
Mt. Everest: Climbing in Thin Air: Feb. 2000, pp. 4-6.
Noisy Knuckles and Henry's Law: Dec. 2000, pp12-12.
Ozone: Molecule with a Split: Sep. 2001, pp. 7-9.
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Try It! Make Your Own Hot Air Balloon: April 2002, p. 6.
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Why do eggs take longer to cook in the mountains? Feb. 2000, p. 16.

13. Electrons in Atoms
Automatic Sunglasses: Dec. 1989, pp. 4-6.
Chemiluminescence, the Cold Light: Oct. 1995, pp. 12-15.
The Color of Gems: Dec. 1988, pp. 7-9.
Iron for Breakfast: Oct. 1994, pp. 13-15.
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Light Your Candy: Oct. 1990, pp. 10-12.
Spectroscopy: Sensing the Unseen: Sep. 2001, pp. 4-6.
Superconductivity: Oct. 1987, pp. 18-21.

14. Periodicity/Periodic Law/Metals, Non-metals and Families
Element X: Dec. 1987, pp. 8-9.
Happy Birthday Helium: Dec. 1995, p. 12.

15. Ionic and Metallic Bonds
Breakfast of Crystals: Oct. 1983, pp. 8-12.
Permanent Waves: April 1993, pp. 8-11.
Matches. Striking Chemistry at Your Fingertips: Dec. 2002, pp. 14-16.
Memory Metal: Oct. 1993, pp. 4-7.
Mighty Thermite: Feb. 2002, pp. 14-15.

16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
Artificial Sweeteners: Feb. 1988, pp. 4-8.
An Atomic Tour: Oct. 1983, pp. 4-7.
Buckeyballs: Dec. 1992, pp. 7-11.
The Disappearing Fingerprints: Feb. 1997, pp. 9-12.
The Explosive History of Nitrogen: Feb. 2003, pp. 8-10.
Images of Anthrax: Dec. 2002, pp. 4-6.
Lava Lite: A Chemical Juggling Act: April 1997, pp. 4-7.
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Mirror Molecules: April 1989, pp. 4-7.
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Polywater: Dec. 1987, pp. 10-13.
Silly Putty: April 1986, pp. 15-19.
Soap: Feb. 1985, pp. 4-7, p. 12.

17. Water, Aqueous Solutions
The Absorbing Story of the Thirsty Polymer: Oct. 1999, pp. 4-5.
Antifreeze Antidote: Oct. 1996, pp. 4-6.
Aquarium Chemistry: Feb. 2002, pp. 6-7.

An Atomic Tour: Oct. 1983, pp. 4-7.
The Case of the Missing Caffeine: April 1999, pp. 12-13.
Caves: Chemistry Goes Underground: April 2002, pp. 7-9.
Detergents: April 1985, pp. 4-6.
Embalming—Chemistry for Eternity: Oct. 1999, pp. 12-13,
Filtered Water vs. Straight from the Tap: Oct. 2002, pp. 8-9.
The Fizz-Keeper: Does it Really Keep the Fizz? Feb. 2002, pp. 11-13.
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Kidney Dialysis. A Working Model You Can Make: April 2001, p. 12.
Laundry Disks: Miracle or Money Down the Drain? April 1997, pp. 14-15.
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Question from the Classroom: Oct. 2002. p. 2.
Scuba: The Chemistry of an Adventure: Feb. 2001, pp. 7-9.
The Search for Martian Water: Oct. 2002, pp. 12-13.
Soap: Feb. 1985, pp. 4-7, p. 12.
Sports Drinks: Don’t Sweat the Small Stuff: Feb. 1999, pp. 11-13.
Super Soakers. Just How Super Are They? Oct. 1999, p. 6.
Survival at Sea: Oct. 1992, pp.4-7.
Swimming Pools: April 1994, pp. 10-12.
Tapping Saltwater for a Thirsty World: Oct. 2002, pp. 4-7.
Urine: Your Own Chemistry: Oct. 2002, pp. 14-45.
Wastewater: April 1992, pp. 12-15.
Why Do Eggs take Longer to Cook in the Mountains? Feb. 2000, p. 16.

18. Reaction Rates and Kinetics

Designer Catalysts: April 1994, pp. 13-15.
The Explosive History of Nitrogen: Feb. 2003, pp. 8-10.
Iron for Breakfast: Oct. 1994, pp. 13-15.
Ozone: Molecule with a Split Personality: Sep. 2001, pp. 7-9.
Ozone—Out of Bounds: Feb. 1998, pp. 12-14.
When Good Ideas Gel: Dec. 1992, pp. 14-15.
Why Do Eggs take Longer to cook in the Mountains? Feb. 2000, p. 16.

19. Equilibrium

Aquarium Chemistry: Feb. 2002, pp. 6-7.
Automatic Sunglasses: Dec. 1989, pp. 4-6.
Fossil Molecules: April 1988, pp. 4-7.
Caves: Chemistry Goes Underground: April 2002, pp. 7-9.
Mt. Everest: Climbing in Thin Air: Feb. 2000, pp. 4-6.
Treasure: April 1987, pp. 4-9.

20. Acid/Bases/pH

Biosphere II: Feb. 1995, pp. 8-11.
Carnivorous Plants: Dec. 1993, pp.4-5.
Caves: Chemistry Goes Underground: April 2002, pp. 7-9.
Detergents: April 1985, pp. 4-6.
Leavening: How Great Cooks Loaf: April 1996, pp. 4-5.
The New Gold Rush: Oct. 1989, pp. 4-4-8.
Permanent Waves: April 1993, pp. 8-11.
Real Leather: April 1990, pp. 4-6.
Swimming Pools: April 1994, pp. 10-12.
Treasure: April 1987, pp. 4-9.
Wastewater: April 1992, pp. 12-15.

21. Organic Chemistry

The Absorbing Story of the Thirsty Polymer: Oct. 1999, pp. 4-5.
Alcohol: Feb. 1985, pp. 8-11.
Antifreeze Antidote: Oct. 1996, pp. 4-6.
Artificial Sweeteners: Feb. 1988, pp. 4-8.
Aspirin: Feb. 1993, pp. 4-7.
A calorie-free fat? April 1999, pp. 9-11.
Carnivorous Plants: Dec. 1993, pp.4-5.
The Case of the Missing Caffeine: April 1999, pp. 12-13.
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Dissolving Plastic: Oct. 1987, pp. 12-15.
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Mirror Molecules: April 1989, pp. 4-7.
Mouthwash: What’s in it for you? Dec. 1996, pp. 6-8.

Natural Dyes: Dec. 1986, pp. 4-8, 12.
Non-Safety Glass: Oct. 1987, pp. 10-11.
Nylon: Dec. 1990, pp. 4-6.
Peanut Brittle: Dec. 1991, pp. 4-7.
Penicillin: April 1987, pp. 10-12.
Permanent Waves: April 1993, pp. 8-11.
Perfume: Feb. 1992, pp. 8-11.
Plants Fight Back: April 1996, pp. 9-11.
Polysaccharides: April 1986, pp. 12-14.
Polymers: April 1986, pp. 4-7.
Real Leather: April 1990, pp. 4-6.
Silly Putty: April 1986, pp. 15-19.
Sizing up Paper: April 1998, pp. 10-12.
Skunk Non-scents: Oct. 1996, pp. 7-9.
The Smell of Danger: Oct. 1988, pp.9-13.
Spider Silk: Spinning a Strong Thread: Feb. 2001, pp. 10-11.
Sports Drinks: Don't Sweat the Small Stuff: Feb. 1999, pp. 11-13.
Soap: Feb. 1985, pp. 4-7, p. 12.
A Successful Failure: Feb. 1998, p. 12.
Swimming Pools: April 1994, pp. 10-12.
Wastewater: April 1992, pp. 12-15.
Zombies: Oct. 1987, pp. 4-9.

22. Redox/Electrochemistry

Apollo 13's Fight for Survival: Feb. 1994, pp. 5-8.
Automatic Sunglasses: Dec. 1989, pp. 4-6.
Colors Bursting in Air: Oct. 1998, pp. 7-9.
Fire in the Hold: April 1997, pp. 11-13.
Friedrich Wohler's Lost Aluminum: Oct. 1990, pp. 14-15.
Insect Arsenals: Oct. 1993, pp. 8-10.
Iron for Breakfast: Oct. 1994, pp. 13-15.
The New Gold Rush: Oct. 1989, pp. 4-4-8.
Mighty Thermite: Feb. 2002, pp. 14-15.
Rockets: Chemistry Model for Liftoff: April 2001.
Permanent Waves: April 1993, pp. 8-11.
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The Smell of Danger: Oct. 1988, pp.9-13.
Treasure: April 1987, pp. 4-9.

ChemMatters Articles indexed for teacher use.

How to Use This Guide

Each item relates an article published in *ChemMatters*, the American Chemical Society's chemistry magazine for students, between February 1983 and December 2002. Each article is referenced to twenty-two general chemistry curricular topics, although such a listing is open to some interpretation. We also point out many of the curricular subtopics to which each article connects. Although these subtopics are not listed among the twenty-two major topics, hopefully listing these can help you decide whether a particular article might prove useful as you teach or review specific content material. When the article appears to have reasonably strong connections to the topics listed for physics and biology curricula, we have listed these connections.

All *ChemMatters* issues from 1983-1998 are on a CD-ROM which can be purchased from the American Chemical Society. The cost for a single user is $49.95 plus S&H. To order, go to: <http://www.chemistry.org/portal/Chemistry?PID=acsdisplay.html&DOC=education\\curriculum\\cmprods.html>. There are plans to produce a second CD-ROM in 2003 that will contain all issues from 1983-2003.

Number and Topic:	**1. Matter and Change** **6. Chemical Names and Formulas/Compounds and Elements** **8. Chemical Reactions** **10. Phases, Solids, Liquids and Gases (States of Matter)** **11. Thermochemistry**,
Source:	*ChemMatters*, Dec. 2002, pp. 14-16, "Matches. Striking Chemistry at Your Fingertips"
Type of Material:	Student Journal Article
Building on:	Chemical names and formulas/compounds and elements, chemical reactions and thermochemistry
Leading to:	Reaction rates, redox reactions
Links to Physics:	Matter, energy, thermodynamics, heat
Links to Biology:	
Good Stories:	Entire article is a "good story"
Activity Description:	Article describes the history of the development of the common match, covering early matches and their inherent weaknesses and dangers. Good review of chemical equations and/or a review or introduction to redox reactions.

Number and Topic:	**1. Matter and Change** **17. Water, Aqueous Solutions**
Source:	*ChemMatters*, Oct. 2002, pp. 4-7, "Tapping Saltwater for a Thirsty World"
Type of Material:	Student Journal Article
Building on:	Classification of matter, water, aqueous solutions

Leading to: Colligative properties, osmosis
Links to Physics: Matter, energy
Links to Biology: Cells
Good Stories:
Activity Description: Article describes different attempts to obtain potable water from saltwater, including reverse osmosis and distillation.

Number and Topic: 1. Matter and Change (Classification of Matter)
14. Periodicity/Periodic Law/Metals, Non-metals and Families
Source: *ChemMatters*, Dec. 1987, pp. 8-9, "Element X"
Type of Material: Student Journal Article
Building on:
Leading to: Periodic Table
Links to Physics:
Links to Biology:
Good Stories: Although Mendeleev's construction of the Periodic Table is considered to be a brilliant intellectual achievement, he was terribly wrong on other predictions, including predicting the existence of "Element X," which would have an atomic weight nearly one-millionth that of hydrogen, rejecting completely the notion that electrons could exist, and stating that petroleum was not formed from decaying plants and animals, but rather from water seeping through rocks.
Activity Description: Article deals with the work of Dimitri Mendeleev, both his successes and his failures.

Number and Topic: 1. Matter and Change (Classification of Matter)
10. Phases, Solids, Liquids and Gases (States of Matter)
16. Covalent Bonds, Molecular Shapes and Intermolecular Forces,
17. Water, Aqueous Solutions
Source: *ChemMatters*, Dec. 1987, pp. 10-13, "Polywater"
Type of Material: Student Journal Article
Building on: Basic properties of water
Leading to: Discovery of "polywater" and how its existence was disproved
Links to Physics: Density, spectra
Links to Biology:
Good Stories: Entire article is a "good story."
Activity Description: This article relates the story behind the discovery of "polywater." It goes into the evidence for its existence, the excitement and hype that accompanied its reported discovery, the enthusiastic acceptance of its existence by some scientists versus the skepticism of others, and how its existence was eventually disproved. Although the article contains a lot of science content and information about the properties of water, its greatest value may very well lie in its exposition of the fact that at times science may take a wrong turn; it includes self-correcting features that work

strongly towards correcting errors and arriving at the truth.

Number and Topic:	**1. Matter and Change (Classification of Matter)**
Source:	*ChemMatters*, Oct. 1984, pp. 14-15, "Robert Bunsen—more than a burner designer"
Type of Material:	Student Journal Article
Building on:	Familiarity with a Bunsen burner
Leading to:	A discussion of Bunsen's real scientific accomplishments.
Links to Physics:	Light, heat, electromagnetic spectrum
Links to Biology:	
Good Stories:	
Activity Description:	This article presents many of the accomplishments of Robert Bunsen, who students naturally associate with the Bunsen burner, but whose real accomplishments were much more significant, the burner being a relatively minor contribution which he really shares with others.

Number and Topic:	**2. Measurement** **4. Atomic Structure**
Source:	*ChemMatters*, Dec. 2002, pp. 9-13, "Nanotechnology, The world of the super small"
Type of Material:	Student Journal Article
Building on:	Matter and change, measurement, atomic structure
Leading to:	Electrons in atoms, bonding
Links to Physics:	Matter, quantum theory, subatomic particles
Links to Biology:	Proteins
Good Stories:	Entire article is a "good story."
Activity Description:	A very good introduction to the general area of nanotechnology for the general student. Describes, in fairly simple and clear terms, both the theoretical foundation and practical applications.

Number and Topic:	**2. Measurement** **10. Phases, Solids, Liquids and Gases (States of Matter)**
Source:	*ChemMatters*, Feb. 2002, p. 10, "How Dense is It?"
Type of Material:	Activity
Building on:	Measurement, density
Leading to:	More of a review
Links to Physics:	Measurement, density
Links to Biology:	
Good Stories:	
Activity Description:	Students make and calibrate a hydrometer to determine the relative densities of solutions.

Number and Topic:	**2. Measurement** **12. Gases/Gas Laws/Kinetic Theory**
Source:	*ChemMatters*, Feb. 2001, pp. 4-6, "Cartesian Divers: Squeeze Play"
Type of Material:	Student Journal Article and Activity
Building on:	Measurement, density
Leading to:	Archimedes' Principle
Links to Physics:	Motion and forces, gravity
Links to Biology:	Fish utilize swim bladders much like Cartesian Divers
Good Stories:	
Activity Description:	Article describes what Cartesian divers are as well as the principles that underlie their operation. Instructions are provided for students to build their own Cartesian divers.

Number and Topic:	**2. Measurement**
Source:	*ChemMatters*, Oct. 1999, pp. 14-15, "The Weighty Matter of the Kilogram Standard"
Type of Material:	Student Journal Article
Building on:	Measurement, metric system
Leading to:	Stoichiometry, Avogadro's number,
Links to Physics:	Forces, gravity, electricity, magnetism
Links to Biology:	
Good Stories:	
Activity Description:	Relates attempts to replace the actual metal cylinder that defines the international kilogram and is housed at the Bureau International des Poids et Measures in France with a standard that does not rely on an actual object. The kilogram is the only base quantity in the SI system of measurement that still does.

Number and Topic:	**2. Measurement** **8. Chemical Reactions** **20. Acids/Bases/pH**
Source:	*ChemMatters*, Feb. 1995, pp. 8-11, "Biosphere II"
Type of Material:	Student Journal Article
Building on:	Measurement, chemical reactions
Leading to:	Acids/bases/pH
Links to Physics:	
Links to Biology:	Ecosystems, respiration, bacterial action
Good Stories:	Entire article is a story
Activity Description:	Article relates the attempt to build a completely enclosed ecosystem in which humans could live for years and the problems that arose, especially those of falling oxygen and rising carbon dioxide levels. A lot of fundamental acid-base chemistry is presented in the article.

Number and Topic:	**3. Problem Solving**
Source:	*ChemMatters*, April 2003, pp. 8-9, Student activity relating to the rate of energy release by a Bunsen burner, an electric hotplate and a microwave oven
Type of Material:	Activity
Building on:	Basic ability to do energy calculations
Leading to:	Measuring and comparing the rate at which water can be heated by a Bunsen burner, and electric hotplate, and a microwave oven.
Links to Physics:	Energy
Links to Biology:	
Good Stories: None	
Activity Description:	This is a student activity measuring and comparing the rate at which water can be heated by a Bunsen burner, and electric hotplate, and a microwave oven.

Number and Topic:	**2. Measurement** **3. Problem Solving**
Source:	*ChemMatters*, Dec. 2002, pp. 17-19, "Murder She Floats"
Type of Material:	Student Journal Article
Building on:	Measurement, problem solving
Leading to:	Archimedes' Principle, buoyancy
Links to Physics:	Forces
Links to Biology:	
Good Stories:	Article is a terrific story
Activity Description:	Article is taken from "expert testimony" at an actual murder case. A murderer tried to sink a woman's body by placing it in a Styrofoam cooler and dumping it in the ocean. When it wouldn't sink, he shot holes in the cooler. It still wouldn't sink. His brother testified in detail exactly what they had attempted. The prosecution's argument was that if a cooler actually would behave in the detailed manner described by the brother, then the story must be true, since he would never have the technical background to predict the cooler's behavior. He was convicted. The article contains fairly simple calculations about why the cooler would behave as it did.

Number and Topic:	**3. Problem Solving** **6. Chemical Names and Formulas/Compounds and Elements**
Source:	*ChemMatters*, Sep. 2001, pp. 14-15, "Global Warming: Hot Topic Getting Hotter"
Type of Material:	Student Journal Article
Building on:	Basic properties of carbon dioxide
Leading to:	Effect of global warming on ecosystems
Links to Physics:	Electromagnetic radiation
Links to Biology:	Ecosystems

Good Stories: Entire article is a "good story."
Activity Description: The article describes the phenomenon of global warming, both from a theoretical and a measurable basis. It goes on to discuss changes in our atmosphere, possible interpretations of what has caused these changes, and the potential consequences that might be attached to them.

Number and Topic: 3. Problem Solving
Source: *ChemMatters*, Oct. 1996, pp. 12-15, "The Crash of Flight 143"
Type of Material: Student Journal Article
Building on: Problem solving
Leading to: Density calculations, importance of units in conversion factors
Links to Physics: Problem solving, metric system
Links to Biology:
Good Stories: Incredibly, Flight 143 crashed because the pilots had to calculate the amount of fuel they needed by hand, since a computer was broken. Using a "conversion factor" without units, they added what they thought was a sufficient amount of fuel. Unfortunately, they had calculated the amount in pounds, when it should have been in kilograms.
Activity Description: Article explains how and why the error occurred and shows the actual calculations that were done and that should have been done.

Number and Topic: 2. Measurement
3. Problem Solving
17. Water, Aqueous Solutions
20. Acids/Bases/pH
21. Organic Chemistry
Source: *ChemMatters*, April 1994, pp. 10-12, "Swimming Pools"
Type of Material: Student Journal Article
Building on: Quantitative calculations, ppm
Leading to: Acids, bases, pH, organic chemistry
Links to Physics:
Links to Biology:
Good Stories:
Activity Description: Article discusses the chemistry involved in keeping a swimming pool clean and safe. It does a good job of illustrating the complexity of the trying to balance different requirements that are often in conflict.

Number and Topic: 3. Problem Solving
7. Moles
17. Water, Aqueous Solutions
Source: *ChemMatters*, Dec. 1991, pp. 8-11, "Homeopathy"
Type of Material: Student Journal Article
Building on: Problem solving, solutions

Leading to: Serial dilutions, process of science
Links to Physics:
Links to Biology: Placebo effect
Good Stories:
Activity Description: Article describes the notion of "Homeopathy," or the use of what are basically infinitely diluted solutions to treat illnesses. While the article contains a lot of good information relating to dilutions, etc., its major value probably lies in its exposition of what constitutes "good science" vs. the claims of pseudoscientific arguments and "scientific experiments" of questionable design.

Number and Topic: 3. Problem Solving
Source: *ChemMatters*, Oct. 1987, p. 17, "Archimedes"
Type of Material: Student Journal Article
Building on: Density
Leading to: Archimedes' Principle
Links to Physics: Density, levels
Links to Biology:
Good Stories: Story of how Archimedes figured out a way to determine whether a "gold" crown had actually been adulterated with silver.
Activity Description: Article describes several of the achievements of Archimedes, including his invention of the lever and the discovery of Archimedes' Principle.

Number and Topic: 4. Atomic Structure
13. Electrons in Atoms
Source: *ChemMatters*, April 2003, pp. 2-3, "Lasers"
Type of Material: Student Journal Article
Building on: Atomic structure
Leading to: Electron transitions in atoms—emission of photons
Links to Physics: Light, Atoms, Electromagnetic spectrum
Links to Biology:
Good Stories:
Activity Description: Article discusses lasers, both the scientific principles behind their operation and their technological design.

Number and Topic: 4. Atomic Structure
8. Chemical Reactions
21. Organic Chemistry
Source: *ChemMatters*, Dec. 2001, pp. 12-13, "Luminol. Casting a Revealing Light on Crime"
Type of Material: Student Journal Article
Building on: Atomic structure, chemical reactions
Leading to: Organic chemistry

Links to Physics: Electromagnetic spectrum
Links to Biology: Living matter, composition of blood
Good Stories: Luminol can be used to detect the possible presence of blood at a crime scene.
Activity Description: Article describes how luminol reacts with blood (and other substances) and how the reaction produces a product whose electrons are in a high energy state but then fall to a lower state with the emission of visible light.

Number and Topic: 4. Atomic Structure
13. Electrons in Atoms
16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
Source: *ChemMatters*, Sep. 2001, pp. 4-6, "Spectroscopy: Sensing the Unseen"
Type of Material: Student Journal Article
Building on: Atomic Structure
Leading to: Discussion of how electromagnetic radiation allows us to detect the presence of different molecules in the atmosphere
Links to Physics: Electromagnetic spectrum, atoms, light, motion and forces
Links to Biology: Except that the atmosphere is a very important part of our ecosystem, and any change in the atmosphere can have significant effects upon life on earth.
Good Stories:
Activity Description: The article discusses the electromagnetic spectrum and how the interaction of light with matter can be used to detect and measure gases present in earth's atmosphere. This is then connected to the NASA EOS-Aura project, a project that will launch a satellite that will carry four state-of-the-art instruments designed to make sophisticated measurements of earth's atmosphere.

Number and Topic: 4. Atomic Structure
5. Radioactivity, Fusion, Fission
Source: *ChemMatters*, Oct. 2000, pp. 4-5, "The Birth of the Elements"
Type of Material: Student Journal Article
Building on: Atomic Structure
Leading to: Fusion, stellar synthesis of elements
Links to Physics: Matter, energy, gravity, sun, atoms, subatomic particles, nuclear
Links to Biology: Evolution
Good Stories:
Activity Description: The article deals with the origins of the elements, starting with hydrogen and helium and then to the stellar synthesis of heavier elements and on to the formation of even heavier elements in events such as supernovae.

Number and Topic: 4. Atomic Structure
5. Radioactivity, Fusion, Fission

Source: *ChemMatters*, April 2000, pp. 6-9, "Radioactivity: It's a Natural"
Type of Material: Student Journal Article containing a personal worksheet for estimating your personal annual radiation dose
Building on: Atomic Structure
Leading to: Radioactivity
Links to Physics: Nuclear, radioisotopes, subatomic particles
Links to Biology: Cells, growth and reproduction
Good Stories: Contains a nice worksheet and some good information about the amount of radioactivity in cigarette smoke.
Activity Description: Article treats radioactivity, what it is, how it is produced, the most common types (alpha, beta, gamma), and their characteristics. It presents some of the history behind the discovery and characterization of radioactivity, the sources of radioactivity in our environment, the possible biological effects of exposure, and ends with the worksheet.

Number and Topic: 4. Atomic Structure
Source: *ChemMatters*, April 1999, pp. 4-7, "A Light of a Different Color"
Type of Material: Student Journal Article
Building on: Atomic Structure
Leading to: Electrons in atoms, emission of light, fluorescence, phosphorescence, triboluminescence
Links to Physics: Electromagnetic spectrum, atoms, kinetic and potential energy, light
Links to Biology:
Good Stories: Shows how Wint-O-Green Lifesavers exhibit the property of triboluminescence.
Activity Description: Discusses the difference between fluorescence, phosphorescence, and triboluminescence. Explains what they are and how they arise as well as some practical applications of these phenomena.

Number and Topic: 4. Atomic Structure
8. Chemical Reactions
11. Thermochemistry
22. Redox/Electrochemistry
Source: *ChemMatters*, Oct. 1998, pp. 7-9, "Colors Bursting in Air"
Type of Material: Student Journal Article
Building on: Atomic structure, electron transitions in atoms
Leading to: Redox
Links to Physics: Electromagnetic spectrum, light, electrons
Links to Biology:
Good Stories:
Activity Description: Article discusses the chemistry and electron transitions that produce the colors seen in fireworks.

Number and Topic: **4. Atomic structure**
8. Chemical Reactions
13. Electrons in Atoms
Source: *ChemMatters*, Oct. 1995, pp. 12-15, "Chemiluminescence, the Cold Light"
Type of Material: Student Journal Article
Building on: Electromagnetic spectrum, chemical reactions, electrons in atoms
Leading to: Organic chemistry
Links to Physics: Atoms, electromagnetic spectrum, light
Links to Biology: Bacteria, bioluminescence
Good Stories: Several interesting stories of how specific organisms utilize bioluminescence in their daily quests for survival.
Activity Description: Article deals with the entire subject of chemiluminescence. It details the kinds of chemical reactions typically involved, presenting specific examples and several practical applications of the phenomenon both in nature and in medicine

Number and Topic: **4. Atomic Structure**
13. Electrons in Atoms
Source: *ChemMatters*, Oct. 1990, pp. 10-12, "Light Your Candy"
Type of Material: Student Journal Article
Building on: Atomic structure
Leading to: Energy levels and changes in atoms and molecules
Links to Physics: Electromagnetic spectrum, quantum theory, energy, light, electrons
Links to Biology:
Good Stories:
Activity Description: Article describes the phenomenon of triboluminescence and how and why the common Wint-O-Green Lifesaver exhibits this phenomenon.

Number and Topic: **4. Atomic Structure**
13. Electrons in Atoms
Source: *ChemMatters*, Dec. 1988, pp. 7-9, "The Color of Gems"
Type of Material: Student Journal Article
Building on: Atomic structure
Leading to: Electron configurations, electron transitions within atoms, crystal structures
Links to Physics: Quantum theory, atoms, electrons, light, electromagnetic spectrum
Links to Biology:
Good Stories:
Activity Description: Article discusses why certain gems exhibit the colors that they do and gets into the electron configurations of atoms and electron transitions between orbitals.

Number and Topic: **4. Atomic Structure**
13. Electrons in Atoms
Source: *ChemMatters*, Oct. 1987, pp. 18-21, "Superconductivity"
Type of Material: Student Journal Article
Building on: Atomic structure and normal electrical conductivity
Leading to: Mechanism of superconductivity
Links to Physics: Electrons, electricity, electrical conductivity
Links to Biology:
Good Stories:
Activity Description: Article describes the history of superconductivity and then attempts to present an explanation of this most unusual and counterintuitive phenomenon.

Number and Topic: **4. Atomic Structure**
5. Radioactivity, Fusion, Fission
7. Moles
Source: *ChemMatters*, Oct. 1985, pp. 14-15, "Bringing Helium Down to Earth"
Type of Material: Student Journal Article
Building on: Basic chemical knowledge
Leading to: Spectroscopy, radioactivity, subatomic particles, properties of noble gases, Rutherford's scattering experiment, transmutation of elements, determination of Avogadro's number
Links to Physics: The sun, light, electromagnetic spectrum, subatomic particles
Links to Biology:
Good Stories:
Activity Description: This article presents the history behind the discovery of helium, first in the sun and later on earth. It continues to discuss the transmutation of elements and how Ernest Rutherford determined Avogadro's number.

Number and Topic: **4. Atomic Structure**
6. Chemical Names and Formulas/Compounds and Elements
10. Phases, Solids, Liquids and Gases (States of Matter)
12. Gases/Gas Laws/Kinetic Theory
16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
17. Water, Aqueous Solutions
Source: *ChemMatters*, Oct. 1983, pp. 4-7, "An Atomic Tour"
Type of Material: Student Journal Article
Building on: Basic knowledge of atomic and molecular structures
Leading to: Modeling, molecular motions, Bolzmann's distribution, composition of air, structure of water, polarity, hydrogen bonds, structure of ice
Links to Physics:
Links to Biology:
Good Stories:
Activity Description: This article, written by the late Isaac Asimov, takes the reader on an

imaginary journey where he/she becomes smaller and smaller until he/she can see individual atoms and molecules. The article goes on to describe several molecular structures and motions.

Number and Topic:	**5. Radioactivity, Fusion, Fission** **8. Chemical Reactions** **12. Gases/Gas Laws/Kinetic Theory**
Source:	*ChemMatters*, Dec. 1999, pp. 12-13, “Volcanoes—Forecasting the Fury”
Type of Material:	Student Journal Article
Building on: Gases,	Radioactivity, chemical reactions
Leading to:	Viscosity, pH, acid rain
Links to Physics:	Heat, nuclear, radioisotopes
Links to Biology:	
Good Stories:	Relates the story of Mt. St. Helens explosion of 1980.
Activity Description:	Discusses volcanic eruptions, how and why they occur and their links to topics such as acid rain.

Number and Topic:	**5. Radioactivity, Fusion, Fission**
Source:	*ChemMatters*, April 1999, p. 16, “Should Food be Irradiated?”
Type of Material:	Student Journal Article
Building on:	Radioactivity
Leading to:	Effect of radiation on molecular structures
Links to Physics:	Atoms, subatomic particles
Links to Biology:	Effect of radiation on molecules contained in meat
Good Stories:	
Activity Description:	Article nicely explains what happens when food is irradiated and tries to dispel irrational fears based on inaccurate science.

Number and Topic:	**5. Radioactivity, Fusion, Fission**
Source:	*ChemMatters*, Oct. 1998, pp. 13-15, “The Radium Girls. Dialing up Trouble”
Type of Material:	Student Journal Article
Building on:	Atoms
Leading to:	Nuclear reactions, radioactivity
Links to Physics:	Atoms, subatomic particles, radioisotopes
Links to Biology:	Cells, mutations, DNA
Good Stories:	Tells about the “radium girls” who painted the hands of watches with radium salts and the terrible physical consequences they suffered because of their absorption of radioactive alpha emitters into their bodies.
Activity Description:	Article deals with both the human and the science side of this terrible tragedy.

Number and Topic: **5. Radioactivity, Fusion, Fission**
6. Chemical Names and Formulas/Compounds and Elements
14. Periodicity/Periodic Law/Metals, Non-metals and Families
Source: *ChemMatters*, Dec. 1995, p. 12, "Happy Birthday Helium"
Type of Material: Student Journal Article
Building on: Elements
Leading to: Spectroscopy
Links to Physics: Electromagnetic spectrum, sun, atoms
Links to Biology:
Good Stories: Relates how helium was discovered in the sun before it was actually discovered on earth!
Activity Description: Article relates the discovery of helium, its source on earth, and some of its very unusual properties.

Number and Topic: **5. Radioactivity, Fusion, Fission**
Source: *ChemMatters*, Feb. 1994, pp. 12-15, "Positron Emission Tomography Scan"
Type of Material: Student Journal Article
Building on: Radioactivity, radioisotopes
Leading to: Biological processes that occur in the human brain
Links to Physics: Radioisotopes
Links to Biology: The human brain, nerve synapses, cocaine addiction
Good Stories: Relates the physiological bases for cocaine addiction.
Activity Description: Article describes how a PET scan works, how it generates the images that it does, and how these kinds of images can be used to determine what is going on inside a human body at the time it is actually occurring.

Number and Topic: **8. Chemical Reactions**
15. Ionic and Metallic Bonds
16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
20. Acids/Bases/pH
21. Organic Chemistry
22. Redox/Electrochemistry
Source: *ChemMatters*, April 1993, pp. 8-11, "Permanent Waves"
Type of Material: Student Journal Article
Building on: Molecular structures, acids and bases
Leading to: Hydrogen bonds, amino acids, proteins,
Links to Physics:
Links to Biology: Structure of human hair, proteins
Good Stories:
Activity Description: Article details the complex structure of human hair and how permanent waves act on hair to produce their effect.

Number and Topic: **5. Radioactivity, Fusion, Fission**
Source: *ChemMatters*, Feb. 1989, pp. 12-15, "Carbon-14 Dating"
Type of Material: Student Journal Article
Building on: Isotopes
Leading to: Nuclear reactions, radioactive decay
Links to Physics: Nuclear, atoms, radioisotopes, subatomic particles
Links to Biology: The carbon cycle
Good Stories:
Activity Description: Article explains what C-14 dating is, how and why it works, its accuracy, and gives several practical examples of its application.

Number and Topic: **5. Radioactivity, Fusion, Fission**
21. Organic Chemistry
Source: *ChemMatters*, Oct. 1985, pp. 4-7, "Hydrogen and Helium"
Type of Material: Student Journal Article
Building on: Basic properties of hydrogen and helium, atomic and molecular weights,
Leading to: Archimedes' Principle
Links to Physics: Abundance of hydrogen and helium in the universe, gravity, the sun
Links to Biology:
Good Stories: The Hindenburg disaster
Activity Description: This article discusses the properties uses and potential uses of hydrogen and helium.

Number and Topic: **6. Chemical Names and Formulas/Compounds and Elements**
8. Chemical Reactions
11. Thermochemistry
16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
18. Reaction Rates and Kinetics
Source: *ChemMatters*, Feb. 2003, pp. 8-10, "The Explosive History of Nitrogen"
Type of Material: Student Journal Article
Building on: Basic chemical knowledge
Leading to: Discussion of bonding in nitrogen compounds and elemental nitrogen, thermochemistry and reaction rates.
Links to Physics: Matter, energy, entropy
Links to Biology:
Good Stories: What caused a terrible explosion aboard a cargo ship loaded with ammonium nitrate on April 16, 1947, killing 576 people?
Activity Description: Article deals with explosive nitrogen-containing compounds and the chemical reasons that underlie their explosive nature.

Number and Topic: **6. Chemical Names and Formulas/Compounds and Elements**
8. Chemical Reactions
12. Gases/Gas Laws/Kinetic Theory

18. Reaction Rates and Kinetics and Kineticsand Kinetics

Source: *ChemMatters*, Sep. 2001, pp. 7-9, "Ozone: Molecule with a Split Personality"
Type of Material: Student Journal Article
Building on: Elements and compounds, chemical reactions, gases
Leading to: Reaction rates, chemical kinetics
Links to Physics: Atoms
Links to Biology: Animals, plants, photosynthesis, ecosystems
Good Stories: Lots of excellent "real-life" connections such as sunburn and pollution
Activity Description: The article describes how ozone is both formed and destroyed in the stratosphere and how it is formed in our immediate breathable atmosphere by the action of sunlight on various pollutants. It explains why ozone in the stratosphere is good, while ozone at street level is harmful. It discusses what is actually happening to earth's protective layer of ozone and why.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
8. Chemical Reactions
12. Gases/Gas Laws/Kinetic Theory

Source: *ChemMatters*, Sep. 2001, pp. 10-11, "Carbon Dioxide: A Pourable Greenhouse Gas"
Type of Material: Lab
Building on: Measurement, properties of compounds
Leading to: Chemical reactions
Links to Physics: Measurement
Links to Biology:
Good Stories:
Activity Description: Students generate carbon dioxide through a simple chemical reaction. They study its properties, both physical and chemical.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements

Source: *ChemMatters*, Feb. 2001, pp. 12-13, "Dinosaurs and Iridium. Traces of an Impact"
" Type of Material: Student Journal Article
Building on: Elements
Leading to: Examination of how a controversial scientific theory is tested and eventually accepted
Links to Physics:
Links to Biology: Ecosystems, adaptations, evolution
Good Stories: Entire article is a "good story."
Activity Description: Article describes how Walter Alvarez hypothesized that the mass extinction that occurred about 65 million years ago was caused by a meteor impact. At first ridiculed, his theory eventually became widely accepted, and the article goes through the experimental data and scientific arguments that carried the day.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
Source: *ChemMatters*, Dec. 1999, p. 16, "Are Living and Nonliving Things Composed of Entirely Different Substances?"
Type of Material: Student Journal Article
Building on: Elements
Leading to: Bonding in carbon compounds
Links to Physics: Atoms, subatomic particles
Links to Biology: Living matter
Good Stories:
Activity Description: Article discusses similarities and differences between the "top ten" elements contained in the human body and the top ten elements in the earth's crust.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
10. Phases, Solids, Liquids and Gases (States of Matter)
17. Water, Aqueous Solutions
21. Organic Chemistry
Source: *ChemMatters*, Dec. 1995, pp. 4-7, "Making Ice Cream"
Type of Material: Student Journal Article and Activity
Building on: Basic chemical knowledge of molecular structures
Leading to: Colloids, lipids, emulsisfiers, sugars, colligative properties
Links to Physics:
Links to Biology: Food, lipids, proteins
Good Stories: Relates the history of ice cream and some government regulations regarding the labeling of the product.
Activity Description: Article discusses the composition of ice cream and the science behind its preparation and ends with a student activity to make home-made ice cream.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
8. Chemical Reactions
13. Electrons in Atoms
17. Water, Aqueous Solutions
18. Reaction Rates and Kinetics
22. Redox/Electrochemistry
Source: *ChemMatters*, Oct. 1994, pp. 13-15, "Iron for Breakfast"
Type of Material: Student Journal Article and Activity
Building on: Chemical names and formulas, electrons in atoms
Leading to: Catalysis, redox reactions
Links to Physics: Magnetism
Links to Biology: Hemoglobin, the function of iron in human biology
Good Stories:

Activity Description: Article relates the nature of iron in human metabolism and the biological effects of having too much or too little.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
15. Ionic and Metallic Bonds
Source: *ChemMatters*, Dec. 1992, pp. 4-6, "Salt"
Type of Material: Student Journal Article
Building on: Formulas and properties of ionic solids
Leading to: Comparison of different salt substitutes
Links to Physics:
Links to Biology: Effect of salt on blood pressure
Good Stories:
Activity Description: Article describes the composition of "salt," different kind of "salt substitutes," and the biological effects of salt.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
Source: *ChemMatters*, Dec. 1992, pp. 7-11, "Buckyballs"
Type of Material: Student Journal Article and Activity
Building on: Geometry, Families of elements
Leading to: Mass spectroscopy, Structure and properties of Buckyballs, an unusual allotrope of carbon
Links to Physics: Matter, isotopes
Links to Biology:
Good Stories: Interesting story about how the research that led to the discovery of buckyballs was considered to be so trivial that it took eighteen months for the person doing the research to get to use the required equipment.
Activity Description: Article describes how buckyballs were discovered, their structure, their properties, and some potential uses. It goes into the geometry of truncated icosahedrons. It should be noted that the article is actually a bit out of date, since much research has been done since it was published. It also includes a student activity to build a model of a buckyball and provides the necessary template.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
8. Chemical Reactions
20. Acid/Bases/pH
21. Organic Chemistry
Source: *ChemMatters*, April 1990, pp. 4-6, "Real Leather"
Type of Material: Student Journal Article
Building on: Names and formulas, chemical reactions, acids, bases, pH
Leading to: Organic chemistry
Links to Physics:

Links to Biology: Structure of collagen, amino acids
Good Stories: Relates the history of leather tanning from ancient times to the present.
Activity Description: Article describes various techniques that can be used to tan leather, going into the chemical reactions involved in different processes.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
11. Thermochemistry
Source: *ChemMatters*, April 1990, pp. 14-15, "Burning Diamonds and Squeezing Peanuts"
Type of Material: Student Journal Article
Building on: Elements, allotropes
Leading to: Thermodynamics of converting graphite into diamonds, phase diagrams
Links to Physics:
Links to Biology:
Good Stories:
Activity Description: This article is an extension of the article, "Burning Diamonds and Squeezing Peanuts" that precedes it. It goes into more thermodynamic detail regarding the conversion of graphite into diamonds, including the phase diagram for the diamond-graphite-liquid system.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
8. Chemical Reactions
20. Acid/Bases/pH
22. Redox/Electrochemistry
Source: *ChemMatters*, Oct. 1989, pp. 4-4-8, "The New Gold Rush"
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Acids, bases, redox
Links to Physics:
Links to Biology: How bacteria can actually be used in some gold recovery processes
Good Stories:
Activity Description: Article discusses the history of gold mining, from crude early methods to modern sophisticated processes, going into detail about the chemical reactions and various processes that are employed.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
8. Chemical Reactions
Source: *ChemMatters*, Feb. 1986, pp. 17-19, "Nitrous Oxide: By no Means a Laughing Matter"
Type of Material: Student Journal Article
Building on: Chemical formulas
Leading to: Properties of different oxides of nitrogen and practical uses of these compounds

Links to Physics:
Links to Biology: Biological effects of the ingestion of nitrous oxide
Good Stories: Early attempts to develop anesthetics
Activity Description: This article discusses various oxides of nitrogen, their formulas and uses, with an emphasis on nitrous oxide.

Number and Topic: **6. Chemical Names and Formulas/Compounds and Elements**
17. Water, Aqueous Solutions
20. Acids/Bases/pH
21. Organic Chemistry
Source: *ChemMatters*, April 1985, pp. 4-6, "Detergents"
Type of Material: Student Journal Article
Building on: Basic knowledge of molecular structures and ions
Leading to: Discussion of anionics, cationics, nonionics, emulsions, micelles, hard water
Links to Physics:
Links to Biology: Eutrophication caused by the presence of phosphates in detergents, bacterial action on surfactants
Good Stories:
Activity Description: Article discusses detergents, what they contain, the function of each ingredient and how they are different from soaps.

Number and Topic **6. Chemical Names and Formulas/Compounds and Elements**
10. Phases, Solids, Liquids and Gases (States of Matter)
15. Ionic and Metallic Bonds
Source: *ChemMatters*, Oct. 1983, pp. 8-12, "Breakfast of Crystals"
Type of Material: Student Journal Article and Activity
Building on: Basic knowledge of chemical formulas
Leading to: Crystal structures, metals, alloys, glass
Links to Physics: Matter
Links to Biology:
Good Stories:
Activity Description: This article discusses several common substances and their crystal structures. It would be a good article for students to read if your course includes a unit on solid structures. The article is followed by a student activity on crystal growing.

Number and Topic: **8. Chemical Reactions**
17. Water, Aqueous Solutions
19. Equilibrium
20. Acid/ Bases/pH
Source: *ChemMatters*, April 2002, pp. 7-9, "Caves: Chemistry Goes Underground"

Type of Material: Student Journal Article
Building on: Chemical Reactions, Water, Aqueous solutions
Leading to: Equilibrium, acids, bases, pH
Links to Physics: Thermodynamics, entropy
Links to Biology: Ecosystems, energy flow
Good Stories: Good stories and photographs about sinkholes swallowing up entire homes
Activity Description: Article deals with how caves are formed. It contains some good examples of the kinds of equilibrium reactions involved and the extent to which these reactions are related to pH.

Number and Topic: 8.Chemical Reactions
11. Thermochemistry
15. Ionic and Metallic Bonds
22. Redox/Electrochemistry
Source: *ChemMatters*, Feb. 2002, pp. 14-15, "Mighty Thermite"
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Thermochemistry and redox
Links to Physics: Matter, energy, thermodynamics, heat, entropy
Links to Biology:
Good Stories:
Activity Description: Article describes the thermite reaction, its history, the thermodynamics behind it, and some of its practical applications

Number and Topic: 8.Chemical Reactions
17. Water, Aqueous Solutions
Source: *ChemMatters*, April 2001, p. 2, "Is Water the Best Fire Extinguisher in the Kitchen?"
Type of Material: Student Journal Article
Building on: Basic knowledge of combustion
Leading to: Structures of polar and nonpolar materials and how they interact
Links to Physics:
Links to Biology:
Good Stories:
Activity Description: Article discusses why water should not be used to put out a grease fire and some possible alternate techniques that can be used if a grease fire breaks out in your kitchen.

Number and Topic: 8. Chemical Reactions
9. Stoichiometry
11. Thermochemistry
12. Gases/Gas Laws/Kinetic Theory
22. Redox/Electrochemistry/Electrochemistry

Source: *ChemMatters*, April 2001, "Rockets: Chemistry Model for Liftoff"
Type of Material: Student Journal Article
Building on: Properties of compounds and elements, chemical reactions, gas laws
Leading to: Redox reactions
Links to Physics: Strong links to motions and forces and kinematics as well as measurement
Links to Biology:
Good Stories:
Activity Description: Article describes the basic principles behind the operation of a model rocket, both chemical and physical.

Number and Topic: 6. Chemical Names and Formulas/Compounds and Elements
8. Chemical Reactions
Source: *ChemMatters*, Dec. 2000, pp. 4-6, "Hydrogen Fuel Cells for Future Cars"
Type of Material: Student Journal Article
Building on: Elements, Chemical Reactions
Leading to: Redox, Electrochemistry
Links to Physics:
Links to Biology: Ecosystems
Good Stories:
Activity Description: Article discusses the need for an alternative to the internal combustion engine and current research to develop cars that can utilize hydrogen fuel cells.

Number and Topic: 8. Chemical Reactions
21. Organic Chemistry
Source: *ChemMatters*, Oct. 2000, pp. 6-8, "Fats: Fitting them into a Healthy Diet"
Type of Material: Student Journal Article
Building on: Molecular structures and names and chemical reactions
Leading to: Organic chemistry, isomerism
Links to Physics:
Links to Biology: Food, lipids
Good Stories: Gives some details about the amount of fat in some common fast-food meals.
Activity Description: The article presents basic information about fats, what they are and how they are formed from glycerol and fatty acids. It goes on to discuss different kinds of fats, such as saturated and unsaturated as well as cis-trans isomers. Various types of fat substitutes are also discussed.

Number and Topic: 8. Chemical Reactions
21. Organic Chemistry
Source: *ChemMatters*, April 1999, pp. 9-11, "A Calorie-Free Fat?"
Type of Material: Student Journal Article
Building on: Organic chemistry

Leading to: Triglycerides, enzymes, carbohydrates, proteins
Links to Physics: Energy
Links to Biology: Food, lipids
Good Stories:
Activity Description: Article describes fats, their structures and formation and then moves on to fat substitutes. It describes how their structures differ from normal lipids and explains why they are "calorie free" when ingested into the human body, even though they would produce calories of heat if burned in a calorimeter.

Number and Topic: 8. Chemical Reactions
18. Reaction Rates and Kinetics and Kinetics
Source: *ChemMatters*, Feb. 1998, pp. 12-14, "Ozone—Out of Bounds"
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Reaction rates
Links to Physics: Electromagnetic spectrum
Links to Biology:
Good Stories:
Activity Description: Article describes how ozone is produced in our atmosphere from VOCs (volatile organic compounds) and nitrogen oxides, explaining how complex the process can be.

Number and Topic: 8. Chemical Reactions
Source: *ChemMatters*, Oct. 1997, pp. 10-12, "CO Control: On the Street, In the House, Where You Live"
Type of Material: Student Journal Article
Building on: Chemical Reactions
Leading to: Function of hemoglobin in the human body
Links to Physics:
Links to Biology: Hemoglobin and its function
Good Stories: Relates some stories of actual cases of CO poisoning of groups of people and even one celebrity.
Activity Description: Discusses how CO is produced by incomplete combustion, the mechanism by which it acts as a poison, and how home CO detectors operate.

Number and Topic: 8. Chemical Reactions
12. Gases/Gas Laws/Kinetic Theory
Source: *ChemMatters*, Feb. 1997, pp. 4-5, "Airbags: Chemical Reaction Saves Lives"
Type of Material: Student Journal Article
Building on: Chemical reactions, gases
Leading to: Reaction rates

Links to Physics: Motions and forces
Links to Biology:
Good Stories: Given the ubiquitous presence of airbags in modern automobiles, it is surprising to realize that the first crash between two automobiles equipped with airbags occurred in 1990.
Activity Description: Article presents the history of the development of airbags and does a thorough job of explaining the chemical reactions and physical processes involved in their operation.

Number and Topic: 8. Chemical Reactions
22. Redox/Electrochemistry
Source: *ChemMatters*, Dec. 1996, pp. 4-5, "Silver Lightning"
Type of Material: Student Journal Article
Building on Chemical reactions
Leading to: Redox and electrochemistry
Links to Physics:
Links to Biology:
Good Stories: Entire article is a "good story."
Activity Description: The article discusses and evaluates the product claims of a product called "Silver Lightning." The product claims to be able to remove tarnish from silver products with no scrubbing. Interestingly enough, the product does work, although a plain piece of aluminum foil will evidently produce the same results at a fraction of the cost.

Number and Topic: 8. Chemical Reactions
21. Organic Chemistry
Source: *ChemMatters*, Oct. 1996, pp. 7-9, "Skunk Non-scents"
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Organic chemistry, cis-trans isomers
Links to Physics:
Links to Biology: How a skunk's defensive mechanism works
Good Stories: Tells how a researcher discovered an effective way to remove the odor from an animal that had been sprayed by a skunk.
Activity Description: Article discusses the structure of the odoriferous chemicals contained in skunk spray, a mixture that can effectively remove the odor, and the chemistry that explains how and why it works.

Number and Topic: 8. Chemical Reactions
20. Acids/Bases/pH
Source: *ChemMatters*, April 1996, pp. 4-5, "Leavening: How Great Cooks Loaf"
Type of Material: Student Journal Article
Building on: Chemical Reactions

Leading to: Acid-base chemistry
Links to Physics:
Links to Biology: Fermentation
Good Stories:
Activity Description: Article discusses the chemistry involved in the leavening of dough. It discusses both biological and chemical leavening and goes into the different types of chemical reactions that might be involved.

Number and Topic: 8. Chemical Reactions
18. Reaction Rates and Kinetics
Source: *ChemMatters*, April 1994, pp. 13-15, "Designer Catalysts"
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Discussion of catalysis and catalysts, activation energy
Links to Physics:
Links to Biology: Enzymes
Good Stories: Contains futuristic thoughts about possible new catalytic applications.
Activity Description: Article discusses catalysts, what they are, and how they operate in both chemical and biological systems.

Number and Topic: 8. Chemical Reactions
22. Redox/Electrochemistry
Source: *ChemMatters*, Feb. 1994, pp. 5-8, "Apollo 13's Fight for Survival"
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Acids and bases, redox, fuel cells
Links to Physics: Motion and forces
Links to Biology: Respiration
Good Stories: Article deals with the Apollo 13 disaster and how the crew and the scientists at mission control were able to bring the astronauts safely back to earth.
Activity Description: The article does a nice job of blending the dramatic nature of the Apollo crises with the chemistry involved in maintaining the life-support system for the astronauts and providing the energy needed to get them back to earth safely.

Number and Topic: 8. Chemical Reactions
21. Organic Chemistry
22. Redox/Electrochemistry
Source: *ChemMatters*, Oct. 1993, pp. 8-10, "Insect Arsenals"
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Organic chemistry, redox

Links to Physics:
Links to Biology: Numerous links to evolution, adaptations, behaviors, heredity
Good Stories: Several interesting stories of unusual methods by which some insects defend themselves against predators.
Activity Description: Article discusses the general topic of how insects utilize chemical defenses and includes several very specific examples, explaining in detail the chemical reactions involved.

Number and Topic: 8. Chemical Reactions
10. Phases, Solids, Liquids and Gases (States of Matter)
Source: *ChemMatters*, Feb. 1993, pp. 12-15, "Saint's Blood"
Type of Material: Student Journal Article and Activity
Building on: Chemical Reactions, phases and phase changes
Leading to: Discussion of thixotropic mixtures and an activity designed to prepare one
Links to Physics:
Links to Biology:
Good Stories: Tells the story of Saint Januarius' feast in Naples, Italy, when a vial holding what is purported to be the clotted blood of Saint Januarius is displayed, moved and turns to a liquid.
Activity Description: The article explains why the "blood" is almost certainly not human blood, but rather a thixotropic mixture that can be prepared in the lab and probably was prepared by an early alchemist.

Number and Topic: 8. Chemical Reactions
19. Equilibrium
Source: *ChemMatters*, Dec. 1992, pp. 14-15, "When Good Ideas Gel"
Type of Material: Student Journal Article
Building on: Density, states of matter
Leading to: Equilibrium
Links to Physics: Density
Links to Biology:
Good Stories:
Activity Description: Article describes and discusses "aerogels," materials that looks like sponges but have a density that is so low that they will float on soap bubbles of carbon dioxide.

Number and Topic: 8. Chemical Reactions
17. Water, Aqueous Solutions
20. Acids/Bases/pH
21. Organic Chemistry
Source: *ChemMatters*, April 1992, pp. 12-15, "Wastewater"
Type of Material: Student Journal Article
Building on: Chemical reactions

Leading to:	Acids/Bases, pH
Links to Physics:	
Links to Biology:	Aerobic bacterial action
Good Stories:	
Activity Description:	Article describes how wastewater is treated and turned into potable water. Article goes into much specific chemistry and is well written by an expert in water treatment.

Number and Topic:	**8. Chemical Reactions** **21. Organic Chemistry**
Source:	*ChemMatters*, Dec. 1990, pp. 4-6, "Nylon"
Type of Material:	Student Journal Article
Building on:	Organic chemistry
Leading to:	Polymers
Links to Physics:	
Links to Biology:	
Good Stories:	Relates how Wallace Carothers and an assistant discovered nylon partly by insight, partly by luck.
Activity Description:	Article describes both the history of nylon, the chemical reactions involved in its creation, and the specific procedures by which a useful fiber is generated.

Number and Topic:	**8. Chemical Reactions** **22. Redox/Electrochemistry**
Source:	*ChemMatters*, Oct. 1990, pp. 14-15, "Friedrich Wohler's Lost Aluminum"
Type of Material:	Student Journal Article
Building on:	Chemical reactions
Leading to:	Oxidation-reduction and electrochemistry
Links to Physics:	
Links to Biology:	
Good Stories:	At one time aluminum was a more precious than gold or silver. The metal was actually displayed along with the French crown jewels.
Activity Description:	The article discusses the history of aluminum and the various processes by which it was isolated from its ores.

Number and Topic:	**8. Chemical Reactions** **13. Electrons in Atoms** **19. Equilibrium** **22. Redox/Electrochemistry**
Source:	*ChemMatters*, Dec. 1989, pp. 4-6, "Automatic Sunglasses"
Type of Material:	Student Journal Article
Building on:	Chemical reactions, electrons in atoms
Leading to:	Equilibrium, redox

Links to Physics: Light, electromagnetic spectrum
Links to Biology:
Good Stories:
Activity Description: Article describes the reactions and mechanisms involved in photochromic sunglasses that darken when exposed to sunlight but turn clear when you come back indoors.

Number and Topic: 8. Chemical Reactions
21. Organic Chemistry
Source: *ChemMatters*, Feb. 1989, pp. 4-7, "Distance Running"
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Organic chemistry, chemical and biological processes involved in human respiration and energy production
Links to Physics:
Links to Biology: Aerobic and anaerobic processes, function of ATP, glycogen, glucose, pyruvic acid and fats in producing energy within the human body
Good Stories:
Activity Description: Article deals with the chemistry and physiology of running.

Number and Topic: 8. Chemical Reactions
11. Thermochemistry
21. Organic Chemistry
Source: *ChemMatters*, Dec. 1988, pp. 13-15, "Fireside Dreams"
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Combustion reactions
Links to Physics:
Links to Biology: Molecular structure of wood
Good Stories: None
Activity Description: Article discusses the composition of wood, how and why it burns, and the chemical processes and reactions that are involved.

Number and Topic: 8. Chemical Reactions
9. Stoichiometry
12. Gases/Gas Laws/Kinetic Theory
Source: *ChemMatters*, April 1988, pp. 12-14, "The Exploding Tire"
Type of Material: Student Journal Article
Building on: Gas laws, chemical reactions
Leading to: Explosive mixtures
Links to Physics: Gas laws
Links to Biology:
Good Stories:

Activity Description: Article deals with a "mystery" explosion of a tire that was being repaired. It discusses how the use of a can of "instant flat tire fixer" was the cause of the explosion, and it goes into the specific chemical reactions involved as well as their stoichiometry.

Number and Topic: **8. Chemical Reactions**
21. Organic Chemistry
Source: *ChemMatters*, Oct. 1987, pp. 12-15, "Dissolving Plastic"
Type of Material: Student Journal Article and Activity
Building on: Basic chemical knowledge
Leading to: Organic structures, polymers, solubility
Links to Physics:
Links to Biology:
Good Stories:
Activity Description: Article describes various types of plastic polymers and how it is possible to create a polymer (polyvinyl alcohol) that is soluble in water.

Number and Topic: **8. Chemical Reactions**
19. Equilibrium
20. Acid/Bases/pH
22. Redox/Electrochemistry
Source: *ChemMatters*, April 1987, pp. 4-9, "Treasure"
Type of Material: Student Journal Article
Building on: Basic chemical knowledge
Leading to: Discussion of acid-base and redox reactions, including equilibrium considerations and then continuing to a discussion of electrolysis, and how all of these chemical concepts can be applied to restoring articles that are recovered from a sunken ship.
Links to Physics: Electricity
Links to Biology:
Good Stories: Stories of the sinking of the ship Atocha and its recovery
Activity Description: Article deals with all the chemistry involved in restoring objects lifted from sunken ships that have been lying at the bottom of the sea for hundreds of years.

Number and Topic: **8. Chemical Reactions**
10. Phases, Solids, Liquids and Gases (States of Matter)
11. Thermochemistry
17. Water, Aqueous Solutions
Source: *ChemMatters*, Feb. 1987, pp. 7-11, "Hot and Cold Packs"
Type of Material: Student Journal Article and Activity
Building on: Chemical reactions
Leading to: Thermodynamics of the dissolving process

Links to Physics: Thermodynamics, heat, energy, entropy
Links to Biology:
Good Stories:
Activity Description: Article discusses both “hot packs” and “cold packs” and how they utilize both chemical reactions and simple crystallization to either release heat or absorb heat from their surroundings.

Number and Topic: 8. Chemical Reactions
Source: *ChemMatters*, Dec. 1986, pp. 13-15, “Going Against the Flow: The Isolation of Fluorine”
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Redox, electrochemical cells, electrolysis
Links to Physics:
Links to Biology: Biological effects of exposure to hydrogen fluoride
Good Stories:
Activity Description: Article details historical attempts to prepare fluorine, including the high number of failures and the chemical reasons for these failures. There is a lot of basic chemistry involved in these attempts, and several early chemists suffered severe health problems and even death due to their attempts to work with highly toxic fluorine compounds.

Number and Topic: 8. Chemical Reactions
21. Organic Chemistry
Source: *ChemMatters*, April 1986, pp. 4-7, “Polymers”
Type of Material: Student Journal Article
Building on: Chemical reactions
Leading to: Organic reactions and the creation of polymers
Links to Physics:
Links to Biology: How the creation of plastic materials helped save the world’s elephants from extinction due to poaching to obtain their tusks for the purpose of making billiard balls.
Good Stories: See above
Activity Description: The article details the creation of several different types of polymeric materials. It presents many of the equations involved in their synthesis and details about many of the processes, for example how a PET bottle is made.

Number and Topic: 8. Chemical Reactions
16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
17. Water, Aqueous Solutions
21. Organic Chemistry
Source: *ChemMatters*, Feb. 1985, pp. 4-7, p. 12, “Soap”
Type of Material: Student Journal Article and Activity

Building on: Basic chemical knowledge of structures
Leading to: Polarity, intermolecular forces, “like dissolves like,” saponification
Links to Physics:
Links to Biology:
Good Stories: Early bathing habits. Queen Isabella of Spain boasted of taking only two baths in her lifetime, once when she was born and another on her wedding day. Queen Elizabeth I of England was a “bathing enthusiast.” Her chronicles record that “she hath a bath every three months whether she needeth it or no.”
Activity Description: This article presents both the history of soap making, the science of soap making, including typical chemical equations, and the “art” of soapmaking. On page 12 there is a student activity relating to how soap works.

Number and Topic: 8. Chemical Reactions
Source: *ChemMatters*, Oct. 1984, pp. 4-5, “The Interrupted Party”
Type of Material: Student Journal Article
Building on: Basic chemical knowledge
Leading to: Requirements for combustion
Links to Physics:
Links to Biology:
Good Stories: The “mystery” surrounding the serious burning (and eventual death) of a person who added lighter fluid to a barbeque that he thought had gone out. The reason for the resulting explosion is not as simple as one might assume.
Activity Description: See above. The article discusses the specific requirements for combustion and how these are related to the terrible accident that occurred.

Number and Topic: 10. Phases, Solids, Liquids and Gases (States of Matter)
17. Water, Aqueous Solutions
Source: *ChemMatters*, Feb. 2002, pp. 8-9, “Maple Syrup. Sweet Sap Boils Down to This”
Type of Material: Student Journal Article
Building on: Phases, phase changes
Leading to: Colligative properties, boiling points vs. concentration
Links to Physics: Matter, energy
Links to Biology: Plants, photosynthesis, food, energy flow
Good Stories:
Activity Description: Article describes how maple syrup is made. It elucidates the science involved along with why maple syrup comes in different grades and how the grade is related to how rapidly and at what temperature the sap is evaporated and the point at which the syrup is harvested from the evaporating sap.

Number and Topic: **10. Phases, Solids, Liquids and Gases (States of Matter)**
17. Water, Aqueous Solutions
Source: *ChemMatters*, Feb. 2002, pp. 11-13, "The Fizz-Keeper: Does it Really Keep the Fizz?"
Type of Material: Student Journal Article and Activities
Building on: Gases, Water, aqueous solutions
Leading to: Gas solubility, Henry's Law
Links to Physics:
Links to Biology:
Good Stories: Commercial products often make invalid claims based upon questionable science
Activity Description: A commercial product called a "Fizz-Keeper" claims to be able to keep opened bottle of carbonated beverages from going flat. It basically doesnít work, and the article clearly goes through the scientific principles that explain why it wouldn't be expected to work. The article also contains some student activities.

Number and Topic: **10. Phases, Solids, Liquids and Gases (States of Matter)**
12 Gases/Gas Laws/Kinetic Theory
17. Water, Aqueous Solutions
Source: *ChemMatters*, Feb. 2001, pp. 7-9, "Scuba: The Chemistry of an Adventure"
Type of Material: Student Journal Article
Building on: States of matter, density, gases, water
Leading to: Heat capacity, refraction, Henry's Law
Links to Physics: Refraction, motion and forces
Links to Biology: Ecosystems
Good Stories: Author relates her personal experiences while learning how to Scuba dive.
Activity Description: Article relates the author's experiences while Scuba diving and then tries to explain the scientific reasons behind the phenomena, for example, why submerged objects appear to be closer or why colors fade.

Number and Topic: **10. Phases, Solids, Liquids and Gases (States of Matter)**
Source: *ChemMatters*, Dec. 2000, pp. 10-11, "Artificial Snow: Powder for the Slopes"
Type of Material: Student Journal Article
Building on: States of matter
Leading to: Thermodynamics
Links to Physics: Matter, energy, kinetic theory, thermodynamics, heat, entropy
Links to Biology:
Good Stories:
Activity Description: Article describes how artificial snow is made and the scientific principles that underlie its creation.

Number and Topic:	**10. Phases, Solids, Liquids and Gases (States of Matter)**
Source:	*ChemMatters*, April 2000, pp. 14-15, "A Supercritical Clean Machine"
Type of Material:	Student Journal Article
Building on:	States of matter
Leading to:	Phase diagrams, specifically that of carbon dioxide and properties of polar and nonpolar materials, especially the "like dissolves like" concept
Links to Physics:	
Links to Biology:	Reducing the emission of toxic substances into the environment
Good Stories:	
Activity Description:	Article discusses the use of supercritical carbon dioxide for dry cleaning clothes. It includes a discussion of the phase diagram of carbon dioxide, what "supercritical" really means, and why supercritical carbon dioxide might be effective for dry cleaning.

Number and Topic:	**10. Phases, Solids, Liquids and Gases (States of Matter)** **17. Water, Aqueous Solutions** **21. Organic Chemistry**
Source:	*ChemMatters*, April 1999, pp. 12-13, "The Case of the Missing Caffeine"
Type of Material:	Student Journal Article
Building on:	Phases, organic chemistry, aqueous solutions
Leading to:	Phase diagrams
Links to Physics:	
Links to Biology:	
Good Stories:	
Activity Description:	Article discusses caffeine, its structure and presence in various beverages. It goes on to explain different methods by which caffeine can be extracted from a beverage. This leads to a discussion of the phase diagram of carbon dioxide and what is meant by the term "supercritical" fluid.

Number and Topic:	**4. Atomic Structure** **10. Phases, Solids, Liquids and Gases (States of Matter)** **15. Ionic and Metallic Bonds**
Source:	*ChemMatters*, Oct. 1993, pp. 4-7, "Memory Metal"
Type of Material:	Student Journal Article
Building on:	Atomic structure, phases
Leading to:	Crystal structures
Links to Physics:	Matter
Links to Biology:	Medical applications of nitinol metal
Good Stories:	How nitinol metal was used to repair shoulder problems in Los Angeles Dodgers pitcher Orel Hershiser.
Activity Description:	Article deals with Nitinol metal, the "memory" metal that returns to any shape that it was initially set in upon heating—even if it has been twisted

or bent into a completely different shape. Article explains why this amazing phenomenon occurs and also shows several practical uses of this unusual property.

Number and Topic: **10. Phases, Solids, Liquids and Gases (States of Matter)**
Source: *ChemMatters*, Feb. 1987, pp. 17-19, "Cooking with Steam"
Type of Material: Student Journal Article and Activities
Building on: Basic knowledge about boiling
Leading to: A more sophisticated discussion of the energetics involved in phase changes
Links to Physics: Energy, heat
Links to Biology:
Good Stories:
Activity Description: Article discusses the scientific principles involved in steaming things such as vegetables, focusing on the energetics involved in the transformation of a liquid to a gas at its boiling point.

Number and Topic: **10. Phases, Solids, Liquids and Gases (States of Matter)**
16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
21. Organic Chemistry
Source: *ChemMatters*, April 1986, pp. 15-19, "Silly Putty"
Type of Material: Student Journal Article
Building on: Basic chemical knowledge
Leading to: Elastomers, dilatancy
Links to Physics: Forces; why silly putty will stretch if pulled slowly but snap if pulled quickly
Links to Biology:
Good Stories: How the material from which Silly Putty is made was considered just a laboratory curiosity until a person observing it just for fun saw its potential as a children's toy.
Activity Description: This article discusses Silly Putty. It explains its unusual properties and relates these properties to its molecular structure.

Number and Topic: **11. Reaction rates**.
21. Organic Chemistry
Source: *ChemMatters*, Oct. 1987, pp. 10-11, "Non-Safety Glass"
Type of Material: Student Journal Article
Building on: Basic chemical knowledge
Leading to: A discussion of ignition temperatures and reaction kinetics, including activation energy.
Links to Physics:
Links to Biology:
Good Stories: How a person trying to cut a piece of safety glass was seriously burned

because of his lack of basic chemical knowledge.
Activity Description: Article describes an attempt to cut a piece of safety glass by using flammable alcohol and the serious accident that occurred. The article discusses the chemical principles that explain why the accident occurred.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory
Source: *ChemMatters*, April 2002, pp. 4-5, "Hot Air Balloons, Gas and Go"
Type of Material: Student Journal Article
Building on: Gas behavior and Gas Laws
Leading to: Archimedes' Principle
Links to Physics: Motion and forces, gravity, heat
Links to Biology:
Good Stories: Good stories about early attempts to fly hot air balloons
Activity Description: A good general treatment of hot air balloons, their history, and the scientific principles that underlie their operation

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory
Source: *ChemMatters*, April 2002, p. 6, "Try It! Make Your Own Hot Air Balloon"
Type of Material: Activity
Building on: Gases/gas laws, kinetic theory
Leading to: Can lead to advanced calculations related to Archimedes' Principle if desired. Sample activities can be found by going to <http://www.chemistry.org/education/ChemMatters.html> and then linking to the Teacher's Guide contained under the cover illustration for the April 2002 issue
Links to Physics: Motion and Forces, Gravity, Heat
Links to Biology:
Good Stories:
Activity Description: This contains directions for constructing and flying a hot air balloon, along with some possible extensions of the activity. The Teacher's Guide contains links to possible alternate activities.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory
17. Water, Aqueous Solutions
Source: *ChemMatters*, Feb. 2002, p. 2, "Hydrogen Beer"
Type of Material: Student Journal Article
Building on: Elements
Leading to: Gases, solubility, Henry's Law
Links to Physics:
Links to Biology:
Good Stories: The entire article is a great "story."
Activity Description: Terrific story about "hydrogen beer," a beer said to contain hydrogen gas

rather than carbon dioxide. Hydrogen beer is a hoax, an "urban legend" but was actually able to fool enough educated people so that it made it to a reputable physics Website as well as a chemistry textbook. Applying simple notions of solubility, etc., should have revealed its obvious non-validity.

Number and Topic:	**12. Gases/Gas Laws/Kinetic Theory**
Source:	*ChemMatters*, Dec. 2001, p. 2, "Do Ducks Get Cold Feet?"
Type of Material:	Student Journal Article
Building on:	Kinetic Theory
Leading to:	Example of a practical application of heat flow in nature
Links to Physics:	Energy, kinetic theory, heat
Links to Biology:	Animals, adaptations
Good Stories:	Interesting story of how a duck uses a clever arrangement of veins and arteries to prevent excessive heat loss through its feet when swimming in icy water
Activity Description:	Given the large surface area of a duck's feet, it would seem that they would lose an excessive, perhaps unrecoverable amount of heat when swimming in icy water. But through an ingenious arrangement of veins and arteries, they manage to keep heat loss to a minimum.

Number and Topic:	**12. Gases/Gas Laws/Kinetic Theory**
Source:	*ChemMatters*, Dec. 2000, pp. 12-12, "Noisy Knuckles and Henry's Law"
Type of Material:	Student Journal Article
Building on:	Gas laws, aqueous solutions
Leading to:	Henry's Law
Links to Physics:	
Links to Biology:	Structure of a knuckle joint
Good Stories:	
Activity Description:	Article describes the structure of the human knuckle and what happens when you "crack" a knuckle. It connects to both biology and to Henry's Law.

Number and Topic:	**12. Gases/Gas Laws/Kinetic Theory** **19. Equilibrium**
Source:	*ChemMatters*, Feb. 2000, pp. 4-6, "Mt. Everest: Climbing in Thin Air"
Type of Material:	Student Journal Article
Building on:	Gases
Leading to:	Dalton's Laws of Partial Pressure, Le Chatelier's Principle
Links to Physics:	Electromagnetic spectrum
Links to Biology:	Cells, respiration, hemoglobin
Good Stories:	Relates challenges involved in trying to scale Mt. Everest
Activity Description:	Discusses how atmospheric pressure changes with altitude and how this

leads to a shortage of oxygen at high altitudes. This is then related to the great challenges that face any person attempting to climb Mt. Everest.

Number and Topic: **12. Gases/Gas Laws/Kinetic Theory**
17. Water, Aqueous Solution
18. Reaction Rates and Kinetics
Source: *ChemMatters*, Feb. 2000, p. 16, "Why Do Eggs take Longer to Cook in the Mountains?"
Type of Material: Student Journal Article including a fun quiz
Building on: Gases
Leading to: Colligative properties of solutions
Links to Physics: Heat, energy
Links to Biology: Coagulation of proteins
Good Stories: There is a "fun" quiz at the end of the article.
Activity Description: Article discusses how pressure varies with altitude and how this affects the boiling point of water, which in turn affects the time required to hard boil an egg.

Number and Topic: **12. Gases/Gas Laws/Kinetic Theory**
17. Water, Aqueous Solutions
Source: *ChemMatters*, Feb. 1996, pp. 13-15, "The Lake Nyos Disaster"
Type of Material: Student Journal Article
Building on: Gases
Leading to: Water, aqueous solutions
Links to Physics:
Links to Biology:
Good Stories: On August 21, 1986, a cloud of carbon dioxide was released from Lake Nyos in Cameroon, West Africa, killing 1,724 people and several thousand animals.
Activity Description: Article explains how carbon dioxide accumulated in Lake Nyos over a period of years, why it remained in the lake at high concentrations, and what probably caused it to be rapidly released, resulting in the disaster.

Number and Topic: **12. Gases/Gas Laws/Kinetic Theory**
Source: *ChemMatters*, Oct. 1984, pp. 10-13, "Popcorn"
Type of Material: Student Journal Article and Activity
Building on: Personal experience with popcorn
Leading to: Scientific principles that underlie its popping behavior
Links to Physics: Gas laws
Links to Biology: The structure of popcorn
Good Stories:
Activity Description: This article discusses the structure of popcorn and what results in its "popping" when heated. The article is followed by a student activity that

investigates and even measures the percent moisture in a popcorn kernel.

Number and Topic: 16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
Source: *ChemMatters*, Dec. 2002, pp. 4-6, "Images of Anthrax"
Type of Material: Student Journal Article
Building on: Chemical formulas
Leading to: Covalent bonds and molecular shapes
Links to Physics: Matter, atoms
Links to Biology: Protein synthesis, adaptations
Good Stories: Entire article is a "good story"
Activity Description: Students in a Milwaukee, WI area high school undertook a project to build the first models of three anthrax-related proteins. The article describes their efforts, experiences, and successes. Very good as a "role model" article for students.

Number and Topic: 16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
Source: *ChemMatters*, Feb. 1997, pp. 9-12, "The Disappearing Fingerprints"
Type of Material: Student Journal Article
Building on: Polar and non-polar compounds
Leading to: Discussion of gas chromatography, mass spectrometry and organic chemistry
Links to Physics:
Links to Biology: Difference between the kinds of oil contained in the skin of children vs. adults.
Good Stories: Relates the disappearance of fingerprints from a child abduction case and how it led to a scientific study of how the chemicals contained in a child's prints are different from those contained in an adult's.
Activity Description: Article relates how the police were perplexed when they could not find a child's fingerprints inside an abductor's car from which they were certain she had escaped. The article goes on to discuss the difference between the composition of the mixture of chemicals that make up a child's prints vs. that of an adult.

Number and Topic: 16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
Source: *ChemMatters*, April 1994, pp. 8-9, "Magic Sand"
Type of Material: Student Journal Article
Building on: Covalent bonds
Leading to: Intermolecular forces, organic groups
Links to Physics: Density
Links to Biology:
Good Stories: Relates how "Magic Sand" is created.
Activity Description: Article discusses the nature of "Magic Sand," sand that repels water. It discusses how it is created, how and why it has the properties it does, and

some practical uses of the product.

Number and Topic:	**16. Covalent Bonds, Molecular Shapes and Intermolecular Forces** **21. Organic Chemistry**
Source:	*ChemMatters*, April 1989, pp. 4-7, "Mirror Molecules"
Type of Material:	Student Journal Article
Building on:	Molecular structures
Leading to:	Optical isomerism, chirality
Links to Physics:	
Links to Biology:	Chirality in nature, such as is found in some shells and umbilical cords
Good Stories:	
Activity Description:	Article discusses "mirror image" molecules and how chirality is found in nature.

Number and Topic:	**16. Covalent Bonds, Molecular Shapes and Intermolecular Forces** **21. Organic Chemistry**
Source:	*ChemMatters*, Feb. 1988, pp. 4-8, "Artificial Sweeteners"
Type of Material:	Student Journal Article and Activity
Building on:	Organic chemistry
Leading to:	Hydrogen bonds, optical isomers
Links to Physics:	
Links to Biology:	Why some molecules taste sweet, the "sweetness triangle"
Good Stories:	How the early Romans used lead acetate to sweeten their food—possibly contributing to the downfall of the Roman Empire.
Activity Description:	Article discusses various kinds of natural and artificial sweeteners, their molecular structures and shapes as well as the history behind their discovery and in some cases their eventual banning by the FDA.

Number and Topic:	**17. Water, Aqueous Solutions**
Source:	*ChemMatters*, Oct. 2002. p. 2, "Question from the Classroom"
Type of Material:	Student Journal Article
Building on:	Chemical formulas, matter and change
Leading to:	General critical thinking
Links to Physics:	Matter
Links to Biology:	Ecosystems, resources and environmental issues
Good Stories:	Entire article is a "good story."
Activity Description:	Article deals with "plans to ban DHMO, one of the most hazardous substances on the planet." A long list of terrible human and environmental consequences caused by the widespread presence of DHMO is presented. All are technically accurate. DHMO turns out to be dihydrogen monoxide, common water!

Number and Topic:	**17. Water, Aqueous Solutions**
Source:	*ChemMatters*, Oct. 2002, pp. 8-9, “Filtered Water vs. Straight from the Tap”
Type of Material:	Activity
Building on:	Matter and Change, Chemical Reactions, States of Matter
Leading to:	Equilibrium
Links to Physics:	Matter, energy
Links to Biology:	Cells,
Good Stories:	
Activity Description:	Detailed laboratory directions for comparing filtered (or distilled) water to tap water for appearance, smell, hardness, calcium, iron and chlorine. Somewhat similar to Lab B7, pp. 35-38 in the 4th edition of the ChemCom textbook.

Number and Topic:	**17. Water, Aqueous Solutions**
Source:	*ChemMatters*, Oct. 2002, pp. 12-13, “The Search for Martian Water”
Type of Material:	Student Journal Article
Building on:	Matter and change, states of matter, electromagnetic spectrum
Leading to:	Remote sensing of molecules
Links to Physics:	Electromagnetic spectrum
Links to Biology:	Cells, evolution, ecosystems
Good Stories:	Article is a good story about how water is detected from a distance and the possible significance of its presence.
Activity Description:	Article describes how the NASA Odyssey project has detected the presence of water on Mars, the techniques by which this is accomplished, and the possible significance of this discovery.

Number and Topic:	**17. Water, Aqueous Solutions**
Source:	*ChemMatters*, Oct. 2002, pp. 14-45, “Urine: Your Own Chemistry”
Type of Material:	Student Journal Article
Building on:	Water, aqueous solutions
Leading to:	Organic chemistry, acids/bases/ pH
Links to Physics:	
Links to Biology:	Living matter, food, energy flow, cells, organisms
Good Stories:	Article contains some interesting tidbits, like why does your urine smell funny after eating asparagus, and why is it bright yellow if you take vitamin pills containing riboflavin (vitamin B2).
Activity Description:	This article obviously deals with urine, what it is and what it contains.

Number and Topic:	**17. Water, Aqueous Solutions** **19. Equilibrium**
Source:	*ChemMatters*, Feb. 2002, pp. 6-7, “Aquarium Chemistry”
Type of Material:	Student Journal Article

Building on: Water, aqueous solutions, gas solubility
Leading to: Equilibrium, pH, buffer solutions
Links to Physics: Refractive index
Links to Biology: Ecosystems, respiration, bacteria
Good Stories: Features some real professional aquarists along with students
Activity Description: Compares problems that professional keepers of large public aquariums must contend with to similar problems involved in maintaining a home aquarium

Number and Topic: 17. Water, Aqueous Solutions
Source: *ChemMatters*, April 2001, p. 12, "Kidney Dialysis. A Working Model You Can Make"
Type of Material: Activity
Building on: Water, properties of solutions, Kinetic theory
Leading to: Osmosis
Links to Physics: Measurement, kinetic theory
Links to Biology: Connects to cells and the transport of materials through membranes
Good Stories: None
Activity Description: This activity uses a simple zip-closing-type bag and a simple solution of tincture of iodine to demonstrate the movement of materials through membranes. It is actually connected to an article on kidney dialysis that appears in the same issue.

Number and Topic: 17. Water, Aqueous Solutions
Source: *ChemMatters*, Dec. 1999, p. 8, "How Many Ways Can You See Red?"
Type of Material: Activity
Building on: Water, aqueous solutions
Leading to: Chromatography
Links to Physics:
Links to Biology:
Good Stories:
Activity Description: Students do a simple paper chromatography experiment with different red candies, such as red M&Ms or Skittles to determine how many different kinds of red food dye they contain. They compare their results to what is reported on the package label.

Number and Topic: 17. Water, Aqueous Solutions
21. Organic Chemistry
Source: *ChemMatters*, Oct. 1999, pp. 4-5, "The Absorbing Story of the Thirsty Polymer"
Type of Material: Student Journal Article
Building on: Water, aqueous solutions
Leading to: Solvation, polymers

Links to Physics:
Links to Biology:
Good Stories:
Activity Description: Discusses how super-absorbing polyacrylate polymers work.

Number and Topic:	**17. Water, Aqueous Solutions**
Source:	*ChemMatters*, Oct. 1999, p. 6, "Super Soakers. Just How Super Are They?"
Type of Material:	Activity
Building on:	Water, Aqueous solutions
Leading to:	Polymers
Links to Physics:	
Links to Biology:	
Good Stories:	
Activity Description:	Activity has students compare the water-absorbing ability of a paper towel alone and when some polyacrylate material has been added to it.

Number and Topic:	**17. Water, Aqueous Solutions**
Source:	*ChemMatters*, Oct. 1999, pp. 12-13, "Embalming—Chemistry for Eternity"
Type of Material:	Student Journal Article
Building on:	Water, aqueous solutions
Leading to:	Organic chemistry
Links to Physics:	
Links to Biology:	Cells
Good Stories:	Relates embalming practices from ancient Egyptians to modern times.
Activity Description:	Article discusses how ancient Egyptians embalmed bodies, focusing on the chemistry involved. Moves on to modern embalming techniques using organic chemicals such as formaldehyde.

Number and Topic:	**17. Water, Aqueous Solutions** **21. Organic Chemistry**
Source:	*ChemMatters*, Feb. 1999, pp. 11-13, "Sports Drinks: Don't Sweat the Small Stuff"
Type of Material:	Student Journal Article
Building on:	Water, aqueous solutions
Leading to:	pH, organic chemistry
Links to Physics:	
Links to Biology:	Cells, Food
Good Stories:	Presents the results of scientific research into the physiological value of sports drinks.
Activity Description:	Article discusses sports drinks such as Gatorade—what they are, what they provide, the rationale that underlies their formulation and the results

of scientific studies regarding their effectiveness compared to pure water.

Number and Topic: **17. Water, Aqueous Solutions**
Source: *ChemMatters*, April 1997, pp. 14-15, “Laundry Disks: Miracle or Money Down the Drain?”
Type of Material: Student Journal Article
Building on: Several chemical concepts relating to molecular structures, heat, and ions
Leading to: An evaluation of the claims made by a producer of “Laundry Disks”
Links to Physics: Electromagnetic spectrum
Links to Biology:
Good Stories: Explains why the scientific claims made by a manufacturer of laundry disks are erroneous and misleading.
Activity Description: Article lists the claims made by a manufacturer of laundry disks-that they can be used for 500-700 loads without having to add anything to them - and why these claims are scientific nonsense.

Number and Topic: **17. Water, Aqueous Solutions**
21. Organic Chemistry
Source: *ChemMatters*, Oct. 1996, pp. 4-6, “Antifreeze Antidote”
Type of Material: Student Journal Article
Building on: Aqueous solutions
Leading to: Organic structures, colligative properties (freezing point depression)
Links to Physics:
Links to Biology: Discusses effect of ethylene glycol on organs such as the brain and kidneys.
Good Stories: Relates the incredible number of animal and human deaths that occur each year due to the ingestion of ethylene glycol antifreeze. Interestingly, the antidote for ethylene glycol poisoning is ethyl alcohol!
Activity Description: Discusses the structure of ethylene glycol and how it functions as an anti-freeze. Goes on to relate its devastating biological effects if ingested and then presents safer alternatives.

Number and Topic: **17. Water, Aqueous Solutions**
Source: *ChemMatters*, Oct. 1995. pp. 8-11, “Ice that Burns”
Type of Material: Student Journal Article
Building on: Solids, liquids and gases
Leading to: Properties of methane, global warming
Links to Physics:
Links to Biology:
Good Stories:
Activity Description: Article discusses the phenomenon of “gas hydrates,” which are ice crystals that trap methane gas and are typically found at the bottom of oceans.

Number and Topic:	**17. Water, Aqueous Solutions**
Source:	*ChemMatters*, Dec. 1993, pp.6-9, “Microwaves”
Type of Material:	Student Journal Article
Building on:	Electromagnetic spectrum, molecular polarity
Leading to:	Molecular motions (rotation of molecules)
Links to Physics:	Electromagnetic spectrum
Links to Biology:	Organic structures found in foods
Good Stories:	Exposes many of the common myths that surround microwave ovens (they cause cancer), but at the same time explains some things that might be surprising to both us and our students, such as the fact that some people can hear microwaves and the fact that they can turn low-grade oil into high-grade oil.
Activity Description:	Article discusses what microwaves are, how a microwave oven works, how microwaves manage to heat food, and why microwaves interact with polar molecules.

Number and Topic:	**17. Water, Aqueous Solutions**
Source:	*ChemMatters*, Oct. 1992, pp.4-7, “Survival at Sea”
Type of Material:	Student Journal Article
Building on:	Water and solutions
Leading to:	Osmosis, reverse osmosis
Links to Physics:	
Links to Biology:	Discusses the role of water in the human body and the effects of lack of water on human physiology.
Good Stories:	Relates the story of the ship the HMS Bounty, and explains how Captain Bligh and all but one of 18 loyal sailors managed to survive 48 days at sea after the mutiny.
Activity Description:	Article discusses the role of water on human physiology and how pure water can be obtained from sea water by utilizing reverse osmosis.

Number and Topic:	**17. Water, Aqueous Solutions** **21. Organic Chemistry**
Source:	*ChemMatters*, Feb. 1992, pp. 8-11, “Perfume”
Type of Material:	Student Journal Article
Building on:	Solutions
Leading to:	Solubility—“like dissolves like”
Links to Physics:	
Links to Biology:	How odors and other types of sensory input are interpreted by the human brain.
Good Stories:	History of perfumes and how much of the cost of a typical perfume actually is related to the perfume itself and how much is related to packaging and advertising.
Activity Description:	Article describes the history of perfumes, what they contain, and how they

are typically prepared.

Number and Topic: **17. Water, Aqueous Solutions**
21. Organic Chemistry
Source: *ChemMatters*, Dec. 1991, pp. 4-7, "Peanut Brittle"
Type of Material: Student Journal Article and Activity
Building on: Chemical Reactions, Solubility
Leading to: Supersaturated solutions, amorphous solids, organic compounds and reactions
Links to Physics:
Links to Biology:
Good Stories:
Activity Description: Article describes what peanut brittle is, how it is made, the chemical reactions involved, and its structure. After the formal article there is a student activity to make peanut brittle.

Number and Topic: **19. Equilibrium**
21. Organic Chemistry
Source: *ChemMatters*, April 1988, pp.4-7. "Fossil Molecules"
Type of Material: Student Journal Article
Building on: Basic chemical knowledge
Leading to: Hydrogen bonds, organic chemistry, use of radioactive tracers
Links to Physics:
Links to Biology: Evolution, collagen, antibodies, amino acids, proteins
Good Stories: The Piltdown Man hoax
Activity Description: Article discusses how antibody binding to proteins can be used to identify and characterize different kinds of fossils.

Number and Topic: **20. Acid/Bases/pH**
21. Organic Chemistry
Source: *ChemMatters*, Dec. 1993, pp.4-5, "Carnivorous Plants"
Type of Material: Student Journal Article
Building on: Chemical names and formulas
Leading to: Organic structures, enzymes, proteins, acids, pH
Links to Physics:
Links to Biology: Plants, enzymes, DNA, evolution, diversity, adaptations, food
Good Stories: Relates the myriad different ways by which about 500 species of plants consumes insects and animals for food.
Activity Description: Although this is a biology topic, the article contains a fairly significant amount of chemistry relating to enzymes, proteins, pH and other topics.

Number and Topic: **21. Organic Chemistry**

Source: *ChemMatters*, Feb. 2001, pp. 10-11, "Spider Silk: Spinning a Strong Thread"
Type of Material: Student Journal Article
Building on: Basic chemical structures
Leading to: Protein synthesis
Links to Physics: Motion and forces
Links to Biology: Amino acids, proteins, adaptations, evolution, behavior—several strong links, including gene manipulation
Good Stories: Spider silk genes have been implanted into goats so proteins used to make spider silk can be recovered from their milk.
Activity Description: A description of the remarkable properties of spider silk and current efforts to obtain this amazing material in larger quantities than can be obtained from spiders themselves

Number and Topic: 16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
17. Water, Aqueous Solutions
21. Organic Chemistry
Source: *ChemMatters*, April 1997, pp. 4-7, "Lava Lite: A Chemical Juggling Act"
Type of Material: Student Journal Article
Building on: Polar and nonpolar bonds and compounds, "like dissolves like"
Leading to: Organic molecules and their structures
Links to Physics:
Links to Biology:
Good Stories: Tells story of the invention of the lava lamp and its high popularity during the "Age of Aquarius" 1960s. A highly guarded secret, the composition of the materials inside the lamp were determined when an alcoholic drank a lamp's contents and the composition of the contents needed to be ascertained in order to save the man's life.
Activity Description: Article describes the structure of lava lamps and how their operation is related to the molecular structures and densities of the materials inside the lamp.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, Oct. 1999, pp. 7-8, "Fabric of Steel"
Type of Material: Student Journal Article
Building on: Organic chemistry
Leading to: Polymers, liquid crystals
Links to Physics: Motion and forces
Links to Biology:
Good Stories:
Activity Description: Article describes what Kevlar is, how it is made, and how it operates when it stops a bullet that strikes a bulletproof vest.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, April 1998, pp. 10-12, "Sizing up Paper"
Type of Material: Student Journal Article
Building on: Student's personal experience with different kinds of paper
Leading to: Organic chemistry, pH
Links to Physics:
Links to Biology:
Good Stories:
Activity Description: Article discusses different kinds of paper, how they differ in their absorbency, and how this is controlled. There are a lot of organic structures presented in the article as well as a discussion of pH and how it affects the lifespan of a paper document.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, Feb. 1998, p. 12, "A Successful Failure"
Type of Material: Student Journal Article
Building on: Organic Chemistry
Leading to: Discussion of elastomers and dilatancy
Links to Physics:
Links to Biology:
Good Stories: Entire article is the fascinating story of how the material from which Silly Putty is made was considered to have absolutely no practical use, eventually because a very popular "toy," earning hundreds of millions of dollars for the person who purchased the rights to the product.
Activity Description: Article not only tells the human side of the Silly Putty story, but also discusses how it is made and some of its properties.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, Dec. 1996, pp. 6-8, "Mouthwash: What's in it for You?"
Type of Material: Student Journal Article
Building on: Organic chemistry
Leading to: Discussion of the action of difference chemicals on bacteria
Links to Physics:
Links to Biology: Bacteria
Good Stories:
Activity Description: Article discusses difference types of mouthwashes, the different kinds of chemicals they contain, and their modes of operation at reducing plaque formation and bad breath.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, April 1996, pp. 9-11, "Plants Fight Back"
Type of Material: Student Journal Article
Building on: Organic Chemistry

Leading to: Biological adaptations using organic molecules
Links to Physics:
Links to Biology: Plants, adaptations,
Good Stories: Entire article is a story.
Activity Description: Article discusses how plants utilize various organic molecules as natural defense mechanisms against the onslaught of different types of insects.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, Feb. 1993, pp. 4-7, "Aspirin"
Type of Material: Student Journal Article
Building on: Organic structures
Leading to: Synthesis of aspirin
Links to Physics:
Links to Biology: Discusses action of aspirin on production of protaglandins
Good Stories: History of the creation of modern aspirin
Activity Description: Article relates the history of the use of salicylates to reduce fever and pain and how these natural compounds were modified to produce modern aspirin. It goes on to explain the mechanism by which aspirin works along with some dangers that are associated with its use.

Number and Topic: 21. Organic Chemistry,
Source: *ChemMatters*, Oct. 1988, pp. 4-8, "Killing for Oil"
Type of Material: Student Journal Article
Building on: Density
Leading to: Organic chemistry
Links to Physics: Density
Links to Biology: The internal processes that allow a sperm whale to remain neutrally buoyant
Good Stories: History of the hunting of sperm whales and efforts to protect them
Activity Description: Article discusses the rather unique substances that are found within the sperm whale, the properties, high value and uses of these substances as well as their specific molecular structures.

Number and Topic: 21. Organic Chemistry
22. Redox/Electrochemistry
Source: *ChemMatters*, Oct. 1988, pp.9-13, "The Smell of Danger"
Type of Material: Student Journal Article
Building on: Chemical reactions, molecular structures
Leading to: Organic chemistry
Links to Physics:
Links to Biology: Anosmia—the inability to detect odors
Good Stories: How propane stored in tanks can lose its ethyl mercaptan odor and thus not protect people in the event of a leak.

Activity Description: The article deals with the addition of mercaptans to propane so as to provide the gas with an odor that can be detected in the event of a gas leak and how and why these mercaptans can be destroyed by reactions that may occur within the storage tank.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, Oct. 1987, pp. 4-9, "Zombies"
Type of Material: Student Journal Article
Building on: Basic chemical and biological knowledge
Leading to: Structures and biological effects of certain organic molecules
Links to Physics:
Links to Biology: The effect of tetrodotoxin, a poison contained in the Puffer fish with a toxicity greater than 1000 times that of cyanide, and how it plays a key role in the creation of "zombies." It also deals with the effects of bufotoxin, a toxic material found in some toads. In discussing the effects of theses types of substances the article delves into the mechanisms of several bodily functions and organs.
Good Stories: How a person who was declared clinically dead returned eighteen years later, having been transformed into a "zombie" by drugs and forced to work as a slave for that entire time.
Activity Description: This article covers the myth of "zombies," the creation of actual "zombies" in Haitian society and the chemical and biological mechanisms that underlie such a transformation.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, April 1987, pp. 10-12, "Penicillin"
Type of Material: Student Journal Article
Building on: Basic chemical knowledge
Leading to: Organic structures and syntheses
Links to Physics:
Links to Biology: How penicillin destroys bacteria by preventing the formation of their cellular walls
Good Stories: How penicillin was discovered many years before any attempt was made to develop it for use.
Activity Description: Article discusses the discovery of penicillin and the attempts made to synthesize it in the laboratory so sufficient quantities could be manufactured.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, Dec. 1986, pp. 4-8, 12, "Natural Dyes"
Type of Material: Student Journal Article and Activity
Building on: Basic chemical knowledge, chemical formulas
Leading to: Organic functional groups, chromophores, mordants

Links to Physics:
Links to Biology: How various insects, plants and mollusks have been used to make dyes over the centuries.
Good Stories: The history of dyes.
Activity Description: Article discusses the history of dyes from as far back as 180,000 BC. It then discusses several common dyes and how they work, going into fairly high detail about their structures and functional groups.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, April 1986, pp. 12-14, “Polysaccharides”
Type of Material: Student Journal Article
Building on: Basic chemical knowledge
Leading to: Viscosity, the structure of polysaccharides
Links to Physics:
Links to Biology: The presence of polysaccharides in natural substances
Good Stories:
Activity Description: This article discusses common polysaccharides, both natural and artificial. It presents many of their structures, sources, and uses.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, Feb. 1985, pp. 8-11, “Alcohol”
Type of Material: Student Journal Article
Building on: Basic chemical knowledge
Leading to: Organic structures and reactions
Links to Physics:
Links to Biology: How the body metabolizes alcohol, Krebs cycle
Good Stories:
Activity Description: This article discusses the chemical reactions that occur in the human body when we consume alcohol. It goes on to state some of the effects of blood alcohol levels on car accident rates and the effects of alcoholism.

Number and Topic: 21. Organic Chemistry
Source: *ChemMatters*, Dec. 1984, pp. 4-9, “Egg Cookery”
Type of Material: Student Journal Article and Activity
Building on: Basic chemical knowledge
Leading to: Organic reactions and structures of proteins
Links to Physics:
Links to Biology: Composition and structure of eggs, lysozymes
Good Stories: Why eggshells tend to crack when boiled.
Activity Description: This article discusses the structure and composition of eggs and goes on to discuss what happens when eggs are boiled, poached or fried. It is followed by a student activity relating to the effect of acid on eggs.

Number and Topic:	**8. Chemical Reactions** **11. Thermochemistry** **22. Redox/Electrochemistry**
Source:	*ChemMatters*, April 1997, pp. 11-13, “Fire in the Hold”
Type of Material:	Student Journal Article
Building on:	Chemical reactions
Leading to:	Oxidation-reduction, Reaction Rates
Links to Physics:	
Links to Biology:	
Good Stories:	Tells of the explosion of a Turkish ship in 1996 that was caused by unintended oxidation of porous iron pellets stored.
Activity Description:	Article explains the scientific principles that resulted in the spontaneous oxidation of the iron pellets—for example, the large surface area that was exposed because of the porous nature of the particles.

Flinn ChemTopic Laboratory Manuals

Flinn Scientific wrote, with the help of seven teachers, a series of 28 ChemTopic Laboratory Manuals for high school chemistry. These lab manuals are written for teachers and each one includes 4-6 labs, 4-5 demos and lots of teacher tips on how to perform the labs and better teach the subject. They are organized around key content areas in the chemistry curriculum. They emphasize key concepts that teachers need to cover and also common student misconceptions. In addition, they indicate where students normally mess up the lab. (This may be the most important part!)

The labs are of varied forms and use many of the current innovations in high school teaching. They include microscale labs, use of technology (including interfacing with computers) and discovery-based labs. All labs include upfront advice on safety and disposal techniques, a topic sorely lacking in many lab books.

The seven teachers provided their best labs, ones that are well used and student tested. Flinn selected the best, edited them, and gave them back to the teachers to add final comments. The teachers who were involved (Full disclosure – I (Lee Marek) am one of the seven.) were:
Bob Becker, Kirkwood High School, Kirkwood, MO
Kathleen J. Dombrink, McCluer North High School, Florissant, MO
Robert Lewis, Downers Grove North High Schol, Downers Grove, IL
John G. Little, St. Mary's High School, Stockton, CA
Lee Marek, Naperville North High School, Naperville, IL
John Mauch, Braintree High School, Braintree, MA
Dave Tanis, Grand Valley State University, Allendale, MI

Twenty-two Flinn ChemTopic Lab Books will be produced eventually. From the ones available to date, the following have been indexed for ARISE:
Reference: Flinn *ChemTopic*™ Lab Manuals <www.flinnsci.com/homepage/jindex.html>

Book #1	Introduction to Chemistry
Book #3	Atomic and Electron Structure
Book #4	The Periodic Table
Book #7	Molar Relationships and Stoichiometry
Book #8	Chemistry of Gases
Book #9	The Gas Laws

Book #10	Thermochemistry
Book #12	Solubility and Solutions
Book #13	Acids and Bases
Book #14	Kinetics
Book #15	Equilibrium
Book #20	Biochemistry – The Molecules of Life
Book #23	Chemistry of Food

Flinn ChemTopic labs – titles only, listed by curriculum area.

1. **Matter and Change**
   Demo: Acid in the Eye – Safety
   Demo: A Burning Candle - Observations
   Demo: Classifying Matter
   Demo: Flaming Vapor Ramp—Safety Demo
   Lab: Observation and Experiment - Introduction to the Scientific Method
   Lab: Separation of a Mixture - Percent Composition
   Lab: What is a Chemical Reaction - Evidence of Change
   Lab: Common Gases—Physical and Chemical Properties
   Lab: Preparing and Testing Hydrogen Gas—A Microscale Approach
   Lab: Carbon Dioxide - What a Gas—Microscale Gas Chemistry

2. **Measurement**
   Activity: Cartesian Divers: Squeeze Play
   Activity: How Dense is It?
   Demo: Mass vs. Density
   Demo: Reading Volumes - Sig. Figs.
   Demo: Mapping Atomic Structure—Building a Scale Model
   Lab: Beverage Density Lab - Sugar Content Analysis
   Lab: Discovering Density - Looking for Patterns and Trends
   Lab: Introduction to Measurement
   Lab: Measurement and Uncertainty
   Lab: Purifying Foul Water (with an inquiry twist)
   Lab: Searching for the Copper Ion
   Lab: What is a Chemical Reaction - Evidence of Change
   Lab: Oxygen - What a Flame—Microscale Gas Chemistry

3. **Problem Solving**
   Activity: Rate of energy release by a Bunsen burner, an electric hotplate and a microwave oven
   Demo: How Big is a Mole? - Imagining the Mole Activities
   Demo: Mole Samples and Molar Mass - Authentic Assessment
   Demo: Stoichiometry and Solubility - Mole Ratios and Chemical Formulas
   Demo: Stoichiometry Balloon Race - Limiting and Excess Reagents
   Demo: Massing Gases—Avogadro's Law
   Demo: Molar Mass of Butane—Ideal Gas Law
   Lab: Boyle's Law in a Bottle—Pressure versus Volume
   Lab: Charles's Law and Absolute Zero—How Low Can You Go?
   Lab: Molar Volume of Hydrogen—Combining the Gas Laws
   Lab: Technology and the Forgotten Gas Law—Pressure versus Temperature
   Webpage: Learning Stoichiometry

4. **Atomic Structure**
   Activity: Quantum Numbers (with an inquiry twist)
   Demo: The Think Tube—A Black-Box Demonstration
   Demo: Energy in Photons—Light Energy Demonstration
   Demo: The Photoelectric Effect–Light Energy Demonstration
   Demo: Measuring the Size of a Molecule
   Demo: Mapping Atomic Structure—Building a Scale Model
   Demo: Excited States—A Musical Demonstration
   Lab/ Activity: Bean Bag Isotopes—Relative Abundance and Atomic Mass
   Lab/Activity: Atomic Target Practice—Rutherford Scattering and the Nuclear Atom
   Lab/Activity: Quantum Leap Lab—Probability and Electron Structure
   Lab: Flame Tests—Atomic Emission and Electron Energy Levels
   Lab: Atomic Spectra—Light, Energy, and Electron Structure
   Lab: Atomic Coatings—The Size of an Atom

5. **Radioactivity, Fusion, Fission**
   Computer Lab: Problem-Based Learning with the PAX Nuclear Reactor
   Lab: Alpha, Beta and Gamma Radiation

6. **Chemical Names and Formulas/Compounds and Elements**
   Activity: Breakfast of Crystals
   Activity: Buckyballs
   Activity: Carbon Dioxide: A Pourable Greenhouse Gas
   Activity: Iron for Breakfast
   Activity: Making Ice Cream
   Demo: Stoichiometry and Solubility - Mole Ratios and Chemical Formulas
   Lab: Determining a Molecular Formula
   Lab: Formula of a Blue Hydrate
   Lab: Magnesium Oxide - Percent Composition and Empirical Formula
   Lab: What is the Copper Formula?

7. **Moles**
   Demo: Conceptual Understanding of Moles
   Demo: How Big is a Mole? - Imagining the Mole Activities
   Demo: Mole Creativity - Make-a-Mole Pattern
   Demo: Mole Samples and Molar Mass - Authentic Assessment
   Demo: Stoichiometry and Solubility - Mole Ratios and Chemical Formulas
   Demo: Stoichiometry Balloon Race - Limiting and Excess Reagents
   Lab: Decomposition of Sodium Chlorate - Mass, Moles and the Chemical Equation
   Lab: Determining a Molecular Formula
   Lab: Formula of a Blue Hydrate
   Lab: Magnesium Oxide - Percent Composition and Empirical Formula
   Lab: Micro Mole Rockets - Hydrogen and Oxygen Mole Ratio
   Lab: Mole Ratios - Copper and Silver Nitrate
   Lab: Who's Counting? - Atoms, Mass and Moles
   Webpage: Learning Stoichiometry

8. **Chemical Reaction**

Activity: Carbon Dioxide: A Pourable Greenhouse Gas
Activity: Dissolving Plastic
Activity: Hot and Cold Packs
Activity: Iron for Breakfast
Activity: Saint's Blood
Activity: Soap
Demo: Buffer Balancing Acts
Demo: The Cool [Endothermic] Reaction
Demo: Flameless Ration Heaters - Applied Chemistry
Demo: Periodic Activity of Metals
Demo: The Pink Catalyst
Demo: The Rainbow Tube
Demo: Safe Swimming with Sodium
Demo: Stoichiometry and Solubility - Mole Ratios and Chemical Formulas
Demo: Stoichiometry Balloon Race - Limiting and Excess Reagents
Demo: Strong vs. Weak Acids
Demo: Sudsy Kinetics - Old Foamey
Demo: Upset Tummy? MOM to the Rescue - Colorful Antacid
Demo: Whoosh Bottle Reaction
Demo: Underwater Fireworks
Demo: Collecting Gases by Water Displacement
Demo: Nails for Breakfast—Food Additive Demonstration
Demo: Iodized Salt—Food Additive Demonstration
Lab: All in the Family - The Halogens and Their Compounds
Lab: Buffers Keep the Balance - Biological Buffers
Lab: Classic Titration - pH Curves and an Unknown
Lab: Decomposition of Sodium Chlorate - Mass, Moles and the Chemical Equation
Lab: Oxygen - What a Flame—Microscale Gas Chemistry
Lab: Common Gases—Physical and Chemical Properties
Lab: Heats of Reaction and Hess's Law - Small-Scale Calorimetry
Lab: Identifying Chemical Activity
Lab: Measuring Acid Strength - K_a Values of Weak Acids
Lab: Measuring Calories - Energy Content of Food
Lab: Micro Mole Rockets - Hydrogen and Oxygen Mole Ratio
Lab: Microscale Titration Percent Acetic Acid in Vinegar
Lab: Mole Ratios - Copper and Silver Nitrate
Lab: Periodic Trends and the Properties of Elements - Alkaline Earth Metals
Lab: The Nature of a Chemical Reaction
Lab: Preparing and Testing Hydrogen Gas—A Microscale Approach
Lab: Carbon Dioxide - What a Gas—Microscale Gas Chemistry
Lab: Molar Volume of Hydrogen—Combining the Gas Laws
Lab: Food Testing Lab—Carbohydrates, Proteins, and Fats
Lab: Milk Is a Natural—Biology, Chemistry, and Nutrition
Lab: Vitamin C Analysis—Fruits and Fruit Juices

Lab: Total Acidity—Titration of Fruit Juices

9. Stoichiometry

Demo: Stoichiometry and Solubility - Mole Ratios and Chemical Formulas
Demo: Stoichiometry Balloon Race - Limiting and Excess Reagents
Lab: Cu Again! - A Copper Cycle
Lab: Decomposition of Sodium Chlorate - Mass, Moles and the Chemical Equation
Lab: Magnesium Oxide - Percent Composition and Empirical Formula
Lab: Mole Ratios - Copper and Silver Nitrate
Lab: Micro Mole Rockets - Hydrogen and Oxygen Mole Ratio
Lab: Who's Counting? - Atoms, Mass and Moles
Lab: Molar Volume of Hydrogen—Combining the Gas Laws
Webpage: Learning Stoichiometry

10. Phases, Solids, Liquids and Gases (States of Matter)

Activity: Breakfast of Crystals
Activity: Hot and Cold Packs
Activity: How Dense is It?
Activity: Making Ice Cream
Activity: Saint's Blood
Demo: Aloha Chemical Sunset—Colloids and Light Scattering
Demo: Solutions, Colloids, and Suspensions—Principles and Properties
Lab: Energy Changes - Heat of Fusion
Lab: Heat of Vaporization of Liquid Nitrogen
Lab: Separation by Distillation

11.Thermochemistry

Activity: Hot and Cold Packs
Demo: Colorful Heat - Temperature vs. Heat
Demo: The Cool [Endothermic] Reaction
Demo: Flameless Ration Heaters - Applied Chemistry
Demo: Specific Heat
Demo: Whoosh Bottle Reaction
Demo: Alka-Seltzer® and Gas Solubility—Effect of Temperature
Demo: Instant Hand Warmers—Supersaturated and Saturated Solutions
Lab: Discovering Instant Cold Packs - Heat of Solution
Lab: Energy Changes - Heat of Fusion
Lab: Exploring Energy Changes - Exothermic and Endothermic Reactions
Lab: Heats of Reaction and Hess's Law - Small-Scale Calorimetry
Lab: Measuring Calories - Energy Content of Food
Lab: Restoring Balance - LeChatelier's Principle and Equilibrium
Lab: Temperature and Reaction Rates - An Inquiry-Based Approach

12. Gases/Gas Laws/Kinetic Theory

Activity: Carbon Dioxide: A Pourable Greenhouse Gas

Activity: Cartesian Divers: Squeeze Play
Activity: Popcorn
Activity: Construction of Gas Volume Cubes—Assessment Activity
Activity: Try It! Make Your Own Hot Air Balloon
Demo: Equilibrium in a Syringe
Demo: Collecting Gases by Water Displacement
Demo: Molar Mass of Butane—Ideal Gas Law
Demo: Diffusion of Gases—Kinetic Energy
Demo/Activity: Cartesian Divers—Boyle's Law Activity
Demo: The Collapsing Can—Pressure Is a Force
Demo: Massing Gases—Avogadro's Law
Lab: Gas Phase Equilibrium - Pressure and Temperature
Lab: Common Gases—Physical and Chemical Properties
Lab: Boyle's Law in a Bottle—Pressure versus Volume
Lab: Charles's Law and Absolute Zero—How Low Can You Go?
Lab: Molar Volume of Hydrogen—Combining the Gas Laws
Lab: Technology and the Forgotten Gas Law—Pressure versus Temperature
Lab: Life on Planet V—A Classroom Activity

13. Electrons in Atoms

Activity: Iron for Breakfast
Demo: The Think Tube—A Black-Box Demonstration
Demo: Energy in Photons—Light Energy Demonstration
Demo: The Photoelectric Effect—Light Energy Demonstration
Demo: Measuring the Size of a Molecule
Demo: Mapping Atomic Structure—Building a Scale Model
Demo: Excited States—A Musical Demonstration
Lab/Activity: Quantum Leap Lab—Probability and Electron Structure
Lab: Flame Tests—Atomic Emission and Electron Energy Levels
Lab: Atomic Spectra—Light, Energy, and Electron Structure
Lab: Atomic Coatings—The Size of an Atom
Project-based learning activity: Alternatives for Producing Electrical Energy: - Student Generated Infomercials

14. Periodicity/Periodic Law/Metals, Non-metals and Families

Activity: Secret Agents
Demo: Periodic Activity of Metals
Demo: Plotting Trends - A Periodic Table Activity
Demo: Safe Swimming with Sodium
Demo: Solubility Patterns
Lab: All in the Family - The Halogens and Their Compounds
Lab: Density is a Periodic Property - Discovering an Element
Lab: Identifying Chemical Activity
Lab: It's in the Cards - Discovering the Periodic Law

Lab and Demo: It’s in the Cards - Investigating Patterns
Lab: Metal or Non-Metal?
Lab: Periodic Trends and the Properties of Elements - Alkaline Earth Metals

15. Ionic and Metallic Bonds
Activity: Breakfast of Crystals
Demo: Membrane Diffusion and Dialysis
Demo: Sorting Out Solutions—Hydrogen Bonding Demonstration
Lab: Discovering Instant Cold Packs - Heat of Solution
Lab: Heats of Reaction and Hess’s Law - Small-Scale Calorimetry
Lab: Measuring Calories - Energy Content of Food
Lab: The Identification of Ions
Lab: Factors Affecting Solution Formation—An Inquiry-Based Approach
Lab: It’s in Their Nature—Solute–Solvent Interactions
Lab: Solubility and Temperature—A Solubility Curve
Lab: Freezing Point Depression—How Low Can You Go?

16. Covalent Bonds, Molecular Shapes and Intermolecular Forces
Activity: Artificial Sweeteners
Activity: Buckyballs
Activity: Soap
Demo: Membrane Diffusion and Dialysis
Demo: Flaming Vapor Ramp—Safety Demo
Demo: The Power of Cheese—Cheese-making Demonstration
Demo: Everyone Screams for Ice Cream—Food Demonstration
Demo: Sorting Out Solutions—Hydrogen Bonding Demonstration
Lab: Identifying Proteins and Amino Acids
Lab: Introduction to Carbohydrates - Structure and Properties
Lab: Physical Properties of Proteins
Lab: Properties of Lipids
Lab: Food Testing Lab—Carbohydrates, Proteins, and Fats
Lab: Milk Is a Natural—Biology, Chemistry, and Nutrition
Lab: Boning Up on Calcium—Microscale Analysis of Calcium in Milk
Lab: Vitamin C Analysis—Fruits and Fruit Juices
Lab: It’s in Their Nature—Solute–Solvent Interactions
Lab: Solubility and Temperature—A Solubility Curve
Lab: Freezing Point Depression—How Low Can You Go?

17. Water, Aqueous Solutions
Activity: Hot and Cold Packs
Activity: How Many Ways Can You See Red
Activity: Iron for Breakfast
Activity: Kidney Dialysis. A Working Model You Can Make
Activity: Making Ice Cream
Activity: Peanut Brittle
Activity: Soap

Activity: Super Soakers. Just How Super Are They?
Demo: Membrane Diffusion and Dialysis
Demo: pH and Protein Solubility
Demo: Iodized Salt—Food Additive Demonstration
Demo: Everyone Screams for Ice Cream—Food Demonstration
Demo: Aloha Chemical Sunset—Colloids and Light Scattering
Demo: Solutions, Colloids, and Suspensions—Principles and Properties
Demo: Alka-Seltzer® and Gas Solubility—Effect of Temperature
Demo: Sorting Out Solutions—Hydrogen Bonding Demonstration
Demo: Instant Hand Warmers—Supersaturated and Saturated Solutions
Lab: Discovering Instant Cold Packs - Heat of Solution
Lab: Purifying Foul Water (with an inquiry twist)
Lab: The Ion Exchange (Which Salts are Soluble?)
Lab: Water Quality
Lab: Factors Affecting Solution Formation—An Inquiry-Based Approach
Lab: It's in Their Nature—Solute–Solvent Interactions
Lab: Solubility and Temperature—A Solubility Curve
Lab: Preparing and Diluting Solutions—Concentration and Absorbance
Lab: Freezing Point Depression—How Low Can You Go?

18. Reaction Rates and Kinetics

Activity: Iron for Breakfast
Demo: The Floating Catalyst - An Enzyme Reaction
Demo: The Iodine Clock Reaction (with an inquiry twist)
Demo: Iodine Clock Reaction - Effect of Concentration, Temperature, and a Catalyst
Demo: Now You See It, Now You Don't - Oscillating Chemical Reaction
Demo: The Pink Catalyst
Demo: A Simple Catalyst Demo
Demo: Sudsy Kinetics - Old Foamey
Demo: The Power of Cheese—Cheese-making Demonstration
Demo: Microbial Madness in Milk—Food Safety Demonstration
Lab: Determining the Rate Law - A "Sulfur Clock" Reaction
Lab: Introduction to Reaction Rates - The "Blue Bottle" Reaction
Lab: Kinetics: A Study of Reaction Rates
Lab: Kinetics of Dye Fading
Lab: The Order of Reaction Effect of Concentration
Lab: Temperature and Reaction Rates - An Inquiry-Based Approach

19. Equilibrium

Demo: Equilibrium in a Syringe
Demo: Equilibrium Water Games - A Classroom Activity
Demo: An Overhead Equilibrium
Demo: Pink and Blue - A Colorful Chemical Balancing Act
Demo: Thionin—The Two-Faced Solution
Demo: Alka-Seltzer® and Gas Solubility—Effect of Temperature
Demo: Instant Hand Warmers—Supersaturated and Saturated Solutions

Lab: The Equilibrium Constant for a Complex Ion Formation
Lab: Disturbing an Equilibrium System
Lab: Exploring Equilibrium - It Works Both Ways
Lab: Gas Phase Equilibrium - Pressure and Temperature
Lab: Measuring Acid Strength - K_a Values of Weak Acids
Lab: Penny-Ante Equilibrium - A Classroom Activity
Lab: Restoring Balance - LeChatelier's Principle and Equilibrium

20. Acid/Bases/pH
Demo: Buffer Balancing Acts
Demo: Glucose Fermentation and Metabolism
Demo: Indicator Sponge - A Discrepant Event
Demo: Periodic Activity of Metals
Demo: pH and Protein Solubility
Demo: The Rainbow Tube
Demo: Safe Swimming with Sodium
Demo: Strong vs. Weak Acids
Demo: Thionin—The Two-Faced Solution
Demo: The Collapsing Bottle
Demo: Upset Tummy? MOM to the Rescue - Colorful Antacid
Demo: Solubility of Carbon Dioxide—The Dry Ice Color Show
Demo: Solubility of Ammonia—Indicator Color Show
Demo: The Power of Cheese—Cheese-making Demonstration
Demo: Nails for Breakfast—Food Additive Demonstration
Lab: Buffers Keep the Balance - Biological Buffers
Lab: Exploring Equilibrium - It Works Both Ways
Lab: How Bonding Affects Acidity
Lab: Measuring Acid Strength - K_a Values of Weak Acids
Lab: Microscale Titration Percent Acetic Acid in Vinegar
Lab: Natural Indicators - Acids, Bases, and the pH Scale
Lab: pH of Familiar Products.
Lab: Physical Properties of Proteins
Lab: Properties of Acids and Bases - Identification and Classification
Lab: Carbon Dioxide - What a Gas—Microscale Gas Chemistry
Lab: Food Testing Lab—Carbohydrates, Proteins, and Fats
Lab: Milk Is a Natural—Biology, Chemistry, and Nutrition
Lab: Vitamin C Analysis—Fruits and Fruit Juices
Lab: Total Acidity—Titration of Fruit Juices

21. Organic Chemistry
Activity: Artificial Sweeteners
Activity: Dissolving Plastic
Activity: Egg Cookery
Activity: Making Ice Cream
Activity: Natural Dyes
Activity: Peanut Brittle

Activity: Soap
Demo: Amino Acid Fingerprints - Ninhydrin
Demo: Glucose Fermentation and Metabolism
Demo: Lactose Intolerance - Enzyme Digestion
Demo: Membrane Diffusion and Dialysis
Demo: pH and Protein Solubility
Demo: Underwater Fireworks
Demo: Microbial Madness in Milk—Food Safety Demonstration
Demo: The Power of Cheese—Cheese-making Demonstration
Demo: Iodized Salt—Food Additive Demonstration
Lab: Identifying Proteins and Amino Acids
Lab: Introduction to Carbohydrates - Structure and Properties
Lab: Physical Properties of Proteins
Lab: Properties of Lipids
Lab: Soaps vs. Detergents
Lab: Milk Is a Natural—Biology, Chemistry, and Nutrition
Lab: Boning Up on Calcium—Microscale Analysis of Calcium in Milk
Lab: Vitamin C Analysis—Fruits and Fruit Juices
Lab: Total Acidity—Titration of Fruit Juices
Lab: It's in Their Nature—Solute–Solvent Interactions

22. Redox/Electrochemistry

Activity: Iron for Breakfast
Demo: Glucose Fermentation and Metabolism
Demo: Thionin—The Two-
Demo: Microbial Madness in Milk—Food Safety Demonstration Faced Solution
Demo: Underwater Fireworks
Demo: Nails for Breakfast—Food Additive Demonstration
Demo: Iodized Salt—Food Additive Demonstration
Lab: How to Copper Plate Your Car Keys
Lab: Introduction to Carbohydrates - Structure and Properties
Lab: Introduction to Reaction Rates - The "Blue Bottle" Reaction
Lab: Oxygen - What a Flame—Microscale Gas Chemistry
Lab: Food Testing Lab—Carbohydrates, Proteins, and Fats
Lab: Milk Is a Natural—Biology, Chemistry, and Nutrition
Lab: Vitamin C Analysis—Fruits and Fruit Juices

Flinn ChemTopic labs – summary of each lab with index to curriculum.

Number and Topic: 1. Matter and Change (Classification of Matter)
Source: Flinn ChemTopic Lab Book #1 - Introduction to Chemistry
Type of Material: Lab: Observation and Experiment - Introduction to the Scientific Method
Building on: Scientific method
Leading to: Observation and experiment
Links to Physics: Physics will have covered this, but here it is from a chemical basis.
Links to Biology: CO_2 gas given up in respiration
Good Stories: This is a discovery lab.
Activity Description: This lab shows that the scientific method is really nothing more than a method of discovery, a way of arriving at knowledge; not some rigid set of rules in a book.

Number and Topic: 2. Measurement
Source: Flinn ChemTopic Lab Book #1 - Introduction to Chemistry
Type of Material: Lab: Introduction to Measurement
Building on: Measurement
Leading to: Metric system, accuracy and precision
Links to Physics: Significant figures and experimental error
Links to Biology: To take good measurements and understand data one needs these skills
Good Stories: It was Lord Kelvin who said:

> I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginnings of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be.

Activity Description: This lab uses the measurement/metric system to learn about significant figures, accuracy and precision and experimental error.

Number and Topic: 2. Measurement
Source: Flinn ChemTopic Lab Book #1 - Introduction to Chemistry
Type of Material: Lab: Discovering Density - Looking for Patterns and Trends
Building on: Measurement, graphing, math relationships
Leading to: Metric system, accuracy and precision. To take good measurements and understand data one needs these skills. Interpreting data and graphs are one of the hardest things for kids to do but also one of the most tested on

	state and national exams. The relationship with algebra is made by the calculation of the slope of the graph.
Links to Physics:	Density, water displacement, mass, and volume
Links to Biology:	Ice/water densities and ocean currents. Marine environments. Gas densities and atmospheric pressure.
Good Stories:	Archimedes and the king's gold crown
Activity Description:	This lab uses the density to learn about accuracy, precision, experimental error, patterns/trends and relationships in data.

Number and Topic:	**2. Measurement**
Source:	Flinn ChemTopic Lab Book #1 - Introduction to Chemistry
Type of Material:	Lab: Beverage Density Lab - Sugar Content Analysis
Building on:	Measurement, graphing, math relationships, and pipeting
Leading to:	Calibration curves, concentration and solutions.
Links to Physics:	Density, mass, volume, buoyancy
Links to Biology:	Sugars, electrolytes.
Good Stories:	How much sugar is in soda/pop?
Activity Description:	This lab uses the density to learn about calibration curves, concentration, and solutions.

Number and Topic:	**1. Matter and Change** (Classification of Matter)
Source:	Flinn ChemTopic Lab Book #1 - Introduction to Chemistry
Type of Material:	Lab: Separation of a Mixture - Percent Composition
Building on:	Mixtures, pure substances and physical change
Leading to:	Percent yield and percent composition
Links to Physics:	Physical properties matter
Links to Biology:	Separation techniques
Good Stories:	Anaxagoras, circa 450 B.C. said: "Wrongly do the Greeks suppose that aught begins or ceases to be; for nothing comes into being or is destroyed; but all is an aggregation or secretion of pre-existing things; so that all becoming might more correctly be called becoming mixed, and all corruption, becoming separate."
Activity Description:	This lab uses separation techniques to learn about matter, mixtures, pure substances, and physical change.

Number and Topic:	**1. Matter and Change** (Classification of Matter) **2. Measurement**
Source:	Flinn ChemTopic Lab Book #1 - Introduction to Chemistry
Type of Material:	Lab: What is a Chemical Reaction - Evidence of Change
Building on:	Chemical reactions, chemical change and chemical properties
Leading to:	Conservation of mass
Links to Physics:	Conservation of mass
Links to Biology:	Biological systems really involve a system of chemical changes.

Good Stories: The French chemist Antoine Lavoisier, who lived from 1743-1794, discovered The Law of Conservation of Mass. One could go into his life and see how the French Revolution cut him short. Lavoisier was certainly not the first to accept this law as true or to teach it, but he is credited as its discoverer. So who ultimately gets credit for a law and the fame associated with it? One could make a case for the following people to be given credit for the law of conservation of mass: Joseph Black, Joseph Priestley, or even Cavendish. "Lavoisier established a radical difference between on the one hand ponderable matter, . . . matter of which the balance proved the invariability before, during, and after combustion; and on the other hand, the igneous fluid, of which the introduction from an outside source, or the withdrawal during combustion, neither increased nor diminished the weight of substances; contrary to what the partisans of phlogiston have thought." (Joseph Priestley accepted the phlogiston theory.)

Great website: < http://www.dbhs.wvusd.k12.ca.us/webdocs/Equations/Conserv-of-Mass.html>

Activity Description: This lab uses chemical reactions to set the basis for the law of conservation of mass.

Number and Topic: **1. Matter and Change** (Classification of Matter) and Safety

Source: Flinn ChemTopic Lab Book #1 - Introduction to Chemistry

Type of Material: Demo: Acid in the Eye - Safety

Building on: Chemical reactions, chemical change, and chemical properties

Leading to: Safety Acid/Bases

Links to Physics: Safety

Links to Biology: How acids and bases can denature proteins

Good Stories: Practice safe science

Activity Description: Acids and bases are added to, and react with, eggs on an overhead projector. This shows what could happen if you get chemicals in your eye. This is a safety demo

Number and Topic:

2. Measurement

Source: Flinn ChemTopic Lab Book #1 - Introduction to Chemistry

Type of Material: Demo: Reading Volumes- Significant Figures

Building on: Measurements

Leading to: Significant figures

Links to Physics: Significant figures, accuracy, precision and uncertainty

Links to Biology: To take good measurements and understand data one needs these skills

Good Stories: It was Lord Kelvin who said:

> I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and

> unsatisfactory kind; it may be the beginnings of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be.

Activity Description: This demo uses the measurement/metric system to learn about significant figures, accuracy and precision and uncertainty.

Number and Topic: 2. Measurement
Source: Flinn ChemTopic Lab Book #1 - Introduction to Chemistry
Type of Material: Demo: Mass vs. Density
Building on: Measurements
Leading to: Density, intensive vs. extensive properties
Links to Physics: Density vs. mass
Links to Biology: Why do you float in water?
Good Stories: Will you float better in the Great Salt Lake or the Dead Sea?
Activity Description: Why do objects float or sink in terms of relative density?

Number and Topic: 1. Matter and Change (Classification of Matter) and Safety
Source: Flinn ChemTopic Lab Book #1 - Introduction to Chemistry
Type of Material: Demo: Classifying Matter
Building on: Classification of matter
Leading to: Elements, compounds, and mixtures
Links to Physics: Atoms, matter
Links to Biology: Thinking on the molecular level. It is the spatial level and the students should try to get a feel/picture of what this level is like.
Good Stories: <http://www.almaden.ibm.com/vis/index.html>
The Visualization Lab (from IBM), a collection of various activities related to Visual Computing. The projects involve animations and movies showing scanning tunneling microscopy and molecular dynamics simulations. These show the real power of the web.
Activity Description: This demo is a simulation for thinking at a molecular level about elements, compounds, and mixtures.

Number and Topic: 1. Matter and Change (Classification of Matter)
Source: Flinn ChemTopic Lab Book #1 - Introduction to Chemistry
Type of Material: Demo: A Burning Candle - Observations
Building on: Observation, scientific method
Leading to: Measurements
Links to Physics: Observation, scientific method
Links to Biology: Combustion, respiration
Good Stories: Michael Faraday - The Chemical History of a Candle - 1860

> I bring before you, in the course of these lectures, the Chemical History of a Candle.

> There is not a law under which any part of this universe is governed which does not come into play and is touched upon in these phenomena . . There is no more open door by which you can enter into the study of natural philosophy than by considering the physical phenomena of a candle.

You can download the book at <http://home.att.net/~a.caimi/faraday.html>

Activity Description: This demo helps students to develop observational skill by observing a candle burning, a classic demo.

Number and Topic: 4. Atomic Structure

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure

Type of Material: Lab/ Activity: Bean Bag Isotopes—Relative Abundance and Atomic Mass

Building on: Atomic number, neutrons, protons, electrons

Leading to: Isotopes, percent abundance, mass number, atomic mass

Links to Physics: Atoms, subatomic particles, isotopes, atomic number, neutrons, protons, electrons

Links to Biology: Tracers (radioactive isotopes) are used in medicine and food irradiation.

Good Stories: "Could anything at first sight seem more impractical than a body which is so small that its mass is an insignificant fraction of the mass of an atom of hydrogen? which itself is so small that a crowd of these atoms equal in number to the population of the whole world would be too small to have been detected by any means then known to science." J. J. Thomson, "*Cathode Rays*" (1897)

Hear J. J. Thomson describing his experiment and see how his experiment works and a video of a Crookes tube in action: <http://www.aip.org/history/electron/jjrays.htm>

Information on mass spectroscopes and how they work: <http://masspec.scripps.edu/information/intro/index.html>

The Berkeley Laboratory Isotopes Project's has a table of isotopes, uses of isotopes, etc.: <http://ie.lbl.gov/education/isotopes.htm>

Web page that defines isotope and gives simple explanation of mass spectroscopy and atomic mass: <http://www.avogadro.co.uk/definitions/isotope.htm>

Activity Description: In this activity, students investigate relative abundance of isotopes for a “bean bag” element and calculate its atomic mass.

Number and Topic: 4. Atomic Structure

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure

Type of Material: Lab/Activity: Atomic Target Practice—Rutherford Scattering and the Nuclear Atom

Building on: Models, atoms

Leading to: Atomic structure, nucleus, atomic mass, nuclear charge

Links to Physics: Atomic structure, nucleus, atomic mass, nuclear charge, forces

Links to Biology:

Good Stories: Rutherford was astonished: "It was as if you fired a 15-inch shell at a sheet of tissue paper and it came back to hit you." From these deflections he was able to calculate the size of the nucleus." Here are applets showing the experiment that was conducted in 1911 by Hans Geiger and Ernest Marsden at the suggestion of Ernest Rutherford:
<http://micro.magnet.fsu.edu/electromag/java/rutherford/>
<http://www.phys.virginia.edu/classes/109N/more_stuff/Applets/rutherford/rutherford.html>
<http://www.sci.tamucc.edu/pals/morvant/genchem/atomic/page7.htm>

Activity Description: A “black box” activity/experiment used to discover by indirect means the size and shape of an unknown object. By tracing the apparent path a marble takes after striking the unseen target from a variety of angles, students can estimate the general size and shape of the target. It is used to simulate the experiment that led to Rutherford’s model for the structure of the atom.

Number and Topic: 4. Atomic Structure
13. Electrons in Atoms

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure

Type of Material: Lab/Activity: Quantum Leap Lab—Probability and Electron Structure

Building on: Atoms, atomic structure, electrons, models,

Leading to: Quantum mechanics, electron energy levels, Heisenberg Uncertainty Principle, atomic orbitals

Links to Physics: Quantum mechanics, electron energy levels, Heisenberg Uncertainty Principle, atomic orbitals, electrons, models, subatomic particles, atoms

Links to Biology:

Good Stories: “The development of quantum mechanics was perhaps the greatest intellectual achievement of the 20th century. While many individuals made contributions, twelve are highlighted in this abbreviated history.”
Found at Thall's History of Quantum Mechanics:
<http://mooni.fccj.org/~ethall/quantum/quant.htm>
Werner Heisenberg (1901-1976), a founder of quantum mechanics and the discoverer of the uncertainty principle, was one of the greatest physicists of the twentieth century. “Quantum theory provides us with a striking illustration of the fact that we can fully understand a connection though we can only speak of it in images and parables.”
Physics and Beyond (New York 1971)
<http://www.aip.org/history/heisenberg/p01.htm>
Heisenberg is out for a drive and is stopped by a traffic cop. The cop says, "Do you know how fast you were going?" Heisenberg says, "No, but I know where I am." (You will get this joke after you understand the uncertainty principle.)

Activity Description: In this activity, students drop marbles onto a target to investigate by analogy the relationship between probability and electron structure. The pattern of marble drops on the target sheets simulates the three-dimensional properties of atomic orbitals.

Number and Topic: 4. Atomic Structure
13. Electrons in Atoms

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure
Type of Material: Lab: Flame Tests—Atomic Emission and Electron Energy Levels
Building on: Electrons, energy levels, light, energy, electromagnetic spectrum
Leading to: Atomic emission, wavelength, frequency and energy of light, excited vs. ground states, flame tests
Links to Physics: Electrons, energy levels, light, energy, atomic emission, wavelength, frequency and energy of light, electromagnetic spectrum
Links to Biology:
Good Stories: Atomic fingerprints or spectra for certain elements are given on the following web page along with the use of these elements in fireworks (pyrotechnics):
<http://www.phschool.com/atschool/chemistry/AW/Student_Area/AWCHEM_SC13_ACT.html> or
<http://mooni.fccj.org/~ethall/spectra/spectra.htm>
SciTech's hands-on version of hydrogen spectra:
<http://66.99.115.200/atom-webexhibit.htm>
An excellent online lab that does the same thing as the hands-on lab, by Dr. Walt Volland, Bellevue Community College:
<http://www.trschools.com/staff/g/cgirtain/Weblabs/spectrolab.htm>
Dual nature of light, color, electromagnetic radiation and more can be found at the following site:
<http://micro.magnet.fsu.edu/primer/lightandcolor/index.html>
Activity Description: In this experiment, students observe or do the classic flame test and look at the colors of light emitted by different metal compounds to identify unknown metal ions.

Number and Topic: 4. Atomic Structure
13. Electrons in Atoms

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure
Type of Material: Lab: Atomic Spectra—Light, Energy, and Electron Structure
Building on: Electrons, light, energy, electromagnetic spectrum, Bohr Model
Leading to: Atomic emission spectrum, quantization of energy, electron energy levels, electron transitions
Links to Physics: Electrons, energy levels, light, energy, atomic emission, wavelength, frequency and energy of light, electromagnetic spectrum, Bohr Model
Links to Biology:
Good Stories: "Anyone who is not shocked by quantum theory has not understood it."
Niels Bohr <http://csep10.phys.utk.edu/astr162/lect/light/bohr.html>
PBS website with video clips about Bohr:
<http://www.pbs.org/hollywoodpresents/copenhagen/story/bohr.html>

Bohr Model and energy levels simulation:
<http://regentsprep.org/Regents/physics/phys05/catomodel/bohr.htm>
Atomic fingerprints or spectra for certain elements are given on the following web page along with their use in fireworks (pyrotechnics):
<http://www.phschool.com/atschool/chemistry/AW/Student_Area/AWCHEM_SC13_ACT.html> or
<http://mooni.fccj.org/~ethall/spectra/spectra.htm>
SciTech's hands-on version of hydrogen spectra:
<http://66.99.115.200/atom-webexhibit.htm>
An excellent online lab that does the same thing as the hands-on lab, by Dr. Walt Volland, Bellevue Community College:
<http://www.trschools.com/staff/g/cgirtain/Weblabs/spectrolab.htm>
Dual nature of light, color, electromagnetic radiation and more can be found at the following site:
<http://micro.magnet.fsu.edu/primer/lightandcolor/index.html>

Activity Description: The emission spectrum lines from an element provide evidence for the existence of electron energy levels in atoms This experiment looks at the emission spectra of different light sources, fluorescent lights, gas discharge tubes, neon signs, and novelty lamps to determine the electron transition energies.

Number and Topic: 4. Atomic Structure
13. Electrons in Atoms

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure
Type of Material: Lab: Atomic Coatings—The Size of an Atom
Building on: Density, mass, volume, redox or chemical reactions, mole concept
Leading to: Atomic size
Links to Physics: Density, mass, volume, atoms
Links to Biology: Atomic size <http://www.eurekalert.org/pub_releases/2001-11/ru-rda110101.php>
Good Stories: The atomic size website—yes there is one for everything!
<http://dl.clackamas.cc.or.us/ch104-07/atomic_size.htm>
Trends in atomic size:
<http://nobel.scas.bcit.ca/chem0010/unit4/4.8_atomicSize.htm>
Activity Description: By knowing the diameter of a zinc atom, students can “count” the number of layers of zinc atoms in a galvanized coating.

Number and Topic: 4. Atomic Structure
13. Electrons in Atoms

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure
Type of Material: Demo: The Think Tube—A Black-Box Demonstration
Building on: Scientific method, observation, hypothesis
Leading to: Model
Links to Physics: Atom, models, subatomic particles, scientific method, observation, hypothesis
Links to Biology: Models, scientific method, observation, hypothesis

Good Stories: An interesting and provocative article by Eric Scerri, “Philosophical Confusion in Chemical Education Research” questions a number of things about constructivism. <http://www.chem.ucla.edu/dept/Faculty/scerri/pdf/confusion_in_chemed.pdf>

Activity Description: A “Think Tube” is used to imagine the nature of the atom. One cannot easily see inside an atom. This black box model shows how we can find out about something without ever seeing it directly.

Number and Topic: 4. Atomic Structure

13. Electrons in Atoms

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure

Type of Material: Demo: Energy in Photons—Light Energy Demonstration

Building on: Energy, light, electrons

Leading to: Phosphorescence, absorbance vs. transmittance, energy and wavelength of light

Links to Physics: Electrons, light, energy, electromagnetic spectrum, color, wavelength, Planck’s Law

Links to Biology: Phosphorescence, color, eye, energy, suntanning

Good Stories: Fluorescence and phosphorescence are shown on the following web pages:
<http://www.glassner.com/andrew/cg/research/fluphos/fluphos.htm>
<http://38.1911encyclopedia.org/P/PH/PHOSPHORESCENCE.htm>
A WebQuest on the electromagnetic spectrum:
<http://can-do.com/uci/ssi2001/emspectrum.html>
NASA website on electromagnetic spectrum:
<http://imagers.gsfc.nasa.gov/ems/index.html>

Activity Description: When white light is shone through different color filters onto a “glow-in-the-dark” phosphorescent strip, only certain spots will glow. The relationship between wavelength, energy, and color is looked at in this demo.

Number and Topic: 4. Atomic Structure

13. Electrons in Atoms

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure

Type of Material: Demo: The Photoelectric Effect—Light Energy Demonstration

Building on: Electrons, energy and wavelength of light, electromagnetic spectrum

Leading to: Photoelectric effect, quantization of energy

Links to Physics: Photoelectric effect, quantization of energy, energy and wavelength of light, electromagnetic spectrum

Links to Biology: Chlorophyll displays photoelectric effect.

Good Stories: “Since the mathematicians have invaded the theory of relativity, I do not understand it myself anymore.” Albert Einstein
The photoelectric effect was the classical paradox that led to the development of the quantum theory of matter. It is what Einstein got his Nobel Prize for—not relativity or $E = MC^2$, but for explaining the photoelectric effect. This was the bridge between the old physics of

Newton and quantum physics. Some good websites describing the photoelectric effect are:
<http://www.colorado.edu/physics/2000/quantumzone/photoelectric.html>
<http://www.faqs.org/docs/qp/chap03.html>
<http://lectureonline.cl.msu.edu/~mmp/kap28/PhotoEffect/photo.htm>

Activity Description: The photoelectric effect is observed when light is shone on certain metal surfaces. The metal may lose electrons if the light has a great enough energy. An electroscope and different types of light sources are used to show the effect.

Number and Topic: 4. Atomic Structure
13. Electrons in Atoms

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure
Type of Material: Demo: Measuring the Size of a Molecule
Building on: Measurement
Leading to: Atomic structure, chemical bonding, molecular size and shape
Links to Physics: Atomic structure, molecular size
Links to Biology: Chemical bonding, molecular shape and size, semipermeable membranes
Good Stories: Oleic acid is an interesting chemical. It is used in the food industry. See the following web page:
<http://www.cas.astate.edu/draganjac/Oleicacid.html>
Another version of this lab online is found at The Chemical Heritage Foundation website. This site is really worth viewing.
<http://www.chemheritage.org/EducationalServices/pharm/antibiot/activity/size.htm>

Activity Description: When a drop of an "oily" material such as oleic acid is added to a pan of water, it disperses to form a very thin film that has a depth of only one molecule. By measuring the area of the film and making a few assumptions, we can estimate the length of the oleic acid molecule.

Number and Topic: 4. Atomic Structure
13. Electrons in Atoms
2. Measurement

Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure
Type of Material: Demo: Mapping Atomic Structure—Building a Scale Model
Building on: Atomic size
Leading to: Atomic nucleus, atomic radius
Links to Physics: Atomic nucleus, atomic radius
Links to Biology: Molecular size. The website below (Good Stories) has some bio-ramifications.
Good Stories: A nice web page that shows orders of magnitude from the very small to the very large:
<http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/>

Activity Description: In this activity, students use a basketball and a map of their city to draw a scale model of their city "atom" that has a basketball "nucleus."

Number and Topic: **4. Atomic Structure**
13. Electrons in Atoms
Source: Flinn ChemTopic Lab Book #3 - Atomic and Electron Structure
Type of Material: Demo: Excited States—A Musical Demonstration
Building on: Energy levels, electrons
Leading to: Excited states, ground state, photon emission
Links to Physics: Energy levels, excited states, ground state, photon emission
Links to Biology: Bonding, reactions
Good Stories: The demo itself is a good story!
Activity Description: A simulation of electrons losing energy in the form of light (different-colored objects) in the transition from a higher energy excited state to a lower energy state set to the musical tune of "I'm So Excited" by the Pointer Sisters!

Number and Topic: **14. Periodicity/Periodic Law**/Metals, Nonmetals and Families
Source: Flinn ChemTopic Lab Book #4 - The Periodic Table
Type of Material: Lab: It's in the Cards - Discovering the Periodic Law
Building on: Chemical and physical properties, trends
Leading to: Periodic law and periodic table
Links to Physics: Graphing, trends, and interpretation of data
Links to Biology: Classification
Good Stories: There is lots of interesting material on Dmitri Mendeleev.
<http://www.chem.msu.su/eng/misc/mendeleev/welcome.html>
Activity Description: This inquiry lab helps students to experience the thought process that Mendeleev went through in developing the periodic table.

Number and Topic: **14. Periodicity/Periodic Law/Metals, Nonmetals and Families**
Source: Flinn ChemTopic Lab Book #4 - The Periodic Table
Type of Material: Lab: Density is a Periodic Property - Discovering an Element
Building on: Density
Leading to: Periodic law, groups
Links to Physics: Graphing, trends, and interpretation of data
Links to Biology: Classification and predictions based on data
Good Stories: There is lots of interesting material available on Dmitri Mendeleev.

> "No law of nature, however general, has been established all at once; its recognition has always been preceded by many presentiments. The establishment of a law, moreover, does not take place when the first thought of it takes form, or even when its significance is recognized, but only when it has been confirmed by the results of the experiment. The man of science must consider these results as the only proof of the correctness of his conjectures and opinions."

J. Kendall, *Young Chemists and Great Discoveries*, Appleton-Century, New York, 1939.

<http://www.chemheritage.org/EducationalServices/chemach/ppt/mm.html>

Activity Description: This lab helps students to experience the thought process that Mendeleev went through in developing the periodic table and why he is credited with it rather than others.

Number and Topic: 14. Periodicity/Periodic Law/Metals, Nonmetals and Families
8. Chemical Reaction

Source: Flinn ChemTopic Lab Book #4 The Periodic Table

Type of Material: Lab: Periodic Trends and the Properties of Elements - Alkaline Earth Metals

Building on: Chemical properties

Leading to: Periodic trends, groups (alkaline earth metals), activity series, and double-replacement reactions

Links to Physics: Trends, thermodynamics, interpreting data

Links to Biology: Acids, bases (These metals are all important in bio systems.)

Good Stories: Marie Curie and her discovery of radium involve some of the chemistry here:
<http://www.aip.org/history/curie//>
<http://www.hum.amu.edu.pl/~zbzw/ph/sci/msc.htm>

Activity Description: This microscale lab helps students to see why Mendeleev would have classified these elements as a group in developing the periodic table. It also serves to introduce the activity series and, by the students carrying out the reactions, reinforces learning of reaction types.

Number and Topic: 14. Periodicity/Periodic Law/Metals, Nonmetals and Families
8. Chemical Reaction

Source: Flinn ChemTopic Lab Book #4 - The Periodic Table

Type of Material: Lab: All in the Family - The Halogens and Their Compounds

Building on: Chemical properties

Leading to: Periodic trends, groups (halogens), activity series, and single replacement reactions

Links to Physics: Trends, thermodynamics, interpreting data

Links to Biology: Halogens are all important in bio systems

Good Stories: Henri Moissan received the Nobel Prize in recognition of his investigation and isolation of the element fluorine and for the adoption in the service of science of the electric arc furnace called after him. Two interesting things are that his death was probably hastened by his work with fluorine and that he got the Nobel Prize in 1906 and died shortly after receiving it. Mendeleev, who probably should have received a Nobel, died the next year and so never got the award. Ummmm… fluorine vs the whole periodic table?
<http://www.nobel.se/chemistry/laureates/1906/moissan-bio.html>

Activity Description: This microscale lab helps students to see why Mendeleev would have classified these metals as a group in developing the periodic table. It also serves to introduce the activity series and reinforce reaction types.

Number and Topic: 14. Periodicity/Periodic Law/Metals, Nonmetals and Families
8. Chemical Reaction
20. Acids/Bases/pH
Source: Flinn ChemTopic Lab Book #4 - The Periodic Table
Type of Material: Demo: Periodic Activity of Metals
Building on: Chemical properties
Leading to: Periodic trends, groups (metals), activity series, single replacement reactions, and acid base indicators
Links to Physics: Trends, thermodynamics, electricity, and forces
Links to Biology: Metals ions are all important in bio systems
Good Stories: This is one of the classic chemistry demos.
Activity Description: This demo helps students to see why Mendeleev would have classified these metals into groups while developing the periodic table. It also serves to introduce the activity series and reinforce reaction types and acid/base reactions.

Number and Topic: 14. Periodicity/Periodic Law/Metals, Nonmetals and Families
8. Chemical Reaction
20. Acids/Bases/pH
Source: Flinn ChemTopic Lab Book #4 - The Periodic Table
Type of Material: Demo: Safe Swimming with Sodium
Building on: Chemical properties, density
Leading to: Single replacement reactions, acid base indicators
Links to Physics: Trends, thermodynamics, electricity, and forces
Links to Biology: Sodium is important in many bio systems. For example, its salts are crucial to maintaining the osmotic pressure of the blood.
Good Stories: This is one of the classic chemistry demos. I might also suggest the video from Flinn with Cliff Schrader and Lee Marek together showing what happens when five pounds of sodium were tossed into a strip-mining quarry to neutralize accumulated low pH water.
Activity Description: This demo helps students to see a classic demo of sodium in water in a safe and interesting way.

Number and Topic: 14. Periodicity/Periodic Law/Metals, Nonmetals and Families
Source: Flinn ChemTopic Lab Book #4 - The Periodic Table
Type of Material: Demo: Plotting Trends - A Periodic Table Activity
Building on: Periodic table
Leading to: 3-D picture of periodic properties
Links to Physics: Trends
Links to Biology:
Good Stories: The following are some very good web based periodic tables.
<http://www.chemicool.com/>

This award winning periodic table was one of the first on the web and was done by David Hsu, who is getting his Ph.D. at UC Berkeley.
<http://pearl1.lanl.gov/periodic/default.htm>
Los Alamos National Laboratory's Chemistry Division did the above table.
<chemlab.pc.maricopa.edu/periodic/periodic.html>
This has a nice picture of each element.

Activity Description: This demo helps students to see a 3-D picture of the periodic properties.

Number and Topic: 14. Periodicity/Periodic Law/Metals, Nonmetals and Families

Source: Flinn ChemTopic Lab Book #4 - The Periodic Table
Type of Material: Demo: Solubility Patterns
Building on: Periodic trends
Leading to: Alkaline metals, double-replacement, ionic compounds, and solubility
Links to Physics: Trends
Links to Biology: Alkaline earth metals are important in bio systems.
Good Stories: $BaSO_4$ is used in x-raying the colon even though barium compounds are toxic! You are able to drink $BaSO_4$ and not die because of its low solubility. The milky-looking suspension of barium sulfate is given by enema to allow x-ray examination of the lower intestinal tract for diagnostic purposes. As much as three or four quarts of the liquid may be required to fill the entire colon. The barium salt absorbs x-rays, leaving a picture of the shape of the hollow inside of the colon. Sometimes some of the barium is released and then air (or CO_2) is injected. This double contrast enema leaves barium coating the colon wall and gives a clear but ghostly image of the lining of the colon.
Activity Description: This demo is microscale.

Number and Topic: 7. Moles
9. Stoichiometry

Source: Flinn ChemTopic Lab Book #7- Molar Relationships and Stoichiometry
Type of Material: Lab: Who’s Counting? - Atoms, Mass and Moles
Building on: Atoms
Leading to: Mole concept, Avogadro’s number, atomic mass
Links to Physics: Atoms
Links to Biology: The molarity of biological solutions is crucial to maintaining life.
Good Stories: Amadeo Avogadro. See the following webpage for why he never even knew his own number! <http://www.bulldog.u-net.com/avogadro/avoga.html>
Activity Description: This lab helps students to develop a feel for Avogadro’s number and for counting by weighing.

Number and Topic: 7. Moles
9. Stoichiometry
6. Chemical Names and Formulas/Compounds and Elements

Source: Flinn ChemTopic Lab Book #7 - Molar Relationships and Stoichiometry

Type of Material:	Lab: Magnesium Oxide - Percent Composition and Empirical Formula
Building on:	Formulas
Leading to:	Empirical and molecular formulas, percent yield and composition
Links to Physics:	Atoms
Links to Biology:	Biochemical reactions follow the same rules of stoichiometry as other chemical reactions.
Good Stories:	Everything you ever wanted to know about magnesium oxide for students on the properties, manufacture and uses of magnesium oxide. <http://www.magspecialties.com/students.htm>
Activity Description:	This is the classic lab for empirical formula.

Number and Topic:	**7. Moles** **9. Stoichiometry** **8. Chemical Reaction**
Source:	Flinn ChemTopic Lab Book #7 - Molar Relationships and Stoichiometry
Type of Material:	Lab: Decomposition of Sodium Chlorate - Mass, Moles and the Chemical Equation
Building on:	Chemical equation
Leading to:	Moles, molecular formula and Stoichiometry
Links to Physics:	Atoms
Links to Biology:	See below under good stories.
Good Stories:	Sodium chlorate is the primary agent used in the production of chlorine dioxide. Chlorine dioxide is the most prominent bleaching agent in the manufacture of pulp. Perhaps of more topical interest, chlorine dioxide is extremely successful in killing anthrax spores and is what was pumped into buildings to kill the anthrax spores. Sodium chlorate is also used in emergency oxygen generators.
Activity Description:	This is lab used to determine a chemical equation by using Stoichiometry.

Number and Topic:	**7. Moles** **9. Stoichiometry** **8. Chemical Reaction**
Source:	Flinn ChemTopic Lab Book #7 - Molar Relationships and Stoichiometry
Type of Material:	Lab: Mole Ratios - Copper and Silver Nitrate
Building on:	Chemical equations and moles
Leading to:	Moles ratio, balanced equation and Stoichiometry
Links to Physics:	Atoms, conservation of mass
Links to Biology:	As required under state law in most States, silver nitrate or an antibiotic substitute is placed in the eyes of almost every hospital-born baby in this country to prevent the development of blindness in case the mother has gonorrhea.
Good Stories:	See above, as silver nitrate was the first “chemical” most babies used to come in contact with. Good question to ask in class.
Activity Description:	This lab is used to determine a chemical equation using Stoichiometry. Mole ratios are also determined.

Number and Topic:	**7. Moles** **9. Stoichiometry** **8. Chemical Reaction**
Source:	Flinn ChemTopic Lab Book #7 - Molar Relationships and Stoichiometry
Type of Material:	Lab: Micro Mole Rockets - Hydrogen and Oxygen Mole Ratio
Building on:	Chemical equations and moles
Leading to:	Moles ratio, reactions, limiting reagents, Stoichiometry
Links to Physics:	Atoms, conservation of mass, thermodynamics, and Newton's laws of motion
Links to Biology:	Biochemical reactions follow the same rules of stoichiometry as other chemical reactions.
Good Stories:	Hydrogen and oxygen are used as fuel in the space shuttle. Hydrogen may replace our oil-based economy as the fuel of the century if we can get it cheaply enough. Fuel cells: <http://www.howstuffworks.com/hydrogen-economy.htm> There is even a hydrogen home page: <http://www.hydrogennow.org/>
Activity Description:	This microscale lab is used to determine limiting reagents and mole ratios and to shoot rockets!

Number and Topic:	**7. Moles**
Source:	Flinn ChemTopic Lab Book #7 - Molar Relationships and Stoichiometry
Type of Material:	Demo: Mole Creativity - Make-a-Mole Pattern
Building on:	Moles
Leading to:	More Moles
Links to Physics:	Atoms
Links to Biology:	Moles are animals.
Good Stories:	Humor is what this mole pattern involves. This demo is a good break from a concept that is hard/abstract for kids. Mike Offutt also has produced a set of mole songs that teach chemistry. They are available through several suppliers. You can also join the Mole Day Foundation for many other ideas; go to the following webpage: <http://www.moleday.org/>
Activity Description:	This is an activity that I suggest you have the kids do. Follow the pattern and bring in the mole for credit. You can have the moles set around your classroom.

Number and Topic:	**7. Moles** **3. Problem Solving**
Source:	Flinn ChemTopic Lab Book #7 - Molar Relationships and Stoichiometry
Type of Material:	Demo: How Big is a Mole? - Imagining the Mole Activities
Building on:	Moles
Leading to:	Moles
Links to Physics:	Atoms
Links to Biology:	Atoms

Good Stories: The mole concept has caused students problems for years. Any measurable amount of matter contains so many atoms that a unit of measure called the mole has been set up to count atoms. Wilhelm Ostwald, the German Nobel Prize-winning physical chemist used the term mole, which comes from Latin meaning "little pile." (This is what many students think of this concept!)

Activity Description: This demo is really an analogy to help kids visualize the size of a mole and how small an atom is in size and mass.

Number and Topic: 7. Moles

Source: Flinn ChemTopic Lab Book #7 - Molar Relationships and Stoichiometry

Type of Material: Demo: Conceptual Understanding of Moles

Building on: Moles

Leading to: Moles

Links to Physics: Atoms

Links to Biology: Thinking on a submicroscopic level (molecular level)

Good Stories:

Activity Description: Students need to develop thinking about chemistry on the particulate or submicroscopic level via the kinetic molecular theory of Dorothy Gabel and others. It is also important that students relate this to the symbolic level that textbooks use and make connections to the macroscopic level and symbolic levels. Chemistry is an abstract subject. To get students to really understand it and develop a conceptual framework one should attempt to get them to "think like a molecule" (my own term). This activity gets the kids to think at a molecular level.

Number and Topic: 7. Moles
3. Problem Solving

Source: Flinn ChemTopic Lab Book #7 - Molar Relationships and Stoichiometry

Type of Material: Demo: Mole Samples and Molar Mass - Authentic Assessment

Building on: Moles

Leading to: Molar mass

Links to Physics: Atoms

Links to Biology: Thinking on a submicroscopic level (molecular level)

Good Stories:

Activity Description: This demo gives kids a feel for the term molar mass and the exercise provides a hands-on way of calculating/working with molar mass.

Number and Topic: 7. Moles
3. Problem Solving
9. Stoichiometry
8. Chemical Reaction

Source: Flinn ChemTopic Lab Book #7 - Molar Relationships and Stoichiometry

Type of Material: Demo: Stoichiometry Balloon Race - Limiting and Excess Reagents

Building on: Moles, mole ratio, Stoichiometry

Leading to: Limiting reagent

Links to Physics: Atoms
Links to Biology: Sodium bicarbonate shows buffering action of Alka-Seltzer and blood.
Good Stories: See bio links above and following webpage: <http://www.factmonster.com/ce6/sci/A0845789.html>
Activity Description: This demo gives kids a visual feel for limiting reagents using common household chemicals.

Number and Topic: 7. Moles
3. Problem Solving
9. Stoichiometry
8. Chemical Reaction
6. Chemical Names and Formulas/Compounds and Elements
Source: Flinn ChemTopic Lab Book #7 - Molar Relationships and Stoichiometry
Type of Material: Demo: Stoichiometry and Solubility - Mole Ratios and Chemical Formulas
Building on: Mole ratio, double replacement reactions and Stoichiometry
Leading to: Solubility rules, chemical formulas
Links to Physics: Atoms, graphing
Links to Biology: Solutions and solubility. The method of continuous variation has uses in bio.
Good Stories: The following websites may help students and teachers in understanding the powerful and useful method of continuous variation. <http://www.wpi.edu/Academics/Depts/Chemistry/Courses/CH2670/jobsmethod.html>
Activity Description: This demo uses a method of continuous variation to determine the mole ratio and chemical formula of a precipitate.

Number and Topic: 7. Moles
3. Problem Solving
9. Stoichiometry
Source: John Brodemus' webpage on teaching Stoichiometry. John is a chemistry teacher at H. L. Richard's High School in Illinois and in the CHEMWEST group. < http://staff.chsd218.org/HLR/brodemuschem/index.htm>
Type of Material: Webpage: Learning Stoichiometry
Building on: Moles and problem solving
Leading to: Limiting reactants
Links to Physics: Atoms, graphing, problem solving
Links to Biology: Problem solving
Good Stories:
Activity Description: Many students have difficulty with Stoichiometry. This is especially evident when topics like limiting reactants are encountered. Traditional approaches have been improved upon somewhat by using amounts tables and the mole/coefficient approach. This paper extends the mole/coefficient approach to its logical meaning. It is not just a simple gimmick to determine a limiting reactant. Chemical equations are viewed as recipes, which can be scaled up for mass production or shrunken down as needed.

All that is needed is a multiplier (or scale factor, or batch factor, or equation factor) for all chemical equations. Without using mole ratios, Stoichiometry by the Recipe (SBR) is applied consistently and successfully from the simplest mole to mole problems to all of the common permutations (mass, L, M, number of molecules or atoms) found in Stoichiometry.

Number and Topic: **8. Chemical Reactions**
12. Gases/Gas Laws/Kinetic Theory
1. Matter and Change

Source: Flinn ChemTopic Lab Book #8 – Chemistry of Gases

Type of Material: Lab: Common Gases—Physical and Chemical Properties

Building on: Physical and chemical properties, physical and chemical changes, density, balancing equations, observations, phlogiston theory, elements and compounds

Leading to: The overthrow of the phlogiston theory, periodic table, chemistry of the atmosphere, atmospheric pollution, atmospheric pressure, Dalton's Law of Partial Pressures, chemical reactions, acid/base

Links to Physics: Energy, heat

Links to Biology: Carbon cycle, global warming, air pollution, ozone–both good and bad (yin & yang), gas densities and atmospheric pressure

Good Stories: There are so many good stories here. You can see some in the Links to Biology section above. I will focus on the idea that modern chemistry really started with the study of gases. One can raise the issue of how old theories and ideas evolve into new ones. Who gets credit for these advances? Consider how the overthrow of the phlogiston theory changed the course of chemistry. Most textbooks make the change seem simple, as though the idea should have been clear to everyone. The arguments, debates and personalities of the players are ignored for lack of time. Or the student does a 50-minute lab, which shows what it took a generation to discover! In science we give lip service to history and the humanities. We really cross over only to dabble a toe or two from time to time in the stream of consciousness of the liberal arts. I suggest you view the play *Oxygen* by Carl Djerassi and Roald Hoffmann. The play gives a view of science as a very human endeavor, searching both for oxygen and for the truth about how the world works. Characters view, explore, and debate the "facts" to get at "the truth." The play presents the story of the 18th century lives of Joseph Priestley, Antoine Lavoisier, and Karl Wilhelm Scheele. Each scientist independently discovered oxygen, and in a series of flashbacks three experiments are presented, reflecting the work of each scientist. To whom does the credit for discovery go? The DVD or video is available from Educational Innovations.
<http://www.teachersource.com/catalog/index.html>
Thall's website on the demise of the phlogiston theory is worth looking at:
<http://mooni.fccj.org/~ethall/phlogist/phlogist.htm>

Activity Description: Prepare five common gases and investigate their physical and chemical properties.

Number and Topic: 8. Chemical Reactions
1. Matter and Change

Source: Flinn ChemTopic Lab Book #8 – Chemistry of Gases
Type of Material: Lab: Preparing and Testing Hydrogen Gas—A Microscale Approach
Building on: Physical and chemical properties, physical and chemical changes, density, observations, phlogiston theory, elements and compounds
Leading to: Flammability, fuels, balancing equations, types of reactions
Links to Physics: Energy, heat, sun, nuclear fusion
Links to Biology: Alternative fuels and the environment—see "Hydrogen in History" by Seth Dunn.
<http://www.theglobalist.com/DBWeb/StoryId.aspx?StoryId=2338>
WebElements: Lists the biological properties of hydrogen and has a great set of links and a Real Audio story about hydrogen.
<http://www.webelements.com/webelements/elements/text/H/key.html>
Good Stories: As the most abundant element in the universe and the first element in the periodic table, hydrogen has many stories to tell. "Cavendish measured the density of hydrogen (then called 'inflammable air') and thus showed that it was distinct from other combustible gases. He also measured the amount of hydrogen that was evolved from a given amount of acid and metal. Early experimenters had obtained the gas, but Cavendish was the first to study it carefully and report on its properties, so he is usually given the credit for having discovered it." (Britannica, Asimov)
<http://www.americanchemistry.com/chemmag.nsf/WebMagazineArticle?ReadForm&mfpk-53ekh3>
The National Hydrogen Association can be found at <http://www.hydrogenus.com/>. U.S. government website from D.O.E. (Alternative Fuels Data Center) contains information on alternative fuels. It claims to be "a one-stop shop for all your alternative fuel and vehicle information needs. This site has more than 3,000 documents in its database, an interactive fuel station mapping system, listings of available alternative fuel vehicles, links to related websites, and much more."
<http://www.afdc.doe.gov/>
WebElements: **Hydrogen** lists the properties of hydrogen and has a great set of links and a Real Audio story about hydrogen.
<http://www.webelements.com/webelements/elements/text/H/key.html>
Activity Description: In this microscale lab students collect, study, and test hydrogen gas.

Number and Topic: 8. Chemical Reactions
2. Matter and Change
22. Redox

Source: Flinn ChemTopic Lab Book #8 – Chemistry of Gases
Type of Material: Lab: Oxygen - What a Flame—Microscale Gas Chemistry

Building on: Physical and chemical properties, physical and chemical changes, observations, demise of the phlogiston theory, elements and compounds

Leading to: Redox, flammability, combustion, fuels, balancing equations, types of reactions, tests for gases

Links to Physics: Energy, heat

Links to Biology: Photosynthesis, respiration, antioxidants, a website on “Why Does The Ozone Hole Form?” at <http://chemistry.beloit.edu/Ozone/>
WebElements: **Oxygen** lists the biological properties of oxygen. <http://www.webelements.com/webelements/elements/text/O/biol.html>
From the “Online Biology Dictionary” come some interesting terms: <http://www.biology-online.org/dictionary.asp?Term=Oxygen>

Good Stories: "What surprised me more than I can well express, was that a candle burned in this air with remarkably vigorous flame." Thus did Joseph Priestley (1733-1804) describe one of his key observations of the gas derived from heating the solid mercury (II) oxide.
WebElements: **Oxygen** lists the chemical properties of oxygen and has a great set of links and a Real Audio story about oxygen.
<http://www.webelements.com/webelements/elements/text/O/key.html>

Activity Description: In this microscale lab students collect, study, and test oxygen gas.

Number and Topic: 8. Chemical Reactions
1. Matter and Change
20. Acids/Bases/pH

Source: Flinn ChemTopic Lab Book #8 – Chemistry of Gases

Type of Material: Lab: Carbon Dioxide - What a Gas—Microscale Gas Chemistry

Building on: Physical and chemical properties, physical and chemical changes, observations, demise of the phlogiston theory, elements and compounds

Leading to: Combustion, balancing equations, types of reactions, tests for gases, acid-base reactions

Links to Physics: Energy, heat

Links to Biology: Respiration, photosynthesis, carbon dioxide as part of the blood buffer system, carbon dioxide as a greenhouse gas
A great site that has biology sites and all kinds of other information on CO_2 is: <http://www.sciencedaily.com/encyclopedia/Carbonated_water>

Good Stories: FIRE IN ICE: Combustion in a Fire Extinguishing Environment - a video from Lee Marek’s home page showing magnesium burning in solid carbon dioxide (dry ice):
<http://www.webct.com/service/ViewContent?contentID=1249565&communityID=858&categoryID=1249537&sIndex=0>
This site has many good stories on it about CO_2:
<http://www.sciencedaily.com/encyclopedia/Carbonated_water>

Activity Description: In this microscale lab students collect, study, and test carbon dioxide gas.

Number and Topic: 8. Chemical Reactions
12. Gases/Gas Laws/Kinetic Theory

Source: Flinn ChemTopic Lab Book #8 – Chemistry of Gases

Type of Material: Demo: Collecting Gases by Water Displacement
Building on: Gas pressure
Leading to: Gas collection
Links to Physics:
Links to Biology:
Good Stories: The early pneumatic chemists collected gases by this method. Priestley was the first pneumatic chemist and is credited with the discovery of eight gases, a record that still stands. See the following website by Bruce Mattson, a modern-day pneumatic chemist who specializes in gas chemistry.
<http://mattson.creighton.edu/History_Gas_Chemistry/Priestley.html>
Activity Description: Classic collection of a gas by water displacement.

Number and Topic: 8. Chemical Reactions
22. Redox
21. Organic Chemistry
Source: Flinn ChemTopic Lab Book #8 – Chemistry of Gases
Type of Material: Demo: Underwater Fireworks
Building on: Redox reactions, properties of chlorine gas
Leading to: Organic chemistry, saturated vs. unsaturated hydrocarbons, addition reactions
Links to Physics:
Links to Biology: Disinfectant, environmental problems, prions
<http://www.pbs.org/wgbh/nova/madcow/>
<http://w3.aces.uiuc.edu/AnSci/BSE/>
Good Stories: A QuickTime movie of this demo can be found here:
<http://www.asdk12.org/schools/west/pages/science/experiment.htm>
There may be many environmental problems associated with chlorine. The debate still rages on. There is a yin and a yang, as with the use of many chemicals.
<http://www.acnatsci.org/research/kye/chlorine.html>
<http://www.eurochlor.org/chlorine/science/chemistry.htm>
Chlorine makes a great disinfectant. It is one of the few materials that will take out prions, which may be linked with Mad Cow disease. It was also used in World War I as a poison gas.
<http://www.lib.byu.edu/~rdh/wwi/1915/chlorgas.html>,
<http://www.firstworldwar.com/weaponry/gas.htm>
Activity Description: A redox reaction underwater with chlorine and acetylene that produces flashes of light.

Number and Topic: 16. Covalent Bonds, Molecular Shapes & Intermolecular Forces
1. Matter and Change
Source: Flinn ChemTopic Lab Book #8 – Chemistry of Gases
Type of Material: Demo: Flaming Vapor Ramp—Safety Demo
Building on: Density, volatility
Leading to: Safety, flammability

Links to Physics: Safety
Links to Biology: Safety
Good Stories: Volatile liquids easily vaporize and the vapors can travel along the floor to any open flame and BOOM. Many fires start in such a manner. Lee Marek personally worked on a case where a science teacher had set part of his class on fire by accident because he did not know this. While the teacher was pouring methanol from a one-gallon can, a nearby open flame ignited the vapors, the can shot out of his hand like a rocket and set fire to several students. Another incident related to a person who was sealing his basement floor using a sealer containing a volatile solvent. The basement gradually filled with fumes, which eventually reached the pilot light in the hot water heater, then he had self-opening windows!
Activity Description: The vapors of a flammable liquid flow down a gutter and then ignite some distance away from the liquid, showing one of the hazards of working with volatile liquids.

Number and Topic: 20. Acids/Bases/pH

Source: Flinn ChemTopic Lab Book #8 – Chemistry of Gases
Type of Material: Demo: The Collapsing Bottle
Building on: Carbon dioxide and pressure
Leading to: Gas solubility, acid base reaction
Links to Physics: Atmospheric pressure
Links to Biology: Respiration, photosynthesis, carbon dioxide as part of the blood buffer system, carbon dioxide as a greenhouse gas
A great site that has biology sites and all kinds of other info on CO_2 is:
<http://www.sciencedaily.com/encyclopedia/Carbonated_water>
Good Stories: FIRE IN ICE: Combustion in a Fire Extinguishing Environment - a video from Lee Marek's home page showing magnesium burning in carbon dioxide (dry ice):
<http://www.webct.com/service/ViewContent?contentID=1249565&communityID=858&categoryID=1249537&sIndex=0>
This site has many good stories on it about CO_2.
<http://www.sciencedaily.com/encyclopedia/Carbonated_water>
Activity Description: Carbon dioxide gas in a plastic bottle reacts with NaOH to form Na_2CO_3, thus using up the gas. This reduction in pressure causes the bottle to collapse.

Number and Topic: 20. Acids/Bases/pH

Source: Flinn ChemTopic Lab Book #8 – Chemistry of Gases
Type of Material: Demo: Solubility of Carbon Dioxide—The Dry Ice Color Show
Building on: Sublimation, carbon dioxide, acid-base reactions
Leading to: Acid-base indicators, triple point
Links to Physics: Color
Links to Biology: Respiration, photosynthesis, carbon dioxide as part of the blood a buffer system, carbon dioxide as a greenhouse gas

A great site that has biology sites and all kinds of other info on CO_2 is: <http://www.sciencedaily.com/encyclopedia/Carbonated_water>

Good Stories: The following web pages list the properties of dry ice and how it is made:
<http://www.dryiceinfo.com/science.htm>
<http://www.sciencedaily.com/encyclopedia/Dry_ice>
Observing and Measuring the Triple Point of Carbon Dioxide - a lab:
<http://www.smes.org/classes/chemistry/firstyear/LabTriplePointCO2.htm>

Activity Description: A series of indicators in basic solutions change color as the solutions are neutralized, then turned slightly acidic by the addition of dry ice (solid CO_2).

Number and Topic: 20. Acids/Bases/pH

Source: Flinn ChemTopic Lab Book #8 – Chemistry of Gases

Type of Material: Demo: Solubility of Ammonia—Indicator Color Show

Building on: Properties of ammonia gas, acid-base reactions

Leading to: Gas solubility, indicators

Links to Physics:

Links to Biology: Ammonia compounds are some of the major fertilizers used in farming.

Good Stories: Other uses of ammonia - explosives and fertilizers (guns and roses):
<http://www.psigate.ac.uk/newsite/reference/plambeck/chem1/p01263.htm>
The classic demo of the ammonia fountain using a round bottom flask—instructions from Bassam Shakhashiri:
<http://paul.brandt.faculty.noctrl.edu/teaching/CHM100/NH3.pdf>

Activity Description: This demonstration shows how very soluble ammonia is in water and how the color of an indicator changes with changes in pH.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory
3. Problem Solving

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws

Type of Material: Lab: Boyle’s Law in a Bottle—Pressure versus Volume

Building on: Pressure, gas properties, atmosphere

Leading to: Boyle’s Law, kinetic-molecular theory

Links to Physics: Energy, pressure, force

Links to Biology: Respiration, “the bends” (solubility of gases in blood)

Good Stories: Thall's History of Gas Laws is a wonderful linked page about all the people who developed the gas laws.
<http://mooni.fccj.org/~ethall/gaslaw/gaslaw.htm>
There is a set of applets that uses virtual labs to develop all the gas laws.
<http://www.chm.davidson.edu/ChemistryApplets/GasLaws/index.html>
Robert Hooke was Robert Boyle's chief assistant, and was partly responsible for Boyle’s Law, which started the scientific study of gases. Hooke is an unsung hero, partly due to his clashes with Newton. The following websites speak a bit to the relationship between Hooke and Boyle—you decide who was the better scientist and read about the interactions with Newton!
<http://www.mhs.ox.ac.uk/features/walk/loc5.htm>

<http://www.microscopy-uk.org.uk/mag/indexmag.html?http://www.microscopy-uk.org.uk/mag/artmar00/hooke1.html>
<http://www-gap.dcs.st-and.ac.uk/~history/Mathematicians/Hooke.html>
<http://starryskies.com/~kmiles/spec/hooks.html>
Boyle's Law and scuba diving <
<http://www.flash.net/~table/gasses/boyle1.htm>
<http://www.chm.bris.ac.uk/webprojects2002/shorrock/effects_of_boyles_law_on_divers.htm>,
<http://www.stmatthewsschool.com/deep/deep2001/14/bckgrnd.html>
The physics of diving <http://library.thinkquest.org/28170/34.html>,
<http://home.gwu.edu/~buchanan/Scuba/archive.htm>
WebQuest on gas laws and scuba diving:
<http://cmcweb.lr.k12.nj.us/webquest/brennan/scubachem.htm>
Good overview of all the gas laws is at the following:
<http://www.chemtutor.com/gases.htm>

Activity Description: Boyle's Law is "discovered " in a tactile way using a syringe, pump, pressure gauge and a soda bottle.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory
3. Problem Solving

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws
Type of Material: Lab: Charles's Law and Absolute Zero—How Low Can You Go?
Building on: Temperature, Boyle's Law
Leading to: Charles's Law, kinetic-molecular theory, absolute zero, heat
Links to Physics: Temperature, heat, density
Links to Biology: Energy transformations
Good Stories: Thall's History of Gas Laws is a wonderful page with links to all the people who developed the gas laws.
<http://mooni.fccj.org/~ethall/gaslaw/gaslaw.htm>
Charles's Law and scuba diving
<http://www.flash.net/~table/gasses/charles.htm>
There is a set of applets that use virtual labs to develop all the gas laws.
<http://www.chm.davidson.edu/ChemistryApplets/GasLaws/index.html>
The development of thermometers and temperature scales:
<http://www.unidata.ucar.edu/staff/blynds/tmp.html>
<http://www.pa.msu.edu/~sciencet/ask_st/012992.html>
As is often true, science and technology proceed hand in hand. The development of hot air balloons in France in the late 1700's is a lovely example of this. The history of ballooning is presented in a nice web page that may be accessed by clicking <http://www.chem.uidaho.edu/~honors/gaslaws2.html>. In 1782 the French paper manufacturer, Joseph Montgolfier and his brother Etienne followed up on Priestley's book, *Experiments and Observations with Different Types of Air*, with experiments on small hot air balloons. In September of 1783 they demonstrated their new machine by launching a

balloon from Versailles with a sheep, a rooster and a duck as passengers. One of the witnesses to this experiment was Ben Franklin, who was ambassador to France at that time. On November 21 Marquis D'Arlandes and Pilatre de Rozier became the first human pilots of this contraption.

Activity Description: Charles’s Law is developed using a syringe and different temperature water baths to find a value for absolute zero.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory
3. Problem Solving
9. Stoichiometry
8. Chemical Reactions

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws
Type of Material: Lab: Molar Volume of Hydrogen—Combining the Gas Laws
Building on: Temperature, Boyle’s Law, Charles’s Law, Dalton’s Law
Leading to: Avogadro’s Law, Ideal Gas Law, molar volume, STP
Links to Physics: Energy, density, pressure
Links to Biology: Energy transformations
Good Stories: Thall's History of Gas Laws is a wonderful linked page to all the people who developed the gas laws.
<http://mooni.fccj.org/~ethall/gaslaw/gaslaw.htm>
The following web page is a Gas Law Simulator. You may need to download the worksheet or just play with the simulation!
<http://www.hn.psu.edu/faculty/dmencer/ideal/ideal1.htm>
Here’s a set of applets that uses virtual labs to develop all the gas laws:
<http://www.chm.davidson.edu/ChemistryApplets/GasLaws/index.html>
Maxwell Distribution—Properties of Ideal Gas Law
<http://jersey.uoregon.edu/vlab/Balloon/index.html>
Activity Description: In this microscale lab students collect a known amount of hydrogen and find the molar volume of hydrogen gas at STP.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory
3. Problem Solving

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws
Type of Material: Lab: Technology and the Forgotten Gas Law—Pressure versus Temperature
Building on: Temperature, Boyle’s Law, Charles’s Law, pressure
Leading to: Amonton’s Law, kinetic-molecular theory
Links to Physics: Temperature, kinetic-molecular theory, heat, force
Links to Biology: Energy transformations
Good Stories: Thall's History of Gas Laws is a wonderful linked page to all the people who developed the gas laws.
<http://mooni.fccj.org/~ethall/gaslaw/gaslaw.htm>
There is a set of applets that use virtual labs to develop all the gas laws.
<http://www.chm.davidson.edu/ChemistryApplets/GasLaws/index.html>
Amonton was the French physicist who developed the air thermometer, which relies on the increase in the volume of a gas (rather than a liquid)

with temperature. Deaf since childhood, Amonton worked on inventions for the deaf, such as the first telegraph, which relied on a telescope, light, and several stations to transmit information over large distances.

Activity Description: Amonton’s Law, which relates pressure and temperature, is derived using a technology-based experiment.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws

Type of Material: Lab: Life on Planet V—A Classroom Activity

Building on: Atmospheric pressure

Leading to: Vacuum

Links to Physics: Kinetic-molecular theory, vacuum, force, pressure, astronomy

Links to Biology: Can life exist in a vacuum? How about at a pressure higher than atmospheric? What is “the bends”?

Good Stories: Students are fascinated about what would happen to them in a vacuum. In the movie *2001*, when Dave wants to get back into the spaceship and HAL, the computer, won't let him, Dave spends some time without a spacesuit. Because of science fiction movies, people think that an unprotected human body would explode in a vacuum. Not really. The human body does fairly well in a vacuum, at least for a short time! At pressures higher than atmospheric, there are problems like the bends etc. The following sites talk more about this.
<http://www.batnet.com/mfwright/2001exp.html>
<http://science.howstuffworks.com/question101.htm>
NASA “Ask an Astronomer” addresses this issue.
<http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970603.html>
Stanley Kubrick, the director of *2001*, showed it correctly by having the space sequences shown in complete silence (or just with background music) since vacuum does not transmit sound. Most other science fiction movies get it wrong!

Activity Description: To understand the concepts of a vacuum and atmospheric pressure, an inquiry-based “mental lab’ asks a series of questions about Planet V that has no atmosphere. How would it be to live in such an environment?

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws

Type of Material: Demo: The Collapsing Can—Pressure Is a Force

Building on: Atmospheric pressure

Leading to: Kinetic-molecular theory, vacuum

Links to Physics: Temperature, kinetic-molecular theory, heat, force, vacuum

Links to Biology: Energy transformations, “the bends”

Good Stories: Thall's History of Gas Laws is a wonderful linked page to all the people who developed the gas laws.
<http://mooni.fccj.org/~ethall/gaslaw/gaslaw.htm>

A 55-gallon drum is crushed by air pressure (a video clip).
<http://www.webct.com/service/ViewContent?contentID=1249567&communityID=858&categoryID=1249537&sIndex=0>
A tanker car is crushed by air pressure!
<http://www.delta.edu/slime/cancrush.html>

Activity Description: A can filled with hot water vapor is crushed as it cools, due to atmospheric pressure.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory
3. Problem Solving,

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws
Type of Material: Demo: Massing Gases—Avogadro’s Law
Building on: Molar mass, buoyancy, density
Leading to: Avogadro’s Law
Links to Physics: Buoyancy, density
Links to Biology: Buoyancy, density. Fish have swim bladders for buoyancy—see fish biology pages:
<http://oceanlink.island.net/ask/fishy.html#anchor28813>
<http://www.aquarium.org/upwelling/upwelling04.htm>
<http://www.howstuffworks.com/question629.htm>

Good Stories: Avogadro’s hypothesis was virtually ignored by chemists because, when it was tested in 1811, scientists did not use appropriate temperatures. Avogadro’s countryman Stanislao Cannizzaro reintroduced it at the first international chemical congress at Karlsruhe in1860. Cannizzaro laid a foundation of modern chemistry with his analysis of experimental atomic weight determinations, but at this Congress he presented his ideas with little effect. Fortunately, his paper was distributed to those in attendance, prompting Lothar Meyer to include the ideas in his influential text of 1864, which developed theoretical chemistry on the basis of Cannizzaro's propositions.
<http://chemistry.mtu.edu/~pcharles/SCIHISTORY/Stanislao_Cannizzaro.html>
There is a set of applets that use virtual labs to develop all the gas laws:
<http://www.chm.davidson.edu/ChemistryApplets/GasLaws/index.html>

Activity Description: A syringe is used to find the molar mass of an unknown gas using Avogadro’s Law.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory
3. Problem Solving

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws
Type of Material: Demo: Molar Mass of Butane—Ideal Gas Law
Building on: Temperature, Boyle’s Law, Charles’s Law, Dalton’s Law, molar mass
Leading to: Ideal Gas Law, STP
Links to Physics: Density, pressure
Links to Biology:

Good Stories: Thall's History of Gas Laws is a wonderful linked page to all the people who developed the gas laws. <http://mooni.fccj.org/~ethall/gaslaw/gaslaw.htm>
The following web page is a Gas Law Simulator. You could download the worksheet or just play with the simulation! <http://www.hn.psu.edu/faculty/dmencer/ideal/ideal1.htm>
There is a set of applets that use virtual labs to develop all the gas laws. <http://www.chm.davidson.edu/ChemistryApplets/GasLaws/index.html>
Maxwell Distribution—Properties of Ideal Gas Law <http://jersey.uoregon.edu/vlab/Balloon/index.html>

Activity Description: Using the Ideal Gas Law the molar mass of butane (obtained from a lighter) is calculated.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws
Type of Material: Demo: Diffusion of Gases—Kinetic Energy
Building on: Kinetic-molecular theory, temperature
Leading to: Diffusion
Links to Physics: Kinetic energy, kinetic-molecular theory, heat
Links to Biology: Diffusion <http://www.pdh-odp.co.uk/diffusion.htm>
Good Stories: Thall's History of Gas Laws is a wonderful linked page about all the people who developed the gas laws. <http://mooni.fccj.org/~ethall/gaslaw/gaslaw.htm>
There is a set of applets that use virtual labs to develop all the gas laws. <http://www.chm.davidson.edu/ChemistryApplets/GasLaws/index.html>
The Happy Molecules is a web page simulation that relates statistical mechanics to gas laws. <http://www.chem.uci.edu/education/undergrad_pgm/applets/happy/happy.htm>
Activity Description: The two gases HCl and NH_3 are used in a glass tube. Measurements are made of their rates of diffusion. Varying the temperature changes the rate of diffusion.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws
Type of Material: Activity: Construction of Gas Volume Cubes—Assessment Activity
Building on: Avogadro's Law, ideal gas, STP, moles
Leading to: Molar volume
Links to Physics:
Links to Biology:
Good Stories: Nice definition of molar volume <http://www.bartleby.com/65/mo/molarvol.html>
Activity Description: A tactile activity where the students construct cubes to represent the volume taken up by different numbers of moles of gas.

Number and Topic: 12. Gases/Gas Laws/Kinetic Theory

Source: Flinn ChemTopic Lab Book #9 – The Gas Laws
Type of Material: Demo/Activity: Cartesian Divers—Boyle's Law Activity
Building on: Density, Boyle's Law, pressure, gas properties, atmosphere
Leading to: Buoyancy
Links to Physics: Kinetic-molecular theory, energy, pressure, force, buoyancy
Links to Biology: Respiration, "the bends" (solubility of gases in blood), buoyancy, density; fish have a swim bladder for buoyancy—see fish biology pages:
<http://oceanlink.island.net/ask/fishy.html#anchor28813>
<http://www.aquarium.org/upwelling/upwelling04.htm>
<http://www.howstuffworks.com/question629.htm>
Good Stories: Thall's History of Gas Laws is a wonderful linked page to all the people who developed the gas laws.
<http://mooni.fccj.org/~ethall/gaslaw/gaslaw.htm>
How did the Cartesian diver get its name?
<http://www.ed.uiuc.edu/courses/CI241-science-Sp95/resources/philoToy/philoToy.html>
Nice variation on this using a pen cap.
<http://www.slb.com/seed/en/lab/diver/>
The following web page relates to buoyancy and Archimedes' Principle but uses English units: <http://www.flash.net/~table/gasses/archem.htm>
Activity Description: Cartesian divers are built and used to show Boyle's Law.

Number and Topic: 11. Thermochemistry
Source: Flinn ChemTopic Lab Book #10 - Thermochemistry
Type of Material: Lab: Exploring Energy Changes - Exothermic and Endothermic Reactions.
Building on: Heat, energy, temperature, conservation of energy, physical and chemical change, chemical reactions
Leading to: Exothermic, endothermic, system and surroundings
Links to Physics: Energy, conservation of energy, heat, thermodynamics
The following site blew me away on making the interconnections and telling a good story. This shows the power of the web.
<http://www.chem.ox.ac.uk/vrchemistry/Conservation/page01.htm>
<http://www.chem.ox.ac.uk/vrchemistry/energy/default.htm>
Links to Biology: Energy
Good Stories: Our whole economy is based on energy/fuels. Many relationships and stories could be told. The websites listed above are great—some of the best I have seen.
Three people worth researching who helped develop the law of conservation of energy are James Joule (1818-1889, English), Sadi Carnot (1796-1832, French), and Count Rumford (Benjamin Thompson - US (1753-1814).
Activity Description: In this technology-based activity, students examine the heat changes in physical and chemical reactions and classify them as exothermic or endothermic.

Number and Topic:	**11. Thermochemistry**
	10. Phases, Solids, Liquids and Gases.
Source:	Flinn ChemTopic Lab Book #10 - Thermochemistry
Type of Material:	Lab: Energy Changes - Heat of Fusion
Building on:	Heat, energy, temperature, conservation of energy, system and surroundings, exothermic and endothermic reactions
Leading to:	Enthalpy change, heats of fusion and vaporization
Links to Physics:	Energy, conservation of energy, electricity, forces, heat, and thermodynamics
Links to Biology:	Energy
Good Stories:	Water has the highest heat of vaporization of liquids. It also has a high heat of fusion. The following website gives some insight as to why. Another good story can be told about why ice floats; most solids sink in their liquid. <http://www.chem.ox.ac.uk/vrchemistry/energy/Page_8.htm> <http://www.chem.ox.ac.uk/vrchemistry/energy/Page_7.htm> Activity Description: In this technology-based activity (which can be done with interfacing or digital thermometer), students examine the heat changes during phase changes and draw a heating curve.

Number and Topic:	**11. Thermochemistry**
	15. Ionic and Metallic Bonds
	17. Water, Aqueous Solutions
Source:	Flinn ChemTopic Lab Book #10 - Thermochemistry
Type of Material:	Lab: Discovering Instant Cold Packs - Heat of Solution
Building on:	Enthalpy change, energy, temperature, conservation of energy, system and surroundings, exothermic and endothermic reactions
Leading to:	Heat of solution, calorimetry
Links to Physics:	Energy, conservation of energy, heat, and thermodynamics
Links to Biology:	Energy
Good Stories:	The following website is good for showing heat of solution and exothermic and endothermic: <http://www.chem.ox.ac.uk/vrchemistry/energy/Page_25.htm>
Activity Description:	In this Inquiry-based activity is to design a calorimetry experiment to determine the enthalpy change that occurs when a “cold pack solid” dissolves in water. A good website for a virtual chemistry experiment like the one is: <http://www.chm.davidson.edu/ChemistryApplets/calorimetry/HeatOFSolutionOfAmmoniumNitrate.html>

Number and Topic:	**11. Thermochemistry**
	15. Ionic and Metallic Bonds
	8. Chemical Reaction
Source:	Flinn ChemTopic Lab Book #10 - Thermochemistry
Type of Material:	Lab: Measuring Calories - Energy Content of Food

Building on:	Enthalpy change, energy, temperature, conservation of energy, system and surroundings, exothermic reactions
Leading to:	Calorimetry, combustion reactions, nutrition and calorie content
Links to Physics:	Energy, conservation of energy, heat, and thermodynamics
Links to Biology:	Energy, nutrition
Good Stories:	Most students are interested in the calorie content of foods. The following website is good for showing heat content in combustion and food: <http://www.chem.ox.ac.uk/vrchemistry/energy/Page_13.htm>
Activity Description:	In this experiment, students use calorimetry to calculate the amount of heat energy released when different snack foods burn and look for calorie content of foods.

Number and Topic:	**11. Thermochemistry** **15. Ionic and Metallic Bonds** **8. Chemical Reaction**
Source:	Flinn ChemTopic Lab Book #10 - Thermochemistry
Type of Material:	Lab: Heats of Reaction and Hess's Law - Small-Scale Calorimetry
Building on:	Enthalpy change, energy, temperature, conservation of energy, system and surroundings, exothermic reactions, heat of reaction
Leading to:	Hess's Law, heat of formation
Links to Physics:	Energy, conservation of energy, heat, and thermodynamics
Links to Biology:	Energy
Good Stories:	Chemistry of magnesium can be found at the following website: <chemed.chem.purdue.edu/demos/main_pages/9.7.html> The best story on this reaction I know of took place here in Chicago. There was a metal scrap warehouse with 3,000 pounds of scrap magnesium. It got wet. One of the employees tried to dry it with a propane torch. Magnesium burns so hot it reacts with water and CO_2; both feed the fire. The only way to put it out is dump salt, not sand, on it. There is a video clip of this warehouse with 3,000 pounds of scrap magnesium burning. Lee Marek's web page has a video clip of magnesium reacting with dry ice, which was done for WEB CT.
Activity Description:	In this microscale experiment students use Hess's Law to determine the heat reaction for the combustion of magnesium by an indirect method. A web version of this lab can be found at: <http://services.juniata.edu/ScienceInMotion/chem/labs/ap/hess.doc> Or <http://www.pitt.edu/~n3lsk/enthmgoproc.html> Or <http://www.dartmouth.edu/~chemlab/info/resources/deltah/deltah.html>

Number and Topic:	**11. Thermochemistry**
Source:	Flinn ChemTopic Lab Book #10 - Thermochemistry
Type of Material:	Demo: Colorful Heat - Temperature vs. Heat
Building on:	Temperature, heat
Leading to:	Relationship of heat and temperature
Links to Physics:	Energy, conservation of energy, heat, and thermodynamics

Links to Biology: Energy
Good Stories: Other good demos or stories on this can be found at:
<http://yesican.yorku.ca/home/h2heat.html>
<http://www.theweatherprediction.com/habyhints/39/>
<http://www.hcc.hawaii.edu/hcconline/sci122/Programs/p20/p20.html>
Activity Description: Uses food coloring and water to show the relationship between heat and temperature.

Number and Topic: 11. Thermochemistry
Source: Flinn ChemTopic Lab Book #10 - Thermochemistry
Type of Material: Demo: Specific Heat
Building on: Temperature, heat, and calorimetry
Leading to: Specific heat, heat capacity
Links to Physics: Energy, conservation of energy, heat, thermodynamics
Links to Biology: Energy
Good Stories:
Activity Description: Three different metals of equal mass are heated to the same temperature in boiling water and added separately to a known mass of cool water. The temperature changes are measured and related to specific heat.

Number and Topic: 11. Thermochemistry
8. Chemical Reaction
Source: Flinn ChemTopic Lab Book #10 - Thermochemistry
Type of Material: Demo: The Cool (Endothermic) Reaction
Building on: Temperature, heat
Leading to: Endothermic changes, entropy
Links to Physics: Energy, conservation of energy, heat, thermodynamics
Links to Biology: Energy, entropy
Good Stories: This demo can be found at the following website along with a video clip:
<http://chemed.chem.purdue.edu/demos/main_pages/21.2.html>
Activity Description: Solid barium hydroxide and ammonium thiocyanate are mixed. The reaction is endothermic and entropy driven.

Number and Topic: 11. Thermochemistry
8. Chemical Reaction
Source: Flinn ChemTopic Lab Book #10 - Thermochemistry
Type of Material: Demo: Whoosh Bottle Reaction
Building on: Temperature, heat
Leading to: Exothermic reactions, combustion reactions, and heat of formation
Links to Physics: Energy, conservation of energy, heat and thermodynamics
Links to Biology: Energy
Good Stories: **There are some dangers associated with this demo. It would pay to read all safety instructions**. For a list of dangerous demos you should avoid go to:

<http://www.msta-mich.org/publications/newsletter/newsletter.february00/page1.html>
This is a great demo worth doing many times during the year, if you follow the safety directions. Be sure to tape the bottle with clear packing tape and use a blast shield. It can be related to many chemistry topics. John Forman's set of drawing/analogies relating this demo to a 4-cycle engine is worth trying to obtain.

Activity Description: A 5-gallon plastic water bottle has a small amount of isopropyl alcohol added to it. This is ignited. The big whoosh! shows an exothermic reaction.

Number and Topic: 11. Thermochemistry
8. Chemical Reaction

Source: Flinn ChemTopic Lab Book #10 - Thermochemistry
Type of Material: Demo: Flameless Ration Heaters - Applied Chemistry
Building on: Temperature, heat
Leading to: Exothermic reactions, heat of reaction
Links to Physics: Energy, conservation of energy, heat, and thermodynamics
Links to Biology: Energy
Good Stories: Unused ration heaters must be disposed of as hazardous wastes - see the following:
<http://aec.army.mil/usaec/publicaffairs/update/sum01/sum0106.htm>
Great webpage on this done by a kid I believe:
<http://chem200.tripod.com/>
Activity Description: This inquiry demo uses the flameless ration heaters developed by the army for heating soldiers' food in the field. The students are asked to figure out how these work.

Number and Topic: 17. Water, Aqueous Solutions
15. Ionic & Metallic Bonds

Source: Flinn ChemTopic Lab Book #12 - Solubility and Solutions
Type of Material: Lab: Factors Affecting Solution Formation—An Inquiry-Based Approach
Building on: Ionic bonds, intermolecular forces, kinetic theory
Leading to: Solution, solubility, solute, solvent
Links to Physics: Energy, kinetic theory, electrical forces
Links to Biology: Planets, fungus, diseases
Good Stories: Solutions of copper sulfate, an important agricultural chemical, are sprayed on grapes and wheat and many other plants to prevent fungus diseases. See the following website:
<http://pmep.cce.cornell.edu/profiles/extoxnet/carbaryl-dicrotophos/copper-sulfate-ext.html>
Video clip of copper sulfate crystallizing; see the following website:
<http://micro.magnet.fsu.edu/moviegallery/chemicalcrystals/coppersulfate/>
A great animation showing the surface phenomenon of dissolving can be found at the following website, click on the "the dissolution of NaCl in

aqueous solution”:
<http://cwx.prenhall.com/petrucci/medialib/media_portfolio/14.html>
Or other excellent animations:
<http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/molvie1.swf>
<http://www.mpcfaculty.net/mark_bishop/NaCl_dissolves.htm>
<http://www.northland.cc.mn.us/biology/Biology1111/animations/dissolve.html>

Activity Description: In this inquiry-based experiment, students must design a series of tests to investigate how changing the crystal size of the solute, the temperature of the solvent, or the mixing of the solution will affect the rate at which copper sulfate dissolves. The results help students understand how and why solutions form.

Number and Topic: 17. Water, Aqueous Solutions
21. Organic Chemistry/Introduction to Biochemistry
15. Ionic & Metallic Bonds
16. Covalent Bonds, Molecular Shapes & Intermolecular Forces

Source: Flinn ChemTopic Lab Book #12 - Solubility and Solutions
Type of Material: Lab: It’s in Their Nature—Solute–Solvent Interactions
Building on: Solubility, solution, homogenous, polar vs. nonpolar, intermolecular forces
Leading to: Solute and solvent, miscibility of liquids
Links to Physics: Energy, kinetic theory, electrical forces
Links to Biology: Body fluids, plant cells
Good Stories: When eating hot peppers or hot spicy foods has left you "breathing fire," drinking water will not relieve the pain, because the water cannot dissolve the oils (nonpolar) which give the spicy taste. A chemist might suggest that the ideal would be to drink a chaser of a nonpolar liquid. But most such liquids are toxic, so gargling with benzene or toluene would not be a good solution! It is better to eat greasy foods like meats, which will dissolve the oils. Alternatively, food like pasta or bread that can absorb the oils will help "put out the fire." The smell and taste of onions and garlic are also due to oils that are not easily washed away by water and are not absorbed well.
A simple animation showing soap dissolving grease in water:
<http://intro.bio.umb.edu/111-112/111F98Lect/soapandoil.html>
A series of animations showing the surface phenomenon of dissolving of ionic compounds can be found at the following websites; click on the “the dissolution of NaCl in aqueous solution” for the first:
<http://cwx.prenhall.com/petrucci/medialib/media_portfolio/14.html>
<http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/molvie1.swf>
<http://www.mpcfaculty.net/mark_bishop/NaCl_dissolves.htm>
<http://www.northland.cc.mn.us/biology/Biology1111/animations/dissolve.html>
The following web page sums up many of the major concepts in solubility:
<http://www.sciencebyjones.com/solubility.htm>

The following is another interesting website: “How Things Dissolve” by Dr. Walt Volland. <http://scidiv.bcc.ctc.edu/wv/09/0009-002-process.html>

Activity Description: Students study the solubility patterns of ionic, polar, and nonpolar compounds in a variety of solvents to understand the types of intermolecular attractive forces that exist.

Number and Topic: 17. Water, Aqueous Solutions
15. Ionic & Metallic Bonds
16. Covalent Bonds, Molecular Shapes & Intermolecular Forces

Source: Flinn ChemTopic Lab Book #12 Solubility and Solutions

Type of Material: Lab: Solubility and Temperature—A Solubility Curve

Building on: Solubility

Leading to: Saturated solution, saturation temperature, solubility curve

Links to Physics: Energy, kinetic theory, electrical forces

Links to Biology: Solubility of oxygen in water

Good Stories: A good website showing solubility curves:
<http://www.scidiv.bcc.ctc.edu/wv/09/0009-004-solub.html>
The recipe for making supersaturated fudge:
<http://www.gi.alaska.edu/ScienceForum/ASF8/871.html>
QuickTime movie of a supersaturated solution:
<http://chemed.chem.purdue.edu/demos/main_pages/15.2.html>

Activity Description: The purpose of this microscale experiment is to construct a solubility curve for potassium nitrate in water by measuring saturation temperatures for six different solution concentrations. Graphical analysis of the data allows students to determine whether a solution is unsaturated, saturated or supersaturated.

Number and Topic: 17. Water, Aqueous Solutions

Source: Flinn ChemTopic Lab Book #12 - Solubility and Solutions

Type of Material: Lab: Preparing and Diluting Solutions—Concentration and Absorbance

Building on: Solution, solvent, solute

Leading to: Concentration, molarity, dilution equation, absorbance

Links to Physics: Light, waves

Links to Biology: How Spectrophotometers are used in biology
<www.bioscience.drexel.edu/Homepage/Fall2003/bio305/docs/docs/Week%203%20Background.doc>
<http://bioweb.wku.edu/courses/Biol121/Protein/Graph_example.htm>

Good Stories: Web pages on Beer’s Law and Concentration and Absorbance:
<http://www.shu.ac.uk/schools/sci/chem/tutorials/molspec/beers1.htm>
<http://www.ic.sunysb.edu/Class/che133/lectures/beerslaw.html>
An Applet on how Beer’s Law is used and calculated can be found at:
<http://www.chm.davidson.edu/ChemistryApplets/spectrophotometry/BeersLaw.html>
I found the following on the web that addresses color and Beer’s Law:

"*The Deeper the Glass,*

the Darker the Brew,
the Less of the Incident
Light that Gets Through"

Activity Description: This is a technology-based experiment where students practice analytical technique as they prepare and dilute a series of copper sulfate solutions of known molarity. They then investigate the relationship between the concentration and absorbance of the solutions and use this information to determine the accuracy of their calculations and their technique.

Number and Topic: 17. Water, Aqueous Solutions
16. Covalent Bonds, Molecular Shapes & Intermolecular Forces
15. Ionic Bonds

Source: Flinn ChemTopic Lab Book #12 - Solubility and Solutions

Type of Material: Lab: Freezing Point Depression—How Low Can You Go?

Building on: Freezing point, concentration, covalent bonds, intermolecular forces, ionic bonds

Leading to: Freezing point, freezing point depression, colligative properties, molality, Debye-Huckle theory, Van't Hoff factor

Links to Physics: Energy, kinetic theory

Links to Biology: Colligative properties—osmotic pressure

Good Stories: Why is salt used on the roads to prevent ice and snow from sticking, or to help melt it? For more info on why salt is used on the roads see:
<http://groups.msn.com/TheAlchemistsCorner/roadsaltandmycarpart1amp2.msnw>
<http://science.howstuffworks.com/question58.htm>
<http://chemistry.about.com/cs/howthingswork/a/aa120703a.htm>
Websites that go through colligative properties are listed below:
<http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/meltpt.html#c1>
<http://library.thinkquest.org/C006669/data/Chem/colligative/colligative.html>
<http://library.thinkquest.org/C006669/data/Chem/colligative/colligative.html?tqskip1=1>
Antifreeze is a liquid that dissolves easily in water. A solution of antifreeze is added to a car's cooling system, lowering the freezing point of cooling water, preventing it from freezing and so ruining the engine. There are even animals that have similar materials in them to keep them from freezing.
<http://www.pbs.org/safarchive/4_class/45_pguides/pguide_704/4574_froze.html>

Activity Description: Students measure the freezing point depression for four different solutes dissolved in water and learn how the concentration and number of dissolved solute particles (colligative properties) affect the freezing point of water.

Number and Topic: 17. Water, Aqueous Solutions
10. Phases, Solids, Liquids and Gases (States of Matter)

Source: Flinn ChemTopic Lab Book # 12 Solubility and Solutions
Type of Material: Demo: Aloha Chemical Sunset—Colloids and Light Scattering
Building on: States of matter, light
Leading to: Colloids, light scattering, Tyndall effect, waves
Links to Physics: Light, scattering, Tyndall effect
Links to Biology: Colloids, "Life is a whim of several billion cells to be you for a while." Quote by John Tyndall
Good Stories: "Life is a wave, which in no two consecutive moments of its existence are composed of the same particles." Quote by John Tyndall.
The following answer the ultimate kid question: "Why is the sky blue?" along with a very nice poem about it:
<http://www.why-is-the-sky-blue.org/why-is-the-sky-blue.html>
<http://www.sky-watch.com/articles/skyblue.html>
Some nice pictures of the Tyndall effect can be found at:
<http://www.silver-lightning.com/tyndall/>
A detailed explanation of the Tyndall effect:
<http://www.svpvril.com/Tyndall.html>
A short biography of John Tyndall:
<http://www.tyndall.ac.uk/general/john_tyndall_biography.shtml>
Activity Description: The reaction of sodium thiosulfate with hydrochloric acid produces elemental sulfur, which precipitates from solution to form a colloidal mixture. When the reaction is carried out on an overhead projector, the light from the projector is scattered by the colloidal sulfur particles and produces a multicolored chemical sunset.

Number and Topic: 17. Water, Aqueous Solutions
10. Phases, Solids, Liquids and Gases (States of Matter)
Source: Flinn ChemTopic Lab Book #12 - Solubility and Solutions
Type of Material: Demo: Solutions, Colloids, and Suspensions—Principles and Properties
Building on: Solution, states of matter, light, Tyndall effect
Leading to: Colloids, light scattering, semipermeable membrane, osmosis, reverse osmosis
Links to Physics: Light, scattering, Tyndall effect
NASA has been doing research on the physics of colloids in space. To see time-lapse photos of colloid experiments aboard the Space Station click on:
<http://www.scipoc.msfc.nasa.gov/videochron.html>
Links to Biology: Colloids, semipermeable membranes, osmosis, cells, diffusion
Web page of how biologist uses semipermeable membranes:
<http://www.pinkmonkey.com/studyguides/subjects/biology-edited/chap3/b0303301.asp> and
<http://www.mansfield.ohio-state.edu/~sabedon/biol1050.htm>
"Life is a whim of several billion cells to be you for a while." Quote by John Tyndall
Good Stories: There is a most interesting demo using cornstarch. It gets more "solid" when exposed to sheer stresses, or when compressed. When you squeeze a

handful of the liquid starch mixture it becomes solid, but when you let go it oozes out of your hand. There is a great David Letterman scene where Lee Marek ran across a pool filled with 500 pounds of the starch mixture (remember it acts as a solid when stressed), but when Letterman stepped in slowly he sank. When he tried to get out, the mixture acted like quicksand and he was stuck. The following colloid rheology study is used to explain how concentrated colloids of rigid particles flow. At high sheer rates colloids can show thickening, as the viscosity increases dramatically with increasing sheer rate.
<http://www.poco.phy.cam.ac.uk/research/model/rheology/>
"Life is a wave, which in no two consecutive moments of its existence is composed of the same particles." Quote by John Tyndall
The uses of reverse osmosis with semipermeable membranes:
<http://chemistry.about.com/library/weekly/blrevosmosis.htm>
Frederick Donnan, the British chemist, whose work was instrumental in the development of colloid chemistry:
<http://www.geocities.com/bioelectrochemistry/donnan.htm>
Some nice pictures of the Tyndall effect can be found at:
<http://www.silver-lightning.com/tyndall/>
A detailed explanation of the Tyndall effect:
<http://www.svpvril.com/Tyndall.html>
A short biography of John Tyndall:
<http://www.tyndall.ac.uk/general/john_tyndall_biography.shtml>

Activity Description: Solutions, colloids, and suspensions are defined and distinguished from one another based on the size of their dispersed particles and on properties such as the ability to settle upon standing, be trapped by a filter, pass through a semipermeable membrane, or scatter light.

Number and Topic: 17. Water, Aqueous Solutions
19. Equilibrium/Acids/Bases/pH
11. Thermochemistry

Source: Flinn ChemTopic Lab Book #12 - Solubility and Solutions
Type of Material: Demo: Alka-Seltzer® and Gas Solubility—Effect of Temperature
Building on: Solubility, acid-base, entropy
Leading to: Gas solubility, reversible reactions, thermal pollution, Henry's Law
Links to Physics: Entropy
Links to Biology: Gas solubility, thermal pollution
Good Stories: Thermal pollution and its effects on the environment are very important. Web pages dealing with this can be found at:
<http://www.willamette.edu/~ecaruso/thermal.htm>
<http://carbon.cudenver.edu/~gcronin/gretchen.pdf>
Gas solubility usually works in the opposite way to that of liquids and solids. Some web pages about that are:
<http://scidiv.bcc.ctc.edu/wv/09/0009-006-henry.html>
<http://www.chem.uidaho.edu/~honors/gassol.html>
<http://www.ursa.kcom.edu/Kristin/>

The Alka-Seltzer® website shows how it works. The history of Alka-Seltzer® is found at:
<http://www.alka-seltzer.com/home/default.htm>

Activity Description: An Alka-Seltzer® tablet is used to look at the effect of temperature on the solubility of a gas.

Number and Topic: 17. Water, Aqueous Solutions
16. Covalent Bonds, Molecular Shapes & Intermolecular Forces
15. Ionic Bonds

Source: Flinn ChemTopic Lab Book #12 - Solubility and Solutions
Type of Material: Demo: Sorting Out Solutions—Hydrogen Bonding Demonstration
Building on: Solubility
Leading to: Miscible liquids, hydrogen bonding, salting out
Links to Physics: Forces
Links to Biology: Salting out can be used in the extraction of DNA. Hydrogen bonding is important in numerous applications in biology.
Good Stories: Pictures of salting out can be found at:
<http://genchem.chem.wisc.edu/demonstrations/Gen_Chem_Pages/11solutionspage/salting_out__making_liquid.htm>
A detailed description of the intermolecular forces involved in salting out can be found at:
<http://chemeducator.org/sbibs/samples/spapers/11smi897.pdf>
Water and hydrogen bonding:
<http://www.northland.cc.mn.us/biology/Biology1111/animations/hydrogenbonds.html>
<http://www.visionlearning.com/library/module_viewer.php?mid=57>
<http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page3.html>
A nice animation showing intermolecular forces can be found at
<http://207.10.97.102/chemzone/lessons/03bonding/mleebonding/hydrogen_bonds.htm>

Activity Description: A two-part demonstration to show the effect of hydrogen bonding and other intermolecular forces on the properties of solutions. When 50 ml of glycerol and 50 ml of water are mixed, the volume of the resulting solution should be 100 ml, but it turns out to be 4% less! Ethyl alcohol and water are miscible. Add an ionic solute to the solution, however, and the solution separates into two layers.

Number and Topic: 17. Water, Aqueous Solutions
11. Thermochemistry
19. Equilibrium

Source: Flinn ChemTopic Lab Book #12 - Solubility and Solutions
Type of Material: Demo: Instant Hand Warmers—Supersaturated and Saturated Solutions
Building on: Solutions, exothermic, endothermic

Leading to: Saturated solution, supersaturated solution, crystallization, exothermic reactions
Links to Physics: Energy
Links to Biology: Solubility, solutions, intermolecular forces
Good Stories: The recipe for making supersaturated fudge:
<http://www.gi.alaska.edu/ScienceForum/ASF8/871.html>
QuickTime movie of a supersaturated solution:
<http://chemed.chem.purdue.edu/demos/main_pages/15.2.html>
Video clips of a demonstration with the hot-pack commercial product, and an explanation can be found on:
<http://jchemed.chem.wisc.edu/JCESoft/CCA/CCA2/MAIN/ACETATE/CD2R1.HTM>
<http://www.csudh.edu/oliver/demos/supersat/supersat.htm>
Activity Description: Instant hand warmers contain a supersaturated solution of sodium acetate. A supersaturated solution is an inherently unstable (non-equilibrium) condition. When the solution is "stressed," by the addition of a seed crystal, lots of heat is released as the crystallization occurs.

Number and Topic: 20. Acids/Bases/pH
Source: Flinn ChemTopic Lab Book #13 - Acids and Bases
Type of Material: Lab: Properties of Acids and Bases - Identification and Classification
Building on: Chemical reactions
Leading to: Acid, bases, pH, indicators, conductivity, active metals, and neutralization
Links to Physics: Atoms, electricity, and forces
Links to Biology: Many biological processes are pH sensitive and involve acids and bases.
Good Stories: From the following web pages the students can teach themselves about acids and bases:
<www.miamisci.org/ph/>
<http://www.chemtutor.com/acid.htm - what>
<http://www.chem.ox.ac.uk/vrchemistry/chapter16/pag01.htm>
<http://chemistry.about.com/cs/acidsandbases/>
<http://www.carlton.paschools.pa.sk.ca/chemical/equilibrium/abindicators.htm>
<http://rs.ed.uiuc.edu/students/erlinger/water/background/ph.html>
Activity Description: This microscale lab is designed to explore the properties of aqueous solutions and classify them as acidic, basic or neutral. Along the way students are introduced to conductivity, indicators, pH, active metals and neutralization. The lab shows the operational definition of acids and bases.

Number and Topic: 20. Acids/Bases/pH
Source: Flinn ChemTopic Lab Book #13 - Acids and Bases
Type of Material: Lab: Natural Indicators - Acids, Bases, and the pH Scale
Building on: Acid and Bases
Leading to: Indicators, pH, weak and strong acids, conjugate acids and bases, and equilibrium

Links to Physics: Atoms, forces

Links to Biology: Many biological processes are pH sensitive and so involve acids and bases. Numerous pH indicators are used in biology.

Good Stories: From the following web pages the students can teach themselves about acids, bases and natural indicators, or view similar labs to this Flinn lab.
<http://www.woodrow.org/teachers/chemistry/institutes/1986/exp23.html
>
<http://www.bhsu.edu/artssciences/chemistry/Chem_106L/Labs/NaturalpH.pdf>
<http://www.okstate.edu/jgelder/acidDemonstrations.html>

Activity Description: In this inquiry-based lab students extract natural indicators from flowers and fruits and then design an experiment to see how the color change of these indicators is related to pH.

Number and Topic: 20. Acids/Bases/pH
8. Chemical Reaction
19. Equilibrium

Source: Flinn ChemTopic Lab Book #13 - Acids and Bases

Type of Material: Lab: Measuring Acid Strength - K_a Values for Weak Acids

Building on: Acid and Bases

Leading to: Weak acids, conjugate bases, equilibrium constants and Bronsted/Lowry acids/bases

Links to Physics: Atoms, forces

Links to Biology: Many biological processes are pH sensitive and involve acids and bases. Indicators are often used in biology.

Good Stories: From the following web pages the students can teach themselves about weak acids and K_a:
< http://www.chem.ox.ac.uk/vrchemistry/chapter16/pag05.htm>
<http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch17/ph.html>

Activity Description: The equilibrium ionization constant (K_a) for an unknown weak acid is measured.

Number and Topic: 20. Acids/Bases/pH
8. Chemical Reaction

Source: Flinn ChemTopic Lab Book #13 - Acids and Bases

Type of Material: Lab: Classic strong acid/strong base titration using an acid of unknown concentration, drawing and analyzing a pH curve.

Building on: Acid and Bases, neutralization reaction

Leading to: Titrations, titration curves, equivalence points, end points, and standard solutions

Links to Physics: Atoms, forces

Links to Biology: Many biological processes are pH sensitive and involve acids and bases. Indicators are often used in biology.

Good Stories: From the following web pages (some are videos) the students can learn about titration.
<http://arg.chem.vt.edu:8080/ramgen/2124/volumetric.rm>

<http://wine1.sb.fsu.edu/chm1045/notes/Aqueous/Stoich/Aqua02.htm>
<http://www.ausetute.com.au/titrcurv.html>

Activity Description: This classic titration lab uses technology to analyze the shape of the titration curve for the neutralization of a solution of HCl with a standard NaOH solution. The data can also be collected and plotted manually.

Number and Topic: 20. Acids/Bases/pH
8. Chemical Reaction

Source: Flinn ChemTopic Lab Book #13 - Acids and Bases
Type of Material: Lab: Microscale Titration - Percent Acetic Acid in Vinegar
Building on: Acid and bases, neutralization reactions and molarity
Leading to: Titrations, equivalence points, end points, and standard solutions
Links to Physics: Atoms, forces
Links to Biology: Two separate biochemical processes (aerobic and anaerobic), both of which require microorganisms, are involved in the production of vinegar.
Good Stories: From the following web pages (and some videos) the students can learn about titration.
<http://www.ausetute.com.au/titrcurv.html>
Virtual chemistry lab for acid-base titration follows:
<http://lrs.ed.uiuc.edu/students/mihyewon/chemlab_experiment.html>
Activity Description: The microscale titration lab uses NaOH solution to determine the strength of vinegar (acetic acid). This lab can easily be adapted to test other commercial products such as aspirin or mustard.

Number and Topic: 20. Acids/Bases/pH
8. Chemical Reaction

Source: Flinn ChemTopic Lab Book #13 - Acids and Bases
Type of Material: Lab: Buffers Keep the Balance - Biological Buffers
Building on: Weak acids and bases, pH
Leading to: Buffers
Links to Physics: Atoms
Links to Biology: Many biological processes are pH sensitive and involve acids and bases and buffers.
Good Stories: Blood chemistry with buffers:
<http://wunmr.wustl.edu/EduDev/LabTutorials/blood.htm>
<http://www.brynmawr.edu/Acads/Chem/Chem104lc/buffers.html>
<http://www.usyd.edu.au/su/anaes/lectures/acidbase_mjb/control.html>
Activity Description: This lab explores the properties of a biological buffer similar to the one found in blood

Number and Topic: 20. Acids/Bases/pH

Source: Flinn ChemTopic Lab Book #13 - Acids and Bases
Type of Material: Demo: Indicator Sponge - A Discrepant Event
Building on: Acids and bases
Leading to: Indicators
Links to Physics: Atoms

Links to Biology: Congo red is a biological stain.
Good Stories: This is a discrepant event and a good lead into indicators
Activity Description: You put a red sponge in a red solution, and the sponge turns blue.

Number and Topic: 20. Acids/Bases/pH
8. Chemical Reaction
Source: Flinn ChemTopic Lab Book #13 - Acids and Bases
Type of Material: Demo: The Rainbow Tube
Building on: Acids and bases
Leading to: Indicators, pH, and neutralization
Links to Physics: Atoms, forces
Links to Biology: Many natural dyes are pH dependent, so they can change color if the pH changes.
Good Stories:
Activity Description: A rainbow column of colors is formed in a test tube showing various pHs.

Number and Topic: 20. Acids/Bases/pH
8. Chemical Reaction
Source: Flinn ChemTopic Lab Book #13 - Acids and Bases
Type of Material: Demo: Upset Tummy? MOM to the Rescue - Colorful Antacid
Building on: Acids, bases and neutralization
Leading to: Solubility, forces
Links to Physics: Atoms
Links to Biology: Stomach acid, antacids
Good Stories:
Activity Description: Milk of Magnesium (MOM) is mixed with universal indicator and hydrochloric acid to simulate an antacid.

Number and Topic: 20. Acids/Bases/pH
8. Chemical Reaction
Source: Flinn ChemTopic Lab Book #13 - Acids and Bases
Type of Material: Demo: Strong vs. Weak Acids
Building on: Strong and weak acids, pH
Leading to: Conjugate base, universal indicator, equilibrium, and common ion
Links to Physics: Atoms, electricity, and forces
Links to Biology: Acid rain, effects of pH on plant life, ecology.
Good Stories: Lakes and rivers with marble or limestone bottoms tend to resist acid rain because of reactions like the ones shown here.
Activity Description: Weak and strong acids are compared in a reaction with calcium carbonate and universal indicator.

Number and Topic: 20. Acids/Bases/pH,
8. Chemical Reaction
Source: Flinn ChemTopic Lab Book #13 - Acids and Bases
Type of Material: Demo: Buffer Balancing Acts
Building on: Weak acids, pH

Leading to: Buffer, conjugate base
Links to Physics: Atoms, electricity and forces
Links to Biology: Many biological processes are pH sensitive and involve acids and bases buffers.
Good Stories: Many consumer products are acids and bases. Some of these are buffered. The “plop-plop-fizz-fizz” of Alka-Seltzer is one such buffered product. See the following web pages:
<http://www.chem.umn.edu/services/lecturedemo/info/Alka-SeltzerBuffer.html>
<www.ar.cc.mn.us/chemistry/ideas/> Inquiry-based labs.
Activity Description: This demo looks at the properties of buffers and how they work.

Number and Topic: 18. Reaction Rates and Kinetics
22. Redox
Source: Flinn ChemTopic Lab Book #14 - Kinetics
Type of Material: Lab: Introduction to Reaction Rates - The “Blue Bottle” Reaction
Building on: Redox, collision theory
Leading to: Kinetics, reaction rate
Links to Physics: Energy
Links to Biology: Dextrose (glucose) is a simple sugar that is the main fuel for metabolism. This oxidation of dextrose in the reaction represents an example of reducing sugars used in biology.
Good Stories: The following site has a video and a demo write up on reducing sugars.
<http://www.uni-regensburg.de/Fakultaeten/nat_Fak_IV/Organische_Chemie/Didaktik/Keusch/D-Video-e.htm>
Activity Description: The blue bottle lab using dextrose and methylene blue is usually done as a demo. Here it is used as an experiment to show how the reaction rate can be measured.

Number and Topic: 18. Reaction Rates and Kinetics
11. Thermochemistry
Source: Flinn ChemTopic Lab Book #14 - Kinetics
Type of Material: Lab: Temperature and Reaction Rates - An Inquiry-Based Approach
Building on: Redox, collision theory, kinetic theory, and energy
Leading to: Kinetics, reaction rate
Links to Physics: Energy, kinetic theory
Links to Biology: Most biological processes are strongly dependent on temperature to proceed correctly. Also, most biological systems are thermally unstable, and only fail to break down due to kinetic stability.
Good Stories: Flameless ration heaters [FRH] have a similar reaction occurring in them. They consist of Mg metal with NaCl and water to produce the heat.
Activity Description: In this inquiry-based lab the students design and carry out a procedure to analyze the rate of the reaction of magnesium with HCl at different temperatures.

Number and Topic: 18. Reaction Rates and Kinetics

Source: Flinn ChemTopic Lab Book #14 - Kinetics

Type of Material: Lab: The Order of Reaction Effect of Concentration

Building on: Rates

Leading to: Rate Law, reaction rate, order of reaction

Links to Physics: Energy, kinetic theory

Links to Biology: Dinosaurs, reaction rates

Good Stories: See the following simulation: <http://www.chem.uci.edu/education/undergrad_pgm/applets/sim/simulation.htm>

Activity Description: This is a microscale starch/iodine clock reaction lab. Students determine the relationship between the rate of a reaction and concentration of reactants to find the order and the rate law.

Number and Topic: 18. Reaction Rates and Kinetics

Source: Flinn ChemTopic Lab Book #14 - Kinetics

Type of Material: Lab: Kinetics of Dye Fading

Building on: Rates

Leading to: Rate Law, reaction rate, colorimetry, order of reaction

Links to Physics: Energy, light

Links to Biology: Most biological processes are strongly dependent on temperature to proceed correctly. Also, most biological systems are thermally unstable, and only fail to break down due to kinetic stability.

Good Stories: A good site for teaching about reaction rates. Beer's Law and other ideas in this lab can be found at the following website: <http://www.vernier.com/cmat/cmatdnld.html>

Activity Description: In this technology-based lab the rate at which phenolphthalein dye fades is measured colorimetrically. From graphs of the data the order and rate of the reaction are determined. This is a more advanced lab.

Number and Topic: 18. Reaction Rates and Kinetics

Source: Flinn ChemTopic Lab Book #14 - Kinetics

Type of Material: Lab: Determining the Rate Law - A "Sulfur Clock" Reaction

Building on: Rates

Leading to: Rate Law, reaction rate, and order of reaction

Links to Physics: Energy

Links to Biology: Most biological processes are strongly dependent on temperature to proceed correctly. Also, most biological systems are thermally unstable, and only fail to break down due to kinetic stability.

Good Stories: Nice website explaining concentrations and reaction rates: <http://www.chem.uidaho.edu/~honors/rate2.html>

Activity Description: The order and rate of the acid-catalyzed decomposition reaction of sodium thiosulfate to give sulfur are determined. This is a more advanced lab.

Number and Topic: 18. Reaction Rates and Kinetics

Source: Flinn ChemTopic Lab Book #14 - Kinetics

Type of Material: Demo: Iodine Clock Reaction – Effects of Concentration, Temperature, and a Catalyst
Building on: Rates
Leading to: Reaction rate, collision theory and catalysts.
Links to Physics: Energy, kinetic theory, heat
Links to Biology: Enzymes are specialized organic substances, composed of polymers of amino acids, that act as catalysts to regulate the speed of the many chemical reactions involved in the metabolism of living organisms. Great site on enzymes: <carnegieinstitution.org/first_light_case/horn/EWE/ewerefs.html>
Good Stories: The following sites may be used to help with this demo: <http://jchemed.chem.wisc.edu/Journal/Issues/1999/May/abs624A.html> <http://www.chem.uci.edu/education/undergrad_pgm/applets/sim/simulation.htm>
Activity Description: This demo uses the classic iodine clock reaction to develop the ideas about what affects the rate of a reaction.

Number and Topic:18 Reaction Rates and Kinetics
Source: Flinn ChemTopic Lab Book #14 - Kinetics
Type of Material: Demo: Now You See It, Now You Don't - Oscillating Chemical Reaction
Building on: Rates
Leading to: Reaction mechanisms, intermediates and catalysts
Links to Physics: Energy
Links to Biology: Enzymes are specialized organic substances, composed of polymers of amino acids, that act as catalysts to regulate the speed of chemical reactions involved in the metabolism of living organisms. Great sites on enzymes are listed in the demo, Iodine Clock Reaction Effect of Concentration, Temperature, and a Catalyst (above).
Good Stories: The following sites on Belousov/Zhabotinsky reactions may be used to help with this demo: <file:///< http///www.ux.his.no/~ruoff/BZ_Phenomenology.html>
Activity Description: This demo is sometimes called the oscillating clock reaction. The reaction changes from colorless to orange every 30 seconds for about a half hour. The chemistry here is rather complex.

Number and Topic: 18 Reaction Rates and Kinetics
8. Chemical Reactions
Source: Flinn ChemTopic Lab Book #14 - Kinetics
Type of Material: Demo: Sudsy Kinetics - Old Foamey
Building on: Rates, decomposition reactions
Leading to: Reaction rate, collision theory, reaction mechanism, intermediate and catalyst
Links to Physics: Energy, kinetic theory
Links to Biology: Harmful hydrogen peroxide forms within many cells. The enzyme catalase catalyzes the breakdown of hydrogen peroxide.

Good Stories: Info on hydrogen peroxide can be found at the following sites:
<http://www.infoplease.com/ce6/sci/A0824724.html>
<www.h2o2.com/>

Activity Description: Uses the decomposition reaction of hydrogen peroxide to teach most of kinetics. This one demo could cover most of the major concepts of kinetics.

Number and Topic: 18. Reaction Rates and Kinetics
8. Chemical Reactions

Source: Flinn ChemTopic Lab Book #14 - Kinetics

Type of Material: Demo: The Pink Catalyst

Building on: Rates, reactions

Leading to: Reaction rate, temperature, reaction mechanism, intermediate and catalyst

Links to Physics: Energy, kinetic theory

Links to Biology: Enzymes are specialized organic substances, composed of polymers of amino acids, that act as catalysts to regulate the speed of chemical reactions involved in the metabolism of living organisms. Great site on enzymes:
<http://www.carnegieinstitution.org/first_light_case/horn/EWE/ewerefs.html>

Good Stories: A great site on catalyst and intermediates:
<http://www.purchon.com/chemistry/catalyst.htm>
Nice stories on how a catalytic converter works and why we use them:
<http://www.howstuffworks.com/catalytic-converter.htm>
<http://www.chemcases.com/converter/converter-19.htm>
<http://www.discoverchemistry.com/dcv2-docroot/student/real_world/environment/cat_converter.html>

Activity Description: A cobalt catalyst is used to speed up the oxidation of tartrate ion. (Note there is a mistake in the amounts of catalyst used in this demo, it should be 0.4 grams not 4 grams.) You get to see the intermediate form and see the catalyst come back at the end.

Number and Topic: 18. Reaction Rates and Kinetics

Source: Flinn ChemTopic Lab Book #14 - Kinetics

Type of Material: Demo: A Simple Catalyst Demo

Building on: Rates, reactions

Leading to: Catalyst

Links to Physics: Energy, kinetic theory

Links to Biology: Enzymes are specialized organic substances, composed of polymers of amino acids, that act as catalysts to regulate the speed of chemical reactions involved in the metabolism of living organisms. Great site on enzymes:
<http://www.carnegieinstitution.org/first_light_case/horn/EWE/ewerefs.html>

Good Stories: A great site on catalyst and intermediates:
<http://www.purchon.com/chemistry/catalyst.htm>

Nice stories on how a catalytic converter works and why we use them:
<http://www.howstuffworks.com/catalytic-converter.htm>
<http://www.chemcases.com/converter/converter-19.htm>
<http://www.discoverchemistry.com/dcv2-docroot/student/real_world/environment/cat_converter.html>

Activity Description: Very cool but simple demo showing chalk and a rock as a catalyst.

Number and Topic: 18. Reaction Rates and Kinetics
8. Chemical Reactions

Source: Flinn ChemTopic Lab Book #14 - Kinetics

Type of Material: Demo: The Floating Catalyst - An Enzyme Reaction

Building on: Rates, reactions

Leading to: Reaction rate, enzyme/catalyst, and reaction rate

Links to Physics: Energy

Links to Biology: Enzymes are specialized organic substances, composed of polymers of amino acids, that act as catalysts to regulate the speed of the many chemical reactions involved in the metabolism of living organisms. Great site on enzymes:
<http://carnegieinstitution.org/first_light_case/horn/EWE/ewerefs.html>
<http://jchemed.chem.wisc.edu/Journal/Issues/1997/Feb/abs210.html>

Good Stories: Catalase is perhaps the best-documented enzyme on the Web. It's even got an entire domain name devoted to it
<http://www.catalase.com/catalase.htm>

Activity Description: Catalase is used as a catalyst to break down hydrogen peroxide

Number and Topic: 19. Equilibrium
20. Acids/Bases/pH

Source: Flinn ChemTopic Lab Book #15 - Equilibrium

Type of Material: Lab: Exploring Equilibrium - It Works Both Ways

Building on: Chemical reactions, acid base chemistry

Leading to: Equilibrium

Links to Physics: Energy, Probabilistic processes (?)

Links to Biology: Hemoglobin function in red blood cells illustrates an application of complex-ion equilibrium found in this lab. You can relate why athletes train at high altitudes in terms of equilibrium. Another equilibrium related to this lab is the acid-base carbonic acid blood buffering system.

Good Stories: How carbon monoxide bonds to the blood. I have heard that carbon monoxide is extremely poisonous. Can you explain why? See following webpage:
<http://www.howstuffworks.com/question190.htm>

Activity Description: This lab introduces equilibrium through an investigation of a complex-ion and acid base equilibrium system. Students see, by observing the color changes that take place, how equilibrium can be shifted. One of the hardest topics in chemistry at both the first year high school level and the freshman college level is equilibrium.

Number and Topic: 19. Equilibrium
11. Thermochemistry

Source: Flinn ChemTopic Lab Book #15 - Equilibrium

Type of Material: Lab: Restoring Balance - Le Chatelier's Principle and Equilibrium

Building on: Thermochemistry, equilibrium

Leading to: Le Chatelier's Principle

Links to Physics: Energy

Links to Biology: Many biological processes involve equilibrium

Good Stories: See previous lab for good stories

Activity Description: One of the classic labs used to show Le Chatelier's Principle. Cobalt complexes are used to shift equilibrium by both temperature and concentration changes. Students see how both of these changes affect the system. This lab may be done microscale.

Number and Topic: 19. Equilibrium

Source: Flinn ChemTopic Lab Book #15 - Equilibrium

Type of Material: Lab: The Equilibrium Constant for a Complex Ion Formation

Building on: Equilibrium

Leading to: Equilibrium constants

Links to Physics: Energy, light

Links to Biology: Many biological processes involve equilibrium. Also, if you type in colorimeter + biology into a search engine, many labs in biology come up that also use a colorimeter.

Good Stories: Many modern tests make use of colorimeters.

Activity Description: This lab develops a mathematical relationship for equilibrium constants. This lab uses technology (an instrument called a colorimeter) and is probably for a more advanced class.

Number and Topic: 19. Equilibrium
12. Gas Laws

Source: Flinn ChemTopic Lab Book #15 - Equilibrium

Type of Material: Lab: Gas Phase Equilibrium - Pressure and Temperature

Building on: Equilibrium

Leading to: Le Chatelier's Principle, reversible reactions

Links to Physics: Energy, pressure

Links to Biology: How gas-phase reactions contribute to air pollution. Nice links to environmental topics of acid rain, green house gases, photochemical smog, ozone (good in the upper atmosphere, but bad here on the ground) and energy

Good Stories: In the 21st century we will have to come up with new or better sources of energy or our society and economy will have major problems. Burning hydrocarbons not only depletes valuable resources and dumps tons of acid anhydrides into the air but also may add to global warming. This lab deals indirectly with that. The story of the destruction of the ozone layer and the Nobel Prize work of Paul Crutzen can be included. <http://www.nobel.se/chemistry/laureates/1995/>

<http://www.gcrio.org/ocp97/box4ch2.html>

Activity Description: The variables that affect the equilibrium concentrations of gas-phase reactions of nitrogen oxides. This lab is done microscale.

Number and Topic: 19. Equilibrium

Source: Flinn ChemTopic Lab Book #15 - Equilibrium

Type of Material: Lab: Penny-Ante Equilibrium - A Classroom Activity

Building on: Equilibrium

Leading to: Equilibrium constant, Le Chatelier's Principle

Links to Physics: Graphing

Links to Biology: Many biosystems are in equilibrium.

Good Stories:

Activity Description: A physical analogy to simulate equilibrium uses pennies in a cooperative learning activity to show, Le Chatelier's principle. The idea of equilibrium constants is also introduced.

Number and Topic: 19. Equilibrium

Source: Flinn ChemTopic Lab Book #15 - Equilibrium

Type of Material: Demo: Equilibrium Water Games - A Classroom Activity

Building on: Equilibrium

Leading to: Equilibrium, constant, Le Chatelier's Principle, reversible reactions

Links to Physics: Graphing

Links to Biology: Many bio systems are in equilibrium.

Good Stories:

Activity Description: A physical analogy to simulate equilibrium is used to show Le Chatelier's Principle. The idea of equilibrium constants is also introduced. This can be done as a cooperative learning activity.

Number and Topic: 19. Equilibrium
12. Gas Laws

Source: Flinn ChemTopic Lab Book #15 - Equilibrium

Type of Material: Demo: Equilibrium in a Syringe

Building on: Gas solubility, acid/base indicators

Leading to: Le Chatelier's principle, reversible reactions, equilibrium and Henry's Law

Links to Physics: Pressure, energy

Links to Biology: Bicarbonate is a buffer in blood. See good stories.

Good Stories: Blood buffer.
<http://www.chemistry.wustl.edu/~edudev/LabTutorials/blood.htm>
<http://www.brynmawr.edu/Acads/Chem/Chem104lc/buffers.html>
<http://www.usyd.edu.au/su/anaes/lectures/acidbase_mjb/control.html>
Impregnating Water with Fixed Air by Joseph Priestley on Making Carbonated Water (1772) the inventor of it! Here is a copy of his book.
<http://www.dbhs.wvusd.k12.ca.us/webdocs/Chem-History/Priestley-1772/Priestley-1772-Start.html>
More sites on carbonated water:

<http://www.softdrink.org.au/html/Ingredients/Carbonated_Water/carbonated_water.html>
<http://www.mhs101.pulski.k12.il.us/page2.htm>
Activity Description: Three types of equilbria, gas-phase, solubility, and acid/base are all seen here. This demo uses carbonated water to study equilibrium.

Number and Topic: 19. Equilibrium
22. Redox/Electrochemistry
20. Acids/Bases/pH
Source: Flinn ChemTopic Lab Book #15 - Equilibrium
Type of Material: Demo: Thionin: The Two-Faced Solution
Building on: Redox reactions, catalysts
Leading to: Photochemistry, reversible reactions
Links to Physics: Energy, light, conservation of energy
Links to Biology: Sunlight catalyses reactions in your skin. See good stories below.
Good Stories: How Do Sunless Tanning Products Work?
<www.chemistry.about.com/library/weekly/aa022602a.htm>
Chemistry of Tanning.
<http://www.globaltechnoscan.com/4thJuly-10thJuly02/chemistry_of_tanning.htm>
Activity Description: This demo is an example of a reversible reaction and the conversion of light energy to chemical energy.

Number and Topic: 19. Equilibrium
Source: Flinn ChemTopic Lab Book #4 Equilibrium
Type of Material: Demo: An Overhead Equilibrium
Building on: Equilibrium
Leading to: Le Chatelier's Principle
Links to Physics: Energy, Probabilistic processes (?)
Links to Biology: Many biosystems are in equilibrium.
Good Stories: Fits in as a demo before or after the lab, The Equilibrium Constant
Complex Ion Formation
Activity Description: This demo shows Le Chatelier's Principle using a series of concentration changes

Number and Topic: 19. Equilibrium
Source: Flinn ChemTopic Lab Book #15 - Equilibrium
Type of Material: Demo: Pink and Blue - A Colorful Chemical Balancing Act
Building on: Equilibrium and thermochemistry
Leading to: Reversible reactions, equilibrium constant
Links to Physics: Energy, Probabilistic processes (?)
Links to Biology: Many bio systems are in equilibrium.
Good Stories:

Activity Description: This demo shows Le Chatelier's principle using a series of concentration and temperature changes. This is a demo version of the lab Restoring Balance - Le Chatelier's Principle and Equilibrium.

Number and Topic: 21. Organic Chemistry /Intro to Biochemistry
22. Redox/Electrochemistry
16. Covalent Bonds, Molecular Shapes and Intermolecular Forces

Source: Flinn ChemTopic Lab Book #20 - Biochemistry – The Molecules of Life
Type of Material: Lab: Introduction to Carbohydrates - Structure and Properties
Building on: Organic Chemistry, redox, classification test, covalent bonds and molecular shapes
Leading to: Carbohydrates, mono- di- and poly-saccharides, reducing and non-reducing agents
Links to Physics: Energy, electricity and forces
Links to Biology: Carbohydrates provide energy for metabolism.
Good Stories: Carbohydrates are the most abundant biological compound. About half of all carbon on the Earth is in the form of carbohydrate compounds. Carbohydrates provide both energy and structure for life. We are talking sugars, starches and cellulose - some of the building blocks of life as we know it! You could use the ideas in this lab to test common foods for the presence of specific carbohydrates.
Activity Description: This lab is to explore the properties of carbohydrates and classify them. The students use a set of tests to find a series of five unknown carbohydrates.

Number and Topic: 21. Organic Chemistry/Intro to Biochemistry
16. Covalent Bonds, Molecular shapes and Intermolecular Forces

Source: Flinn ChemTopic Lab Book #20 - Biochemistry – The Molecules of Life
Type of Material: Lab: Identifying Proteins and Amino Acids
Building on: Organic chemistry, classification test, covalent Bonds, molecular shapes and intermolecular forces
Leading to: Proteins, amino acids
Links to Physics: Energy, electricity, forces
Links to Biology: Proteins, cells, DNA, respiration, enzymes to name a few!
Good Stories: Proteins are the center of life (and amino acids the building blocks); they catalyze our metabolic reactions, carry oxygen to our body tissues, protect the body from infection and maintain cell and tissue structure. The chemical sodium nitroprusside (also called sodium nitroferricyanide) is a pharmaceutical drug used in the treatment of high blood pressure and congestive heart disease. Nitroprusside is used in medical labs to test for cysteine in urine, which can be a symptom of disease.
Activity Description: This lab is to identify proteins and amino acid properties and classify them. The students use chemical tests to find out about peptide linkage and protein structure.

Number and Topic: 21. Organic Chemistry /Intro to Biochemistry

16. Covalent Bonds, Molecular shapes and Intermolecular Forces
20. Acids/Bases/pH

Source: Flinn ChemTopic Lab Book #20 - Biochemistry – The Molecules of Life
Type of Material: Lab: Physical Properties of Proteins
Building on: Organic chemistry, classification test, covalent Bonds, molecular shapes and intermolecular forces, proteins, acids/bases and pH
Leading to: Properties of proteins, folding
Links to Physics: Energy, electricity, forces
Links to Biology: Proteins, cells, DNA, respiration, enzymes, how structure of proteins relates to their biological function
Good Stories: In architecture there is a saying, “Form follows function.” The same can be said for the structure of proteins <http://www.rcsb.org/pdb/> and the way this relates to how they fulfill their biological function. The shape of the protein molecule is determined by forces (such as dipoles and hydrogen bonds), which cause the protein chains to twist and fold in a variety of ways. Using computers we can look at the shape of protein molecules, noticing their characteristic folding. Mistakes in protein structure, and hence folding, may give rise to a number of diseases such as Alzheimer’s and cystic fibrosis. Poisons, heat and irradiation of certain kinds can all ‘denature’ or unfold the protein molecule. Bacteria can be killed by all of these methods, as proteins so denatured are unable to function biologically.
Activity Description: This lab is to identify possible physiological and environmental factors that lead to protein de-naturation and activity.

Number and Topic: 21. Organic Chemistry /Intro to Biochemistry
16. Covalent Bonds, Molecular shapes and Intermolecular Forces

Source: Flinn ChemTopic Lab Book #20 - Biochemistry – The Molecules of Life
Type of Material: Lab: Properties of Lipids
Building on: Organic chemistry, covalent bonds, molecular shapes and intermolecular forces, solubility, saturated and unsaturated molecules
Leading to: Properties of lipids, fats, oils, triglycerides and extraction
Links to Physics: Energy, electricity and forces
Links to Biology: Food, energy flow, hydrocarbons, nutrition, and lipids
Good Stories: We hear every day about saturated, unsaturated and polyunsaturated fats. How and why these are used in food products is answered in this lab to some extent. A great spin-off of this is to have the students make soap. <www.mvtechprep.org/educator/ties2000/curriculum/bfgsoapcur.pdf>
Activity Description: The purpose of this experiment is to classify lipids and examine their properties. Students study the real-life processes that are used to obtain and characterize lipids. The results allow students to compare their results with information provided on the nutritional labels of a variety of food items.

Number and Topic: 21. Organic Chemistry /Intro to Biochemistry
16. Covalent Bonds, Molecular shapes and Intermolecular Forces

15. Ionic Bonds
17. Water, Aqueous Solutions

Source: Flinn ChemTopic Lab Book #20 - Biochemistry – The Molecules of Life
Type of Material: Demo: Membrane Diffusion and Dialysis
Building on: Organic chemistry, covalent bonds, molecular shapes and intermolecular forces, solubility, ionic compounds
Leading to: Diffusion, colligative properties and osmosis
Links to Physics: Energy, electricity and forces
Links to Biology: How cell membranes work
Good Stories: Kidney dialysis - a great website on this follows:
<http://www.chemistry.wustl.edu/~edudev/LabTutorials/Dialysis/Kidneys.html>
<http://www.kdf.org.sg/indexkdf.htm>
Activity Description: This demonstration compares the diffusion of small and large molecules across a semi-permeable membrane to illustrate the process of diffusion in cells.

Number and Topic: 21. Organic Chemistry /Intro to Biochemistry
20. Acids/Bases/pH
22. Redox/Electrochemistry

Source: Flinn ChemTopic Lab Book #20 - Biochemistry – The Molecules of Life
Type of Material: Demo: Glucose Fermentation and Metabolism
Building on: Organic chemistry, redox, and acid/base
Leading to: Fermentation, metabolism
Links to Physics: Energy, electricity, forces
Links to Biology: Fermentation, metabolism, and bacteria
Good Stories: Stories about Louis Pasture would fit in well here as seen on these websites:
<www.ambafrance-ca.org/HYPERLAB/PEOPLE/_pasteur.html>
<http://www.lucidcafe.com/library/95dec/pasteur.html>
Activity Description: In this demonstration an acid/base indicator is used to detect the production of carbon dioxide. A redox indicator is used to show the fermentation process.

Number and Topic: 21. Organic Chemistry /Intro to Biochemistry

Source: Flinn ChemTopic Lab Book #20 Biochemistry – The Molecules of Life
Type of Material: Demo: Lactose Intolerance - Enzyme Digestion
Building on: Organic chemistry
Leading to: Enzymes, monosaccharides and di-saccharides
Links to Physics: Energy
Links to Biology: Enzymes, digestion
Good Stories: Stories about lactose intolerance can be found at these websites:
<http://digestive.niddk.nih.gov/ddiseases/pubs/lactoseintolerance/index.htm>
<http://kidshealth.org/teen/food_fitness/nutrition/lactose_intolerance.html>

<http://www.foodsci.uoguelph.ca/dairyedu/chem.html>
Activity Description: This demonstration uses yeast as a model of a lactose intolerant organism to illustrate the use of the commercial enzyme product Lactaid™ in milk digestion.

Number and Topic: 21. Organic Chemistry /Intro to Biochemistry
Source: Flinn ChemTopic Lab Book #20 - Biochemistry – The Molecules of Life
Type of Material: Demo: Amino Acid Fingerprints - Ninhydrin
Building on: Organic chemistry
Leading to: Amino acids, ninhydrin, and forensic chemistry
Links to Physics: Electrostatics (?)
Links to Biology: Amino acids, oils
Good Stories: Detectives use ninhydrin to reveal fingerprints left behind at crime scenes. <http://www.cryptome.org/gummy.htm>
Activity Description: This demonstration uses ninhydrin in forensic chemistry to detect latent fingerprints on porous materials.

Number and Topic: 21. Organic Chemistry /Intro to Biochemistry
20. Acids/Bases/pH
17. Water, Aqueous Solutions
Source: Flinn ChemTopic Lab Book #20 - Biochemistry – The Molecules of Life
Type of Material: Demo: pH and Protein Solubility
Building on: Organic chemistry, acid/base and pH, solubility
Leading to: Protein, isoelectric point
Links to Physics: Electrostatic repulsion (is the cause of steric effects, which are responsible for the manner in which a protein folds).
Links to Biology: How the structure of proteins relates to their biological function.
Good Stories: 80% of the protein in milk is casein. It can be separated by the action of acid, the enzyme rennin, or bacteria (souring); it is also the main protein in cheese. Casein is used as a protein supplement in the treatment of malnutrition and is used commercially in cosmetics, glues, and as a sizing for coating paper. The following web pages may be of interest:
<http://jchemed.chem.wisc.edu/Journal/Issues/1999/Apr/abs488A.html>
<http://www.foodsci.uoguelph.ca/dairyedu/chem.html>
Activity Description: This demonstration examines the effects of pH on solubility and structure of the milk protein, casein.

Number and Topic: 21. Organic Chemistry/Intro to Biochemistry
8. Chemical Reactions
16. Covalent Bonds, Molecular Shapes & Intermolecular Forces
20. Acids/Bases/pH
22. Redox
Source: Flinn ChemTopic Lab Book #23 - Chemistry of Food
Type of Material: Lab: Food Testing Lab—Carbohydrates, Proteins, and Fats
Building on: Organic chemistry, redox, reactions, acid-base, covalent bonds, molecular shapes, complex ions

Leading to: Benedict's test, starch–iodine test, biuret test, Sudan III test, biochemistry
Links to Physics: Energy
Links to Biology: Food pyramid, nutrition, energy, carbohydrates, proteins, fats, Benedict's test, starch–iodine test, biuret test, Sudan III test, food, growth
Good Stories: NIH has a web page: The International Bibliographic Information on Dietary Supplements (IBIDS) database provides access to bibliographic citations and abstracts from published international scientific literature on dietary supplements.
<http://ods.od.nih.gov/showpage.aspx?pageid=48>
The Food and Nutrition Information Center (FNIC), part of the U.S. Department of Agriculture (USDA), has a great site with Child Nutrition, Health Food Composition, USDA Nutrient Database, Food Guide Pyramid, Food Safety for Children, Nutrition Education, Science Fair Projects at: <http://www.nal.usda.gov/fnic/>
Tufts University has a good site on nutrition: <http://navigator.tufts.edu/>
Government nutrition site: <http://www.nutrition.gov/home/index.php3>
Food and Drug administration has a web page for the Center for Food Safety and Applied Nutrition at: <http://vm.cfsan.fda.gov/list.html>
Other good government websites on understanding the food pyramid can be found at:
<http://www.health.gov/dietaryguidelines/dga2000/document/build.htm>
<http://www.pueblo.gsa.gov/cic_text/food/food-pyramid/main.htm>
Activity Description: The purpose of this experiment is to identify the biochemical nutrients in a variety of foods using a series of classification tests. Students gain an understanding of the chemical make-up of the substances found in their favorite foods.

Number and Topic: 21. Organic Chemistry/Intro to Biochemistry
8. Chemical Reactions
16. Covalent Bonds, Molecular Shapes & Intermolecular Forces
20. Acids/Bases/pH
22. Redox
Source: Flinn ChemTopic Lab Book #23 - Chemistry of Food
Type of Material: Lab: Milk Is a Natural—Biology, Chemistry, and Nutrition
Building on: Organic chemistry, redox, reactions, acid-base, covalent bonds, molecular shapes, separation techniques
Leading to: Protein, carbohydrate, fat, reducing sugar, biuret and Benedict's tests, biochemistry
Links to Physics: Energy
Links to Biology: Food pyramid, nutrition, energy, carbohydrates, proteins, fats, Benedict's test, starch–iodine test, biuret test, Sudan III test, cells, food
Good Stories: "Why Milk Matters Now for Children and Teens" from The National Institute of Child Health and Human Development (NICHD):
<http://www.nichd.nih.gov/milk/milk_facts.htm>
Food and Drug Administration has a web page for the Center for Food Safety and Applied Nutrition on Guidance on How to Understand and Use

the Nutrition Facts Panel on Food Labels at:
<http://vm.cfsan.fda.gov/~dms/foodlab.html>
National Digestive Diseases Information Clearinghouse has a good website on lactose intolerance at:
<http://digestive.niddk.nih.gov/ddiseases/pubs/lactoseintolerance/index.htm>

Activity Description: Students considered the statement often heard in commercials about milk—that it is a natural, nutritionally complete food source. In this lab they separate the protein and carbohydrate components of skim milk, analyze their properties, confirm their identity and verify their findings with the information provided on the *Nutrition Facts* label for skim milk.

Number and Topic: 21. Organic Chemistry/Intro to Biochemistry
16. Covalent Bonds, Molecular Shapes & Intermolecular Forces

Source: Flinn ChemTopic Lab Book #23 - Chemistry of Food

Type of Material: Lab: Boning Up on Calcium—Microscale Analysis of Calcium in Milk

Building on: Accuracy and precision, titration, organic chemistry, redox reactions, acid-base, covalent bonds, molecular shapes, separation techniques

Leading to: Calcium in nutrition, EDTA–complex ion formation, biochemistry

Links to Physics: Energy

Links to Biology: Food pyramid, nutrition, energy, cells, food, bones, calcium

Good Stories: National Institutes of Health (NIH) has launched the first large-scale clinical trial to determine the safety and efficacy of EDTA chelation therapy in individuals with coronary artery disease, the leading cause of death for both men and women in the United States. EDTA is also used to treat heavy metal poisoning.
<http://nccam.nih.gov/news/2002/chelation/pressrelease.htm>
National Center for Chronic Disease Prevention and Health Promotion has a National Bone Health Campaign and links to National Osteoporosis Foundation at:
<http://www.cdc.gov/nccdphp/dnpa/bonehealth/bonehealth.htm>
"Why Milk Matters Now for Children and Teens" from The National Institute of Child Health and Human Development (NICHD) gives info on calcium and milk: <http://www.nichd.nih.gov/milk/milk_facts.htm>
Food and Drug Administration has a web page for the Center for Food Safety and Applied Nutrition on Guidance on How to Understand and Use the Nutrition Facts Panel on Food Labels at:
<http://vm.cfsan.fda.gov/~dms/foodlab.html>
National Digestive Diseases Information Clearinghouse has a good website on lactose intolerance at:
<http://digestive.niddk.nih.gov/ddiseases/pubs/lactoseintolerance/index.htm>

Activity Description: Microscale experiment that measures the amount of calcium in milk by titrating with EDTA and a metal-ion indicator to check nutrition-label information

Number and Topic: **21. Organic Chemistry/Introduction to Biochemistry**
8. Chemical Reactions
16. Covalent Bonds, Molecular Shapes & Intermolecular Forces
20. Acids/Bases/pH
22. Redox

Source: Flinn ChemTopic Lab Book #23 - Chemistry of Food

Type of Material: Lab: Vitamin C Analysis—Fruits and Fruit Juices

Building on: Redox, titration, end-point, organic chemistry

Leading to: Vitamin C

Links to Physics:

Links to Biology: Vitamins, scurvy, food pyramid, nutrition, energy, food

Good Stories: History behind scurvy and vitamin C can be found at:
<http://www.people.virginia.edu/~rjh9u/vitac.html>
<http://www.mc.vanderbilt.edu/biolib/hc/journeys/book6.html>
Some web pages on vitamin C:
<http://www.foodstandards.gov.uk/healthiereating/vitaminsminerals/vitsminsaz/vitamin c/>
Food and Drug Administration has a web page for the Center for Food Safety and Applied Nutrition on Guidance on How to Understand and Use the Nutrition Facts Panel on Food Labels at:
<http://vm.cfsan.fda.gov/~dms/foodlab.html>

Activity Description: The purpose of this microscale experiment is to determine the amount of Vitamin C in different fruit juices by means of a redox titration using a special dye.

Number and Topic: **21. Organic Chemistry/Introduction to Biochemistry**
8. Chemical Reactions
20. Acids/Bases/pH

Source: Flinn ChemTopic Lab Book #23 - Chemistry of Food

Type of Material: Lab: Total Acidity—Titration of Fruit Juices

Building on: Acid–base neutralization, stoichiometry, titration, concentration and molarity

Leading to: Organic acids, Lewis acids

Links to Physics:

Links to Biology: Taste, sugars

Good Stories: Sites related to taste (including the newly identified taste receptors) can be found at:
<http://www.britishsoftdrinks.com/htm/qa/AdditivesIngredients/acids/acids.htm>
<http://www.discoverychannel.co.uk/kitchen/taste_flavour_facts.htm>
<http://pubs.acs.org/cen/coverstory/7937/7937taste.html>
MSG (monosodium l-glutamate) may be the most widely used flavor enhancer after salt and pepper. There is a fifth taste, "umami," from the Japanese word "umai," which means delicious. The taste is distinct from the four known primary tastes: sour, sweet, salty, and bitter. On its own, MSG doesn't have much taste but adding a pinch of MSG to food

containing certain nucleotides enhances the umami taste up to eight times the original.

Activity Description: The purpose of this experiment is to compare the citric acid content in a variety of fruit juices. The concentration of citric acid in each juice is determined by acid–base titration with sodium hydroxide

Number and Topic: 21. Organic Chemistry/Introduction to Biochemistry
16. Covalent Bonds, Molecular Shapes & Intermolecular Forces
20. Acids/Bases/pH
18. Reaction Rates & Kinetics

Source: Flinn ChemTopic Lab Book #23 - Chemistry of Food
Type of Material: Demo: The Power of Cheese—Cheese-making Demonstration
Building on: Colloids, solubility, acid-base
Leading to: Enzyme activity, biotechnology
Links to Physics:
Links to Biology: Curds and whey, enzyme activity, cheese, biotechnology, bacteria, yeast, fermentation, fats, protein
Good Stories: Nowadays calf stomachs are no longer necessary for obtaining chymosin for cheese making so you can have vegetarian cheese:
<http://www.eufic.org/gb/tech/tech02e.htm>
<http://www.foodstudents.com/deutsch/themenarchiv/july_003_e..html>
Activity Description: Cheese is made from milk by using an enzyme that curdles milk. The enzyme responsible for the curding process, called chymosin, is one of the first “bio-engineered” products to be approved by the Food and Drug Administration.

Number and Topic: 21. Organic Chemistry/Intro to Biochemistry
18. Reaction Rates & Kinetics
22. Redox

Source: Flinn ChemTopic Lab Book #23 - Chemistry of Food
Type of Material: Demo: Microbial Madness in Milk—Food Safety Demonstration
Building on: Redox, indicators, reaction rates & kinetics
Leading to: Microbiology
Links to Physics:
Links to Biology: Pasteurization, bacteria, organisms
Good Stories: “The more I study nature, the more I stand amazed at the work of the Creator. Into his tiniest creatures, God has placed extraordinary properties that turn them into agents of destruction of dead matter.” Louis Pasteur
Pasteurization websites:
<http://www.terrace.qld.edu.au/academic/lote/french/yr5pas.htm>
<http://ambafrance-ca.org/HYPERLAB/PEOPLE/_pasteur.html#pasteurization>
<http://scienceworld.wolfram.com/biography/Pasteur.html>
Activity Description: Pasteurization is illustrated in this demonstration using a redox indicator to monitor the oxygen depletion that occurs when bacteria are allowed to grow in milk.

Number and Topic:	**8. Chemical Reactions** **20. Acids/Bases/pH** **22. Redox**
Source:	Flinn ChemTopic Lab Book #23 - Chemistry of Food
Type of Material:	Demo: Nails for Breakfast—Food Additive Demonstration
Building on:	Redox, acid-base
Leading to:	Food additives, iron, complex ions
Links to Physics:	Magnetism
Links to Biology:	Nutrition, stomach acid, minerals
Good Stories:	Cereals are fortified with iron and other essential minerals and vitamins. In some cases the iron is actually added in the form of metallic, elemental iron. To see why iron is an essential mineral, see the following web pages: <http://www.indiadiets.com/foods/food_nutrients/Minerals/Iron.htm> <http://www.thebakersfieldchannel.com/health/1192247/detail.html> The Food and Drug Administration has a web page for the Center for Food Safety and Applied Nutrition on Guidance on "How to Understand and Use the Nutrition Facts Panel on Food Labels" at: <http://vm.cfsan.fda.gov/~dms/foodlab.html>
Activity Description:	Iron is extracted from cereal using a magnetic stirring bar. The amount of iron is compared with the nutritional label information. Reacting the iron with hydrochloric acid simulates what happens when the iron dissolves in the acidic contents of the stomach.

Number and Topic:	**21. Organic Chemistry/Intro to Biochemistry** **8. Chemical Reactions** **17. Water, Aqueous Solutions** **22. Redox**
Source:	Flinn ChemTopic Lab Book #23 - Chemistry of Food
Type of Material:	Demo: Iodized Salt—Food Additive Demonstration
Building on:	Saturated solutions, redox, halogens
Leading to:	Food additives, iodine, thyroid hormone function
Links to Physics:	
Links to Biology:	Food additives, iodine, thyroid hormone, starch, goiter
Good Stories:	The controversial topic of food additives is debated all the time. One constantly hears "I want no chemicals in my food!" Iodine, in the form of potassium iodide, was the first additive approved by the federal government for use in foods. It is added to salt to prevent thyroid hormone deficiency caused by a lack of iodine in the diet. From the Salt Institute the "Iodized Salt Home Page": <http://www.saltinstitute.org/37.html> All you want to know about iodine and your health can be found on the ATSDR fact sheet: <http://www.atsdr.cdc.gov/tfacts158.pdf> From the Bureau of Radiation Control comes a fact sheet on potassium iodine and its use in connection in radiation poisoning:

<http://www.doh.state.fl.us/environment/radiation/KI-Fact-Sheet.pdf>
<http://www.michigan.gov/documents/Potassium_Iodide_63321_7.pdf>

Activity Description: The presence of potassium iodide in iodized salt can be detected using the classic starch test for the iodine produced when iodide ions are oxidized.

Number and Topic: 16. Covalent Bonds, Molecular Shapes & Intermolecular Forces
17. Water, Aqueous Solutions

Source: Flinn ChemTopic Lab Book #23 - Chemistry of Food

Type of Material: Demo: Everyone Screams for Ice Cream—Food Demonstration

Building on: Freezing point depression, colligative properties

Leading to: Colloids

Links to Physics: Energy, kinetic theory

Links to Biology: Colligative properties—osmotic pressure

Good Stories: Why is salt used to melt ice and snow or prevent it from sticking on the roads? Why does salt depress the freezing point? For more info about why salt is used on the roads see:
<http://groups.msn.com/TheAlchemistsCorner/roadsaltandmycarpart1amp2.msnw>
<http://science.howstuffworks.com/question58.htm>
<http://chemistry.about.com/cs/howthingswork/a/aa120703a.htm>
Websites that describe colligative properties are listed below:
<http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/meltpt.html#c1>
<http://library.thinkquest.org/C006669/data/Chem/colligative/colligative.html >
Other versions of the same demo/lab making ice cream can be found at:
<http://www.kent.k12.wa.us/staff/cwattles/chemistry/ch9icecreamlab.html >
Antifreeze is a liquid that dissolves easily in water. The addition of a suitable solution of antifreeze added to a car's cooling water lowers its freezing point and so prevents it from freezing and ruining the engine. There are animals that have similar antifreeze compounds in them to keep them from alive in very cold weather.
<http://www.pbs.org/safarchive/4_class/45_pguides/pguide_704/4574_froze.html>

Activity Description: Make ice cream by cooling the ingredients (contained in a Ziplok bag) with a mixture of salt and ice. A temperature lower than 0 Celsius can by obtained by mixing salt with ice.

ICE LABS - Laboratory Leadership Workshop Labs

<http://129.93.84.115/Chemistry/LABS/LABS00.html>

We may well be witnessing the slow demise of the high school chemistry lab program. Many schools and teachers are cutting back the time spent in hands-on lab work. The causes are many - cost, disposal of wastes, safety, scheduling problems, lack of trained teachers, and time, to name a few. To address these issues and come up with a rationale for continuing to include (and even increase) the lab experience ICE (the Institute for Chemical Education) sponsored the meeting of 20 teachers at the Lawrence Hall of Science, Berkeley from 1987 to 1989. I (Lee Marek) was involved with this project for two of the three years.

We were charged with investigating the role of the laboratory in high school chemistry. To be more specific, we were:

1) To define the contemporary role of the laboratory as part of secondary school chemistry instruction by more clearly identifying knowledge, skills, and attitudes that students should be able to demonstrate as a result of their laboratory learning.
2) To develop assessment methods and items designed to measure and reward the student learning that occurs in the laboratory. These methods are to include more than paper and pencil assessments and be suitable for administering nationally as well as locally.
3) To plan for revision and further development experiments that address questions of skills, knowledge, cost and safety, and take into account the growing presence of the computer as an interfacing instrument.

What came out of this project were a series of 18 well-done labs and rationalization in terms of the latest educational theories [as of 1989] for lab work and why it is important at the high school level. All of the labs and most of the educational theory are available on the web (see above) or from the book that was published, LABS (Laboratory Assessment Builds Success). The labs are spread chronologically across most of a year's general chemistry teaching at the secondary school level and they feature various patterns of laboratory activity including computer interfacing, microscale techniques, and a variety of hands-on, minds-on efforts to make important concepts of chemistry very understandable to high school students.

ICE labs, indexed to curriculum topics:

Number and Topic: 2. Measurement
Source: ICE Laboratory Leadership
Type of Material: Lab 3. Measurement and Uncertainty
Building on: 2. Measurement
Leading to: 3. Problem solving. 8. Chemical reactions. 18. Reaction rates and kinetics.
Links to Physics: Building on same topic taught in Physics
Links to Biology: Enzymes, metabolic rates
Good Stories:
Activity Description: Everyone deals with measurements every day. We hear statements such as "The time at the tone is **10 p.m**." "It is currently **79 degrees** and sunny." "**7.82 gallons** of gas - That will be **$8.60**." The measured values in these three statements are printed in boldface type. Are these and other measurements always exact? An exact measurement is a perfectly correct value containing no error. Right now, before you begin this activity, select the one statement below you think is most correct.
A. Measurements are exact if correctly done.
B. Measurements may or may not be exact. It depends who did them and how they were done.
C. There is some inexactness in every measurement.
To study the nature of measurement and gather data which will help determine whether statement A, B, or C is most correct; to determine whether matter is conserved.

Number and Topic: 2. Measurement
Source: ICE Laboratory Leadership
Type of Material: Lab 18. Searching for the Copper Ion
Building on: 2. Measurement
Leading to: 3. Problem solving. 8. Chemical reactions. 18. Reaction rates and kinetics.
Links to Physics: Light
Links to Biology: Enzymes, metabolic rates
Good Stories:
Activity Description: To learn how a spectrophotometer can be used to determine the concentration of a colored solution. Volumetric or gravimetric determination of ions can be quite complicated and time-consuming. At times ion concentrations are too low to be determined with accuracy. When this occurs chemists will consider using an instrument that measures the quantity of light energy that is absorbed by dissolved ions as light is passed through the solution. A colorimeter or spectrophotometer can be used as the tool to determine the concentration of these solutions. If the ions do not produce an intensely colored solution they can sometimes be converted to complex ions that are brightly colored, absorbing light in the visible range. A typical example is Cu^{2+} ion which is converted to the

intensely colored $Cu(NH_3)_4^{2+}$ ion by addition of concentrated aqueous ammonia $NH_3(aq)$. The percent transmittance at various concentrations is collected and graphed to determine the concentration of copper (II) in an unknown solution.

Number and Topic: 6. Chemical Names and Formulas
Source: ICE Laboratory Leadership
Type of Material: Lab 5. What is the Copper Formula?
Building on: 8. Chemical reactions
Leading to: 7. Moles.
9. Stoichiometry.
13. Electrons in atoms.
Links to Physics: Structure of the atom
Links to Biology: Determining levels of trace elements in biological systems
Good Stories:
Activity Description: To determine experimentally the percent copper in a compound and to select the formula of that copper-containing compound from a list of possible formulas. All compounds have a definite composition in terms of the relative masses and the number of atoms of elements. However, the same elements may unite in different ratios. Compounds often can be identified by the relative amount of a particular element they contain. For example, by knowing the amount of copper that can be removed from a copper compound, the formula of the compound can be selected from a number of possible choices.

Number and Topic: 6. Chemical Names and Formulas
7. Moles.
Source: ICE Laboratory Leadership
Type of Material: Lab 6. Formula of a Blue Hydrate
Building on: 2. Measurement
Leading to: 9. Stoichiometry
Links to Physics: Energy
Links to Biology: Function of water in complex systems (?)
Good Stories:
Activity Description: To determine the formula of a blue hydrate. Hydrates have a variety of practical applications. Their ability to gain or lose their waters of hydration makes them versatile. One formula unit of a hydrate contains one formula unit of an anhydride bonded to a fixed number of water molecules. Careful heating removes the water so that the ratio of water molecules to anhydride formula units can be determined, provided the molar mass of the anhydride is known. A hydrate is represented by the formula of the anhydride followed by a raised dot that represents the "weak" bond between the anhydride and the number of water molecules, i.e. $MgSO_4 \bullet 7\ H_2O$.

Number and Topic: 6. Chemical Names and Formulas,

7. Moles.

Source: ICE Laboratory Leadership
Type of Material: Lab 7. Determining a Molecular Formula
Building on: 8. Chemical reactions 12. Gases/Gas Laws/Kinetic theory
Leading to: 9. Stoichiometry
Links to Physics: Gas behavior (?)
Links to Biology: Analysis of complex molecules
Good Stories:
Activity Description: The molecular (true) formula for a substance is not always the same as its empirical (simplest) formula. Both acetylene and benzene have the empirical formula CH. However, the molar mass for acetylene is 26 g/mol, while the molar mass of benzene is 78 g/mol. This is because the molecular formula for acetylene is C_2H_2 while the molecular formula for benzene is C_6H_6.
To determine the molar mass of a gaseous substance and to use this value to find the molecular formula of the substance.

Number and Topic: 8. Chemical Reactions
Source: ICE Laboratory Leadership
Type of Material: Lab 1 Cu Again! - A Copper Cycle
Building on: 1. Matter and change. 11. Thermochemistry
Leading to: 6. Chemical names and formulas.
9. Stoichiometry;
Links to Physics: Energy
Good Stories: Smelting of metals, alchemists.
Activity Description: Chemical reactions are often accompanied by formation of a precipitate, evolution of gas, change in color, or pronounced temperature change. In this activity, you will observe these characteristics of chemical reactions. Enjoy the variety!

Number and Topic: 8. Chemical Reactions
Source: ICE Laboratory Leadership
Type of Material: Lab 2. The Nature of a Chemical Reaction
Building on: 1. Matter and change
Leading to: 17.Water and aqueous solutions.
11. Thermochemistry.
Links to Physics: Energy, energy transformation
Links to Biology: Poisons, enzymes.
Good Stories: Did the Romans poison themselves with the lead they used for pipes and containers?
Activity Description: Changes go on about you all the time. Some changes are chemical changes, such as gasoline burning or a nail rusting. But what is happening when a chemical change occurs? What is the nature of a chemical reaction?
To examine the behavior of matter in a chemical reaction, focusing on the behavior of the individual particles of each substance involved.

Number and Topic: **8. Chemical Reactions**
14. Periodicity
Source: ICE Laboratory Leadership
Type of Material: Lab 8. Identifying Chemical Activity
Building on: 9. Stoichiometry
Leading to: 15. Ionic and metallic bonds
Links to Physics: Statics
Links to Biology: Some metals are more appropriate than others for biological use (as insulin pumps, etc.)
Good Stories: "Sacrificial" metals are often attached to iron or steel underground structures.
Activity Description: To determine the relative reactivity of several metallic elements. "Silver and Gold Coins Recovered from Ocean Shipwreck" is a possible news headline, while "Iron Coins Recovered..." would be less likely to appear. The difference in reactivity among metals is very important in selecting building materials and the types of products we use.

Number and Topic: **10. States of Matter**
Source: ICE Laboratory Leadership
Type of Material: Lab 16. Heat of Vaporization of Liquid Nitrogen
Building on: 1. Matter and Change
Leading to: 11. Thermochemistry
Links to Physics: Energy
Links to Biology: Heat transfer is an important part of many biological reactions.
Good Stories:
Activity Description: To determine the heat energy needed to vaporize (boil) one gram of liquid nitrogen. Nitrogen, the major component of air, is a gas at room temperature with the formula N_2 (g). It can be stored in its liquid form in a specially insulated bottle called a Dewar flask. In this laboratory activity, you will determine the energy needed to vaporize (boil) liquid nitrogen by letting a known mass interact with warm water. The energy given up by the warm water will cause the nitrogen to boil until it is completely converted to gaseous nitrogen. This energy is called the heat of vaporization.

Number and Topic: **14. Periodicity**
Source: ICE Laboratory Leadership
Type of Material: Lab and Demo 4. It's in the Cards - Investigating Patterns
Building on: 3. Problem solving
Leading to: 8. Chemical reactions. 13. Electrons in atoms.
Links to Physics: Structure of the atom
Links to Biology: Patterns
Good Stories:
Activity Description: In Part I, you will use information provided on cards to organize these cards in a particular pattern. In Part II (teacher demo) you will use periodic

properties as a tool for organizing and predicting properties of elements. Then, in Part III, you will conduct a laboratory exploration of some chemical properties of a few elements and examine the regularities in these properties. The properties observed for the elements will be used to predict the properties of other elements.

Number and Topic: 15. Ionic and Metallic Bonds
Source: ICE Laboratory Leadership
Type of Material: Lab: 10. The Identification of Ions
Building on: 17. Water and aqueous solutions 14. Periodicity
Leading to: 8. Chemical Reactions
Links to Physics: Atomic energy levels and quantum numbers
Links to Biology: Solubility in the ambient medium is an important factor in many biological reactions.
Good Stories:
Activity Description: To verify the presence of a certain ion in solution, the properties of the ion must be known. To determine the relative solubilities of sulfates, oxalates, chromates, and carbonates of the alkaline earth metals and to use that information to analyze an unknown solution containing one alkaline earth cation. In this activity, you will determine the relative solubility of compounds formed from alkaline earth metal ions. The alkaline earth elements (magnesium, calcium, strontium, and barium) are all members of the same family of the periodic table. Also, you will devise and use a scheme to identify these ions in a solution.

Number and Topic: 17. Water, Aqueous Solutions
Source: ICE Laboratory Leadership
Type of Material: Lab 9. The Ion Exchange (Which Salts are Soluble?)
Building on: 8. Chemical reactions
Leading to: 14. Periodicity
Links to Physics: Energy
Links to Biology: Many ions which are soluble in water can affect biological systems. Examples are heavy metals in water, which can have deleterious effects, and fluoride in water, which can have variable effects depending on its concentration.
Good Stories: Boilers can blow up if ‘hard water’ causes the circulating system to clog up.
Activity Description: To determine which ions react to produce precipitates by analyzing data regarding mixtures of ionic compounds. What do stalagmites and stalactites found in caverns have in common with the deposits found on old water faucets? How were many minerals, now mined as ores, originally formed? The answers to both questions can be found in a study of precipitates. If a positive ion (cation) of a dissolved salt reacts with the negative ion (anion) of a different compound to form a new salt with low solubility, chemists say that a precipitate has formed.

Number and Topic: 18. Reaction Rates and Kinetics
Source: ICE Laboratory Leadership
Type of Material: Lab 13. Kinetics: A Study of Reaction Rates
Building on: 8. Chemical reactions 7. Moles.
Leading to: 19. Equilibrium
Links to Physics: Energy
Links to Biology: Enzyme systems
Good Stories:
Activity Description: To design a procedure to measure the rate or speed of the Mg/HCl reaction. You will then identify two factors other than catalysis to alter the speed of this reaction and examine each factor quantitatively. Have you ever wondered how chemists slow down reactions that are potentially explosive or speed up reactions to synthesize a product in a shorter period of time? In this laboratory activity, we will use a familiar reaction:

$Mg(s) + 2 HCl(aq) \text{-->} MgCl_2(aq) + H_2(g)$

To investigate this problem. The rate may be measured in several different ways. For example, it may be expressed as the volume of $H_2(g)$ produced per second or as the mass of magnesium metal used per second.

Number and Topic: 19. Equilibrium
Source: ICE Laboratory Leadership
Type of Material: Lab 14. Disturbing an Equilibrium System
Building on: 18. Reaction rates and kinetics
Leading to: 20. Acids/Bases/pH
Links to Physics: Energy
Links to Biology: Enzyme systems, ecosystems
Good Stories:
Activity Description: To study factors which can disturb an equilibrium system. Many chemical reactions reach a state of equilibrium if conditions are right. In an equilibrium system, forward and reverse reactions occur at equal rates so that no net change is produced. When equilibrium is reached by a reaction in a test tube, it appears that changes have stopped in the tube. Once equilibrium has been reached, is it possible to produce further observable changes in the tube? If so, can you control the kinds of changes? If not, why are further observable changes impossible? You will observe several chemical systems in this laboratory activity. A careful study of your observations will enable you to answer these questions.

Number and Topic: 20. Acids, Bases and pH
Source: ICE Laboratory Leadership
Type of Material: Lab 11. pH of Familiar Products.
Building on: 8. Chemical reactions
Leading to: 21. Organic chemistry
Links to Physics: Energy (?)

Links to Biology: Many biological systems are pH dependent

Good Stories: Don't breathe too hard! Hyperventilation changes the pH of the blood and can lead to fainting!

Activity Description: To determine the pH of common household products and classify each based on its acidic or basic properties using the pH scale The numerical scale called pH indicates how acidic or basic an aqueous (water) solution is, or whether that solution is neutral. Many products we use daily for personal hygiene, home and auto care, or eating and drinking are suitable for pH testing. For this laboratory activity, you may bring to class as many products, in their original, closed containers, as you wish to test.

Number and Topic: 20. Acids/Bases/pH

Source: ICE Laboratory Leadership

Type of Material: Lab 17. How Bonding Affects Acidity

Building on: 8. Chemical reactions

Leading to: 19. Equilibrium

Links to Physics: Energy

Links to Biology: The ambient pH affects many biochemical reactions.

Good Stories:

Activity Description: To determine experimentally the number of ionizable H^+ ions in an unknown solid acid and to form hypotheses regarding relations between bonding and acidity. In many common acids you have used in laboratory work, all hydrogens are acidic. This is true for acids such as sulfuric acid (H_2SO_4), nitric acid (HNO_3), and hydrochloric acid (HCl). In this laboratory activity, you will learn that only some hydrogen atoms within selected acid molecules may be capable of forming H^+.

Number and Topic: 21. Organic Chemistry

Source: ICE Laboratory Leadership

Type of Material: Lab 12. Soaps vs. Detergents

Building on: 8. Chemical reactions 17. Water, aqueous solutions

Leading to:

Links to Physics: Energy (?)

Links to Biology: Soaps and detergents are designed to interact with both inorganic and organic molecules.

Good Stories:

Activity Description: To investigate the chemical action of soap vs. detergents in hard water and the use of a precipitation reaction to soften hard water. Water that contains calcium ions, Ca^{2+}, and magnesium ions, Mg^{2+}, is said to be hard water. These ions are leached from ground water flowing over rock formations containing limestone and other minerals. Hard water interferes with the cleaning action of soaps. When soap is added to hard water, insoluble compounds form which appear as sticky scum. This scum leaves a deposit on clothes, skin, and hair. You could have ring around the collar! When boiled, hard water leaves a deposit of calcium carbonate, $CaCO_3$. This scale builds up inside tea kettles and water heaters. Detergents have replaced soap for many cleaning jobs around the home. The development of synthetic detergents by chemists was a great advantage for people with relatively hard tap water in their homes. Do you know whether the tap water used in your home is soft or hard? How could you test it to find out? Why do you use detergents for many household cleaning jobs? These are some of the questions you will be able to answer after completing this laboratory investigation.

Number and Topic:	**22. Redox/Electrochemistry**
Source:	ICE Laboratory Leadership
Type of Material:	Lab 15. How to Copper Plate Your Car Keys
Building on:	2. Measurement. 13. Electrons in atoms.
Leading to:	15. Ionic and metallic bonds
Links to Physics:	Electoplating/cathodic protection
Links to Biology:	Many biological reactions include redox processes.
Good Stories:	
Activity Description:	To investigate the mass changes, if any, at each electrode during electroplating and to calculate the charge on the copper ion through application of Faraday's Laws. Electroplating can be used to deposit a layer of metal such as chromium, copper, gold, nickel, or zinc on another metal. This deposit can provide a protective and decorative coating for the metal that lies beneath it. This laboratory activity will show you how to electroplate a copper coating on a car key or other suitable metallic object.

Technology-Adapted Labs

Number and Topic:	**2. Measurement** **17. Water, Aqueous Solutions**
Source:	*ChemCom*, Fourth Edition, Unit I, Section A, Lab Activity A.2, p. 8. Modified by: Bill Grosser, Glenbard South High School
Type of Material:	Lab: Purifying Foul Water (with an inquiry twist)
Building on:	An introductory lab to start the chemistry year
Leading to:	Dissolved ions, physical properties, writing formulas
Links to Physics:	Boiling points, distillation
Links to Biology:	Organic materials are among those removed in this activity.
Activity Description:	This is a great example of how some minor changes to a lab along with the inclusion of technology can turn a terrible lab into a favorite engaging activity for students.
The original lab:	This is the first lab activity done in the ChemCom course. The purpose of the lab is to purify a sample of water contaminated with oil, coffee grounds, dirt, dissolved salt and garlic.
Topics introduced:	Measurement techniques, percent calculations, data analysis (mean, median, range, histograms), density, solubility, conductivity, distillation
Modifications:	The original lab did most of the thinking for the students. The instructions consisted of 24 steps for the students to follow to "correctly purify" the water sample. The instructions were changed to one simple task: Purify this sample of water. Success will be judged on three criteria: 1. Percentage of original sample recovered as pure 2. Conductivity of the sample 3. Clarity of the sample Students design and document their own purification techniques. After each purification procedure, students use technology to quantitatively measure their progress.

Technology used to Enhance Instruction*:* Vernier probes change this from a qualitative lab to a quantitative lab. A Vernier conductivity probe measures the conductivity of samples after each student purification technique is employed. A Vernier turbidity meter measures the clarity of samples after each step in the process. These tools greatly enhance the lab by making comparisons between samples easy. Posting class data on a spreadsheet, and using a simple scoring system along with the spreadsheet enables us to come up with a definitive "winner" for the class. Deciding how to weight each category is an important part of the learning process for the students. **It should also be noted that this type of technology inclusion could be done with a single computer in the classroom** (a situation that unfortunately is often defined as a high-tech classroom). In this instance it can be a powerful tool!

Summary: By changing this lab from a 24-step cookbook activity to a one-sentence, open-ended challenge, the involvement level of the students increases exponentially! The use of technology improves the lab and further engages the students. Instead of demonstrating distillation techniques and telling students what will happen, students clamor to know how and why some groups obtained low conductivities while others still have high conductivities. One of my favorite experiences was a group of students who brought in a commercial flocculent. Their sample had by far the lowest turbidity reading, but their conductivity was off the chart. These kinds of teachable moments do not occur with closed-ended lab activities.

Moral: Not all lab activities can be opened up, but when the opportunity arises, a new course should jump at the opportunity to increase the inquiry component!

Number and Topic: 4. Atomic Structure

Source: Bill Grosser, Glenbard South High School

Type of Material: Activity: Quantum Numbers (with an inquiry twist)

Building on: Basic structure of atom

Leading to: Electron orbitals, molecular shapes, valence electrons etc.

Links to Physics: Builds on basic atomic structure

Activity Description: Concrete sequential thinking. Students and lecture-based instructors love teaching and learning about quantum numbers. Present the rules, memorize the rules, and repeat the rules. This is remembering, not thinking! Many students are simply bored off their chairs. The solution . . . turn the introduction to quantum numbers to an inquiry-based/pattern recognition activity where the kids construct in their own minds the rules for placing electrons into energy levels.

The Set up/Materials Required: Place a giant laminated blank periodic table that contains only symbols and atomic numbers across the front board. Students receive a copy of a similar blank table to work with.

The Rule: Students must be called on to share all ideas. Shouting out answers is not allowed during the activity. This allows the teacher to let the lesson progress at a rate that allows thinking to continue by the majority of students, even after a few pick up the patterns.

A Typical Lesson/Dialog:

Teacher: Today we are going to continue our investigation of how atoms are constructed. So far we know that protons and neutrons make up the nucleus and electrons orbit the nucleus. The question today is "where exactly do all those electrons reside?" To describe the location or "address" of electrons, electron configurations are used. For example, let's start with hydrogen. How many electrons does a neutral atom of hydrogen have?

Students: *1*

Teacher: Excellent, and this is the address where that electron resides. (Teacher writes a large $1s^1$ on the hydrogen square.) Everyone get it . . .

good. (At this point the complaining starts as they all are completely lost.) Let's move on to helium . . . (Usually under much protest.) Helium has how many electrons?
Students: *2*
Teacher: Great, and who thinks they can tell me the electron configuration of helium?
Students*: Answers are usually submitted like 2, 2s, $2s^2$, and finally $1s^2$ (as nothing more than a lucky guess).*
Teacher: Perfect, see Sue gets it! (This usually drives the other students nuts.) Now lets move on to lithium. Lithium has three electrons. Their electron configuration of course would be . . . .
Students*: Always answer $1s^3$.*
Teacher: Oh! So close but no, I am sorry it is not $1s^3$. (By now all the students are always totally engaged in trying to crack the "code." With some coaxing sometimes the answer comes; otherwise the teacher can provide the correct configuration of $1s^2$, $2s^1$.) How about beryllium? How many electrons, and where do they live?
Students: *$1s^2$ $2s^2$ (Usually comes pretty quick.)*
Teacher: Perfect, who thinks they get it? (Many hands go up by now.) Can anyone tell me what some of the numbers mean? (At this point most students can relate the superscript to the number of electrons. Note taking starts with all the students engaged trying to get information that will help crack the rest of the code.) Who would like to try boron? (Many hands go up at this point, as they are full of false confidence!)
Students*: $1s^2$, $2s^3$*
Teacher: Ooooh, so close but no! (Chaos usually erupts at this point. The teacher then provides the correct answer of $1s^2$, $2s^2$, $2p^1$. At this point some definitions can be offered to the students. Define principal energy levels and sub-levels.) Can anyone give me a rule for how many electrons can reside in an "s" sub-level? (This kind of questioning continues as students construct their own rules for each principle energy level and each sub-level.) The same type of questioning can lead students to write rules for the number of electrons allowed in a p-sub-level, how the d-sub level drops down or overlaps, where the "blocks" are located, valence electrons etc.
Moral**:** A new course should stress inquiry lessons whenever possible. Part of the teacher-training program should be to take experienced and new teachers though this type of lesson modification and indoctrinate them in the methodology so that students can be actively engaged in the content, even when the topic is something like electron configurations.
Multi-Media: This is the time to follow up with Mike Offutt's excellent chemistry song about electron configurations. (Chemistry Song-Bag I from Flinn Scientific.) Adding the musical component helps many students move the information to long-term memory.

Number and Topic: **5. Radioactivity, Fusion, Fission**
Source: Bill Grosser, Glenbard South High School
Type of Material: Computer Lab: Problem-Based Learning with the PAX Nuclear Reactor
Building on: Isotopes, atomic structure
Leading to: Applied science/technology, science literacy, and nuclear chemistry
Links to Physics: Atomic structure, isotopes, and transfer of energy
Links to Biology: Nuclear waste, effects of radiation
Good stories: Links to Chernobyl, Three Mile Island. Great opportunities to discuss the pros and cons of a complicated issue.
Activity Description: The PAX nuclear reactor simulator is freeware that originated back around 1990. The software was developed by Penn State University to train their nuclear engineering students. The software presents students with a pressurized water reactor control room. Algorithms in the software actually allow the students to simulate running the fission reactor, generating electricity, and also to monitor many of the vital functions of the plant. (Handouts, software, screenshots and sample student projects are attached in the problem based learning section.) The software is old but can't be beat! Students can learn to run the reactor in a half-hour then can experiment on the reactor using open-ended problems indefinitely.
Inquiry Driven**:** The software can hook students of all levels into wanting to learn exactly how a nuclear power plant works. After their first try students either generate miniscule amounts of power or drive the plant to emergency shutdown mode. After their first experience students are begging to know exactly what the primary and secondary loops are, how boron affects the plant, exactly what role the control rods play, how the core temperature and change in water temperature affect power output, etc.
Interactive Nuclear Labs**:** The entire topic of nuclear chemistry is tough to incorporate a lot of lab activities. This is a great way to get out of the lecture and worksheet mode and into the experiential mode.
Problem Based Learning**:** This software provides a great opportunity to incorporate a problem-based learning activity into the existing curriculum. A number of partially defined problems, such as "What is the maximum power output of the plant?" can be given to the students to explore. Students must first decide what constitutes "maximum output." A one-time spike, a sustainable output, etc. Students design experiments that can be run on the plant, collect and graph data, use math skills to analyze the data, then present their findings to the class.
Technology**:** This is a great example of how technology can be used to involve students in a truly interactive activity that otherwise would not be possible.
Moral: Use technology when it fits and enhances the curriculum. Problem-based learning is one of many great teaching methods and is a perfect fit for this activity. Any new course should strive to blend in different types of learning experiences and different types of teaching styles.

Number and Topic:	**5. Radioactivity, Fusion, Fission**
Source:	*ChemCom*, Fourth Edition, Unit 6: Nuclear Interactions, Section B, Lab Activity B.4, p. 434. Bill Grosser, Glenbard South High School
Type of Material:	Lab: Alpha, Beta and Gamma Radiation
Building on:	Radiation
Leading to:	Transmutations, half-life labs, background radiation
Links to Physics:	Atomic structure
Links to Biology:	Biological effects of radiation exposure
Good stories:	Excellent way to bring in discussion of Yucca Mountain, spent fuel storage, medical uses of radiation, etc.
Activity Description:	This is a three-part lab that explores basic behavior of alpha, beta and gamma radiation by collecting data using a Vernier radiation probe and Excel graphing software. Part 1: Explores the effect of distance on radiation levels. Part 2: Compares the penetrating ability of alpha, beta and gamma radiation sources. Part 3: Explores methods of radiation shielding.
Technology:	Radiation monitors are expensive, but this lab lends itself to being done effectively as a class lab or interactive demonstration. Using a projection device and **one computer** in the classroom, the teacher can project the meter so the entire class can view and record the data. I have found that general to lower level students enjoy doing interactive demos such as this with the entire class. Excel or other simple graphing programs can be used to prepare graphs of the data. This is a great lab/interactive demo. It engages the students and can be enhanced significantly using only one computer in a classroom.

Number and Topic:	**10. Phases, Solids, Liquids and Gases (States of Matter)**
Source:	Vernier: Chemistry with Computers *ChemCom*, Fourth Edition, Unit III, Section A, Lab Activity A.2, p. 178. Bill Grosser, Glenbard South High School
Type of Material:	Lab: Separation by Distillation
Building on:	Organic chemistry, fractional distillation, polar substances and non-polar substances.
Leading to:	Heat of vaporization.
Links to Physics:	Energy transfers
Links to Biology:	Polarity and partial polarity are important concepts in understanding the behavior of many biomolecules.
Good stories:	This is a great time to discuss how fractional distillation is used in the petroleum industry to separate fractions in crude oil.
Activity Description:	In this lab students are given a mixture of two liquids and asked to separate and identify the liquids based on boiling points and reaction with iodine.

Technology: We do this lab using Vernier probes in our technology lab. Students become very actively engaged with the data as it is graphed on the screen as the distillation takes place. This is also a good model to show how resources such as Vernier's prepared labs can be modified to fit with other curriculum. Vernier provides all their labs as Word documents that can be modified by the teacher. The original Vernier lab and the modified lab are both attached to this write-up.

Number and Topic: 13. Electrons in Atoms

Source: Bill Grosser, Glenbard South High School. **See attached student handout** along with a CD containing a finished student project.

Type of Material: Project-based learning activity: Alternatives for Producing Electrical Energy: Student Generated Infomercials

Building on: Conservation of energy
Subtopics - Exothermic reactions, energy calculations

Leading to: Environmental chemistry

Links to Physics: Conservation of energy

Links to Biology: Ecological impacts of energy production

Good stories: Field trip to local power plant works great to increase student interest.

Activity Description: Students research different methods of generating electricity and present their research as 3-5 minute video infomercials. This is an information-based blended (project/problem-based) research activity that is used in chemistry after students study energy transfer and combustion reactions. This project lays the groundwork to start investigations into atmospheric chemistry/gas laws, and nuclear chemistry/fusion and fission. This is a great project that allows students to see the practical application of many concepts that are taught as isolated units in the curriculum. For example, this year a group of students were researching Ocean Thermal Energy Conversion. We got into great discussions of energy transfer, heat of vaporization (ammonia), the effect of pressure on boiling points, etc. For the first time these students saw the very practical application of many of the concepts taught in the class. These types of projects produce many such teachable moments.

Technology: Apple's superb iMovie software is used along with the Internet and several subscription databases for research.

Number and Topic: 14. Periodicity/Periodic Law/Metals, Non-metals and Families

Source: *ChemCom*, Fourth Edition, Unit II, Section A, Lab Activity A.3, p. 97.
Bill Grosser, Glenbard South High School

Type of Material: Lab: Metal or Non-Metal?

Building on: Physical and chemical properties, elements, atoms.

Leading to: Periodicity, families, and atomic structure.

Links to Physics: Builds on basic atomic structure, electrical conductivity and resistance.

Links to Biology: Heavy metal poisoning.

Good stories: After the lab is complete, the idea of the development of semiconductors can be discussed with students.

Activity Description: This is an introductory lab used to begin the exploration of the periodic table. It is a great way to have the students begin to classify the elements into groups that exhibit similar properties. Students measure three physical and two chemical properties of seven different elements. Elements are then classified as metals, non-metals, or semi-metals based on their experimental results. Using an ohmmeter instead of a simple conductivity meter can enhance the lab. This leads to discussions of electrical uses of different metals and semi-metals. This is an outstanding lab that gets students engaged in a lab-based activity that is often introduced and dealt with in lecture format only.

Number and Topic: 14. Periodicity/Periodic Law/Metals, Non-metals and Families

Source: I wish I could credit the teacher who originally conceived this but I do not know where it came from. It is not my work. It is an excellent activity and a very good way to introduce the periodicity of the elements.
Bill Grosser, Glenbard South High School

Type of Material: Activity: Secret Agents

Building on: Physical and chemical properties, elements, atoms

Leading to: Periodicity, families, and atomic structure

Links to Physics: Builds on basic atomic structure and properties

Links to Biology: Understanding the properties of elements is requisite to understanding their behavior in biological systems.

Good stories: An opportune moment to introduce Mendeleev and the struggles he had introducing and promoting his “radical” thinking.

Activity Description: This is an introductory activity used to begin the exploration of the periodic table. Students are given a set of cards with pictures of “secret agents.” Students are asked to arrange the agents into columns and rows based on similarities. When finished, students are then asked to draw the next secret agent in the sequence.

Number and Topic: 17. Water, Aqueous Solutions

Source: *ChemCom*, fourth Edition, Unit I, p.3.
Bill Grosser, Glenbard South High School

Type of Material: Lab: Water Quality

Building on: Solubility of solids and gases, aqueous solutions, applied chemistry

Links to Physics: Behavior of particles in complex systems

Links to Biology: Ecology of ecosystems

Good stories: Water testing is a ripe field for stories of fish kills. A quick search on the Internet for “fish kills” can produce many dramatic stories to share with the kids.

Activity Description: The first unit in the *ChemCom* textbook focuses on a hypothetical fish kill. Students determine what killed the fish after learning how to do a number of water analysis tests. This approach is enhanced by incorporating the use of the Water Quality Index, a standardized series of nine tests that produces a quantitative value for the overall quality of water in a stream or lake.

Problem/Project Based Learning: This is a very good applied-chemistry project for the students. Discussing the results of the tests often leads to numerous open ended questions.

Number and Topic: 18. Reaction Rates and Kinetics

Source: CHEMISTRY, Nelson, British Columbia Edition 1996. Chapter 5 Solutions. Section 5.3 Reactions in Solution. Investigation 5.2 Page 194. ** Students in the honors chemistry course at Glenbard South use this book. The activity chosen can be used with any level student. How far the teacher takes the post-lab discussion would depend on the level of students in the class.
Bill Grosser, Glenbard South High School

Type of Material: Demo: The Iodine Clock Reaction (with an inquiry twist)

Building on: Solution chemistry, moles, solution concentration, and student experimental design

Leading to: Catalysts, reaction rates, net ionic equations

Links to Physics: Structure of matter, electrons and ions

Links to Biology: Reaction rates in cells, concentration

Good stories: This is a classic demonstration. Two colorless solutions turn dark black/purple as time passes. Ancient tales of alchemy can easily be spun by the teacher to hook students.

Activity Description: What makes this activity engaging is that it is presented with minimal instructions for the students. It is a classic example of a lab that traditionally was done with 10-20 steps for students to follow, but here it has been changed so that student thinking and involvement are increased dramatically. The book gives the students a simple problem: "Make solution A react with solution B in a time of 20 ± 1 seconds." Students may manipulate any variable they choose. Temperature, concentration, volume etc. can all be changed and their effects measured. Students design their own experiments, collect their own data, and share their data with the class. Learning is assessed by their performance as well as their written work. This is an outstanding lab that really engages the students in an authentic investigation. A set of alternative instructions developed by Mike Heinz (Glenbard South) is included. This activity provides a striking example of how an open-ended investigation is a much more effective learning experience than is a cookbook lab.

D. TEACHING CHEMISTRY

Some Reflections.

By Bill Grosser

Inquiry in the Chemistry Classroom

The ARISE program is proposing major changes in the typical order that curriculum is presented to students. To really have a significant impact the methodology of instruction needs to also be looked at carefully before we reinvent the wheel again. One of the biggest challenges to the typical chemistry course is to take the labs and instructional methods from the lowest end, lecture till they die approach, to the ideal of an inquiry-driven, lab-based course. This is easier said than done. Often teachers are asked to make huge leaps instead of taking manageable steps. The article attached is a powerful tool that should be incorporated into the development of a new curriculum AND, more importantly, into the teacher training that will accompany a successful program.

I have included below the URL for an article by Alan Colburn titled “How to make lab activities more open ended.” The article contains a table that originally appeared in a CSTA Journal article by McComas (1997). The table allows typical classroom activities to be classified into levels of open-endedness. A level “0” activity would define the problem for the students, tell them the steps to take in a lab to solve the problem, then tell them the answer they should obtain. At the other end of the scale are level 3 activities that would fall into the category of true problem-based learning.

Enjoy the read! It is a great article and may be useful to establish a common language for the future development team to operate under.
<http://www.exploratorium.edu/IFI/resources/workshops/lab_activities.html>

I think it is important to recognize the existence and importance of all the different “levels” of activities that take place in a classroom. I think it is also important that teachers at least recognize the “level” at which they are currently operating. It is only after teachers identify where they are, then identify a specific goal to move to with their curriculum that change can begin to occur.

Some of the best activities that I will recommend are activities that have started out low on the scale and moved to higher levels of open-endedness.

Gerry Wheeler’s friend from Montana is, I believe, an expert at taking traditional activities and moving them up on the scale. His name is Gary Freebury and he was involved in the original ARISE workshop in 1998.

Chemistry Objectives and Learner Outcomes

I came across this material and website while working on the project and thought it might help when the actual "Mostly Chemistry" course is written.

The source is the British Columbia Dept. of Education. We currently use a chemistry book from British Columbia and I have been impressed with the material that comes out of Canada. It contains a very complete list of learning outcomes for a student taking a traditional chemistry course. Let's not reinvent the wheel!

Incorporating Project and Problem Based Learning into Chemistry and the Three Year ARISE Curriculum

Abstract: ARISE has the unique opportunity to build an integrated three-year curriculum that incorporates a logical sequence of project-based, blended and problem-based units into the curriculum. This paper delineates between these three methodologies and then offers specific recommendations for the ARISE curriculum.

Chemistry is often taught as a series of isolated units, interconnected with each other, but often disconnected with the world in which the students live. Often in a teacher's effort to maximize "coverage," little or no time is spent allowing students to apply their skills and knowledge. Project-based learning, problem-based learning and blended activities offer opportunities to explore the meaningful connections between curriculum and the world. First, some definitions.

Definitions:
Problem based learning is the ultimate in inquiry-based instruction. Engaged, inquisitive students define their own questions after observing some phenomenon in the world around them. Class time is spent allowing students to clearly define their problem, gather new facts and perform research to expand their understanding of the topic, and finally, report back to the class with results of their research enlightening all those in attendance. Often with a class of 29 general ability 15-16 year olds, this type of instruction is simply not possible. Limitations exist in the ability of both teachers and students. Teaching this way requires an enormous amount of expertise in multiple disciplines, technologies, teaching methodology and classroom management. Limitations also exist in the ability of students. This is the type of work that scientists do in the real world; however, it is important to remember that many students, especially the general student, do not have the time management skills, cognitive ability, technical skills or motivation to stay on task during a prolonged self-guided voyage of discovery. Hormones, sports, jobs and MTV often dictate otherwise.

A project based curricular unit, an alternative to true problem-based leaning, is much more structured than a true problem-based learning unit. The objective, the method and the assessment are all outlined by the instructor. A project-based learning unit does force student and teacher out of the daily content grind and allows both to embark on a prolonged activity with emphasis on the application of knowledge, not just the acquisition of new facts.

A blended project falls somewhere between the two extremes.

McComas (1) designed a table to rate the "openness" of a lab activity. The more open a lab, the more decisions are left up to the student. Alan Colburn (2) used this table in his excellent article on making lab activities more open-ended. I would like to propose a similar grid system teachers can use to begin to plan new project-based, problem-based or blended curricular unit.

Project/Problem-Based Learning Matrix

	Objective or Problem	Student Activities / Research Method	Assessment
Project based.	Teacher defined.	Teacher defined.	Teacher defined.
Blended	Teacher guided.	Teacher guided.	Choice of teacher defined options.
Problem based.	Student defined.	Student defined.	Student defined and developed.

Information Based vs. Process Based: It is important to delineate between classroom projects that center on information retrieval and processing vs. projects that are process based. Both types of activities fit under the umbrella of project- and problem-based learning. Often the focus is on information based instead of process based. For example, the 4th edition of the ChemCom text from the American Chemical Society attempts to incorporate project-based and blended investigations into each unit of the curriculum. Many of these activities are very worthwhile; however, all are information based and fall short of the way a lab-based science course should be structured.

Examples:
Problem-based learning: During the last century global temperatures appeared to be increasing. Define and investigate a research question related to this fact.

Blended learning: Prepare a 5-10 minute presentation that shows that current global warming trends may not be a result of human activities.

Project-based learning: Create a 5-10 minute documentary using iMovie that provides evidence that global temperatures are being affected by the burning of hydrocarbons.

As these examples show, the project-based unit is the most narrow but also may be the most appealing for a number of reasons. The teacher narrowed the topic. This facilitates research and may build on specific content already covered in class. The unit defines the method of assessment. This limits the types of materials and technology the teacher must become familiar with and have in the classroom for students to use. The problem-based learning example is much more open-ended. With the right students this may be an outstanding question to pursue, but within the context of a typical course, this may be more than the student can tackle, or the teacher is willing to manage. The project-based unit may also be a great place to start for a teacher first stepping outside the traditional curriculum. As years pass, and expertise expands, the teacher may allow the unit to evolve to a more open-ended activity.

Other Examples:
Project-based learning: The "sludge" project in the established IPS curriculum. Students are given an unknown mixture of substances that they are to separate and identify using physical properties. This is an outstanding project. The objective is defined and there is a known answer; however, students are forced to construct their own research methods applying process skills learned in the previous few months.

Project-based learning: Determine the water quality in a local river using the standardized water quality index. (3) Similar to the IPS sludge project, students are forced to apply laboratory skills learned in the chemistry class to analyze water from a local aquatic system. Often this type of project-based activity can lead to problem-based learning. Open-ended questions often arise out of the activity. Is the river getting better or worse? What can be done to improve the quality of the water, etc?

Blended learning: Create a 3-5 minute infomercial using I-movie that describes an electrical generation technique. You must describe the chemistry involved and include advantages, disadvantages, and recommendations for the future.

> *The Power of ARISE: ARISE has the unique opportunity to build an integrated three-year curriculum that incorporates a logical sequence of project-based, blended and problem-based units into the core curriculum. Fourteen-year-old freshmen just entering the program may very well not be capable of functioning at a true problem-based learning level; however, they may be very engaged and challenged by an extended project-based unit.*

Recommendations: The new ARISE curriculum should include 5-10 days per semester with students involved in project-, blended or problem-based learning activity. If one occurrence is planned for each semester, a student completing the course will have participated in six different projects.

Freshman Year, Mostly Physics:
Semester 1 A process-based research project. Students should apply lab skills acquired in the course to solve a teacher-defined problem. Results should be presented to the class.
Semester 2 A blended science-literacy research project illustrating the physics of everyday phenomena.

Sophomore Year, Mostly Chemistry:
Semester 1 A blended research project involving the PAX nuclear reactor software. (See PAX nuclear reactor write up.)
Or
An applied field trip such as determining the Water Quality Index based on the chemical properties of a local aquatic system.

Semester 2: A blended science literacy research project investigating the chemistry involved in global problems such as ozone depletion, acid rain deposition or global warming.

Junior Year, Mostly Biology:

Semester 1: Process-based research project based on a live specimen, i.e., plant or animal. Student defined problem. Results presented to class.

Semester 2: Culminating problem-based learning research activity. Information or process based. Project should include research in the physics, chemistry and biology of a problem of the student's choosing.

Final Thoughts: As teachers we dream of teaching a course that has a significant impact on each student. In reality much of what is taught is not retained. It has been my experience that when students return years later, they never remember or want to talk about stoichiometry or calculating molar masses. What they do remember AND talk about years later are the field trip to the river, the sludge test their freshman year or writing letters to their congressperson about global warming etc. Incorporating an integrated planned series project-based, problem-based and blended curriculum units will make the entire three-year ARISE sequence a much more meaningful and memorable educational experience for the students.

References:

(1) McComas, W. E (1997, spring). The nature of the laboratory experience: A guide for describing, classifying and enhancing hands-on activities. CSTA Journal 6-9.
(2) Alan Colburn, "How to Make Lab Activities More Open-Ended," CSTA Journal 1997, pp. 4-6 and at <http://www.exploratorium.edu/IFI/resources/workshops/lab_activities.html>.
(3) Stapp,William B. and Mark K. Mitchell. Field Manual for Water Quality Monitoring, Twelfth Edition. ISBN 0-7872-6801-1.

Incorporating Technology into the Three Year ARISE Curriculum

I. Using Technology to Engage Students

The first thing for any teacher to remember is that the class they teach, and the classroom they manage must be fun! This certainly does not mean each day should be a party, but it does mean that chances for learning to take place will increased when the students want to be in class and are engaged in the lesson presented. Students use technology every day! I don't understand it, but they choose e-mail and instant messaging over talking on the phone. They e-mail themselves notes and papers instead of carrying them around. Entertainment takes place by manipulating things on a screen instead of in their hands. The fact is, students are comfortable with and enjoy using technology, so why not incorporate it in appropriate ways in the science curriculum.

II. Using Technology to Make Possible the Impossible

Technology sometimes can allow explorations to take place in the science classroom that would not be possible without the aid of computers and technology.

Interactive Simulations
In chemistry and physics students can use simulations such as the PAX nuclear reactor (more information in activities, demos, labs section). This software allows students to interact with a nuclear reactor as if they were an actual reactor operator. There are electrical circuit simulations that also do the same thing for physics/physical science. Students can build circuits on the computer, and the results can be monitored and measured.

Physical science classes can experiment and learn about earthquakes using excellent interactive simulations such as virtual earthquake, one of several virtual software packages available over the Internet from Southern Cal University.
<http://www.sciencecourseware.com/VirtualEarthquake/>

Biology: Interactive Fruit Fly Breeding using the Internet. <http://biologylab.awlonline.com/> This is one of the only pay-per-use ($100.00 for 10 stations) sites that I have seen that is well worth the investment. The site allows students to log in and then crossbreed fruit flies. Students can manipulate genetic traits and view the results of their breeding in seconds instead of days or weeks. The fly lab is just one of many available at the Biology Labs website. Simulations also can be used in Biology classes to simulate the growth of plants while changing multiple variables. Riverdeep Software markets programs that have solid algorithms built in that allow the students to study plant growth by changing variables, conducting experiments, and collecting data. The University of Arizona also has excellent interactive biology sites that include karyotyping labs.

The important thing with these types of simulations is to follow them up whenever possible with actual hands-on activities. Howard Gardner maintains that "Knowledge is a performance." Just because students know how to design a circuit on a computer screen, certainly does not mean they can hook actual wires and batteries up to achieve the same thing. Growing plants or cross-breading flies on a screen is a great way to introduce a topic, but the leaning will increase exponentially when students are asked to follow up computer simulations with actual experiments. Finding the epicenter of an earthquake in a tutorial is great, but doing the same thing with a hard copy of data can drastically show the limitations of "virtual learning."

Instrumentation that Extends the Senses

Computer-Aided Labs: Chemistry, physics and biology probes and monitors can be used to collect data in real time. Vernier does a real nice job with all their instruments and software at a price that is a fraction of many of the competitors. Collecting and displaying data in real time often adds significant meaning to the experiment for students. Temperature probes can graph fractional distillation data allowing students to see the plateaus resulting from the phase changes taking place. Motion detectors can be used in physics to display properties such as speed and acceleration simultaneously in real time. This allows students to see for themselves things that without the technology would just be theoretical. The real nice part of the Vernier package is that all their labs are provided in word format. Many of their labs are well written, but written as confirming labs instead of inquiry labs. New ARISE curriculum should definitely incorporate inquiry-based labs whether done on with the aid of a computer or not.. Being able to modify lab procedures allows labs to be tailored to meet the academic ability of the students in a class. A freshman-level physics class would certainly need questions written at a significantly different level than a senior-level class. Building on resources such as the Vernier package would allow writers to customize the labs for specific target audiences.

Many easy-to-use instruments that extend student senses are also available. Turbidity measurements can be made using Vernier turbidity monitors and software. Turbidities can be measured in the classroom or field using a small vial instead of in only in the field with a Secchi disk and deep water.

Vernier radiation monitors hooked up to computer monitors can put numbers onto a clicking Geiger counter. Quantifying a student's experience with radiation makes it possible to manipulate variables, collect data and have a quantitative experience with radioactive sources.

III. Using Multimedia Technology to Enhance Curriculum

Students can use digital cameras and scope-cams to capture images and insert them directly into reports. Students can use video cameras in physics to capture the motion of objects. Using software like iMovie in a frame-by-frame super slow motion mode, students can analyze their data. In chemistry students can use scope-cams and/or video cameras to record and project to the class small demonstrations such as crystal growth. In biology students can easily use equipment such as Ken-a-Vision scope-cam hooked up to a computer to copy and paste images from their microscopes into their lab reports. The actual images can be annotated. This is a quantum leap over a distorted sketch of air bubbles trapped under the cover slip. Having a student's microscopic images displayed on a computer monitor also allows the teacher and student to both interact with the image on the screen. This leads to many teachable moments.

Students can use presentation software such as iMovie or PowerPoint to research and present the results of information-based research projects. All science standards include a component of developing science literacy and historical the historical significance of science. Having students include projected documents such as Einstein's letter to President Truman expressing his concerns about nuclear fission can have a powerful impact.

IV. The Internet and Interactive Textbooks

Many textbooks now link to solid web resources using NSTA's Sci-Links. This is a nice improvement, but the future can be seen in textbooks such as an AP physics book that allows students to use the "book's" website to take practice tests, obtain feedback on questions they missed and obtain guided practice on correcting the mistakes they made based on their answers. Yes, the web site actually diagnoses their mistakes and guides their leaning. This service is available to students at home and even has a component that e-mails the teacher scores, etc. This is most likely a worthwhile direction to head when developing a new curriculum.

The Internet and teacher web pages can also be used to post data sets from class experiments. This allows students to look at larger data sets than would be available from a single class. This technique allows different classes to post results from different experiments. Students can share data between classes within the same building, or collaborate with students in different states.

Conclusion: Students love technology, and it certainly has a place in any new course being developed. The key is to keep good inquiry teaching at the core. Technology can only enhance a good classroom experience; it certainly cannot replace either the teacher or the hands-on experiences needed for any high school student to truly learn physics, chemistry, biology or earth or space sciences.

Vernier Products

Vernier makes an entire set of probes and attachments that aid in combining lab-based science and computers. Attached is the cover of one of the books (Chemistry with Computers) that can be purchased with the hardware. There are similar books for biology and physics.

Vernier has provided labs for almost any topic that can be covered in the three courses. Vernier also provides all their labs to the teacher as Word documents. This allows labs to be modified to fit perfectly with any curriculum.

One example of a modified lab is attached. Vernier had a Fractional Distillation lab written for use with their temperature probes. ChemCom had a similar lab. By modifying the lab three things were accomplished:
*The lab was changed from a confirmation lab to a more inquiry-based investigation.
*The instructions were simplified significantly. I think it is important to differentiate with the students the three distinct phases of a computer based lab activity. setting up the computer, actually doing the lab, and analyzing the data. The modified lab separates these three activities making the instructions less overwhelming for a student.
*Questions could be customized to fit with the curriculum or book being used.

Reference:
Vernier: Chemistry with Computers ISBN # 0-918731-95-X
ChemCom, Fourth Edition, ISBN# 0-7167-3551-2
Unit III, Section A, Lab Activity A.2, Separation by Distillation.

Standard Lab Write Up

A standard method for writing up labs is used for all science courses at Glenbard South. This format was arrived at after much discussion with all the science staff. This is a powerful tool that gives students a framework within which they can express their data, observations and thoughts on what was learned.

This lab form is very similar to many other schools and districts. What makes it unique is that our entire building adopted the same form. This frees students from having to learn a different technique each time they change teachers or courses.

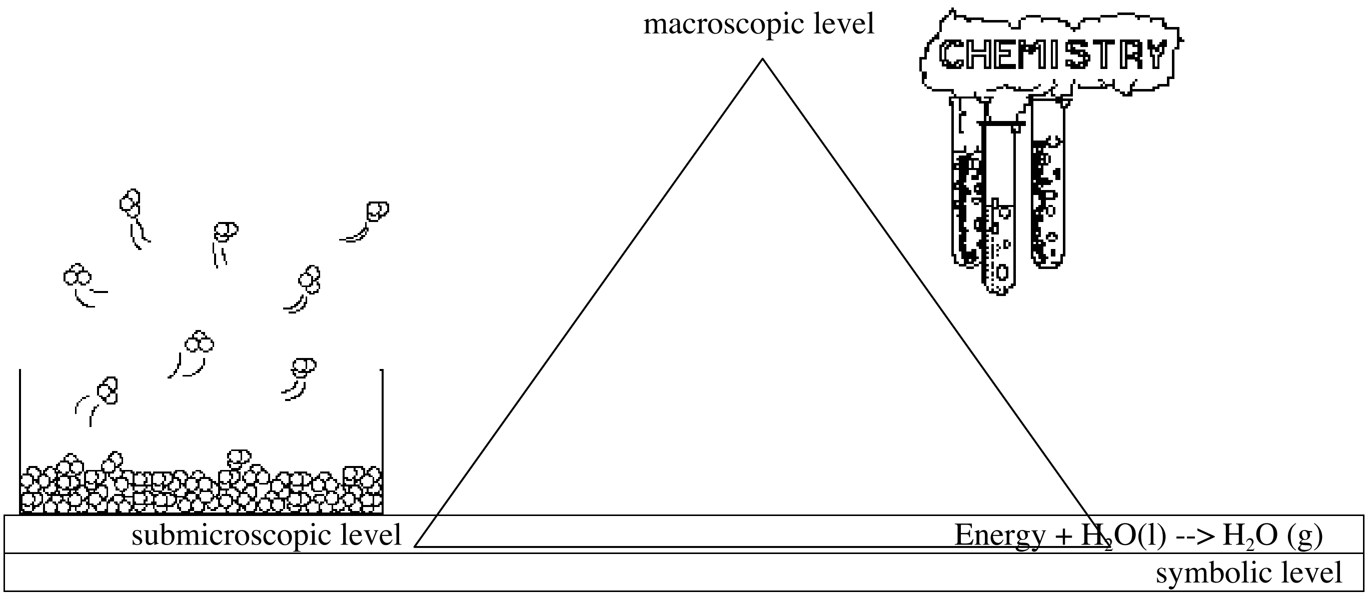
The form forces students to analyze what will be measured and manipulated prior to doing the experiment. The form also forces them to revisit data collected in order to formulate their final conclusion. Encouraging students to write up their own labs instead of filling in preformatted lab forms greatly increases student thinking and learning.

Any three-year curriculum should start by indoctrinating the students in how scientists think and process and share information. The use of a standard form should start in freshman year and continue during the three-year experience.

Some Reflections on Teaching Chemistry

by Lee Marek

The “ARISE White Paper” discussed two levels of knowing chemistry. There are at least three levels (perhaps four if one includes math, but I like the triangle better- it is more to the point!). I want to link the following three levels that show how students think about chemistry.



Macroscopic level: This is the level you and I see things at in the every day world. This would be a demo or lab. Something you can see, feel, hear, etc. An example would be water evaporating—the amount seen in a beaker decreases.

Submicroscopic level: This is the molecular level. What is really happening down there! It is the spatial level and the students should try to get a feel/picture of what this level is like. To some extent it is imaginary. It is also hard to teach because the picture is not static! There are now many wonderful simulations on the web for this. Examples are the following web pages
<http://www.nyu.edu/pages/mathmol/modules/water/water_concepts.html>
<http://www.matse.psu.edu/matsc81/Lecturenotes/Lec17-Hydrogen Bonding/hydrogenbond.html>

Symbolic level: This is the abstract level. It may involve math or some form of symbols to describe something.
Example would be water evaporating. Energy + $H_2O(l)$ --> $H_2O(g)$
or
<science.widener.edu/svb/pset/stoichio.html>

One should use and refine the phenomenological approach to teaching. The phenomenological approach (coined as far as I know by Earl Zwicker from IIT) introduces each topic with a lab, demo or some kind of computer or video simulation. This phenomenological approach is mainly on the macroscopic level. Students need to develop thinking about chemistry on the particulate or submicroscopic level via the kinetic molecular theory as espoused by Dorothy Gabel and others. It is also important that students relate this to the symbolic level that textbooks use and make connections to the other two levels.

Chemistry is an abstract subject. To get students to really understand it and to develop a conceptual framework from which to explore, one should attempt to get them to “think like a molecule”(my own description). In order for students to become good problem solvers, they must first understand the concepts upon which the problems are based and how they are linked to each other; see my method for problem solving below. Otherwise students just develop and memorize a set of algorithms for cranking out answers without knowing why they work. Students (and most of us for that matter) would rather do exercises than solve problem. Teachers in general do not recognize the complexity of the matrix of concepts they are teaching. The first time a teacher teaches something it may seem complex, but once she becomes comfortable with it, she tends to forget just how difficult chemistry can be for students. What appears to be very simple to a teacher or a scientist is not so clear and unambiguous to the student. Chemistry is like a foreign language with many irregular verbs; (See article from CHEM 13 News, 1/89, #182, “Earthchemspeak is Obscure, Contradictory Say Dr. Og”). Teachers need to develop analogies, demonstrations and models that help students through this maze we call chemistry. This can be one heck of a task for the basic chemistry level since only about 40% (I am not sure on this number) of students think on the “formal” Piagetian level. This is why teachers need to temper chemistry with concrete demos and analogies. You can find more information on this in the seminal article by J. Dudley Herron. (Herron J.S. “Piaget for Chemist” Journal for Chemical Education 52, pp. 146-150, 1975) The following webpage is one chemistry teacher’s impressions of Herron’s work. (There is also Herron’s work “The Chemistry Classroom” from the ACS, 1996.)
Others, such as Eric Scerri, in “The State of Research in Chemical Education” Scerri, Eric R. J. Chem. Educ. 2003 80 468 takes exception to this way of thinking - constructivism. <JChemEd.chem.wisc.edu/Journal/Issues/2003/May/abs468.html>
The paper makes the claim that there is a careless use of philosophical terms such as constructivism, behaviorism and relativism. The relevance of these developments to the Science Wars debate is briefly examined, and some positive recommendations are proposed to remedy the situation. In Scerri’s opinion “ chemical education is currently too simplistic in its underlying ideas” (p. 475). He challenges some of the ideas of George Bodner such as those that have appeared in Journal for Chemical Education, in Bodner, G. 1986. “Constructivism: A theory of knowledge,” Journal of Chemical Education, 63(10), pp. 873-877.

This article, “Constructivism: A theory of knowledge,” outlines the constructivist model of knowledge and describes how this model relates to Piaget’s theory of intellectual development. The constructivist model is contrasted with the traditional views of knowledge. The author discusses how this model can help explain how knowledge is arrived at and what happen in chemistry classrooms. He takes Herron's work and that of others and synthesizes them in this pivotal article that should be read by all chemistry teachers.

Something else to ponder—Has the pendulum swung too far? There needs to be a balance between both process and content. I rallied for more process 30 years ago. BUT PROCESS WITHOUT CONTENT IS JUST AS BAD! One needs a human "Rolodex of Knowledge," (my term). In chemistry you ought to know some things. This may mean, here it comes, the dreaded M word! You may have to memorize a few things to actually know them! WOW! An article by Rubin Battino, "On the Importance of Rote Learning" Chem. Ed. 69, 135-7 (1992), addressed these ideas very well. In chemistry, maybe students should know how to use a B.O.O.K. (Bound Organic Organized Knowledge (my term) to access information. I am thinking of patenting such a device. It would be made of cellulose material and the PowerPoint slides joined together with milk based polymer (Elmer's glue). This would be a cellulose encapsulated database acquisition look-up-system. To operate it you would need a photon supply or source in the 10^{14} Hertz range.

I have found that telling a good story captures kids interest. These stories should deal with the topic at hand. I tell them stories sometimes with demos, sometimes with analogies and sometimes from the latest research or from the news (Mars probe crashed because of English to Metric conversion problems, $125,000,000 mistake). Kids remember stories that are personalized. They also remember demos that involve them. I found that the people at Golden Apple are focusing on the same thing. There is a wonderful person at Northwestern University, Dr. Rivis Collins, who spoke to us on storytelling. Rubin Battino does not address this directly, but it is indirectly in the following article, "The Importance of Being Impressive—The Opening Lecture". Chem. Ed. 57, 67 (1980) and in R. W. Ramette's article, "Exocharmic Reactions," Chem. Ed. 57, 68 (1980), another must read.

The kids in my class were required to tell me "stories." This is really literacy. I tell them they should be able to tell me a story about how or why certain things work in chemistry. By this I mean that, when as part of a test, they will be asked to tell me a story such as, Why can we use the ideal gas law? not just plug into a formula and get an answer, but the dreaded "why does it work?" Another question might be, "What is the kinetic molecular theory?" These stories should be written so that a person reading their test can follow the narrative and will it accept as true! I tell them, "Do not make them cute like I may do in class, but hit the main points in your own words. Be able to explain it so I know you really understand."

I send a letter home to each parent of my general chemistry students who does not show up to the first open house. You can find these on my web page at:
<http://www.chem.uic.edu/marek/apintropage/parent1/parent1.html - lettertoparents>.
This has advice and is a guide for the parents and the student on how to succeed in chemistry. It puts the responsibility for doing well in my class where it belongs—on the students and the parents. I had very few phone calls asking, "What I can do to help my kid?" Also posted is advice from the U.S. Department of Education (from both a Republican and Democratic administration) on the importance of homework. Gee, is time on task important? A very small part of a report you may have heard of from the National Commission on Excellence in Education—A Nation at Risk is posted on my site. The purpose of the commission was to help define the problems afflicting American education and to provide solutions. Also posted is the

1986 U.S. Department of Education report, commissioned by the President, "What Works, Research about Teaching and Learning." Lastly, some of the ideas from the Prisoners of Time—a report of the National Education Commission on Time and Learning, 1994 are posted on my site.

Finally if you look at NSTA's "The Science Teacher" for 1/03, p. 38, you will find an article on "Connecting Algebra and Chemistry" by Sean O'Connor. I know him well; he was on one of our history of science trips and in one of the methods classes I run at UIC. Also, in the same issue there is a good article on helping students write clear lab reports.

Listening to George Bodner, Cliff Schrader and Ken Spengler over the years, I developed this method of problem solving. I took their ideas and modified them for my classes.

Problem Solving

Problem: Whenever there is a gap between where you are now and where you want to be and you don't know how to cross that gap, you have a problem. (Hays, 1980)

Problem Solving: What you do when you don't know what to do. (Wheatley, 1984)

"THE METHOD" FOR PROBLEM SOLVING"

1. Read the problem.
2. Read the problem again.
3. Write down what you hope is relevant info (given).
4. Draw a picture, make a list, write an equation or formula or chemical formula/equation.
5. Try something—trial and error is legit!
6. Try something else.
7. See where it gets you.
8. Read the problem again.
9. Try something else.
10. See where it gets you.
11. Test intermediate results to see if you are making progress.
12. Read the problem again.
13. AAHHAA! - You see it!
14. Write down an answer (not necessarily "THE" answer).
15. Test your answer to see if it makes sense.
16. Start over if you have to, celebrate if you don't.

Note: An "algorithm" (rules for calculating something that can be followed more or less with the brain on autopilot) may work for some things, but don't count on it for the test or for real learning. You need to KNOW what the heck you are doing. Take time to read the chapter, listen in class (and reflect on what is being said) and do the homework in a timely fashion. Be able to "tell a story" (put in your own words) about the major concepts in a chapter. If you can explain it (the chemistry) to someone else in your own words, you have a better chance at deeper understanding.

I have run workshops for teachers for more than 20 years. First at Fermilab, the NSF four-week Summer Institute for Science and Mathematics, then for Woodrow Wilson National Fellowship Foundation one-week workshops and now one-week workshops for the Flinn Foundation. One of the frustrations we have heard over the years from many chemistry teachers is the lack of quality laboratory manuals. Teachers don't like to use the textbook lab manuals (many times they are like filling out your income tax form, with little learning except following directions), and teachers don't have time to develop their own labs. The excitement expressed by teachers attending the workshops when they do quality labs is further confirmation that they desire better labs. It is hoped that experiments allow students to build connections linking pervious knowledge in physics, physical science (from junior high) and biology (here from junior high).

Science is a verb; it is a hands-on process. Through the use of well-planned laboratory experiments the scientific method becomes a way of thinking and looking at things not encountered in most other subjects. The student becomes physically, not just mentally, involved in the process. There is an old Chinese saying that puts laboratory work into proper perspective: "I hear, and I forget. I see, and I remember. I do, and I understand." Doing labs is essential in science. Teaching science without labs is like teaching typing without a keyboard. Lab work is the heart of a good science class. Labs are interdisciplinary; they sharpen students' skills in: reading and writing; in applying math to real problems and interpreting data; in student-student interpersonal relations. HOWEVER, if the lab is little more than mindless manipulation and direction following, then the major cognitive skill developed is an ability to accurately follow directions. Real learning will take place only during lab activities that are "minds-on" as well as hands on.

Labs also add a teamwork dimension to the classroom, as they are done in groups of two to four students working cooperatively. They share the lab experience and try to work as a team to organize the data. Such group work makes creativity, problem solving and critical thinking easier for all involved. Since "real life" involves this type of teamwork, I think it is important that students begin to develop it in school.

A word about micro-scale (better called small-scale) labs.

Small-scale chemistry uses small, inexpensive plastic apparatus to perform the labs. The following are some of the reasons you will want to do small-scale labs:

1. Cost: You use very small amounts of materials and chemicals. In these days of budget cuts this is very important.
2. Disposal: There are so many guidelines and regulations governing disposal of laboratory waste that much time and expense can be avoided by using these techniques. This is an environmentally friendlier technique.
3. Safety: It is obvious that the smaller the amounts the safer the lab, especially in this time of growing class sizes.

4. Time for both the teacher and the student: Small-scale allows for much shorter set-up times because of the nature of the equipment and the amounts of solutions. The labs are generally much faster to do, so the students may be able repeat them in one period. Generally speaking, the first time through a lab the students are just trying to figure out what is going on with all the new directions, chemicals, equipment, and techniques. Maybe some learning is going on! But the second time through, the students may be able to focus on "the chemistry".

5. Paradigm Shift in Teaching: You may be able to change your whole philosophy of teaching to a lab-based, lab-driven course because these labs are fast to do and you can use many minilabs to drive the content! You may be able to use the lab to teach problem solving, critical thinking, effective writing (writing across the curriculum, literacy, or what ever buzz work your school system uses!), engage the students in minds-on, hands-on science. Move from a teacher-centered to a student-centered classroom. One of the goals of science teaching should be for students to understand scientific ideas deeply enough so they can talk about them in their own words, apply them to show how things work, use them to find answers to new questions, and see connections within them. There is a story told of Lord Rutherford, when he was head of the Cavendish Labs. He is supposed to have said: "A physicist's theories are worthless unless he can explain them to the barmaid at the local pub." Some may disagree with this quote for a variety of reasons, see: www.etext.org/Politics/Progressive.Sociologists/socgrad/93/mar9

General Form of Lee Marek's Formal Lab Report Write-Up Form

On my webpage <http://www.chem.uic.edu/marek/apintropage/aplabwriteup/aplabwriteup.htm> is a link to this format. This is for a formal lab report; one would not do this for all labs. For some labs you would choose much shorter forms, parts of this or even group write-ups.

All reports should be word-processed. All data should be typed in tables—learn to use and make tables on your computer, this will prove useful to you in real life! If you make a mistake when taking data, simply draw a single line through affected data and note the reason. If you type it up on a word processor so it looks really cool, you MAY get up to 10% added on to your grade.

TITLE - This is a general statement about what is being done in the laboratory.

PURPOSE - This is a specific statement or question about what is being looked at in the experiment.

PROCEDURE - This is an abstract only. It should be only a 3-7-sentence reference to the method used in the lab and stated in the laboratory handout.

THE ABOVE THREE SHOULD BE DONE ALONG WITH A DATA TABLE <u>BEFORE</u> YOU COME TO DO THE LAB. IF I CHECK IT AND IT IS NOT DONE. YOU WILL NOT DO THE LAB—SORRY.

OBSERVATIONS - This should include all observations. Every lab should have this section.

MEASUREMENTS (DATA TABLE) - This includes any and all measurements made during the lab. The measurements should be made using as much precision as the instruments offer. These measurements should include all units and be well organized. Keep results separate from measurements.

RESULTS - Carefully labeled sample calculations should be included for each significant type of calculation. Then display all of the calculation results in tabular form. If the experiment has only a few numerical results, make sure they are clearly labeled and set apart from the measurements so that they are easy to find. Use significant figures and scientific notation.

ERRORS - List source of errors, as many as you can. Do not tell me you massed it wrong unless you did. No human error! Tell me how the errors would or did affect your results. Give me the % error if you know the true value. If not, get the % precision, which can be a real pain. I will go through an example with you on this. Take notes about it when I do.

CONCLUSIONS - This is an interpretation of the results and a summary. What did you discover? This is not a place to restate the results. If you did come up with a number like “the density was 4.56 g/ml,” you should put it in here.

CHARTS and GRAPHS - The data and results should be recorded properly in the appropriate type of chart or graph. Make graphs the [click here->] right way.

CHEMICAL EQUATIONS - If there were any chemical reactions that were done during the experiment, you should show a balanced equation.

LATE REPORT - There will be 25% taken off the total grade per day if the report is turned in late. Most lab reports are due the day after the lab is completed. Check with me on this one.

ORIGINAL DATA - The original data, just as it has been recorded, “should” be included with the lab report. BUT I DO NOT WANT THIS. When you go out and work for industry, they would have you keep this each day, and initial it.

In addition to the labs in each manual there are the demos. The teaching of chemistry should involve the “Phenomenological” approach to teaching science—introducing a topic with a demonstration or lab so that students have something concrete on which to focus. The teacher wants to keep the students coming back mentally. Teachers cannot communicate with students who are not “mentally present.” If you want “presence,” you have to capture attention and awaken the students’ desire to learn. One technique to do this is with demonstrations to liven up the material, to hook the students into looking forward to chemistry class and to focus on the day’s topic. Color changes, flames, explosions, and discrepant events (a phenomenon which occurs that seems to run contrary to one’s first line of reasoning or current set of ideas) are good ways to capture attention. These demonstrations set the stage and induce (maybe seduce!) the student into learning. They create excitement. They provide a reason for investigating (as opposed to merely memorizing) the topic. Discrepant events and demonstrations aid students in developing their reasoning and problem-solving skills. The student is then involved in a cognitive conflict. The demonstrations in the Flinn book and others I will include (if time permits) will have some of these pedagogical properties. Rubin Battino addresses this in the following articles: “The Importance of Being Impressive—The Opening Lecture,” J. Chem. Ed. 57, 67 (1980); “On the Importance of Being Passionate.” J. Chem. Ed., 67, 945 (1990); “The Importance of Being Eccentric,” J. Chem. Ed.59, 584-5 (1982) and as does R. W. Ramette’s article, “Exocharmic Reactions” J. Chem. Ed. 57, 68 (1980).

If you only know chemistry as a ritual of facts, measuring the physical phenomena and mathematical formula, then perhaps you have missed the soul of chemistry. Static images such as pictures, diagrams, words, formulas and even QuickTime movies on the web often leave the student with only vague notions of the science. Verbal, mathematical and pictorial representations of concepts fall short in intensity and instructive impact. If one asks students what kind of course material they talk about, write home about, and remember twenty years later, demonstrations are it. Most teachers and college professors have much anecdotal evidence for this from former students. Henry A. Bent summed this idea up nicely at the ACS Chicago meeting 6/84: “When something happens in the lab they (students) never know what is happening. But with demos you can explain ‘it’ (the chemistry) when ‘it’ happens—they can really see chemistry.”