IODINE

By Phyllis A. Lyday

Three producers of crude iodine supplied about 29% of domestic demand; the remainder was imported. Because some exports and imports are in product categories rather than crude products, net imports are not clearly distinguished. The largest producer, Chile, produced iodine as a coproduct of sodium nitrate. The world's second largest producer, Japan, produced iodine from brines associated with gas production.

Legislation and Government Programs

The Strategic and Critical Materials Stock Piling Act, as amended, gives the U.S. Department of Defense (DOD) authority to maintain a stockpile of strategic and critical materials to supply the military, industry, and essential civilian needs of the United States for national defense. By 1968, 3.7 million kilograms (8.1 million pounds) of iodine had been acquired. In 1992, Public Law 102-484 reduced the stockpile goal to zero, and Congress authorized the sale of excess material. The DOD Annual Materials Plan (AMP) proposed sale of iodine for fiscal year 1997 (October 1, 1996 through September 20, 1997) was 204,117 kilograms (450,000 pounds). On August 25, the 204,117 kilograms of iodine proposed in the AMP were sold by negotiated bid for a value of $3,630,070. The total amount was awarded to three companies: AMLON Metals, Inc., NY; Helm Chemical Corp., NJ; and Incasa Industria E. Com. Catarinense S/A, Brazil. At yearend, the excess iodine in the stockpile remained at 2,123,715 kilograms (4,681,984 pounds).

Production

Domestic production data for iodine were derived from a voluntary survey of U.S. operations by the U.S. Geological Survey (USGS). Of the three operations to which a survey request was sent, all responded, representing 100% of the total production. (*See tables 1 and 6*.)

In 1987, IOCHEM Corp. began producing iodine by the blowingout process at a plant 1.2 kilometers east of Vici, Dewey County, OK. IOCHEM is a privately held joint venture between Tomen America Inc. and a private family. The majority of production was shipped to Schering AG, Germany, under a long-term contract. IOCHEM reported to have nine production wells and four injection wells with a total production capacity of 1,400 metric tons per year at Vici.

North American Brine Chemicals, owned by Beard Oil (40%), Godoe Ltd. (50%), and Mitsui and Co. Ltd. (10%), began operating a miniplant at Dover in Kingfisher County, OK, in 1983. The company presently operates two plants. One is at an oilfield injection disposal site that obtains brines from about 50 wells in the Oswego Formation. Iodine concentrations were as much as 1,200 parts per million. Because of the low market prices for iodine in 1993, the company closed a world class plant that began operating in 1991. The plant reopened in 1996 as prices increased.

Woodward Iodine Corp., which began production in 1977 was purchased by Asahi Glass Co. of Japan in 1984 and sold to Ise Chemical Industries Co. Ltd. in 1994. Woodward operated the plant in Woodward County, OK, that produced iodine from 22 brine production wells using the blowingout process and injected waste through 10 injection wells.

Consumption

Estimated end use by percentage for iodine in 1996 were estimated from a USGS canvass of consumers as follows: sanitation (39%); pharmaceutical (24%); heat stabilizers (13%); catalyst (9%); animal feed (7%); and other (8%). Other smaller uses included inks and colorants, photographic chemicals, laboratory reagents, production of batteries, high-purity metals, motor fuels, and lubricants. (*See table 2*.)

Commercial crude iodine normally has a minimum purity of 99.5%. Impurities are chiefly water, sulfuric acid, iron, and insoluble materials. The U.S. Pharmacopoeia (U.S.P.) XVII specifies an iodine content not less than 99.8%. The committee on Analytical Reagents of the American Chemical Society (ACS) allows a maximum impurity level of 0.005% total bromine and chlorine and 0.010% nonvolatile.

Akzo Nobel planned to sell one-half interest in its industrial fibers business to Turkish conglomerate Sabanci Holding. Iodine is used as a catalyst in the production of nylon. GAkzo's industrial fibers business manufactures polyester, nylon 6,6, and rayon used to make industrial goods such as conveyor belts, car seat belts, tires, air bags, ropes, and nets (Reisch, 1997a).

AlliedSignal Inc. is the leader in production of an iodine catalyst for the production of nylon for use in carpets. With corporate headquarters in Morristown, NJ, Allied Signal is an advanced technology and manufacturing company with 70,500 employees at 300 facilities in 40 countries. It serves customers worldwide with advanced materials, aerospace and automotive parts, chemicals, fibers, and plastics. It is one of 30 companies included in the Dow Jones Industrial average (The PointCast Network, AlliedSignal to expand amorphous metals business through technology licensing agreement with General Electric, accessed February 24, 1998, at URL http://www.pointcast.com).

Arizona Chemical Co., Hercules Inc., and Westvaco Corp. are U.S. companies that use iodine to stabilize tall oil rosin (TOR). TOR is made from crude tall oil (CTO), a pulping byproduct, which is fractionated into rosin and tall oil fatty acid. Rosins are further processed into such products as sizing, adhesives, tacifiers, and ink resins. Rosins prices were gaining at yearend (Brown, 1997). The resurgence of the pulp and paper industry drove the CTO market into oversupply during 1997 resulting in consecutive quarterly declines in price in TOR for the last half of the year. The main competition for TOR was hydrocarbon resins made from byproducts of ethylene production. Consumption increased from 792,922 metric tons in 1996 (852,000 short tons) to 809,209 metric tons (892,000 short tons) in 1997. This was reflected in increased consumption of iodine (Scheraga, 1997).

Eastman Chemical is a consumer of iodine as a catalyst in the

production of acetic acid used to produce acetate fiber. Eastman's Chairman and chief executive received the Commercial Development Association's 1997 Honor Award for leadership in global growth strategy to increased sales outside the United States to 50% by 2000. The chairman was elected last year to the National Academy of Engineering and is a former chairman of the CMA, where he headed an industry drive for regulatory reform (Peaff, 1997).

Two Eli Lilly and Co. products, Evista and Gemzar, trade marked names, are new products that use iodine compounds in their manufacture. Lilly's Evista is among the first in a new class of drugs called selective estrogen receptor modulators. Evista appears to act like estrogen in some tissues, such as bone, but not in the breast or uterus. Clinical trials have shown that Evista preserves bone and increases bone mineral density, as one of several benefits to menopausal women. Lilly has studied more than 13,000 women worldwide.

Sales of Gemzar, an oncolytic agent for the treatment of locally advanced or metastatic pancreatic cancer, tripled during 1997. Gemzar was submitted to the Food and Drug Administration in August 1997 for approval for the treatment of locally advanced or metastatic non-small-cell lung cancer. Clinical trials for new drug studies in patients with bladder and breast cancer and planning studies for those with ovarian cancer are being conducted. The potential benefits of this new class of drugs if implemented into current drug therapy would be to create new demand for iodine compounds (Dix Weaver, Eli Lilly Tippecanoe Laboratories, written commun., 1998, p. 4).

Fisher Scientific International, Inc., a consumer of iodine, experienced decreased sales during 1997 as a result of the ongoing impact of the strike against United Parcel Service of America Inc. Fisher Scientific is the world leader in serving science, providing more than 245,000 products and services to research, health care, industrial, educational, and government customers in 145 countries. Some of the many products are iodine and iodine compounds (The PointCast Network, Fisher Scientific reports 1997 fourth-quarter and full-year results, accessed February 27, 1998, at URL http://www.pointcast.com).

Hercules Inc. is a global manufacturer of chemical specialty products used in a variety of home, office, and industrial products. These core businesses include resins for hydrocarbon and rosin resins used in adhesives using iodine during the processing. A list of the industry adhesives can be found at URL http://www.herc.com.

In September, Celanese announced a capacity expansions that included a plant in Bucks, AL, which manufactures acetic acid, using iodine. The acquisition of Celanese in 1987 by Hoechst, vaulted Hoechst into first place in terms of sales among world chemical companies (Reisch, 1997b). Hoechst Aktiengesellschaft, Germany, announced that the Hoechst Group combined the former Hoechst Global Basic Chemicals division and Global Cellulose Acetate to form Celanese. Celanese was a U.S. company that began operations in the 1920's to produce cellulose acetate, for textile fibers, film, cigarette filter, and protective coatings (Chemical & Engineering News, 1997a).

International Specialty Products (ISP), Wayne, NJ, has agreed to purchase Polaroid Corp.'s Freetown, MS, fine chemicals manufacturing facility. Iodine is used in color films as a promoter in the manufacture of acetate for the film and as a light sensitive material in the form of silver halide. ISP will supply imaging chemicals and polymers to Polaroid under a long-term agreement. ISP plans to upgrade the plant to allow its use for manufacture of pharmaceutical intermediates (Chemical & Engineering News, 1997d).

Mallinckrodt Inc. health care business includes three major divisions: respiratory care, medical imaging, and pharmaceutical specialities. Iodine is used in medical imaging in the products Conray, Hexabrix, and Optiray. Optiray is only sold in the United States. Currently about 5% of patients undergoing a coronary X-ray angiogram experience serious side effects, including renal failure and limb loss or death, which may be caused by the insertion of the catheter and the high dosage of iodinated radio-opaque dye (Epix Medical, Inc., The current procedure—X-ray angiography, accessed June 30, 1998, at URL http://www.epixmed.com/mrxray.html). During 1997, EPIX Medical Inc. and Mallinckrodt, jointly announced the start of clinical trials for MS-325, EPIX's injectable magnetic resonance imaging contrast agent that uses gadolinium compounds rather than iodine and is designed for multiple cardiovascular indications. Contrast agents administered to patients are designed to improve the quality of medical images (The PointCast Network, Epix medical, and Mallinckrodt begin phase II clinical trial of mri vascular contrast agent for radiology indications, accessed June 27, 1997, at URL http://www.pointcast.com).

Mallinckrodt Medical, Inc. was issued a license by the Nuclear Regulatory Commission (NRC) on January 6, 1975. Mallinckrodt medical makes various radioactive material, including iodides for medical usage. A NRC review in April 1997 resulted in a ruling that Mallinckrodt pay a civil penalty as a result of a violation. The NRC staff determined that Mallinckrodt was not in compliance with NRC requirements (Nuclear Regulatory Commission, 1997).

Westvaco Corp. is a major producer of paper envelopes, packaging, and specialty chemicals, including tall oil resins that are stabilized with iodine. The company owns 0.61 million hectares of timberland in the United States and Brazil (The Pointcast Network, Westvaco announces new shareholder rights plan, accessed September 23, 1998, at URL http://www.pointcast.com).

The World Health Organization (WHO) estimates that about 2 billion people are at risk for iron, iodine, and vitamin A deficiencies. Ending micro nutrient malnutrition is the most achievable international health goals of the decade. Iodine deficiency is the world's leading cause of mental defects in the form of severe retardation, deaf-mutism, and partial paralysis, as well as more subtle problems, such as clumsiness, lethargy, and reduced learning capacity. Iodine is an essential part of a thyroid hormone that contributes to fetal brain development and metabolism after birth. A lack of iodine in the diet can cause goiters, a thyroid disorder.

A worldwide effort is underway in 118 countries with an estimated 1,571 million people to eliminate iodine-deficiency disorders by fortifying the world's salt supply. Universal salt iodization for eliminating iodine deficiency disorder (IDD) has been endorsed by WHO. Table salt in the United States has been fortified with potassium iodide since 1924, when the State of Michigan first introduced iodized salt. In 1974, the Food and Drug Administration sought more information in Total Diet Study. In 1980, the National Academy of Sciences recommended 0.15 milligrams of iodine per day for adults. WHO issued a statement that summarizes the cumulative scientific and epidemiological evidence in this regard as follows: WHO specifies that a safe daily intake of iodine should be between a minimum of

50 micrograms and a maximum of 1,000 micrograms. A generally accepted desirable adult intake is 100 to 300 micrograms per day.

Although potassium iodide was first used in salt iodization, the use of iodate is now recommended since it is more stable than iodide under varying climatic conditions. Average daily salt intakes vary from country to country from 5 to 15 grams per day. Instead of increasing salt consumption, the quantities of iodate added to salt should be adjusted to provide approximately 150 micrograms of iodine per day. Sea fish, other seafood, and seaweed are rich in iodine (World Health Organization, Iodine in salt—A statement by WHO press release, accessed October 9, 1998, at URL http://www.who.ch/press).

In remote areas, iodine is sometimes used instead of chlorine to purify drinking water. This can add 1,000 to 2,000 micrograms to the daily iodine intake of the people who drink this water.

Seaweeds have been used to cure what ails within and without since ancient times and is an excellent source of iodine. Greek and Roman records from the first century B.C. mention herbal medicines and cosmetics. American Indians on both coasts have long used kelp in their traditional diets, and Australian Aborigines still prepare several seaweed dishes. Seaweed is rich in iodine, an essential element of an enzyme that regulates the thyroid and magnesium, calcium, potassium, carotene, chlorophyll enzymes, and fibers. It is one of nature's riches sources of vegetable protein and vitamin B-12. Seaweed is higher in vitamins and vital trace minerals than any other food. More importantly, seaweeds have been an important food source for thousands of years, according to Chinese writer Chi Han, who noted their importance in 300 B.C. China is now the world's largest harvester of mixed-purpose seaweeds with an annual crop of 2.5 million tons. Japan nets nearly $1 billion on its harvest, and in 1994, Ireland's crop weighed in at 34,600 tons, securing its position as one of the world's most important seaweed producers (Preet, 1998).

Brown seaweed of the Laminaria family contains up to 0.45% iodine by weight on a dry basis and can yield ash containing 1.4% to 1.8% iodine when burned. The iodine content of 1 gram of dried seaweed can be as high as 4,500 micrograms. Nori, the green-black seaweed sheets used extensively in sushi preparation, is found in oceans all over the globe and contains about 50 milligrams of iodine per kilogram. Hijiki, a seaweed native to Japan's waters, has the appearance of thin, crumbled, black twigs when dry, but develops a soft, chewy texture after being reconstituted in warm water for about 20 minutes. Dulse, a thickly crumpled red-brown seaweed with a pungent briny taste, is unique to North Atlantic and Pacific Northwest waters. Carrageen, also called Irish Moss, grows in clusters of purple brown fan shapes. It is found on stones and rocks all along the Atlantic Coast. Kelp is a seaweed used for many purposes that is found in many forms in both the Pacific and Atlantic Oceans. In Japan it is known as "kombu." Pickled kelp, can be found in Asian speciality stores. A company now supplies 30 tons per year across the Canada and United States (Preet, 1998).

Prices

Crude iodine prices quoted in trade journals increased in 1997. The average declared c.i.f. value for imported crude iodine was $14.66 per kilogram. The average declared cost, insurance, and freight (c.i.f.) value for imported crude iodine from Japan was $15.41 per kilogram. The average declared c.i.f. value for iodine imported from Chile was $14.28 per kilogram. Quoted yearend U.S. prices for iodine and its primary compounds are shown in table 3.

Since 1977, when the first United States plant in Oklahoma was built, iodine c.i.f. prices per kilogram have been as follows: 1977, $4.39; 1978, $4.72; 1979, $6.57; 1980, $13.80; 1981, $13.12; 1982, $12.92; 1983, $12.06; 1984, $10.58; 1985, $11.86; 1986, $12.52; 1987, $15.26; 1988, $17.46; 1989, $17.67; 1990, $15.19; 1991, $10.16; 1992, $9.03; 1993, $7.90; 1994, $7.56; 1995, $9.88; and 1996, $12.90. At the same time, U. S. capacity has increased to 3 million pounds and world production from 9 million kilograms in 1977 to 16 million kilograms in 1997. The price increases during 1997 are a result of a shortage of iodine in the market that is being alleviated by capacity increases in Chile.

Foreign Trade

The General Agreement on Tariffs and Trade (GATT) was signed into law in December 1994 and took effect January 1, 1995. GATT lowers chemical tariffs by an average of 30%. Chemicals, including iodine, are the Nation's largest export commodity, as more than 10 cents out of every export dollar is a product of the chemical industry. The agreement's intellectual property provisions include greater patent protection for products developed by American firms. GATT changes patent enforcement from 17 years from the date of issue to 20 years from the date of application. Patents issued on applications filed before June 8, 1995, will be enforceable for either 17 years from the issue date or 20 years from the filing date, whichever is longer.

The U.S. Government adopted the Harmonized Commodity Description and Coding System (Harmonized System) as the basis for its export and import tariff and statistical classification systems. The system is intended for multinational use as a basis for classifying commodities in international trade for tariff, statistical, and transportation purposes. The Harmonized System, as proposed, includes resublimed and crude iodine under the same code and a free duty rate. Values that differ significantly could be a result of items being placed in the wrong category. (*See tables 4 and 5*.)

The ministers of the World Trade Organization met in December and approved the permanent establishment of the Committee on Trade and the Environment (CTE). The U.S. chemical industry will be an active participant because there are several major environmental issues affecting trade that it would like to see resolved. The Chemical Manufacturers Association (CMA), as a major representative of the U.S. chemical industry, finds eco-labeling to be one area on which it and its European counterparts cannot agree. Ecolabels list specific environmental standards on packaging, recycling, and even production processes before the product can be imported into Europe. In a policy paper, CMA stated, "The proliferation of different types of environmental labeling systems contributes to the creation of nontariff barriers." Problems arise when countries try to unilaterally use trade measures to achieve environmental goals. The issue of flexibility in achieving international environmental objectives will continue at future CTE meetings (Hanson, 1997).

World Review

Australia.—The U.S. company Ecolab Inc., St. Paul, MN,

announced an offer for Gibson Chemical Industries Ltd., Melbourne, Victoria, Australia. Gibson is a manufacturer and marketer of cleaning and sanitizing products, primarily for the Australian and New Zealand institutional, health care, and industrial markets. Ecolab acquired 98% of Gibson shares by December 8. Ecolab is the leading global developer and marketer of premium cleaning, sanitizing, maintenance, and pest elimination products and services for the hospitality, institutional, and industrial markets (The PointCast Network, Ecolab to tender for Australian firm shares, accessed August 29, 1997, at URL http://www.pointcast.com).

Chile.—Chile was the second leading producer of iodine, and new projects continued to be announced to increase production. Atacama Minerals Corp., formerly Boron Chemical International Ltd., Vancouver, Canada, received approval of an environmental impact statement for the Aguas Blancas project in Region II, northern Chile, for the production of iodine, sodium sulfate, and potassium nitrate. The approval is necessary for the completion of other permitting and the commencement of construction at the site. Atacama has claim through its sister subsidiary Minera Teslin Ltd. (Green Markets, 1997). The project is scheduled to begin production of 1,000 tons of iodine, 300,000 tons of sodium sulfate, and 70,000 tons of potassium nitrate per year by 1999 (Chemical Market Reporter, 1997a). The caliche ore body is 95 kilometers southeast of the port of Antofagasta. By using a cutoff grade of 200 parts per million iodine, the proven and probable reserves are 29.5 million metric tons; most of the caliche averages 683 parts per million iodine. The ore is shallow, and mining depth will reach a maximum of 7 meters. Overburden is less than 1 meter (Coligandro, 1997). Processing of the ore involves crushing, leaching with fresh water, thickening, filtration, and iodine precipitation. The direct capital costs are expect to be $74.6 million. The breakdown is as follows in million dollars (U.S.): Mining, 6.8; roads, 2.4; process facility, 59.3; and water infrastructure, 6.1 (North American Minerals News, 1998).

Compania de Salitre y Yodo de Chile (Cosayach) part of Inverraz S.A., mines iodine and nitrates from caliche reserves in the first and second region of Chile. Reserves consist of more than 90,000 hectares, which correlate to 300,000 tons of iodine and 50 million tons of sodium nitrate. The Cala-Cala plant, begun in 1991, has a capacity of 648 tons per year. The Negreiros plant, begun in 1995, has a capacity of 1,080 tons per year. The Soledad plant, to begin in 1997, will have a capacity of 1,080 tons per year. Total capacity in 1996 was 2,808 tons per year. The mining uses bulldozers and trucks to transport ore to a leaching area where it is deposited 4 to 4.5 meters high on a waterproof liner of polyvinyl chloride. A sprinkling system provides water to dissolve the salts in the ore. The solutions are captured and sent to the iodine plant for recovery where iodide is reduced with sulfur dioxide to iodine. The precipitate is refined and washed to produce 99.7% pure iodine. The solution is concentrated by a two-stage crystallizer and solar evaporator to achieve a nitrate-rich solution, which produces sodium nitrate or potassium nitrate. The design capacity is 200,000 tons per year of nitrates. Nitrate production was expected to reach more than 400,000 tons by the end of 1999 (Sarah Hall, Tamaya Chemical Corp., written commun., 1997).

KAP Resources Ltd., Vancouver, Canada, announced that its Chilean subsidiary, Cia Minera Yolanda SA, revised construction plans for an $80-million facility that was completed at yearend 1997. Gulf Fertilizers and Chemicals has signed a 3-year contract to market the iodine (Green Markets, 1997). The revisions did affect the initial mining and no less caliche ore is being produced than is required to run the processing facility. Production of iodine during 1997 totaled 4,000 kilograms. Revised production levels for 1998 have been set at 250,000 kilograms of iodine (Industrial Minerals, 1997, 1998).

Sociedad Quimica y Minera de Chile (SQM) produced 99.5% iodine as a byproduct of nitrate production. In recent years, SQM has diversified into downstream products. Sales to more than 80 countries are divided approximately between speciality fertilizers (55%), iodine and iodine derivatives (13%), and other revenues including fertilizers distribution (13%). The company controls 35% of the world's iodine production capacity through SQM Iodo SA. (Harben and Edwards, 1997).

SQM has mining rights to the world's largest known deposits of nitrates and iodine in caliche, once known as white gold. Caliche-based operations and parts per million iodine were Pedro de Valdivia (379), Maria Elena (392), and Sierra Gorda (529). After blasting to break the caliche, the caliche ore mined at Valdivia and Elena is transported 17 kilometers and 25 kilometers, respectively, to the processing operation. The ore is crushed to approximately 12.5 millimeters (one-half inch) and transferred to leaching vats for removal of the water-soluble minerals. At Sierra Gorda, mine tailings are heap leached with water to obtain iodine solutions. The size of the mine tailings material is related to the recovery of iodine. Satellite plants produced about 1,000 tons per year of crude iodine. One satellite plant, owned by Cimin, a subsidiary of SQM Iodo (a subsidiary of SQM) is about 100 kilometers from the main mines. In August, Cimin's Pinto plant came on-line at 1,000 tons per year. This plant complements a 500-ton-per-year unit. Cimin brought on-line 1,500 metric tons of added capacity during 1996. All the iodine production was in Chile's Region II. Construction during 1997 was in Region I, the northern most part of Chile's 13 regions. SQM planned a 1,500-ton-per-year plant in the same area at its Minera Mapocho plant, acquired by SQM in 1996, which added 400 tons of iodine capacity. Overall, SQM has planned to invest $30 million in iodine expansion that will take its total production capacity to more than 8,000 tons in 1997 (Chemical Market Reporter, 1997b).

SQM Research and Development Centre, which was established at Antofagasta in 1989 to improve the quality and consistency of the iodine products, has been involved in researching various production and processing methods. These include the patent method for prilled iodine, obtaining ISO certification, and the heap-leaching of iodine. SQM is presently building and developing processes for iodine derivatives that can be marketed internationally through sales offices and transportation based on its fertilizer and nitrate business (Harben and Edwards, 1997).

Chile is the second largest producer of crude iodine in the world and the United States depends on imports for more than one-half of its supply. Chile was invited to join the North American trade bloc, which links Canada, Mexico, and the United States at the first Summit of the Americas in December 1994. Chile has, however, declined to go forward until the U.S. Congress passes fast-track authority. With fast track, lawmakers would vote either for or against any trade agreement with no opportunity for amendments. Trade between Chile and the United States passed the $6 billion mark during 1996. The United States imports Chilean salmon, wine, and fresh fruit; and U.S. companies are investing, for the most part, in mining.

Europe.—The International Council for Control of Iodine Disorders was founded in 1986 to eliminate iodine deficiency disorder (IDD) in all countries by 2000. There are more than 400 members in some 70 countries and regions. The Council was admitted into official relations with the WHO in 1994.

Arizona Chemical will double its European capacity of high-viscosity hard resins for offset ink. Resins from Arizona's European tall oil refineries will be supplemented with gum rosin purchases sufficient to sustain the new capacity. The expansion is the second in Europe since acquiring DSM Andeno B.V.'s ink resins business in late 1995. Arizona Chemical produces ink resins in Niort, France, Sandarne, Sweden, and Valkeakoski, Finland (Chemical Market Reporter, 1997a).

Israel.—Israeli Salt Co. Ltd., Eilat, planned and completed a salt iodization and conditioning plant using technology and equipment from Krebs Swiss, Zurich. Capacity is estimated at 35 tons. The Krebs process significancy improves the quality and consistency of refined salt. The system also maintains stability of the salt and additive blend throughout packing, transportation, and storage (Chemical Market Reporter, 1997c).

Japan.—Japan was the world's leading producer of iodine. Six companies operated 17 plants with a total production capacity of 9,000 tons per year. Production of iodine was from underground brines associated with natural gas. Two plants that closed in midyear 1994 reopened with total output reported to be 1,000 tons per year (Chemical Market Reporter, 1997b).

Netherlands.—DSM has split its fine chemicals activities into two business groups that include DSM Fine Chemicals and a new group, DSM Speciality Intermediates. DSM is a producer in Chile that exports iodine for consumption into the United States.

Switzerland.—Krebs Swiss has been engaged in developing unconventional and innovative processes that are inexpensive, yet achieve the highest levels of salt purity. Humans use about 30% of total salt production to support their physiological functions and eating habits (Sedivy, 1996).

Turkmenistan.—According to information from the U.S. Embassy in Ashgabat reported by the Business Information Service for the Newly Independent States (Bisnis) at the U.S. Department of Commerce, Turkmenistan is seeking investors for a number of industrial minerals production projects proposed by Turkmenistan's Ministry of Energy and Industry, which Turkmenistan believes along with energy have the potential to generate significant revenue for the country (U.S. Department of Commerce, July 29, 1997, IMI—Turkmenistan—List of investment projects in the chemical industry, accessed June 4, 1998 at URL http://www.itaiep.doc.gov/bisnis/cables/970730t2.htm).

Investors were being sought to upgrade the Nebitdag iodine and bromine production plant 30 kilometers from Nebitdag in the village of Vyshka. The plant reported production capacities of 300 tons per year of iodine and 3,000 tons per year of ferrous bromide, as well as 1,300 tons per year of bromine derivatives and 100 tons of sodium hypochlorite. It was commissioned in 1969 and has 33 employees.

Investors were being sought for a number of new iodine and bromine production projects. These include the Boyadag iodine and bromine plant at the Boyadag field 55 kilometers from Nebitdag. The field reportedly contains water with a concentration of 380 grams of bromine and 35 grams of iodine per cubic meter. Plans call for the plant to produce 2,500 tons per year of bromine and 250 tons per year of iodine.

Investors were being sought for the construction of the Gograndag iodine and bromine plant at the Gograndag-Garadshali field 60 kilometers from Nebitdag. The field reportedly contains water with a concentration of 403 grams bromine and 32.5 grams of iodine per cubic meter. The plant is planned to produce 5,000 tons per year of bromine and 500 tons per year of iodine.

Investors are being sought for construction of the Goturdepe iodine and bromine production plant at the Goturdepe oilfield 32 kilometers from Cheleken and 78 kilometers from Nebitdag where several oil wells are in operation. The field reportedly contains water with a concentration of 190 grams of bromine and 28 grams of iodine per cubic meter. The plant is projected to produce between 1,000 and 1,300 tons per year of bromine and between 100 and 150 tons per year of iodine.

Investors were also being sought for construction of the Achak iodine and bromine plant at a gasfield 18 to 20 kilometers from the village of Gasachak. Reportedly, the bromine construction of the water is 370 grams of bromine and 15 grams of iodine per cubic meter of water. (*See table 6.*)

United Kingdom.—Hoechst Celanese filed claims against BP Chemicals for using its process to remove iodide contamination during the production of acetic acid. BP has appealed the High Court decision. If BP is found to be guilty, another hearing will be held to determine damages or whether BP has to pay the profits made utilizing the technology (European Chemical News, 1997a).

Current Research and Technology

Traditionally, photographic films are processed by using a series of developing, fixing, and rinsing baths that require silver halides, such as silver iodide. In the DryView process, exposed film is developed by heat, thereby eliminating the series of chemical baths, and, therefore, the need for iodine. The second annual Presidential Green Chemistry Challenge Awards were presented at ceremonies at the National Academy of Sciences. The awards are the only presidential awards specifically recognizing work in the chemical sciences for outstanding accomplishments that bring chemical principles to bear on pollution reduction. Imation Corp., Oakdale, MN, received the Alternative Reaction Conditions Award for its DryView film development technology used in medical imaging (Chemical & Engineering News, 1997c).

A new spectroscopic technique has allowed University of California, Berkeley, chemists to observe chemical femtosecond-scale solvent effects on the photo dissociation of an iodine-argon cluster. Anion femtosecond photoelectron spectroscopy involves first dissociating the clusters with a laser, then bombarding them with a second pulse that detaches the extra electron from the anion (Chemical & Engineering News, 1997b).

Outlook

During the past decade, iodine production capacity in Chile and the United States has doubled, thus ensuring an adequate world supply. Future overall growth in traditional uses is projected to grow by 2% per year (Chemical Product Synopsis, 1996). Uses for iodine in specialty chemicals have remained stable. Recent developments in digital images using computers can produce electronic prints and overhead transparencies without the need for wet processing. By using a digital camera or scanning the film

and converting to a digital format, the images that are produced can be stored on hard drives, disks, tape, or other magnetic or optical storage media.

Future use of iodine in films and processing could be limited to specialty imaging in the next decade as digital imagery technology improves and cost of acquisition of equipment becomes more affordable. Digital imaging is used for recording sporting events, game shows, and situation comedies for television broadcast. From 75% to 85% of all televised programs seen during prime time are recorded on 35-millimeter motion picture film and then transferred to video tape or laser disc for display. Furthermore, the majority of feature films for movie theater presentations are shot and printed on film for better image quality. A frame of 35-millimeter color negative film contains about 6.6 million pixels, or about 15 times that of the best current high-definition television system and 4 times that of the digital systems now in development. Most popular home video rentals have been box office movie hits that were filmed and then transferred to video.

New uses of fluoroiodocarbon as halogen replacements may cause an increased demand for iodine. More tests need to be completed on the iodated fluorocarbons before they are approved, but preliminary tests are promising (Chemical Market Reporter, 1997b).

Supplemental programs designed to alleviate IDD in China and India are expected to consume large amount of iodine. X-ray contrast media, containing up to 60% iodine, continues to have between 4% and 5% annual growth (Chemical Market Reporter, 1997b).

In Chile and Mexico, the use of individual water purification units that use iodine are a new application. Purification applications could become significant consumers of iodine (Chemical Market Reporter, 1997b).

Automotive International reports that the director of engineering material at E. I. du Pont de Nemours and Company, automotive foresees a 72% increase in the use of nylon during the next 8 years; iodine is used as a stabilizer in nylon. This would result in about 7 kilograms of nylon in the average car in the United States by 2005. Air intake manifolds provide the greatest growth area, although nylon is also making inroads into other components, such as cylinder-head covers (The PointCast Network, Iodine on the up, accessed May 20, 1997, at URL http://www.pointcast.com).

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
SALIENT IODINE STATISTICS 1/

(Thousand kilograms unless otherwise specified)

	1993	1994	1995	1996	1997
United States:					
Production	1,940	1,630	1,220	1,270	1,320
Imports for domestic consumption 2/ 3/	3,620	4,360	3,950	4,860 r/	6,380
Exports 2/ 3/	1,220	1,200	1,220	2,410 r/	2,760
Consumption:					
Reported 4/	3,550	3,690	3,680	3,920 r/	4,500
Apparent 5/	4,330	4,780	3,540	3,700	5,140
Price, imports, average c.i.f. value, 6/ dollars per kilogram	$7.98	$8.02	$10.32	$12.82	$14.74
World: Production	16,100 r/	14,300 r/	13,400 r/	15,600 r/	15,500 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits, except prices; may not add to totals shown.
2/ Bureau of the Census.
3/ Only the crude iodine "content" of the potassium iodide as declared by tables 4 and 5 is incorporated in data or calculations for this table.
4/ Reported by voluntary response to the U. S. Geological Survey from a survey of domestic establishments.
5/ Defined as "Imports minus exports plus adjustments for Government and domestic industry stock changes."
6/ Bureau of the Census. "Cost, insurance, and freight" (c.i.f.).

TABLE 2
DOMESTIC CONSUMPTION OF CRUDE IODINE, BY PRODUCT 1/

(Thousand kilograms)

	1996		1997	
Product	Number of plants	Quantity	Number of plants	Quantity
Inorganic compounds:				
Resublimed iodine	6	345 r/	8	197
Potassium iodide	7	893	5	750
Sodium iodide	6	380	5	392
Ammonium iodide	1	W	1	W
Calcium iodate	2	125	2	W
Cuprous iodide	3	21	2	W
Hydriodic acid	3	255	3	248
Potassium iodate	5	82	4	115
Other inorganic compounds	8	412	5	530
Total	XX 2/	2,510 r/	XX 2/	2,230
Organic compounds:				
Ethylenediamine dihydroiodide	5	480	2	W
Methyl and/or ethyl iodide	3	20	3	40
Povidone-iodine (idophors)	2	W	3	686
Other organic compounds	5	905	6	1,540
Total	XX 2/	1,410	XX 2/	2,270
Grand total:				
Reported consumption 3/	XX 2/	3,920 r/	XX 2/	4,500
Apparent consumption 4/	XX	3,700	XX	5,140

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other inorganic/organic compounds," respectively. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Nonadditive because some plants produce more than one product concurrently.
3/ Reported by voluntary response to the U.S. Geological Survey in a survey of domestic establishments.
4/ Calculated by using domestic production plus imports minus exports plus adjustments for Government and domestic industry stock changes.

TABLE 3
YEAREND 1997 PRICES OF ELEMENTAL IODINE AND SELECTED COMPOUNDS

Elemental iodine/ compounds	Value (dollars) Per kilogram 1/	Per pound 1/
Calcium iodate, FCC drums, f.o.b. works	16.42	7.45
Calcium iodide, 50-kilogram drums, f.o.b. works	30.00	13.61
Iodine, crude, drums	16.00-17.00	7.26-7.71
Iodine, U.S.P., drums	15.01	6.80
Potassium iodide, U.S.P., drums, 5,000-pound lots, delivered	26.48	12.01
Sodium iodide, U.S.P., crystals, 5,000-pound lots, drums, freight-equalized	36.38	16.50

1/ Conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiations and/or somewhat different price quotations.

Source: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials; v. 253, no. 1, January 5, 1998, p. 22-29.

TABLE 4
U.S. CRUDE IODINE AND POTASSIUM IODIDE IMPORTS FOR DOMESTIC CONSUMPTION, BY COUNTRY OF ORIGIN 1/

(Thousand kilograms and thousand dollars)

Material type and country of origin 2/	1996 Quantity	1996 Value 3/	1997 Quantity	1997 Value 3/
Iodine, crude:				
Canada	9	75	6	72
Chile	2,340	32,000	4,000	57,100
Germany	4	93	2	46
Japan	2,250	27,400	2,020	31,200
Russia	54	560	--	--
Belgium	--	--	(4/)	(4/)
Total	4,660	60,100	6,030	88,400
Iodide, potassium: 5/				
Canada	182	1,920	310	4,990
Chile	11	175	24	409
India	5	64	--	--
Japan	1	9	2	18
Other 6/	--	--	16	276
Total	199	2,230	352	5,690
Grand total	4,860	62,300	6,380	94,100

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Import information for "Crude iodine" and "Potassium iodide" are reported by HTS numbers 2801.20.0000 and 2827.60.2000, respectively.
3/ Declared c.i.f. valuation.
4/ Less than 1/2 unit.
5/ Gross potassium iodide contains 76% crude iodine.
6/ Includes Germany, Israel, and the Netherlands.

Source: Bureau of the Census.

TABLE 5
U.S. EXPORTS OF CRUDE IODINE AND POTASSIUM IODIDE,
BY COUNTRY OF DESTINATION 1/

(Thousand kilograms and thousand dollars)

Material type and country of origin 2/	1996		1997	
	Quantity	Value 3/	Quantity	Value 3/
Iodine, crude/resublimed:				
Canada	50	948	89	1,560
Egypt	2	34	2	40
France	35	524	65	1,190
Germany	370	4,540	480	7,090
India	10	143	19	350
Israel	4	45	2	31
Italy	36	469	--	--
Mexico	1,670	9,190	1,820	10,100
Netherlands	90	1,070	3	15
Turkey	16	22	9	114
United Kingdom	15	191	17	310
Other 4/	15	390	126	1,980
Total	2,320	17,600	2,630	22,800
Iodide, potassium: 5/				
Australia	(6/)	2	--	--
Belgium	11	155	7	67
Canada	38	713	64	1,290
Mexico	7	82	12	171
Netherlands	10	138	3	54
Thailand	(6/)	10	(6/)	12
Turkey	15	246	21	381
Other 7/	6	147	29	520
Total	88	1,490	136	2,500
Grand total	2,410	19,100	2,760	25,300

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Export information for "Iodine: Crude/resublimed" and "potassium iodide" are reported by HTS numbers "2801.20.0000" and "2827.60.2000," respectively.
3/ Declared "Free alongside ship" (f.a.s.) valuation.
4/ Includes Australia, China, Denmark, El Salvador, Equador, Finland, Hong Kong, Indonesia, Japan, Lebanon, Malaysia, Portugal, Spain, Saudi Arabia, Taiwan, Thailand, Venezuela, and United Arab Emirates.
5/ Gross potassium iodide contains 76% crude iodine.
6/ Less than 1/2 unit.
7/ Includes France, Indonesia, Jamaica, Malaysia, Peru, the Philippines, Switzerland, Taiwan, United Kingdom, and Venezuela.

Source: Bureau of the Census.

TABLE 6
CRUDE IODINE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand kilograms)

Country	1993	1994	1995	1996	1997 e/
Azerbaijan e/	500	400	350	300	300
Chile 3/	5,958 r/	5,644 r/	5,444 r/	6,895 r/	6,900
China e/	500	500	500	500	500
Indonesia	14	89	77	75 e/	73
Japan	6,489	5,592	5,492	6,178 r/	6,000
Russia e/	180	160	160	150	150
Turkmenistan e/	500	251	137 4/	255	250
United States	1,940	1,630	1,220	1,270	1,320 4/
Total	16,100 r/	14,300 r/	13,400 r/	15,600 r/	15,500

e/ Estimated. r/ Revised.

1/World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 10, 1998.

3/ Includes iodine production reported by Servicio Nacional de Geologia y Minería (SERNAGEOMIN) as follows in thousand kilograms: 1993--1,121; 1994--1,268; 1995--1,644; 1996--1,885; and 1997--1,500 (estimated).

4/ Reported figure.