UNITED STATES DEPARTMENT OF COMMERCE
ALEXANDER B. TROWBRIDGE, *Secretary,*
NATIONAL BUREAU OF STANDARDS · A. V. ASTIN, *Director*

Selected Values of Electric Dipole Moments for Molecules in the Gas Phase

Ralph D. Nelson, Jr.

Chemistry Department
Middlebury College
Middlebury, Vermont 05753

AND

David R. Lide, Jr. and Arthur A. Maryott

Institute for Basic Standards
National Bureau of Standards
Washington, D.C. 20234

NSRDS-NBS 10
National Standard Reference Data Series-
National Bureau of Standards 10

(Category 3—Atomic and Molecular Properties)

Issued September 1, 1967

(Supersedes the data on dipole moments
included in NBS Circular 537)

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price 40 cents

Foreword

The National Standard Reference Data System is a government-wide effort to give to the technical community of the United States optimum access to the quantitative data of physical science, critically evaluated and compiled for convenience. This program was established in 1963 by the President's Office of Science and Technology, acting upon the recommendation of the Federal Council for Science and Technology. The National Bureau of Standards has been assigned responsibility for administering the effort. The general objective of the System is to coordinate and integrate existing data evaluation and compilation activities into a systematic, comprehensive program, supplementing and expanding technical coverage when necessary, establishing and maintaining standards for the output of the participating groups, and providing mechanisms for the dissemination of the output as required.

The NSRDS is conducted as a decentralized operation of nation-wide scope with central coordination by NBS. It comprises a complex of data centers and other activities, carried on in government agencies, academic institutions, and nongovernmental laboratories. The independent operational status of existing critical data projects is maintained and encouraged. Data centers that are components of the NSRDS produce compilations of critically evaluated data, critical reviews of the state of quantitative knowledge in specialized areas, and computations of useful functions derived from standard reference data.

For operational purposes, NSRDS compilation activities are organized into seven categories as listed below. The data publications of the NSRDS, which may consist of monographs, loose-leaf sheets, computer tapes, or any other useful product, will be classified as belonging to one or another of these categories. An additional "General" category of NSRDS publications will include reports on detailed classification schemes, lists of compilations considered to be Standard Reference Data, status reports, and similar material. Thus, NSRDS publications will appear in the following eight categories:

Category	*Title*
1	General
2	Nuclear Properties
3	Atomic and Molecular Properties
4	Solid State Properties
5	Thermodynamic and Transport Properties
6	Chemical Kinetics
7	Colloid and Surface Properties
8	Mechanical Properties of Materials

The present compilation is in category 3 of the above list. It constitutes the tenth publication in the new NBS series known as the National Standard Reference Data Series.

A. V. ASTIN, *Director.*

Contents

Selected Values of Electric Dipole Moments for Molecules in the Gas Phase

Ralph D. Nelson, Jr., David R. Lide, Jr., and Arthur A. Maryott

This table revises, brings up to date, and extends the coverage on numerical values for dipole moments which was included in NBS Circular 537, Tables of Dielectric Constants and Electric Dipole Moments of Substances in the Gaseous State, prepared by Maryott and Buckley in 1953. A recommended value with an estimate of accuracy is presented for more than five hundred organic and inorganic compounds. Extensive comments are given on the definition of dipole moment and principal methods of dipole moment measurement, as well as an exposition of the criteria employed in selecting the tabulated data.

Key Words: Dielectric constant, electric dipole moments, gas phase, microwave, microwave absorption, molecular beam, permittivity, refractive index, spectroscopy.

1. Introduction

This table of selected values of electric dipole moments for molecules in the gas phase was prepared under a program for the critical evaluation of the data of science and technology sponsored by the National Bureau of Standards through the National Standard Reference Data System. The table revises and brings up to date the data on dipole moments included in the National Bureau of Standards Circular 537, prepared by A. A. Maryott and F. Buckley in 1953. It gives a recommended value for each compound and an estimate of the accuracy of this value. The most significant experimental values and the methods used to obtain them are tablulated, as well as a complete list of references. Where precise information on two or more vibrational states or isotopic species is available, it has been included in supplemental tables in the appendices.

2. Arrangement and Explanation of Table

2.1. Ordering of Compounds

Compounds are divided into two groups: (a) those containing no carbon atoms (inorganic), arranged with the elemental symbols of the empirical formulas in alphabetical order, and listed alphabetically, and in ascending order of the empirical formula subscripts; (b) compounds containing carbon, ordered as in (a) with the exceptions that carbon is listed first and hydrogen second. Monatomic and homonuclear diatomic molecules, which have no dipole moment in the ground electronic state because of symmetry considerations, are not included.

2.2. Nomenclature

The recommendations of the International Union of Pure and Applied Chemistry Reports on Symbolism and Nomenclature published in J. Am. Chem. Soc. **82**, 5517–84 (1960), are followed. The common, or trivial, names are sometimes included in parentheses.

2.3. Units and Corrections

Values of the dipole moment, μ, are expressed in the cgs system of units, since this is the system universally used by workers in the field. The numerical values are in debye units, D, ($1\ \text{D} = 10^{-18}$ electrostatic units of charge × centimeters). The conversion factor to the Système International is $1\ \text{D} = 3.33564 \times \cancel{10^{-24}}$ coulomb-meter. 10^{-30}

Appropriate corrections have been made to values reported in the original literature. In particular, dipole moments which were measured relative to some secondary standard (for example, the OCS molecule) have been corrected in accordance with the best current value for the reference dipole moment (0.7124 D in the case of OCS). Corrections have also been made for changes in the fundamental physical constants. In some cases the primary experimental data have been reanalyzed. Therefore, many of the dipole moments listed in this table differ slightly from the values reported by the original authors.

2.4. Selected Moments

The recommended value of the dipole moment of each compound is listed in the column headed *Selected Moment* and is accompanied by a letter code indicating its estimated accuracy. The selected values are arbitrarily rounded off to 0.01 D except for moments less than 1 D, where an additional significant figure has been given when warranted. The accuracy code and related notation are given in the following table; a discussion of the basis for assigning the reliability is given in section 6.

Code symbol	Estimated accuracy of value
A	±1% or, for $\mu < 1.0$ D, ±0.01 D
B	±2% or, for $\mu < 1.0$ D, ±0.02 D
C	±5% or, for $\mu < 1.0$ D, ±0.05 D
D	±10% or, for $\mu < 1.0$ D, ±0.10 D
Q	Questionable value
S	$\mu \equiv 0$ on grounds of molecular symmetry
i	The significance of these values may involve some ambiguity because of the possibility of different conformations or spatial isomers.

The Q code symbol has been used where there is a serious question about the best value to select or where there is insufficient information on which to base a meaningful estimate of accuracy. The symbol is also used when only one component of the dipole moment vector has been measured. All values in this category have been placed in parentheses to emphasize their questionable nature. They may be regarded as giving a rough estimate of the magnitude of the moment but are not of sufficient accuracy for quantitative use. The symbol xQ, without a numerical value being given, indicates that the reported values of the dipole moment are so doubtful that they could be misleading. When the symbol i appears without a numerical value, it indicates the probable presence, in significant amounts, of two or more conformational isomers which may have quite different dipole moments. In such cases the average moment and its temperature dependence are indicated in a footnote.

Further discussion regarding the definition and significance of the dipole moment, the experimental methods for its determination, and the criteria for evaluation of the data may be found in sections 4, 5, and 6.

2.5. Basic References

The column headed *Basic References* lists the reference number to the Bibliography (sec. 8), the experimental method, and the dipole moment (in that order) of all sources that were taken into consideration in arriving at the selected value and the estimate of its accuracy. The method code is

MW = microwave spectroscopy
MB = molecular beam electric resonance
DT = permittivity (dielectric constant) as a function of temperature
DR = permittivity and refractive index data
NR = nonresonant microwave absorption or dispersion
↗ = an arrow following the listed value of the moment indicates that the reference contains information about its orientation relative to the molecular framework.

2.6. Other Data

The last column lists additional references not used in obtaining the selected value. These include published reports of a preliminary nature, other articles which contain essentially the same information as in the *Basic References*, or work considered to be of lesser reliability. Reference to supplemental information contained in the appendices is noted by

Vib – refers to data on dipole moments in excited vibrational states (appendix I)
Iso – refers to data on dipole moments of different isotopic species (appendix II).

3. Bibliographic Compilation Procedure

A number of literature searches for information on dipole moments have previously been carried out. We have made use of these in collecting the bibliography on which the present table is based. The following compilations were particularly helpful:

Tables of Experimental Dipole Moments by A. L. McClellan (W. H. Freeman and Co., San Francisco, 1963).

Tables of Dielectric Constants and Electric Dipole Moments of Substances in the Gaseous State by A. A. Maryott and F. Buckley (U.S. National Bureau of Standards Circular 537, 1953).

Digest of Literature on Dielectrics, 29 volumes (National Academy of Sciences-National Research Council publication, annual) (order from the Staff Executive, Conference on Electrical Insulation, N.A.S.-N.R.C., 2101 Constitution Ave., NW., Washington, D.C. 20418).

Microwave Spectral Tables NBS Monograph 70 (Diatomic Molecules, Vol. 1) by P. F. Wacker, M. Mizushima, J. D. Peterson, and J. R. Ballard (U.S. Government Printing Office, 1964).

Microwave Gas Spectroscopy Bibliography 1954–1964, by Paolo G. Favero (Laboratorio di Spettroscopia a Radiofrequenza, University of Bologna, Bologna, Italy, 1963, 1966).

Bibliographie mikrowellenspektroskopischer Untersuchungen an Molekülen in den Jahren 1945–1962 by B. Starck (Physikalisches Institut der Universität, Freiburg i. Br., Germany, 1963).

Table of Electric Dipole Moments by L. G. Wesson (The Technology Press, Cambridge, Mass., 1948).

Landolt-Börnstein Tabellen (6 Auflage) (1951) Parts 142061–142063 (H. Stuart).

Microwave Spectroscopy by C. H. Townes and A. L. Schawlow (McGraw-Hill Book Co., Inc., New

York, 1955) Appendix VI (by G. C. Dousmanis).

Molecular Microwave Spectra Tables by P. Kisliuk and C. H. Townes (U.S. National Bureau of Standards Circular 518, 1952).

Table of Electric Dipole Moments by S. Crompton, Master's Thesis, Duke Univ. (Durham, N.C., 1948).

Several of the above compilations were based on comprehensive searches of *Chemical Abstracts* and similar sources. As a result of this overlap, we may have a high degree of confidence that very few references have been overlooked. This conclusion was supported by a check of the 1952 and 1953 *Chemical Abstracts* in which no new references were uncovered. A certain number of incorrect or irrelevant references were discovered in previous compilations. These have been corrected or eliminated in the present bibliography.

The bibliography has been limited, as far as possible, to the regular published literature. References to theses, reports, abstracts of meetings, and private communication are included in only a few cases where they cover important data which are not otherwise available. Certain preliminary notes on results which were later published in more detail have also been excluded.

An effort has been made to provide complete coverage of the literature through the end of 1965. Some references to papers appearing in 1966 are also included, but the coverage for this year is not complete.

The bibliography (sec. 8) is ordered primarily by year of publication, secondarily by the first-named author's last name, and finally by the next-named authors. The references are numbered serially, the most recent references having the highest numbers. Since some additions and deletions in the bibliography were made prior to publication of the tables, there are several reference numbers which are unused, and several 1966 references are not ordered according to the above scheme. The journal names have been abbreviated according to the 1961 listing in *Chemical Abstracts*.

4. Definition of Dipole Moment

We have attempted in this tabulation to select the best value of the dipole moment of each compound on which measurements have been made. Some discussion is therefore in order concerning the extent to which the electric dipole moment can be considered a well-defined molecular property. The permanent dipole moment of an isolated molecule is normally defined as

$$\boldsymbol{\mu}=\left\langle\sum_i e_i\mathbf{r}_i\right\rangle, \qquad (1)$$

where the summation extends over all charges e_i (nuclei and electrons) in the molecule. The position vectors $\mathbf{r}_i$ may be referred to any origin as long as the molecule has no net charge. Since the expectation value in eq (1) implies a particular stationary state, an important question arises concerning the dependence of $\boldsymbol{\mu}$ on rotational, vibrational, and electronic state. At present there is no evidence of significant variation of dipole moment with rotational state. The variation with vibrational state would be expected to be larger, and, indeed, changes of 1 to 2 percent per quantum of vibrational excitation have been observed (see appendix I). The dependence on electronic state is much more critical; changes of 30 percent or more have been reported (see CH_2O). Another source of variation lies in isotope effects. Replacement of hydrogen by deuterium has been found to change dipole moments by several percent in some cases. However, for atoms other than hydrogen, the effect is very much smaller (see appendix II).

In view of these considerations we have chosen to define the dipole moment of a compound as the moment of a molecule of the dominant isotopic species of that compound in its ground electronic and vibrational state. The selected values in the present table are, in principle, based on this definition. This allows the dipole moment of a compound to be uniquely specified, at least to the extent that the influence of molecular rotation can be ignored. Dipole moments determined by spectroscopic methods (see sec. 5) always refer to a particular vibrational and electronic state and to a single isotopic species; the present definition is therefore the most convenient one to use when dealing with spectroscopic results. However, moments determined from measurements of bulk dielectric properties represent an average over the equilibrium population of vibrational (and, in principle, electronic) states and over the natural abundance of the various isotopic species. While this introduces a certain ambiguity in the comparison of moments determined by the two methods, an examination of the best available data indicates that the distinction is of little practical importance except in special cases. That is, the average moment determined from bulk dielectric properties at ordinary temperatures is unlikely to differ by more than 1 percent from the moment of the dominant isotopic species in its ground state.

Certain difficulties do arise in comparing spectroscopic and dielectric results on molecules which can rapidly interconvert between spatially distinct forms. For example, two conformational isomers of a compound may have quite different dipole moments. Spectroscopic measurements permit the moments of the individual isomers to be determined, while dielectric measurements yield an average moment appropriate to a particular temperature. Where spectroscopic results were available, we have treated such conformational isomers as separate compounds and listed the individual dipole moments in the table. However, where there were only dielectric measurements, an average moment has been listed with a notation that conformational isomers are probably present; information on temperature dependence of the average moment is given in footnotes. The problem of dealing with conformational isomerism is discussed in more detail in sections 5 and 6.

5. Principal Methods of Dipole Moment Measurement

5.1. Microwave Spectroscopy (MW)

When a polar molecule is placed in an external electric field of magnitude E, the rotational energy levels of the molecule are split through the Stark effect. If the total angular momentum of the molecule in the absence of the field is described by the quantum number J, application of the field results in $2J+1$ states which are designated by a quantum number $M=J, J-1, \ldots, -J$. In the most common case, where the Stark splitting can be adequately described by second-order perturbation theory, the correction ΔW to the rotational energy has the form

$$\Delta W=(A+BM^2)E^2. \qquad (2)$$

Thus each rotational level splits into $J+1$ distinct sublevels, and the magnitude of this splitting is quadratic in the applied field. For easily obtainable laboratory fields the splitting is large enough to be resolved in pure rotational transitions observed in the microwave region of the spectrum. Measurement of the splitting of a spectral line as a function of the applied field allows an accurate determination of the coefficients A and B in eq (2).

The A and B coefficients depend upon the dipole matrix elements connecting the level in question with all other rotational levels and upon the corresponding energy separations. If the dipole moment $\boldsymbol{\mu}$ is resolved into components μ_g along suitable molecule-fixed axes (usually the principal inertial axes a, b, c), each dipole matrix element may be written as the product of μ_g times a matrix element of a direction cosine between the molecule-fixed and external axis systems. A complete analysis of the microwave spectrum provides enough information to calculate the direction cosine matrix elements by well-known methods; likewise, the energy-level separations can be accurately calculated. It is therefore possible to extract the dipole components μ_g from the experimentally determined A and B coefficients.

A special case arises when degeneracies exist among the rotational levels. If the degenerate levels are connected by a dipole matrix element, a first-order Stark effect occurs which is of the form

$$\Delta W=\pm CME. \qquad (3)$$

The coefficient C is proportional to μ_g and can be readily calculated. Degeneracies which lead to first-order Stark effects occur systematically in symmetric-top molecules, and they are frequently present in asymmetric rotors as well. When there is a near, but not exact, degeneracy, the Stark effect may be neither linear nor quadratic but can have a more complicated form.

The first and second-order Stark perturbation terms are almost always sufficient to permit a measurement of the dipole moment with an uncertainty of 1 percent or less. However, for more accurate work, and in a few special cases, higher order terms must be considered. The next important terms are the fourth-order contribution from the permanent dipole moment and the second-order contribution from the induced moment. These may be of comparable magnitude. In calculating direction cosine matrix elements and energy separations it is sometimes necessary to take centrifugal distortion into account.

The microwave method of measuring dipole moments offers many advantages. Determination of the moment with an uncertainty of 1 percent (which requires that the Stark splittings be measured to within only 2 percent if the Stark effect is second-order) can generally be done without particular difficulty. The same percentage accuracy is possible with small moments, even those less than 0.1 D. The purity of the sample is not important. The measurement is made on a specific vibrational state and isotopic species, so that variation of the moment with these factors can be studied. Where two or more rotational isomers are present in significant concentrations, their moments may be individually measured. Finally, since the separate components of the dipole moment vector are determined, information is available on the orientation of the moment relative to the molecular framework.

In spite of these advantages, a fair number of dipole moments measured by the microwave method are not accurate to within 1 percent, and the uncertainty is quite large in some reported values. There are several reasons for this. Many spectra are complicated by nuclear quadrupole hyperfine structure, which introduces another perturbation which may be comparable in magnitude to the Stark effect. If the Stark shifts can be made much larger or much smaller than the hyperfine structure, the analysis is fairly straightforward, and the accuracy of measurement should be as high as when hyperfine structure is absent. In the intermediate case, however, the analysis of the data is more complicated, and misleading results can be obtained unless the calculations are done very accurately. In some of the earlier microwave measurements this problem does not appear to have been sufficiently appreciated, and the resulting dipole moments are correspondingly less reliable.

Another difficulty sometimes arises when the Stark effects of all accessible transitions are sensitive to one dipole component but quite insensitive to the others. Thus only one component can be determined with high accuracy, and the total moment is subject to a sizable uncertainty. A high density of lines in the spectrum also presents problems, since it is sometimes difficult to avoid the overlapping of Stark components from different lines.

The accuracy of a dipole moment determined from the Stark effect is dependent, of course, on the measurement of the electric field strength. While there is no problem in measuring the applied voltage accurately, the effective spacing between electrodes is not so easily determined. This problem has been discussed in several places (222, 360, 712). It has become common practice to calibrate the effective electrode spacing by measuring the Stark effect of the OCS molecule, whose dipole moment is accurately known. Most of the dipole moments determined by the microwave method have, in fact, been measured relative to OCS. In view of this practice, it seems highly desirable to use OCS as the primary standard for field-strength calibration whenever possible, in order that all reported moments be on a common basis.

The most accurate determination of the OCS dipole moment is that of Marshall and Weber, who obtained 0.7124 D. Independent measurements in other laboratories indicate that the uncertainty of this value is no greater than 0.1 percent. Other convenient molecules for use as secondary standards are CH_3CN (3.918 D), CH_3F (1.847 D), and CHF_3 (1.646 D). These values should be accurate to within at least 0.5 percent. Full references to these compounds may be found in the main table.

5.2. Molecular Beam Electric Resonance (MB)

This method is very similar in principle to that discussed under microwave spectroscopy, since it makes use of the Stark effect of rotational transitions. However, the measurement is carried out on a molecular beam, where the spectral line widths are much smaller, and the accuracy with which the Stark splittings can be measured is greatly improved. Furthermore, the apparatus can be designed so that the electric field is more uniform and its absolute value more accurately measureable than is possible in the normal microwave absorption cell. The transitions which are studied can lie anywhere in the radiofrequency or microwave regions. It is thus possible to measure the Stark splittings within a single rotational level as well as the Stark effect of rotational transitions. The accuracy is usually greater for the former measurement; however, in order to extract the dipole moment from the Stark splittings it is necessary to know accurately the spacing between rotational levels. This may be determined by measurement of rotational transitions, either by beam techniques or by conventional microwave spectroscopy. Some very accurate dipole moments have been derived from a combination of molecular beam measurements in the radiofrequency region and conventional microwave measurements of rotational transitions.

The molecular beam technique offers the highest inherent accuracy of any known method of dipole moment determination. Uncertainties approaching 0.02 percent have been claimed by some investigators, and the precision is an order of magnitude higher than this. It is thus possible to detect very small changes of dipole moment with vibrational state and isotopic species.

The chief limitation of the molecular beam technique is the very restricted class of molecules to which it can be applied. Practically all measurements reported so far have been on diatomic molecules, except for a very few triatomics. This limitation results from the fact that the population is distributed over a large number of states in more complicated molecules, with a resulting loss of sensitivity.

A few early measurements of dipole moments were based on the deflection of molecular beams by static electric fields (017, 018, 086, 107, 114, and other references). This is a much cruder technique than the electric resonance method discussed above, since the measurements were of limited accuracy and there was little control of the constitution of the beam. Determinations of this type have been given no weight in the present tabulation, but the references are included in the *Other Data* column.

5.3. Dielectric (DT, DR, NR)

Prior to the development of microwave and molecular beam techniques in the late 1940's, the more reliable determinations of dipole moments were all based upon application of the Debye equation to measurements of the low frequency, or "static" permittivity (dielectric constant). The molar polarization, P, is defined by

$$P=\frac{\epsilon-1}{\epsilon+2}V=\frac{4\pi N\alpha}{3}+\frac{4\pi N\mu^2}{9kT}=A+\frac{B}{T} \qquad (4)$$

where

ϵ = permittivity (dielectric constant)
V = molar volume
α = molecular polarizability (electronic plus vibrational)
N = Avogadro's number
k = Boltzmann's constant
T = temperature, absolute (°K).

Equation (4) has been used in two ways, one direct and the other indirect, to derive values for the dipole moment. Recently a third procedure, based on measurements of the complex permittivity (dispersion or absorption) at the lower microwave frequencies, has been used to a limited extent. The latter method is limited primarily to symmetric top molecules (symmetry C_{nv} with $n \geqslant 3$).

5.4. Temperature-Variation Procedure (DT)

In this method P is measured as a function of $1/T$ and the dipole moment obtained from the slope B and the relation

$$\mu = 0.01281\ (\mathrm{B})^{1/2},$$

if B is given in cm^3 mol^{-1} °K. This is the direct and preferred procedure, but it requires precise data over an extended temperature range. In addition the mean squared moment, averaged over the thermal distribution of vibrational and rotational states must be essentially independent of temperature. Under favorable conditions, values accurate to within 1 percent are obtained.

5.5. Indirect (Optical) Procedure (DR)

In some instances available data are either limited to one temperature or are of limited precision and scope and do not permit a reliable determination of B. The substance may, for example, have a low volatility and restricted range of thermal stability. In other cases there may be an equilibrium between different conformational isomers with different dipole moments which is temperature dependent. An effective dipole moment is then computed for any given temperature by

$$\mu = 0.01281[(P - A)T]^{1/2} \tag{5}$$

with an assumed value for A. Since direct knowledge of the vibrational contribution to the polarization is generally lacking, various arbitrary or empirical assumptions have been made. Sometimes the vibrational polarization is taken as a fixed percentage of the electronic contribution (e.g., 5, 10, or 15 percent). Theoretically, however, the vibrational and electronic polarizations are unrelated. The most common convention has been to ignore the vibrational contribution to the polarizability and to replace A by the molar refraction, R_D, for the sodium line. If R_D is not known directly, it can usually be estimated with sufficient reliability (especially for organic compounds) by summing tabulated atomic or bond refractions. Then

$$\mu \leqq 0.01281[(P - R_D)T]^{1/2}, \tag{6}$$

since this convention tends to set an upper limit to the value for the dipole moment consistent with the experimental data. Equation (6) is used in the present tabulation unless otherwise noted. In structurally simple molecules with relatively large dipole moments, the uncertainty in the use of Equation (6) may be less than 2 percent.

5.6. Nonresonant Microwave Absorption or Dispersion (NR)

This method is applicable in special cases where there are nonvanishing dipole matrix elements connecting degenerate or nearly degenerate rotational states, in particular symmetric-top molecules. The resulting absorption and dispersion are characterized by a relaxation, or Debye-type, spectrum. By suitable choice of frequencies and pressures, this spectrum can be observed without significant interference from the ordinary rotational spectrum. Details of the method applied to absorption are contained in references [337] and [343] of the Bibliography and in reference [416] for the case of dispersion. In essence, the method enables one to obtain a fractional part of the total dipolar polarization in eq (4), namely fB/T, the fraction f being readily computed provided the moments of inertia are known. The method is particularly useful for substances with very small values of the dipole moment. Values as low as 0.1 D may be determined with an uncertainty of the order of 2 percent, and values much smaller than this may be determined with somewhat poorer accuracy.

5.7. Comments on Dielectric Methods

Compared to the spectroscopic techniques, the dielectric methods have certain limitations and disadvantages. Since they involve bulk property measurements, substances of high purity and chemical stability are required and the experimental variables, density and temperature, must be accurately known. In addition the derived moments represent averages over the various molecular states of the system and, as noted previously, cannot be as precisely defined as the spectroscopic values. For relatively simple rigid molecules this ambiguity is probably trivial for most purposes. This is borne out by intercomparison of results in the more favorable cases where the value of the dipole moment is greater than one debye. In such cases agreement between the spectroscopic and dielectric (DT) methods is usually of the order of 1–2 percent, the differences being comparable with the overall experimental uncertainties.

Dielectric methods, on the other hand, have frequently been applied to molecules of greater molecular complexity than those ordinarily studied by spectroscopic methods. In many instances such molecules can exist, at least in principle, in two or more spatial conformations with different dipole moments. The analysis and interpretation in such cases may be somewhat arbitrary, depending on intuitive judgment or additional independent information. We may define two rather limiting situations.

(I) The molar polarization varies with temperature but definitely not in the manner shown explicitly by eq (4), so that $\langle \mu^2 \rangle$ is a function of temperature. Simple examples are the 1,2-disubstituted ethanes (XCH_2CH_2X') which exist in equilibrium mixtures of "trans" (nonpolar if $X=X'$) and dipolar "gauche" isomers.

(II) The polarization varies inversely with T and gives a reasonable value for the intercept A so that there appears to be no significant variation of $\langle \mu^2 \rangle$ with T. Alternative interpretations of case II are: (a) only one conformation exists to a significant extent over the temperature range of observation, (b) the different conformations have essentially the same dipole moment, (c) differences in energies of the various conformations are small and the equilibrium distribution insensitive to temperature.

6. Criteria for Evaluation

The evaluation of the data on dipole moments was carried out in two stages. It was first necessary to assess the accuracy of results obtained by each experimental technique and to rationalize discrepancies in duplicate measurements by the same method. This was done for each compound by an evaluator who was familiar with the particular technique. Secondly, in cases where results had been reported by more than one technique, a decision had to be made on the final selected value and its accuracy. The factors which were taken into account in the evaluation process are discussed below.

6.1. Microwave Measurements

When the original investigator has given an uncertainty with his dipole moment value (and this is not always the case), this fact has been taken into consideration. However, the primary data have also been examined whenever they were published in order to obtain some independent feeling for the overall accuracy of the measurement. The following factors were taken into account:

1. Number of Stark components whose shifts were measured.
2. Number of data points for each component.
3. Scatter of these data points.
4. Range of frequency shifts.
5. Internal consistency among the different components (when the number of components measured was greater than the minimum required for the dipole moment determination).
6. Approximations used in the Stark effect calculation.
7. Complicating effects such as hyperfine structure and internal rotation (and the degree to which these effects were considered in the calculations).
8. Method of calibration of field strength.

Consideration of the above factors gave some feeling, at least in a subjective way, of the confidence which could be placed in the reported dipole moment. In addition, the general pattern of results from a given laboratory during a given period was studied. When comparisons could be made on molecules which were subsequently remeasured with greater accuracy, it sometimes became obvious that the original error estimates were too low. These observations were taken into account in the assignment of reliability to results obtained in that laboratory.

Unfortunately, many papers do not give enough details for a meaningful evaluation to be made. This is particularly true in abstracts and short notes published during the 1945–50 period. In such cases the evaluators have been conservative in estimating the reliability.

6.2. Molecular Beam Measurements

The uncertainty in most dipole moments measured by molecular beam techniques is appreciably less than 1 percent (see sec. 5). These values have been placed in category A, and no further evaluation has been made. In one or two cases where discrepancies of more than 1 percent occur between duplicate measurements, the more recent results have been accepted.

6.3. Dielectric Methods

Only a few values of dipole moments have been reported from the study of nonresonant spectra (NR). These have usually been obtained from measurements of the imaginary part of the complex permittivity (loss index, ϵ'') but occasionally from the dispersion of the real part, ϵ'. Precise resonant cavity techniques, which should be relatively free of systematic errors, have been used. The method has been applied primarily to substances having dipole moments substantially less than 1 D. The accuracy of these values are generally regarded as in the A or B categories.

In the case of low frequency measurements of permittivity, the original data have been reexamined to determine, in the opinion of the evaluator, the best procedure for analysis (DT or DR). Preference has been given to the temperature-variation procedure (DT), where warranted by the precision and scope of the data, where there appeared to be no thermal decomposition, and where there was no evidence that the effective dipole moment varied with temperature. In these cases values of A and B (eq (4)) were obtained by the method of least squares, if this was not done in the original reports.

Values analyzed by the indirect procedure (DR) were recomputed, where necessary, to conform to the present convention (i.e., $A=R_D$). Values averaged over the temperature range are listed. If there appears to be a significant variation of dipole moment with temperature, no value is listed in the main table. The effective values obtained at the extreme ends of the temperature range are then given in footnotes.

The above procedures were used in the previous tabulation, NBS Circular 537, and most of the values included in the Basic References during the period prior to 1953 are identical with these. In some instances, however, a reconsideration of the data has led to a change in the method of analysis. It should be emphasized that the dipole moment attributed to a given reference is not necessarily the same as the value originally reported, either because of a difference in our treatment of the data or because of the small corrections to the moments resulting from changes in the values of the physical constants.

In estimating accuracy consideration is given to various factors such as

1. Chemical purity.
2. Scope and precision of data (statistical precision index in least squares for DT method).
3. Likely uncertainty in use of DR method due to neglect of vibrational polarization (depending on molecular type and magnitude of the moment).
4. Overall consistency and agreement of work in given laboratory with reliable, independently established data.

6.4. Choice of Selected Moments

In many cases where results on the same compound had been obtained by more than one method there was a fairly obvious choice of the most accurate value. For example, with moments less than about 0.5 D microwave (MW) values are known to be significantly more accurate than DR or DT values. In other cases the microwave determination was complicated by hyperfine structure or other factors, and the dielectric values were clearly more reliable. In such situations the selection of the best value was fairly straightforward. In other cases different values of comparable reliability were in agreement within their estimated uncertainties. Here an average value was adopted, weighted in favor of the method which seemed more accurate. Finally, there were a few compounds for which unresolved discrepancies existed between the moments obtained by two techniques. In such cases an average was taken, and an uncertainty which was large enough to include both values was assigned.

We feel that this procedure leads to the most meaningful set of selected values which can be obtained from a collection of data from such diverse sources. However, it is obvious that no well-defined statistical estimator can be assigned to specify the uncertainty of the final selected value. We have therefore used an accuracy code A, B, C, D to indicate the limits within which, in our best judgment, the selected value can be trusted. The code is explained in section 2. If a value is placed in category A, for example, it can be concluded with high confidence that the true dipole moment does not differ by more than 1 percent from the value given (or by more than 0.01 D, in case of moments less than 1 D).[1] While this procedure involves many subjective factors and rests heavily on the judgment of the evaluators, it is felt to be the most useful way of presenting the results.

Where the selected value is based solely on dielectric methods, and the presence in significant amounts of two or more conformational isomers is possible, the value is followed by the symbol i. Such values are conditional in two respects: (a) if only one conformation is present in significant amounts, independent data may be needed to specify the particular conformation; and (b) the dipole moment may be more uncertain than suggested by the reliability code because of a small, but not obvious, variation of $\langle\mu^2\rangle$ with T. Therefore, the interpretation of these dipole moments as specific molecular properties should be made with caution.

---

[1] It should be pointed out that the uncertainty in some of the A values is appreciably less than 1 percent.

7. *Table of selected dipole moments*

7.1. Selected moments (compounds not containing carbon)

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
AgCl	Silver chloride	5.73 C	580 MW 5.73	
AlCl	Aluminum chloride	x Q	564 MW 1 to 2	
AlF	Aluminum fluoride	1.53 D	564 MW 1.53	512
$AsCl_3$	Arsenic trichloride	1.59 C	117 DT 1.59	
AsF_3	Arsenic trifluoride	2.59 B	485 MW 2.61	219
			446 DT 2.57	
AsH_3	Arsine	0.20 C	239 MW 0.22[a]	
			016 DT 0.16	
As_2O_3	Diarsenic trioxide	x Q	....	028
BCl_3	Boron trichloride	0 S	298 DT 0	117
BF_3	Boron trifluoride	0 S	115 DT 0	
			123 DT 0	
B_2H_6	Diborane	0 S	102 DT 0	
$B_3H_6N_3$	Triborotriazine (Borazine)	0 S	102 DT 0.7[b]	
B_5H_9	Pentaborane	2.13 B	294 MW 2.13	259
BaO	Barium oxide	7.95 A	526 MB 7.954	500, Vib
BrCl	Bromine chloride	(0.6) Q	224 MW 0.57	
BrF	Bromine fluoride	(1.3) Q	223 MW 1.29	
BrF_3	Bromine trifluoride	(1.1) Q	358 MW 1.0	
			326 DR 1.19	
BrF_5	Bromine pentafluoride	1.51 D	339 DT 1.51	
BrH	Hydrogen bromide	0.82 B	007 DT 0.80	
			392 MW 0.83[c]	
BrH_3Si	Bromosilane	1.33 B	265 MW 1.33	217
BrK	Potassium bromide	10.41 B	274 MB 10.41	114, 107, Vib
BrLi	Lithium bromide	7.27 A	535 MB 7.2680[d]	293, Vib, Iso
BrNO	Nitrosyl bromide	(1.8) Q	579 MW 1.80[e]	396
BrRb	Rubidium bromide	x Q	....	017
Br_2Hg	Mercury dibromide	0 S	095 DT 0	
Br_4Sn	Tin tetrabromide	0 S	131 DT 0	
ClCs	Cesium chloride	10.42 A	341 MB 10.42	284, 241, 017, Vib
ClF	Chlorine fluoride	0.88 C	190 MW 0.881	

[a] For $^1H_2\,^2H^{75}As$.

[b] The finite reported value is probably due to thermal instability.

[c] For $^2H^{79}Br$.

[d] For $^{79}Br^6Li$.

[e] Component along *a* axis.

7.1. Selected moments (compounds not containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
$ClFO_3$	Perchloryl fluoride	0.023 A	361 NR 0.023 595 MW[a] 0.025	335, 565
ClF_3	Chlorine trifluoride	0.6 D	326 DT 0.65 336 DT 0.56	264
$ClGeH_3$	Chlorogermane	2.13 A	265 MW 2.13[b] 150 DR 2.03	188
ClH	Hydrogen chloride	1.08 B	128 DT 1.08 050 DT 1.08 007 DT 1.05 344 DT 1.10 392 MW 1.12	067, 015, 005, 006
ClH_3Si	Chlorosilane	1.31 A	265 MW 1.310 129 DT 1.29	189, 188, 215
ClI	Iodine chloride	(0.6) Q	181 MW[a] 0.65 073 DT 0.54	
ClK	Potassium chloride	10.27 A	282 MB 10.48 306 MW 10.1 591 MB 10.2688	086, 114, 107, Vib
$ClLi$	Lithium chloride	7.13 A	537 MB 7.1195[c] 591 MB 7.1289[c]	Vib, Iso
$ClNa$	Sodium chloride	9.00 A	306 MW 8.5 473aMB 9.002	Vib
$ClNO$	Nitrosyl chloride	(1.9) Q	391 MW 1.86[d]	244
$ClNO_2$	Nitryl chloride	0.53 A	579 MW 0.53 393 MW 0.53	386
$ClTl$	Thallium chloride	4.44 B	254 MB 4.444 379 MW 5.1	
Cl_2F_3P	Dichlorotrifluorophosphorus	0.68 C	561 DT 0.68	
Cl_2H_2Si	Dichlorosilane	1.17 B	129 DT 1.17	
Cl_2Hg	Mercury dichloride	0 S	095 DT 0	

[a] Calculated from microwave intensities.

[b] For $^{37}Cl^{74}Ge^{1}H_3$.

[c] For $^{35}Cl^{6}Li$.

[d] Component along *a* axis.

7.1. Selected moments (compounds not containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
Cl_2OS	Thionyl chloride	1.45 B	143 DT 1.45	
Cl_2O_2S	Sulfuryl chloride	1.81 B	143 DT 1.81	
Cl_3F_2P	Trichlorodifluorophosphorus	0 S	561 DT 0	
Cl_3HSi	Trichlorosilane	0.86 B	129 DT 0.86	
Cl_3P	Phosphorus trichloride	0.78 C	072 DT 0.78	
Cl_4FP	Tetrachlorofluorophosphorus	0.21 B	567 NR 0.21	
Cl_4Ge	Germanium tetrachloride	0 S	131 DT 0	
Cl_4Si	Silicon tetrachloride	0 S	298 DT 0	
Cl_4Sn	Tin tetrachloride	0 S	131 DT 0	
Cl_4Ti	Titanium tetrachloride	0 S	131 DT 0	
CsF	Cesium fluoride	7.88 A	341 MB 7.875	293, 203, 167, 169, 192, Vib
CsI	Cesium iodide	x Q	....	114, 107
FH	Hydrogen fluoride	1.82 A	525 MB 1.8195	465, 462
			163 DT 1.91	
			176 DT 1.91	
			532 MB 1.83	
FH_3Si	Fluorosilane	1.27 B	218 MW 1.268	
FH_5Si_2	Fluorodisilane	1.26 A	578 MW 1.26 ↗	
FK	Potassium fluoride	8.60 A	421 MB 8.60	210
FLi	Lithium fluoride	6.33 A	527 MB 6.328[a]	309, Vib, Iso, 268
			591 MB 6.325	
$FMnO_3$	Permanganyl fluoride	(1.5) Q	296 MW 1.5[b]	
FNO	Nitrosyl fluoride	1.81 B	242 MW 1.81 ↗	
FNO_2	Nitryl fluoride	(0.47) Q	267 MW 0.47	
FNa	Sodium fluoride	8.16 A	536 MB 8.1558	501, Vib
			528 MB 8.19	
FO_3Re	Perrhenyl fluoride	0.85 D	406 MW 0.85[b]	385
FRb	Rubidium fluoride	8.55 A	382 MB 8.80	Vib
			591 MB 8.5465	
FTl	Thallium fluoride	4.23 A	397 MB 4.2282	374, 380, Vib, Iso
			379 MW 3.99	
F_2HN	Difluoramine	1.92 A	513 MW 1.921 ↗	
F_2H_2Si	Difluorosilane	1.55 A	353 MW 1.55	
F_2N_2	*cis*-Difluorodiazine	0.16 A	510 MW 0.16	
F_2O	Oxygen difluoride	0.297 A	460 MW 0.297	417
			419 DR 0.4	

[a] For $^{19}F^{6}Li$.

[b] In excited vibrational state $v_5 = 1$.

7.1. Selected moments (compounds not containing carbon) – Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
F_2OS	Thionyl fluoride	1.63 A	290 MW 1.627↗	
F_2O_2	Dioxygen difluoride	1.44 C	478 MW 1.44	
F_2O_2S	Sulfuryl fluoride	1.12 B	355 MW 1.116	256
F_2S_2	Sulfur monofluoride ($S{=}SF_2$ isomer)	1.03 C	536aMW 1.03↗	
F_2S_2	Sulfur monofluoride (FSSF isomer)	1.45 B	536aMW 1.45	
F_2Si	Silicon difluoride	1.23 B	571 MW 1.23	
F_3HSi	Trifluorosilane	1.27 B	275 MW 1.27	257
F_3N	Nitrogen trifluoride	0.235 A	297 MW 0.236 275 MW 0.235[a] 115 DT 0.25 102 DT 0.22	
F_3NS	Nitridotrifluorosulfur	1.91 B	481 MW 1.91	
F_3OP	Phosphoryl fluoride	1.76 B	275 MW 1.78 258 MW 1.70 216 MW 1.735	
F_3P	Phosphorus trifluoride	1.03 A	275 MW 1.03 219 MW 1.030	
F_3PS	Thiophosphoryl fluoride	0.64 B	258 MW 0.636	
F_4N_2	Tetrafluorohydrazine, *gauche* conformation.	0.26 B	405 MW 0.26	
F_4S	Sulfur tetrafluoride	0.632 A	498 MW 0.632 419 DR 1.0	
F_4Si	Silicon tetrafluoride	0 S	094 DT 0	
F_5P	Phosphorus pentafluoride	0 S	123 DT 0	
F_5I	Iodine pentafluoride	2.18 C	326 DR 2.18	
F_6S	Sulfur hexafluoride	0 S	546 DT 0 446 DT 0 094 DT 0	149, 133
F_6Se	Selenium hexafluoride	0 S	....	149
F_6Te	Tellurium hexafluoride	0 S	....	149
F_6U	Uranium hexafluoride	0 S	336 DT 0 243 DT 0 171 DT 0	
$F_{10}S_2$	Disulfur decafluoride	x Q	....	235
HI	Hydrogen iodide	0.44 B	392 MW 0.443[b] 007 DT 0.42	375, 487a

[a] For $^{19}F_3{}^{15}N$.
[b] For $^{2}H^{127}I$.

7.1. Selected moments (compounds not containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)		Basic references	Other data
HLi	Lithium hydride	5.88	A	442 MB 5.882	462, Vib, Iso
HN	Imidyl radical			561b ([a])	
HNO_3	Nitric acid	2.17	A	556 MW 2.17↗	
				435 MW 2.17↗	
HN_3	Hydrogen azide (hydrazoic acid)	(0.8)	Q	205 MW 0.847[b]	
HO	Hydroxyl radical	1.66	A	570 MW 1.660	322, 568a
				455 MW 1.65	
				506 MW 1.60	
$H_2N_2O_2$	Nitroamine (nitramide)	(3.6)	Q	522 MW 3.57[b]	
H_2O	Water	1.85	A	062 DT 1.85	001, 023, 033a,
				097 DT 1.84	044, 091, 092,
				106 DT 1.84	173, 174, 178,
				157 DT 1.85	179, 197, 209,
				253 DT 1.85	252, 539
				594 MW 1.85	
H_2O_2	Hydrogen peroxide	2.2	D	323 MW 2.26	301
H_2S	Hydrogen sulfide	0.97	A	561aMW 0.974	234, 015
				344 DT 0.98	
				027 DT 0.92	
				250 DT 0.89	
H_2Se	Hydrogen selenide	x	Q	331 MW 0.24	369, 390, 414
				368 MW 0.62	
H_3N	Ammonia	1.47	A	230 MW 1.468	168, 161, 561,
				013 DT 1.47	001, 016, 040,
				096 DT 1.47	078, 493, 047
				170 DT 1.46	055
				182 DT 1.44	
				342 DT 1.44	
H_3P	Phosphine	0.58	A	285 MW 0.575[c]	
				375 MW 0.576	
				239 MW 0.55	
				016 DT 0.55	
H_3Sb	Stibine	0.12	C	239 MW 0.116[d]	

[a] The following values have been obtained for excited electronic states by observing the Stark effect of the electronic emission spectrum: $\mu(A^3\Pi) = 1.31$, $\mu(c^1\Pi) = 1.70$, $\mu(a^1\Delta) = 1.49$ D.

[b] Component along *a* axis.

[c] Average for $^2H^2H_2P$ and $^1H_2{}^2HP$.

[d] For $^1H_2{}^2H^{121}Sb$.

7.1. Selected moments (compounds not containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
H_4N_2	Hydrazine	1.75 C	479 MW 1.75	
H_4Si	Silane	0 S	094 DT 0	
H_6OSi_2	Disilyl ether (disiloxane)	0.24 B	548 DT 0.24	
H_6Si_2	Disilane	0 S	094 DT 0	
H_9NSi_3	Trisilylamine	$\leq$0.1 D	524 DT $\approx$0	
HgI_2	Mercury diiodide	0 S	095 DT 0	
IK	Potassium iodide	x Q	……………………	114, 107, 086, 017
ILi	Lithium iodide	7.43 A	552 MB 7.4285[a]	293, Vib
INa	Sodium iodide	x Q	……………………	086, 017
ITl	Thallium iodide	x Q	……………………	017
I_4Sn	Tin tetraiodide	0 S	……………………	131
NO	Nitrogen monoxide (nitric oxide)	0.153 A	376 MW 0.158 407 NR 0.148 094 DT 0.16	075
NO_2	Nitrogen dioxide	0.316 A	508 MW 0.316 533 MW 0.294[b] 139 DT 0.29 081 DT 0.39	116
N_2O	Dinitrogen oxide (nitrous oxide)	0.167 A	219 MW 0.167 187 MW 0.16 094 DT 0.17 083 DT 0.14	202, 045, 031, 015
OS	Sulfur monoxide	1.55 A	543 MW 1.55	
OS_2	Disulfur monoxide	1.47 B	408 MW 1.47↗	
OSr	Strontium oxide	8.90 A	562 MB 8.900	Vib
O_2S	Sulfur dioxide	1.63 A	231 MW 1.60 487bMW 1.615 126 DT 1.59 213 DT 1.63 344 DT 1.63 013 DT 1.63	566, 015, 010, 001, 003, 240, Vib
O_3	Ozone	0.53 B	286 MW 0.53 209 DT 0.52	279, 260, 236, 330
O_3S	Sulfur trioxide	0 S	126 DT 0	
O_4Os	Osmium tetroxide	0 S	149 DT 0	

[a] For $^{127}I^{6}Li$.

[b] For $^{15}N^{16}O_2$.

7.2. Selected dipole moments (compounds containing carbon)

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
$CBrF_3$	Bromotrifluoromethane	0.65 C	314 DT 0.65	
CBr_2F_2	Dibromodifluoromethane	0.66 C	314 DT 0.66	133
$CClF_3$	Chlorotrifluoromethane	0.50 A	434 NR 0.496 451 MW 0.50 343 NR 0.50 314 DT 0.46	475, 450, 209, 133
$CClN$	Cyanogen chloride	2.82 B	219 MW 2.82 [a]	180
CCl_2F_2	Dichlorodifluoromethane	0.51 C	076 DT 0.51	209, 133
CCl_2O	Carbonyl chloride (phosgene)	1.17 A	477 MW 1.17 472 DT 1.18 088 DT 1.19	
CCl_2S	Thiocarbonyl chloride	0.29 C	143 DT 0.29	
CCl_3F	Trichlorofluoromethane	0.45 C	076 DT 0.45	133
CCl_3NO_2	Trichloronitromethane	1.89 C	088 DR 1.89	
CCl_4	Carbon tetrachloride	0 S	298 DT 0 113 DT 0	112, 012, 115
CFN	Cyanogen fluoride	2.17 C	523 MW 2.17	439
CF_2	Carbon difluoride	0.46 B	588 MW 0.46	
CF_2O	Carbonyl fluoride	0.95 A	483 MW 0.95	
CF_3I	Iodotrifluoromethane	0.92 C	314 DT 0.92 305 MW 1.0	
CF_3NO	Triflurornitrosomethane	(0.3) Q	530 DR 0.31	
CF_3NO_2	Trifluoronitromethane	1.44 C	576 MW 1.44	
CF_4	Carbon tetrafluoride	0 S	115 DT 0 102 DT 0 546 DT 0	133
CN_4O_8	Tetranitromethane	0 S		131
CO	Carbon monoxide	0.112 A	375 MW 0.112 344 DT 0.14 094 DT 0.10 182 DT 0.12 027 DT 0.10	019, 015, 002, 004, 558,[b] 487a
COS	Carbonyl sulfide	0.712 A	360 MB 0.7124 525 MW 0.7120 222 MW 0.7085 246 MW 0.712 175 DT 0.72 027 DT 0.67	200, 566, 162, 180
$COSe$	Carbonyl selenide	0.73 B	199 MW 0.73	Vib

[a] For $^{12}C^{36}Cl^{14}N$.

[b] $\mu = 1.38 \pm 0.02$ D. in the excited $a^3\Pi$ electronic state.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
CO_2	Carbon dioxide	0 S	025 DT 0 050 DT 0 125 DT 0	001, 004, 013, 015, 019, 041, 056, 094, 115
CS	Carbon monosulfide	1.98 A	324 MW 1.98	
CSTe	Thiocarbonyl telluride	0.17 A	291 MW 0.173[a]	
CS_2	Carbon disulfide	0 S	298 DT 0	112, 031, 027, 045, 048
$CHBrF_2$	Bromodifluoromethane	1.50 D	133 DR 1.50	
$CHBr_3$	Tribromomethane	0.99 B	271 DT 0.99	015
$CHClF_2$	Chlorodifluoromethane	1.42 B	471 MW 1.43 076 DT 1.41	487, 133, 441
$CHCl_2F$	Dichlorofluoromethane	1.29 B	076 DT 1.29	133
$CHCl_3$	Trichloromethane (chloroform)	1.01 B	153 DT 1.01 113 DT 1.02	446, 112, 024, 012
CHFO	Formyl fluoride	2.02 A	430 MW 2.02 ↗	420
CHF_3	Trifluoromethane	1.65 A	587 MW 1.646 246 MW 1.646 446 DT 1.65 257 MW 1.65 314 DT 1.62 102 DT 1.60	Iso, 191
CHN	Hydrogen cyanide	2.98 A	415 MW 2.986 275 MW 3.01 088 DT 2.95 115 DR 3.00 050 DT 2.91	221, 037
CHNO	Hydrogen isocyanate	(1.6) Q	246 MW 1.592[b]	248
CHNS	Hydrogen isothiocyanate	(1.7) Q	207 MW 1.72[b]	
CHP	Methylidyne phosphide (methinophosphide)	0.390 A	547 MW 0.390	
CH_2Br_2	Dibromomethane	1.43 B	153 DT 1.43 271 DT 1.43	022
CH_2ClF	Chlorofluoromethane	1.82 B	344 DT 1.82	

[a] In excited vibrational state 010.

[b] Component along *a* axis.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
CH_2ClNO_2	Chloronitromethane........................	2.91 B	157 DR 2.91	
CH_2Cl_2	Dichloromethane...........................	1.60 B	266 MW 1.63 153 DT 1.57 113 DT 1.54	112, 022, 012
CH_2F_2	Difluoromethane............................	1.97 A	262 MW 1.97	
CH_2N_2	Cyanogen amide (cyanamide)...........	4.27 C	413 MW 4.3 494 MW 4.24[a]	
CH_2N_2	Diazomethane...............................	1.50 A	493aMW 1.50	377
CH_2N_2	Diazirine..	1.59 C	490 MW 1.59	
CH_2O	Methanal (formaldehyde)................	2.33 A	246 MW 2.34 428 MW 2.33 237 MW 2.31 160 DR 2.29	534, 184, 584[b]
CH_2O_2	Methanoic acid (formic acid)............	1.41 A	480 MW 1.415↗ 058 DR 1.52 130 DR 1.4	378
CH_3BF_2	Methyl difluoroborane.....................	1.66 B	364 MW 1.67 342 DT 1.62	
CH_3BO	Carbonyl borane............................	1.80 B	198 MW 1.795[c]	
CH_3Br	Bromomethane...............................	1.81 A	219 MW 1.81 089 DT 1.80 113 DR 1.81 271 DT 1.83 118 DT 1.76	100, 042, 566
CH_3Cl	Chloromethane..............................	1.87 A	193 MW 1.87 219 MW 1.88 113 DR 1.89 038 DT 1.87 062 DT 1.87	100, 042, 043, 024, 012, 035
CH_3F	Fluoromethane..............................	1.85 A	511 MW 1.8555 113 DT 1.85 089 DT 1.81 587 MW 1.8471	Iso, 191, 275
CH_3F_3Ge	Methyl trifluorogermane..................	x Q	424 MW 3.8	

[a] For $^{12}C^{2}H_2{}^{14}N_2$.

[b] $\mu = 1.56 \pm 0.07$ D in the excited $^1A_2$ electronic state.

[c] For $^{12}C^{1}H_3{}^{10}B^{16}O$.

7.2. Selected dipole moments (compounds containing carbon) – Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
CH_3I	Iodomethane	1.62 B	321 DT 1.64 113 DR 1.62 089 DT 1.60 219 MW 1.65 118 DR 1.67	100, 042, 021
CH_3NO	Hydroxyliminomethane (formaldoxime).	0.44 A	484 MW 0.44↗ 491 MW 0.46↗	
CH_3NO	Formyl amide (formamide)	3.73 B	351 MW 3.73↗ 064 DR 3.25	
CH_3NOS	Methyl sulfinylamine	1.70 B	572 MW 1.70	
CH_3NO_2	Nitritomethane (methyl nitrite)	i	507 DR ([a])	
CH_3NO_2	Nitromethane	3.46 A	340 MW 3.48 298 DT 3.43 088 DT 3.44 118 DR 3.57	
CH_3NO_3	Methyl nitrate	3.12 B	448 MW 3.12	
CH_3N_3	Methyl azide	2.17 B	589 MW 2.17	
CH_4	Methane	0 S	094 DT 0	012, 078
CH_4F_2Si	Methyl difluorosilane	2.11 A	389 MW 2.11↗	
CH_4O	Methanol	1.70 A	140 DT 1.71 113 DT 1.70 098 DT 1.70 033 DT 1.70	141, 229, 280, 001, 172
CH_4S	Methanethiol (methyl mercaptan)	1.52 C	427 MW 1.52↗	350, 245
CH_5FSi	Methyl monofluorosilane	1.71 A	387 MW 1.71↗	
CH_5N	Methyl amine	1.31 B	354 MW 1.33[b]↗ 170 DT 1.30 113 DT 1.26 119 DT 1.35 062 DT 1.24	263, 137, 052, 055, 047
CH_5P	Methyl phosphine	1.10 A	452 MW 1.10	
CH_6Ge	Methyl germane	0.643 A	401 MW 0.635 444 MW 0.644 587 MW 0.6425	372, 373, Iso
CH_6OSi	Methoxysilane	1.17 B	548 DT 1.17	
CH_6Si	Methyl silane	0.735 A	349 MW 0.73 214 MW 0.73 587 MW 0.7351	Iso

[a] $\mu = 2.22$ D at 308 °K.

[b] For $^{12}C^2H_3{}^{14}N^2N_2$.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
CH_6Sn	Methyl stannane	0.68 C	238 MW 0.68	
C_2ClF_3	Chlorotrifluoroethylene	0.40 D	325 DT 0.38	
			344 DR 0.58	
			314 DT 0.40	
C_2ClF_5	Chloropentafluoroethane	0.52 C	314 DT 0.52	133
$C_2Cl_2F_4$	1,2-Dichlorotetrafluoroethane	(0.5) Qi	336 DT 0.53	133, 416
			344 DT 0.46	
C_2F_3N	Trifluorocyanomethane	1.33 D	499 DR 1.33	
C_2F_6	Hexafluoroethane	0 S	....	133
C_2F_6O	Bis(trifluoromethyl) ether	0.54 D	314 DT 0.54	
C_2N_2	Dicyanogen (cyanogen)	0 S	115 DT 0	050
C_2N_2S	Dicyano sulfide	3.02 A	569 MW 3.04	
			527aMW 3.01	
C_2HBr	Bromoacetylene	≤0.10 D	129 DT 0.0[a]	
C_2HCl	Chloroacetylene	0.44 A	204 MW 0.44	
			129 DT 0.45	
C_2HCl_5	Pentachloroethane	0.92 C	201 DT 0.92	
C_2HF	Fluoroacetylene	0.73 C	523 MW 0.73	413, 440
C_2HF_3	Trifluoroethylene	1.40 C	518 MW 1.40	
$C_2HF_3O_2$	Trifluoroethanoic acid (trifluoroacetic acid).	2.28 D	233 DR 2.28	
C_2HF_5	Pentafluoroethane	1.54 C	314 DT 1.54	
C_2H_2	Acetylene	0 S	009 DT 0	540[b]
			094 DT 0	
$C_2H_2Cl_2$	1,1-Dichloroethylene	1.34 A	477 MW 1.34	
$C_2H_2Cl_2$	*cis*-1,2-Dichloroethylene	1.90 B	153 DT 1.90	
$C_2H_2Cl_2F_2$	1,1-Dichloro-2,2-difluoroethane	i	315 DR (c)	
$C_2H_2Cl_2O$	Chloroacetyl chloride	2.23 Ci	065 DT 2.23	
$C_2H_2Cl_3F$	1,1,2-Trichloro-2-fluoroethane	i	315 DR (d)	
$C_2H_2Cl_4$	1,1,2,2-Tetrachloroethane	1.32 Ci	201 DT 1.32	
			104 DR 1.36	
C_2H_2FN	Fluorocyanomethane	3.43 C	474 MW 3.43↗	
$C_2H_2F_2$	1,1-Difluoroethylene	1.38 A	196 MW 1.366	Iso
			587 MW 1.385	
			445 DR 1.41	
$C_2H_2F_2$	*cis*-1,2-Difluoroethylene	2.42 A	453 MW 2.42	

[a] Although the structure is unsymmetric, the dipole moment appears to be virtually zero.

[b] Observation of a microwave transition of $^{12}C_2\,^1H^2H$ indicates that the dipole moment of this unsymmetric isotopic species is on the order of 0.01 D.

[c] $\mu = 1.34$ D at 334 °K; 1.47 D at 474 °K.

[d] $\mu = 1.38$ D at 379 °K; 1.44 D at 512 °K.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
$C_2H_2N_2O$	1,2,5-Oxadiazole	3.38 A	573 MW 3.38	
$C_2H_2N_2O$	1,3,4-Oxadiazole	3.04 B	582 MW 3.04	
$C_2H_2N_2S$	1,2,5-Thiadiazole	1.56 A	505 MW 1.565	
$C_2H_2N_2S$	1,3,4-Thiadiazole	3.29 B	468 MW 3.29	
C_2H_2O	Methylene carbonyl (ketene)	1.42 B	261 MW 1.414	Vib
			166 DR 1.45	
			227aDR 1.46	
C_2H_3Br	Bromoethylene	1.42 B	135 DT 1.42	
C_2H_3Cl	Chloroethylene	1.45 B	135 DT 1.45	
			426 MW 1.420[a]	
$C_2H_3ClF_2$	1-Chloro-1,1-difluoroethane	2.14 B	315 DT 2.14	133
C_2H_3ClO	Acetyl chloride	2.72 C	065 DT 2.72	
$C_2H_3ClO_2$	Methyl chloroformate	i	138 DR ([b])	
$C_2H_3Cl_3$	1,1,1-Trichloroethane	1.78 B	153 DT 1.79	
			155 DR 1.77	
$C_2H_3Cl_3$	1,1,2-Trichloroethane	i	315 DR ([c])	195, 201
C_2H_3F	Fluoroethylene	1.43 A	456 MW 1.427↗	
C_2H_3FO	Acetyl fluoride	2.96 A	409 MW 2.96↗	
$C_2H_3F_3$	1,1,1-Trifluoroethane	2.32 B	219 MW 2.33	
			257 MW 2.28	
			133 DR 2.35	
$C_2H_3F_3$	1,1,2-Trifluoroethane	1.58 B	516 MW 1.58[d]	541,[e] 515,[e] 517,[e] 488
C_2H_3I	Iodoethylene	1.30 D	135 DR 1.30	
C_2H_3N	Cyanomethane (acetonitrile)	3.92 A	275 MW 3.94	208
			446 DR 3.90	
			118 DT 3.96	
			113 DR 3.84	
			592 MW 3.918	
C_2H_3N	Isocyanomethane	3.85 B	275 MW 3.85	
C_2H_3NO	Methyl isocyanate	(2.8) Q	504aMW 2.81[f]	
C_2H_3NS	Methyl thiocyanate	(4.0) Q	568 MW 4.03[f]	
C_2H_4	Ethylene	0 S	009 DT 0	
			094 DT 0	

[a] Component along *a* axis.

[b] $\mu = 2.41$ D at 308 °K; 1.55 D at 481 °K.

[c] $\mu = 1.41$ D at 363 °K; 1.48 D at 513 °K.

[d] For the *gauche* rotational isomer, which belongs to point group C_1.

[e] These references give measurements on different rotational isomers of several isotopic species.

[f] Component along *a* axis.

7.2. Selected dipole moments (compounds containing carbon—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
C_2H_4BrCl	1-Bromo-2-chloroethane	i	063 DR (a)	
$C_2H_4Br_2$	1,2-Dibromoethane	i	063 DR (b) 151 DR (b)	059
C_2H_4ClF	1-Chloro-2-fluoroethane, *gauche* conformation.	2.72 C	567aMW 2.72	
C_2H_4ClF	1-Chloro-2-fluoroethane	i	315 DR (c)	
$C_2H_4ClNO_2$	1-Chloro-1-nitroethane	3.27 B	157 DT 3.27	
$C_2H_4Cl_2$	1,1-Dichloroethane	2.06 B	153 DT 2.06	032
$C_2H_4Cl_2$	1,2-Dichloroethane	i	057 DR (d) 158 DR (d) 151 DR (d)	032, 053, 059, 061
$C_2H_4Cl_2O$	Bis(chloromethyl) ether	i	312 DR (e)	
$C_2H_4F_2$	1,1-Difluoroethane	2.27 B	429 MW 2.30↗ 233 DT 2.24	
C_2H_4Ge	Germyl acetylene	0.136 A	581 MW 0.136	
C_2H_4O	Oxirane (ethylene oxide)	1.89 A	232 MW 1.89 026 DT 1.90 113 DR 1.91 346 DT 1.91	
C_2H_4O	Ethanal (acetaldehyde)	2.69 B	348 MW 2.69↗ 160 DR 2.72 065 DR 2.72	
$C_2H_4O_2$	Ethanoic acid (acetic acid)	1.74 C	058 DR 1.74	049
$C_2H_4O_2$	Methyl methanoate (methyl formate).	1.77 B	394 MW 1.77↗	
C_2H_4S	Thiirane (ethylene sulfide)	1.85 A	232 MW 1.85	
C_2H_4Si	Silyl acetylene	0.316 A	514 MW 0.316	
C_2H_5Br	Bromoethane	2.03 A	118 DT 2.02 089 DT 2.03	042, 112, 100, 021
C_2H_5BrO	Bromomethoxymethane	2.05 Ci	312 DR 2.05 [f]	

[a] $\mu = 1.16$ D at 339 °K; 1.35 D at 436 °K.

[b] Reference 063 gives $\mu = 1.02$ D at 339 °K; 1.19 D at 436 °K; reference 151 gives $\mu = 0.91$ D at 339 °K; 1.19 D at 496 °K.

[c] $\mu = 1.84$ D at 309 °K; 1.97 D at 506 °K.

[d] Reference 057 gives $\mu = 1.19$ D at 305 °K; 1.63 D at 544 °K; reference 151 gives $\mu = 1.24$ at 308 °K; 1.60 D at 525 °K; reference 158 gives $\mu = 1.24$ D at 307 °K; 1.46 D at 412 °K.

[e] $\mu = 1.78$ D at 296 °K; 1.92 D at 467 °K.

[f] μ seems to be constant in the temperature range 301 °K to 412 °K.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)		Basic references			Other data
C_2H_5Cl	Chloroethane	2.05	A	371 038 062 113 175	MW DT DT DR DR	1.745[a] 2.06 2.03 2.07 1.98	035, 308, 024, 042, 043, 10
C_2H_5ClO	2-Chloroethanol	1.78	Ci	064	DR	1.78	
C_2H_5ClO	Chloromethoxymethane		i	315 312	DR DR	(b) (b)	
C_2H_5F	Fluoroethane	1.94	B	320 089	MW DT	1.96↗ 1.92	
C_2H_5I	Iodoethane	1.91	B	425 089 118	MW DT DR	1.77↗ 1.92 1.90	021, 042, 100, 112
C_2H_5N	Iminoethane (ethyleneimine)	1.90	A	281	MW	1.90	
C_2H_5N	Methyliminomethane ($CH_3N=CH_2$)	1.53	B	545	MW	1.53	
C_2H_5NO	Acetyl amine (acetamide)	3.76	Bi	539	DR	3.76	
C_2H_5NO	Methylaminomethanal (*N*-methylformamide).	3.83	Bi	539	DR	3.83	
$C_2H_5NO_2$	Nitritoethane (ethyl nitrite)	2.40	Ci	083 313	DR DR	2.38 2.42	
$C_2H_5NO_2$	Nitroethane	3.65	B	157 118	DR DR	3.69 3.61	
C_2H_6	Ethane	0	S	009 094	DT DT	0 0	
C_2H_6AlCl	Dimethylaluminum chloride	x	Q				154
C_2H_6BF	Dimethyl fluoroborane	1.32	C	342	DT	1.32	
C_2H_6O	Ethanol	1.69	Bi	033 060 098	DR DT DT	1.69 1.70 1.68	509, 014, 411 140
C_2H_6O	Dimethyl ether	1.30	A	503 026 062 113 119 561	MW DT DT DT DT DT	1.302 1.30 1.30 1.29 1.31 1.29	034, 043

[a] Component along *a* axis.

[b] Reference 315 gives $\mu=2.03$ D at 347 °K; 2.07 D at 507 °K; reference 312 gives $\mu=1.77$ D at 296 °K; 1.92 D at 467 °K.

7.2. Selected dipole mements (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)		Basic references			Other data
C_2H_6OS	Dimethylsulfoxide	3.96	A	532a	MW	3.96↗	
$C_2H_6O_2$	1,2-Ethanediol (ethylene glycol)	2.28	Ci	064	DR	2.28	
$C_2H_6O_2S$	Dimethyl sulfoxylate (dimethyl sulfone).	4.49	B	143	DR	4.49	
C_2H_6S	Ethanethiol	1.58	Bi	108	DT	1.58	
C_2H_6S	Dimethyl sulfide	1.50	A	459	MW	1.50	
C_2H_6Si	Silyl ethylene	0.66	A	457	MW	0.662	
$C_2H_7B_5$	2,4-Dicarbaheptaborane	1.32	B	550	MW	1.32	
C_2H_7N	Aminoethane (ethyl amine)	1.22	Ci	206	DT	1.22	052
C_2H_7N	Dimethyl amine	1.03	B	170	DT	1.03	137, 055, 052, 047
				119	DT	1.03	
				062	DT	0.97	
C_2H_7P	Ethyl phosphine	1.17	Bi	352	DT	1.17	
C_2H_7P	Dimethyl phosphine	1.23	A	519	MW	1.23	
$C_2H_8N_2$	1,2-Diaminoethane	1.99	Ci	064	DR	1.99	
C_2H_8Si	Dimethyl silane	0.75	A	458	MW	0.75	
C_2H_8Si	Ethyl silane	0.81	B	436	MW	0.81	
$C_3Cl_3F_3$	1,1,2-Trichloro-3,3,3-trifluoropropene.	1.28	D	273	DR	1.28	
C_3O_2	Dicarbonyl carbon (carbon suboxide).	0	S	352	DT	0	
C_3HF_3	3,3,3-Trifluoropropyne	2.36	B	247	MW	2.36	
C_3HF_7	1,1,2,2,3,3,3-Heptafluoropropane	1.62	Di	325	DT	1.62	
C_3HN	Cyanoacetylene	3.72	A	226	MW	3.6	
				593	MW	3.724	
$C_3H_2N_2$	Dicyanomethane	3.73	A	422	MW	3.735	
C_3H_2O	Propynal	2.47	B	319	MW	2.47↗	585 [a]
$C_3H_2O_3$	Vinylene carbonate	4.55	A	304	MW	4.53	
				583	MW	4.57	
C_3H_3Br	3-Bromopropyne	1.54	C	345	DR	1.54	
C_3H_3Cl	3-Chloropropyne	1.68	C	449	MW	1.68↗	381
				345	DR	1.67	
$C_3H_3F_3$	3,3,3-Trifluoropropene	2.45	B	273	DR	2.45	
C_3H_3N	Cyanoethylene	3.87	B	307	MW	3.91↗	
				160	DT	3.83	
C_3H_3NO	Acetyl cyanide	3.45	B	400	MW	3.45↗	
C_3H_3NS	Thiazole	1.62	B	467	MW	1.62	
C_3H_4	Cyclopropene	0.45	A	398	MW	0.454	
C_3H_4	Propyne	0.781	A	136	DR	0.78	257, Iso
				115	DT	0.72	
				275	MW	0.75	
				587	MW	0.781	

[a] In the excited $^1A''$ electronic state, the a component of the moment is 0.7±0.2 D.

7.2. Selected dipole moments (compounds containing carbon)—*Continued*

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
C_3H_4	Propadiene (allene)	0 S	115 DT 0	
$C_3H_4Cl_2$	1,1-Dichlorocyclopropane	1.58 B	473 MW 1.58	
$C_3H_4Cl_2$	1,3-Dichloropropene, bp 104 °C isomer.	i	195 DR 1.79	
$C_3H_4Cl_2$	1,3-Dichloropropene, bp 112 °C isomer.	i	195 DR 1.81	
$C_3H_4Cl_2$	2,3-Dichloropropene	i	195 DR (a)	
$C_3H_4Cl_2O$	1,1-Dichloropropanone	i	311 DR (b)	
$C_3H_4Cl_4$	1,1,2,2-Tetrachloropropane	i	362 DR (c)	302
C_3H_4O	Ethylidene carbonyl (methyl ketene)	1.79 B	590 MW 1.79↗	469
C_3H_4O	Propenal, *trans* conformation (acrolein).	3.12 B	370 MW 3.12↗ 166 DR 3.04 [d]	
$C_3H_4O_2$	2-Oxoöxetane (β-propiolactone)	4.18 A	333 MW 4.20↗ 551 MW 4.17	
$C_3H_4O_2$	Vinyl formate	1.49 A	544 MW 1.49↗	
C_3H_5Br	3-Bromopropene	(1.9) Q	020 DR 1.93	
C_3H_5Cl	2-Chloropropene	1.66 B	165 DT 1.66 020 DR 1.66	
C_3H_5Cl	*cis*-1-Chloropropene	1.67 C	529 MW 1.64↗ 165 DR 1.71	
C_3H_5Cl	*trans*-1-Chloropropene	1.97 C	165 DR 1.97	
C_3H_5Cl	3-Chloropropene	1.94 Ci	121 DT 1.90 165 DR 1.98	100, 042
C_3H_5ClO	Chloropropanone	i	065 DR (e)	
$C_3H_5ClO_2$	Ethyl chloroformate	i	138 DR (f)	
$C_3H_5Cl_3$	1,2,2-Trichloropropane	i	362 DR (g)	303
C_3H_5F	*cis*-1-Fluoropropene	1.46 B	470 MW 1.46↗	
C_3H_5F	*trans*-1-Fluoropropene	(1.9) Q	365 MW 1.86 [h]	
C_3H_5F	2-Fluoropropene	1.61 B	410 MW 1.61↗	
C_3H_5F	3-Fluoropropene, *cis* conformation	1.76 A	560 MW 1.765↗	
C_3H_5F	3-Fluoropropene, *gauche* conformation.	1.94 A	560 MW 1.939↗	

[a] $\mu=1.74$ D at 397 °K; 1.77 D at 518 °K.

[b] $\mu=1.93$ D at 338 °K; 2.07 D at 468 °K.

[c] $\mu=1.56$ D at 372 °K; 1.59 D at 467 °K.

[d] There was no apparent change in the average value of the dipole moment over the temperature range 377 to 478 °K. Although other conformations are possible, the microwave spectrum indicates that the *trans* conformation is predominant at room temperature.

[e] $\mu=2.21$ D at 336 °K; 2.29 D at 454 °K.

[f] $\mu=1.57$ D at 308 °K; 1.47 D at 480 °K.

[g] $\mu=1.63$ D at 354 °K; 1.67 D at 468 °K.

[h] Component along *a* axis.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
C_3H_5N	Cyanoethane (propionitrile)	4.02 A	402 MW 4.02↗ 118 DT 4.05 160 DR 4.00	
$C_3H_5NO_2$	3-Nitritopropene (allyl nitrite)	i	507 DR ([a])	
C_3H_6	Cyclopropane	0 S	113 DT 0	
C_3H_6	Propene	0.366 A	356 MW 0.366↗ 074 DT 0.35 094 DT 0.34	
$C_3H_6Br_2$	1,2-Dibromopropane	i	362 DR ([b])	303
$C_3H_6ClNO_2$	1-Chloro-1-nitropropane	3.48 Bi	157 DT 3.48	
$C_3H_6Cl_2$	1,2-Dichloropropane	i	195 DR ([c])	
$C_3H_6Cl_2$	1,3-Dichloropropane	2.08 Bi	104 DT 2.08[d]	
$C_3H_6Cl_2$	2,2-Dichloropropane	2.27 C	153 DR 2.27	
C_3H_6O	Oxetane (trimethylene oxide)	1.94 A	418 MW 1.94 346 DT 1.94	317
C_3H_6O	Methyl oxirane (propylene oxide)	2.01 A	367 MW 2.01↗	
C_3H_6O	Propanone (acetone)	2.88 A	412 MW 2.90 344 DT 2.88 272 DT 2.89 026 DT 2.87 113 DR 2.87 065 DR 2.88	112
C_3H_6O	2-Propen-1-ol (allyl alcohol)	1.60 C	099 DT 1.60	
C_3H_6O	Propanal, *cis* conformation (propionaldehyde).	2.52 B	531 MW 2.52↗ 160 DT 2.72[e]	
$C_3H_6O_2$	Propanoic acid	1.75 Ci	058 DR 1.75	
$C_3H_6O_2$	Methyl acetate	1.72 Ci	138 DT 1.72 066 DR 1.72	
$C_3H_6O_2$	Ethyl formate	1.93 Ci	066 DT 1.93	
$C_3H_6O_3$	Dimethyl carbonate	i	122 DR ([f])	
$C_3H_6O_3$	1,3,5-Trioxane	2.08 A	542 MW 2.07 227 MW 2.09	

[a] $\mu=2.25$ D at 298 °K.

[b] $\mu=1.17$ D at 354 °K; 1.41 D at 467 °K.

[c] $\mu=1.46$ D at 345 °K; 1.68 D at 506 °K.

[d] The value of the dipole moment appears to be constant over the temperature range 374 to 485 °K.

[e] Equilibrium mixture of conformations in which the average dipole moment is essentially constant over the temperature range 354 to 508 °K.

[f] $\mu=0.90$ D at 328 °K; 1.05 D at 479 °K.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
C_3H_6S	Thietane (trimethylene sulfide)..........	1.85 C	577 MW 1.85	
C_3H_6S	Methyl thiirane (propylene sulfide).....	1.95 A	504 MW 1.95	
C_3H_7Br	1-Bromopropane...........................	2.18 Ci	118 DR 2.18	100, 042
C_3H_7Br	2-Bromopropane...........................	2.21 C	118 DR 2.21	
C_3H_7Cl	1-Chloropropane..........................	2.05 Bi	062 DT 2.05	112, 100, 043, 042, 053, 035
C_3H_7Cl	2-Chloropropane..........................	2.17 C	118 DR 2.17	
C_3H_7F	1-Fluoropropane, *gauche* conformation.	1.90 C	476 MW 1.90 ↗	
C_3H_7F	1-Fluoropropane, *trans* conformation.	2.05 B	476 MW 2.05 ↗	
C_3H_7I	1-Iodopropane............................	2.04 Ci	118 DR 2.04	100, 042
C_3H_7N	3-Aminopropene...........................	(1.2) Q	020 DR 1.20	
C_3H_7NO	N,N-Dimethylformamide................	3.82 Bi	539 DR 3.82	
C_3H_7NO	Acetyl methylamine (*N*-Methylacetamide).	3.73 Bi	539 DR 3.73	
$C_3H_7NO_2$	1-Nitritopropane (*n*-propyl nitrite)......	i	507 DR ([a])	
$C_3H_7NO_2$	2-Nitritopropane (isopropyl nitrite).....	i	313 DR ([b])	
$C_3H_7NO_2$	1-Nitropropane...........................	3.66 Bi	118 DR 3.60 155 DR 3.72	
$C_3H_7NO_2$	2-Nitropropane...........................	3.73 B	155 DR 3.73	
C_3H_8	Propane....................................	0.084 A	431 MW 0.083 587 MW 0.085	352, 277, 094, 074, Iso
C_3H_8O	1-Propanol................................	1.68 Bi	033 DT 1.69 099 DT 1.67	
C_3H_8O	2-Propanol................................	1.66 Bi	098 DT 1.60 127 DT 1.69	
C_3H_8O	Methoxyethane (methyl ethyl ether)...	1.23 Ci	194 DT 1.23	
$C_3H_8O_2$	Dimethoxymethane.......................	i	109 DR ([c])	
C_3H_9Al	Trimethyl aluminum.....................	x Q	....	154
C_3H_9As	Trimethyl arsine..........................	0.86 B	404 MW 0.86	
$C_3H_9BF_3N$	Trimethyl amine—boron trifluoride complex.	(5) Q	438 MW 5	
C_3H_9N	Trimethyl amine..........................	0.612 A	383 MW 0.612 423 NR 0.61 343 NR 0.60 170 DT 0.65 119 DT 0.67 062 DT 0.61	137, 055, 052, 047
C_3H_9N	1-Aminopropane (*n*-propylamine)........	1.17 Ci	228 DT 1.17	020

[a] $\mu=2.42$ D at 298 °K.
[b] $\mu=2.58$ D from 256 to 332 °K.
[c] $\mu=0.77$ D at 307 °K; 1.17 D at 482 °K.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
C_3H_9P	Trimethyl phosphine	1.19 A	384 MW 1.192	
$C_3H_{10}Si$	Trimethyl silane	0.525 A	437 MW 0.525	
$C_4Cl_3F_7$	2,2,3-Trichloroheptafluorobutane	(0.9) Qi	336 DT 0.85	
C_4F_8	Perfluorocyclobutane	0 S	314 DT 0	
C_4F_8O	Perfluoroöxolane (perfluorotetramethylene oxide).	0.56 D	325 DT 0.56	
$C_4F_{10}O$	Perfluoro(ethoxyethane)	0.47 Di	325 DT 0.51	
			314 DT 0.42	
$C_4H_2N_2$	*trans*-1,2-Dicyanoethylene	0 S	....	151
C_4H_4	1-Buten-3-yne	(0.4) Q	496 MW 0.43[a]	
$C_4H_4Cl_2$	1,4-Dichloro-2-butyne	2.10 Bi	363 DR 2.10	
$C_4H_4F_2$	1,1-Difluoro-1,3-butadiene (*trans* conformation).	1.29 A	549 MW 1.29	
$C_4H_4N_2$	1,2-Dicyanoethane	i	151 DR (b)	
C_4H_4O	Furan	0.66 A	249 MW 0.664	
			278 DT 0.72	
C_4H_4O	3-Butyne-2-one	(2.4) Q	521 MW 2.4	
$C_4H_4O_2$	Diketene	3.53 B	160 DR 3.53	
C_4H_4S	Thiophene	0.55 C	278 DT 0.55	
			108 DT 0.56	
C_4H_5Cl	4-Chloro-1,2-butadiene	2.02 Ci	165 DR 2.02	
C_4H_5Cl	1-Chloro-2-butyne	2.19 C	345 DR 2.19	
C_4H_5F	2-Fluoro-1,3-butadiene (*trans* conformation).	1.42 A	486 MW 1.417↗	
C_4H_5N	Pyrrole	1.84 C	270 DT 1.84	327
C_4H_5N	*cis*-1-Cyanopropene	4.08 B	502 MW 4.08↗	
C_4H_5N	*trans*-1-Cyanopropene	4.50 B	160 DR 4.50	
C_4H_5N	2-Cyanopropene (methacrylonitrile)	3.69 C	166 DR 3.69	
C_4H_6	Cyclobutene	0.132 A	563 MW 0.132	
C_4H_6	1-Butyne	0.80 C	136 DR 0.80	
C_4H_6	1,2-Butadiene	0.403 A	357 MW 0.403↗	
C_4H_6	1,3-Butadiene	0 S	159 DT 0[c]	

[a] Component along *a* axis.

[b] μ=3.47 D at 443 °K; 3.59 D at 513 °K.

[c] Although unsymmetric conformations may exist, the *trans* conformation predominates at normal temperatures.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
C_4H_6O	Cyclobutanone	2.99 B	500aMW 2.99	
C_4H_6O	*trans*-2-Butenal (crotonaldehyde)	3.67 Bi	160 DR 3.67	
C_4H_6O	2-Methylpropenal (methacrolein)	2.68 Ci	166 DR 2.68	
C_4H_6O	3-Butene-2-one	3.16 B	557 MW 3.16↗	
$C_4H_6O_2$	2,3-Butanedione	(0) Qi	151 DT ([a])	063
$C_4H_6O_3$	Acetyl acetate (acetic anhydride)	(2.8) Qi	082 DR 2.8	
C_4H_6S	Divinyl sulfide	1.20 D	165 DR 1.20	
C_4H_7Cl	1-Chloro-2-methylpropene	1.95 Bi	160 DT 1.95 165 DR 1.85	
$C_4H_7Cl_3$	1,1,2-Trichloro-2-methylpropane	1.86 Ci	362 DR 1.86	
C_4H_7F	Fluorocyclobutane	1.94 A	586 MW 1.94	
C_4H_7N	1-Cyanopropane	4.07 Bi	118 DR 4.07	
C_4H_8	1-Butene	0.34 Ci	009 DT 0.38 115 DT 0.30	
C_4H_8	*cis*-2-Butene	0.3 D	344 DT 0.33	
C_4H_8	*trans*-2-Butene	0 S	115 DT 0	
C_4H_8	2-Methylpropene	0.50 A	454 MW 0.503 115 DT 0.49	
$C_4H_8Br_2$	1,2-Dibromo-2-methylpropane	i	362 DR ([b])	
$C_4H_8Cl_2$	1,4-Dichlorobutane	2.22 Ci	195 DR 2.22	
$C_4H_8Cl_2$	1,2-Dichloro-2-methylpropane	i	362 DR ([c])	303
C_4H_8O	Tetrahydrofuran	1.63 C	346 DT 1.63	
C_4H_8O	*cis*-2,3-Dimethyloxirane	2.03 A	464 MW 2.03↗	
C_4H_8O	Butanal	2.72 Bi	160 DR 2.72	
$C_4H_8O_2$	1,4-Dioxane	0 S	111 DT 0 087 DT 0	
$C_4H_8O_2$	Ethyl acetate	1.78 Ci	066 DT 1.78	
C_4H_9Br	1-Bromobutane	2.08 Ci	118 DT 2.08	
C_4H_9Br	2-Bromobutane	2.23 Ci	118 DR 2.23	
C_4H_9Cl	1-Chlorobutane	2.05 Bi	105 DT 2.05 118 DR 2.14	
C_4H_9Cl	2-Chlorobutane	2.04 Ci	155 DT 2.04	

[a] Although unsymmetric *gauche* conformations are possible, the polarization shows no dependence on temperature and is consistent with the *trans* conformation. This interpretation, however, implies an exceptionally large vibrational polarization.

[b] $\mu = 1.20$ D at 354 °K; 1.27 D at 412 °K.

[c] $\mu = 1.56$ D at 339 °K; 1.66 D at 467 °K.

7.2. Selected dipole moments (compounds containing carbon) – Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
C_4H_9Cl	1-Chloro-2-methylpropane	2.00 Ci	155 DT 2.00	
C_4H_9Cl	2-Chloro-2-methylpropane	2.13 B	155 DR 2.13	
C_4H_9F	2-Fluoro-2-methylpropane	1.96 A	384 MW 1.959	269
C_4H_9I	1-Iodobutane	2.12 Ci	118 DR 2.12	
C_4H_9NO	Propanoyl methylamine (N-methylpropionamide).	3.61 Bi	539 DR 3.61	
C_4H_9NO	Acetyl dimethylamine (N,N-dimethylacetamide).	3.81 Bi	539 DR 3.81	
$C_4H_9NO_2$	2-Nitrito-2-methylpropane (t-butyl nitrite).	2.74 Ci	508 DR 2.77 313 DR 2.71	
$C_4H_9NO_2$	1-Nitrobutane	3.59 Bi	118 DR 3.59	
$C_4H_9NO_2$	2-Nitro-2-methylpropane	3.71 B	155 DR 3.71	
C_4H_{10}	Butane	$\leq$ 0.05 Ci	277 DT $\leq$ 0.05	115
C_4H_{10}	2-Methylpropane	0.132 A	384 MW 0.132 337 NR 0.132 277 DT 0.13	432, 115, Iso
$C_4H_{10}O$	1-Butanol	1.66 Bi	099 DT 1.65 033 DT 1.67	112
$C_4H_{10}O$	2-Methylpropan-1-ol (isobutanol)	1.64 C	098 DT 1.64	
$C_4H_{10}O$	Diethyl ether	1.15 Bi	194 DT 1.13 026 DT 1.15 062 DT 1.11 119 DT 1.19	146, 044, 038, 034, 014
$C_4H_{10}S$	Diethyl sulfide	1.54 Ci	108 DT 1.54	
$C_4H_{11}N$	1-Aminobutane (n-butylamine)	(1.0) Qi	228 DT 1.00[a]	
$C_4H_{11}N$	Diethyl amine	0.92 Ci	206 DT 0.92	052
C_5F_{12}	Perfluoropentane	$\leq$ 0.10 Di	233 DT 0[b]	
C_5F_{12}	Perfluoro (2-methylbutane)	$\leq$ 0.10 Di	233 DT 0[b]	
C_5H_5N	Pyridine	2.19 B	329 DT 2.23 289 MW 2.15	
C_5H_5N	1-Cyano-1,3-butadiene	3.90 Ci	166 DR 3.90	
C_5H_6	1,3-Cyclopentadiene	0.419 A	164 DR 0.53 574 MW 0.419 334 MW 0.418	

---

[a] The extrapolated value of polarization (vs $1/T$) determined for this compound is inconsistent with the other aminoalkanes. The dipole moment given is probably low.

[b] Although unsymmetric conformations are likely, the dipole moment appears to be virtually zero.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)		Basic references			Other data
C_5H_8	Cyclopentene	0.20	B	555 492	MW MW	0.190[a] 0.22	
C_5H_8	1-Pentyne	0.81	Ci	136 559	DR DR	0.86 0.81[b]	
C_5H_8	*trans*-1,3-Pentadiene	0.68	Di	159	DR	0.68	
C_5H_8	2-Methyl-1,3-butadiene (*trans* conformation).	0.25	A	538	MW	0.25 ↗	159
$C_5H_8Br_4$	1,3-Dibromo-2,2-bis(bromomethyl) propane.	x	Q	....			068
C_5H_8O	Cyclopentanone	(3.3)	Q	399	MW	3.30[c]	
$C_5H_8O_2$	Acetylacetone		Ci	082	DR	3.05[d]	
C_5H_9N	1-Cyanobutane	4.12	Bi	097	DT	4.12	
C_5H_9N	2-Cyano-2-methylpropane	3.95	A	489	MW	3.95	
C_5H_{10}	Ethylcyclopropane	(0.5)	Q	020	DR	0.47	
C_5H_{10}	1-Pentene	(0.5)	Q	020	DR	0.51	
$C_5H_{10}O_3$	Diethyl carbonate	1.10	Ci	110	DT	1.10	
$C_5H_{11}Br$	1-Bromopentane	2.20	Ci	314	DR	2.20	
$C_5H_{11}Cl$	1-Chloropentane	2.16	Ci	118	DR	2.16	
C_5H_{12}	Pentane	< 0.1	Di	277 352	DT DT	< 0.07 < 0.05	098, 020, 112
C_5H_{12}	2-Methylbutane	0.13	C	352 277	DT DT	0.13 0.1	
C_5H_{12}	2,2-Dimethylpropane	0	S	277	DT	0	
$C_5H_{12}O_2$	Diethoxymethane		i	110	DR	(e)	
$C_5H_{12}O_4$	Tetramethoxymethane	0	Qi	038	DT	≈ 0	030
$C_6H_2Cl_2O_2$	2,5-Dichloro-1,4-cyclohexadienedione	0	S	131	DT	0	
C_6H_4BrF	*p*-Bromofluorobenzene	(0.5)	Q	156	DR	0.5	
$C_6H_4ClNO_2$	*o*-Chloronitrobenzene	4.64	B	120	DR	4.64	
$C_6H_4ClNO_2$	*m*-Chloronitrobenzene	3.73	B	120	DR	3.73	
$C_6H_4ClNO_2$	*p*-Chloronitrobenzene	2.83	B	120	DR	2.83	
$C_6H_4Cl_2$	*o*-Dichlorobenzene	2.50	B	194 156	DR DT	2.48 2.52	120
$C_6H_4Cl_2$	*m*-Dichlorobenzene	1.72	C	120	DR	1.72	
$C_6H_4Cl_2$	*p* Dichlorobenzene	0	S	120	DR	0	
C_6H_4FI	*p*-Iodofluorobenzene	0.89	D	156	DR	0.89	
$C_6H_4FNO_2$	*p*-Fluoronitrobenzene	2.87	B	156	DR	2.87	
$C_6H_4F_2$	*m*-Difluorobenzene	1.58	B	194	DT	1.58	

---

[a] Component along *b* axis. The component along *c* axis was estimated to be 0.05 to 0.10 D.

[b] Allowance for vibrational polarization has been made. See reference 559.

[c] Component along *a* axis.

[d] Mixture of enol and keto forms.

[e] $\mu = 1.26$ D at 329 °K; 1.32 D at 476 °K.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)		Basic references			Other data
$C_6H_4N_2O_4$	*p*-Dinitrobenzene	0	S	131	DT	0	
$C_6H_4O_2$	1,4-Cyclohexadienedione (*p*-benzoquinone).	0	S	131	DT	0	068
C_6H_5Br	Bromobenzene	1.70	B	097	DT	1.70	
				321	DT	1.70	
				156	DR	1.77	
C_6H_5Cl	Chlorobenzene	1.69	B	101	DT	1.71	156, 273, 539
				084	DT	1.70	
				194	DT	1.67	
				520	MW	1.78	
C_6H_5ClO	*o*-Chlorophenol		i	148	DR	(a)	
C_6H_5ClO	*p*-Chlorophenol	2.11	C	148	DR	2.11	
C_6H_5F	Fluorobenzene	1.60	C	101	DT	1.58	
				194	DR	1.60	
				395	MW	1.66	
C_6H_5I	Iodobenzene	1.70	C	156	DR	1.70	
				321	DT	1.71	
$C_6H_5NO_2$	Nitrobenzene	4.22	B	101	DT	4.22	
				084	DR	4.27	
C_6H_6	Benzene	0	S	084	DT	0	157, 112, 011, 336
				113	DT	0	
				074	DT	0	
$C_6H_6N_2O_2$	*p*-Aminonitrobenzene (*p*-nitroaniline)	x	Q	...			068, 080
C_6H_6O	Phenol	1.45	C	120	DR	1.45	
$C_6H_6O_2$	*p*-Dihydroxybenzene	x	Q	...			068
C_6H_7N	Aminobenzene (aniline)	1.53	C	120	DR	1.53	
C_6H_8	1,3-Cyclohexadiene	0.44	B	553	MW	0.437	
C_6H_8	1,5-Hexadiyne		i	559	DR	0.57[b,c]	
$C_6H_8N_2$	*o*-Diaminobenzene	1.53	Di	148	DR	1.53	
$C_6H_8N_2$	*m*-Diaminobenzene	1.81	Di	148	DR	1.81	
$C_6H_8N_2$	*p*-Diaminobenzene	1.53	Di	148	DR	1.53	
$C_6H_8O_2$	1,4-Cyclohexanedione	(1.4)	Qi	463	DR	1.41	
C_6H_{10}	Cyclohexene	0.55	D	121	DR	0.55	
C_6H_{10}	1-Hexyne	0.83	Ci	559	DR	0.83[b]	
				136	DR	0.89	

[a] $\mu = 1.24$ D at 421 °K; 1.37 D at 562 °K.

[b] An allowance has been made for vibrational polarization. See reference 559.

[c] At 308 °K.

7.2. Selected dipole moments (compounds containing carbon) – Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
C_6H_{10}	2-Methyl-1,3-pentadiene	0.65 D	164 DR 0.65	
C_6H_{10}	3-Methyl-1,3-pentadiene	0.63 Di	164 DR 0.63	
C_6H_{10}	3,3-Dimethyl-1-butyne	0.66 A	489 MW 0.661	
C_6H_{10}	2-Ethyl-1,3-butadiene	(0.45) Qi	164 DR 0.45	
C_6H_{10}	2,3-Dimethyl-1,3-butadiene	0.52 Di	159 DR 0.52	
$C_6H_{10}BrCl$	*trans*-1-Bromo-2-chlorocyclohexane	i	463 DR 2.19[a]	
$C_6H_{10}Br_2$	*trans*-1,2-Dibromocyclohexane	i	463 DR 2.00[a]	
$C_6H_{10}Cl_2$	*cis*-1e,2a-Dichlorocyclohexane	3.11 C	287 DR 3.11	
$C_6H_{10}Cl_2$	*trans*-1,2-Dichlorocyclohexane	i	287 DR 2.31[a] 463 DR 2.29[a]	
$C_6H_{10}O_3$	Ethyl acetoacetate	i	082 DR 2.98[b]	
$C_6H_{12}N_2$	Diisopropylidene hydrazine (dimethyl ketazine).	1.53 Bi	151 DT 1.53	
$C_6H_{12}O_2$	Pentyl formate (n-amyl formate)	1.90 Ci	066 DT 1.90	
$C_6H_{12}O_3$	2,4,6-Trimethyl-1,3,5-trioxane (paraldehyde).	1.43 C	212 DT 1.43	
C_6H_{14}	Hexane	$\leqslant 0.1$ Di	090 DT ≈ 0 098 DR ≈ 0	
$C_6H_{14}O$	Dipropyl ether	1.21 Ci	119 DT 1.21 062 DR 1.30	034
$C_6H_{14}O$	Diiospropyl ether	1.13 Di	251 DT 1.13	
$C_6H_{14}O_2$	1,1-Diethoxyethane	i	110 DR (c)	
$C_6H_{15}N$	Triethyl amine	0.66 Ci	206 DT 0.66	052
$C_6H_{18}OSi_2$	Bis(trimethylsilyl) ether	(0.66) Qi	318 DR 0.66	
$C_7H_4ClF_3$	*o*-Chloro(trifluoromethyl)benzene	3.46 B	273 DR 3.46	
$C_7H_4ClF_3$	*p*-Chloro(trifluoromethyl)benzene	1.58 C	273 DR 1.58	
$C_7H_4N_2O_2$	*p*-Cyanonitrobenzene	(0) Q	131 DT ≈ 0	
$C_7H_5F_3$	(Trifluoromethyl)benzene	2.86 B	273 DR 2.86	
C_7H_5N	Cyanobenzene (benzonitrile)	4.18 B	299 MW 4.18[d] 084 DR 4.42	
C_7H_7Cl	*o*-Chlorotoluene	1.56 C	273 DR 1.56	
C_7H_7Cl	*p*-Chlorotoluene	2.21 B	273 DR 2.21	

[a] Mixture of *ee* and *aa* conformational isomers.

[b] Mixture of keto and enol forms.

[c] $\mu = 1.11$ D at 328 °K; 1.22 D at 476 °K.

[d] Recalculated from the original data.

7.2. Selected dipole moments (compounds containing carbon)—Continued

Formula	Compound name	Selected moment (debyes)	Basic references	Other data
C_7H_7F	*o*-Fluorotoluene	1.37 C	194 DR 1.37	
C_7H_7F	*m*-Fluorotoluene	1.86 C	194 DR 1.86	
C_7H_7F	*p*-Fluorotoluene	2.00 C	194 DR 2.00	
$C_7H_7NO_3$	*o*-Nitro(methoxy)benzene	4.83 Bi	120 DR 4.83	
$C_7H_7NO_3$	*m*-Nitro(methoxy)benzene	4.55 Bi	120 DR 4.55	
$C_7H_7NO_3$	*p*-Nitro(methoxy)benzene	5.26 B	120 DR 5.26	
C_7H_8	1,3,5-Cycloheptatriene	0.25 C	554 MW 0.25	
C_7H_8	Toluene	0.36 C	142 DT 0.36 074 DT 0.36	
C_7H_8O	Phenylmethanol (benzyl alcohol)	1.71 C	288 DR 1.71	
C_7H_8O	Methoxybenzene (anisole)	1.38 C	120 DR 1.38	
C_7H_9NO	*o*-Amino(methoxy)benzene	1.61 Ci	148 DR 1.61	
C_7H_{10}	1,6-Heptadiyne	i	559 DR $0.81^{a,b}$	
C_7H_{12}	1-Heptyne	0.86 i	136 DR 0.87 559 DR 0.85^{b}	
C_7H_{14}	Methylcyclohexane	(0) Qi	142 DT ≈0	
$C_7H_{14}O$	Methoxycyclohexane	1.35 Di	120 DR 1.35	
$C_7H_{14}O_2$	Pentyl acetate (*n*-amyl acetate)	1.75 Ci	066 DT 1.75	
$C_7H_{15}Br$	1-Bromoheptane	2.16 Ci	105 DR 2.16	
C_7H_{16}	Heptane	$\leqslant 0.1$ Di	098 DT ≈0 090 DT ≈0	112, 020
$C_8H_4N_2$	*p*-Dicyanobenzene	0 S	131 DT 0	
C_8H_8	Styrene	(0) Q	164 DR ≈0	
C_8H_8O	Acetylbenzene (acetophenone)	3.02 B	097 DT 3.02	
$C_8H_8O_2$	2,5-Dimethyl-1,4-cyclohexadienedione	0 S	131 DT 0	
$C_8H_9NO_2$	Methyl (*o*-aminophenyl)formate	x Q	....	018
$C_8H_9NO_2$	Methyl (*m*-aminophenyl)formate	x Q	....	018
$C_8H_9NO_2$	Methyl (*p*-aminophenyl)formate	x Q	....	018
C_8H_{10}	Ethylbenzene	0.59 C	142 DT 0.59	
C_8H_{10}	*o*-Xylene	0.62 C	156 DR 0.62^{c}	
C_8H_{10}	*p*-Xylene	0 S	156 DR 0	
$C_8H_{10}O$	Ethoxybenzene (phenetole)	1.45 Di	120 DR 1.45	
$C_8H_{11}N$	(Dimethylamino)benzene	1.68 D	120 DR 1.68	
C_8H_{12}	1,7-Octadiyne	i	559 DR $0.88^{a,b}$	
$C_8H_{12}O_2$	Tetramethylcyclobutane-1,3-dione	0 S	131 DT 0	

[a] At 308 °K.

[b] An allowance has been made for vibrational polarization. See reference 559.

[c] The vibrational polarization plus electronic polarization was set equal to the total polarization for *p*-xylene.

7.2. Selected dipole moments (compounds containing carbon)—*Continued*

Formula	Compound name	Selected moment (debyes)		Basic references			Other data
$C_8H_{12}O_2$	Ethyl 2,4-hexadienoate (ethyl sorbate).	(2.07)	Qi	166	DR	2.07	
$C_8H_{14}O_4$	Diethyl butanedioate (diethyl succinate).		i	064	DR	(a)	
C_8H_{16}	Ethylcyclohexane	(0)	Q	142	DT	≈0	
C_8H_{18}	Octane	$\leqslant 0.1$	Di	157	DR	≈0	
$C_8H_{18}O$	Dibutyl ether	1.17	Ci	119	DT	1.17	
C_9H_7N	Quinoline	2.29	C	329	DR	2.29	
C_9H_7N	Isoquinoline	2.73	C	329	DR	2.73	
$C_9H_{10}O_2$	Ethyl phenylformate (ethyl benzoate)	2.00	Ci	097	DR	2.00	
C_9H_{12}	Isopropylbenzene	(0.79)	Q	142	DR	0.79	
$C_9H_{12}O_8$	Tetrakis(methyl carboxylate)methane	x	Q	....			068
C_9H_{14}	1,8-Nonadiyne		i	559	DR	1.09[b,c]	
C_9H_{18}	Isopropylcyclohexane	(0)	Q	142	DT	≈0	
$C_{10}H_8$	Azulene	0.80	B	575	MW	0.796	
$C_{10}H_{14}$	*t*-Butylbenzene	(0.83)	Q	142	DR	0.83	
$C_{10}H_{14}BeO_4$	Bis(2,4-pentanedionato) beryllium	0	S	131	DT	0	
$C_{10}H_{18}O$	1,3,3-Trimethyl-2-oxabicyclo[2.2.2]octane.	1.42	D	255	DR	1.42	
$C_{10}H_{20}$	*t*-Butylcyclohexane	(0)	Q	142	DT	≈0	
$C_{11}H_{16}$	*p*-*t*-Butyltoluene	x	Q	....			142
$C_{12}H_8Br_2O$	Bis(*p*-bromophenyl) ether	1.02	D	132	DR	1.02	
$C_{12}H_9BrO$	*p*-Bromophenoxybenzene	1.98	C	132	DR	1.98	
$C_{12}H_9NO_3$	*p*-Nitrophenoxybenzene	4.54	B	132	DR	4.54	
$C_{12}H_{10}$	Acenaphthene	(0.85)	Q	347	DR	0.93	
				310	DR	0.81	
$C_{12}H_{10}$	Phenylbenzene (diphenyl)	0	S	....			029, 030
$C_{12}H_{10}O$	Diphenyl ether	(1.3)	Q	120	DR	1.43	018
				132	DR	1.23	
$C_{13}H_{10}O$	Diphenyl carbonyl	x	Q	....			018
$C_{13}H_{11}BrO$	*p*-Bromophenoxy-*p*-toluene	2.45	C	132	DR	2.45	
$C_{13}H_{12}$	Diphenylmethane	x	Q	....			018
$C_{13}H_{20}O_8$	Tetrakis(acetoxymethyl)methane	x	Q	....			068
$C_{14}H_{14}O$	Bis(*p*-tolyl) ether	1.54	C	132	DR	1.54	
$C_{15}H_{21}AlO_6$	Tris(2,4-pentanedionato) aluminum	0	S	131	DT	0	
$C_{15}H_{21}CrO_6$	Tris(2,4-pentanedionato) chromium (III).	0	S	131	DT	0	
$C_{15}H_{21}FeO_6$	Tris(2,4-pentanedionato) iron (III)	0	S	....			131
$C_{20}H_{28}O_8Th$	Tetrakis(2,4-pentanedionato) thorium.	0	S	....			131

[a] $\mu = 2.35$ D at 430 °K; 2.41 D at 519 °K.

[b] At 308 °K.

[c] An allowance for vibrational polarization has been made. See reference 559.

7.3. Appendix I. Variation of Dipole Moment With Vibrational State

The following table summarizes the best available information on the vibrational dependence of dipole moments. Only those cases are included where the precision of the measurement was high enough to make a meaningful comparison of the dipole moment in different vibrational states. A few other cases have been reported in the literature, but the changes were not felt to be experimentally significant. All results in this table were obtained from Stark effect measurements.

The table includes the original investigator's estimate of the precision of his measurements. Since very few authors have specified the statistical estimator used in stating their precision, the precision entries for different compounds are in general not comparable. However, the data in this table on different vibrational states of a single compound were always obtained by the same investigator on the same apparatus. The precision quoted by the investigator can thus be regarded as a rough indication of the reproducibility of a measurement on a given vibrational state. Since systematic errors should be virtually the same for all states, the quoted precision gives an idea of the significance of the variation of the dipole moment with vibrational state.

It should be emphasized that the accuracy of the dipole moments given in this table is much lower than the precision. In most cases the uncertainty resulting from possible systematic errors is at least an order of magnitude greater than the precision which is quoted.

APPENDIX I. *Variation of dipole moment with vibrational state*

Compound	Vibrational state	Dipole moment (debyes)	Precision (debyes)	References
BaO—Barium oxide..............................	$v=0$	7.954	0.002	526, 500
	$v=1$	7.997	0.002	
	$v=2$	8.039	0.002	
	$v=3$	8.079	0.002	
BrK—Potassium bromide.......................	$v=0$	10.41	0.02	274
	$v=2$	9.93	0.02	
^{79}Br^{6}Li—Lithium bromide......................	$v=0$	7.2680	0.0001	535
	$v=1$	7.3523	0.0001	
	$v=2$	7.4377	0.0001	
^{81}Br^{6}Li—Lithium bromide.......................	$v=0$	7.2678	0.0001	535
	$v=1$	7.3521	0.0001	
	$v=2$	7.4376	0.0001	
ClCs—Cesium chloride..........................	$v=0$	10.420[a]	0.001	341
	$v=1$	10.476	0.001	
ClK—Potassium chloride.......................	$v=0$	10.2688[b]	0.001	591
	$v=1$	10.3288	0.001	
	$v-2$	10.3877	0.001	

[a] Calculated from the equation $\mu_v = 10.42 + 0.056\ v$, which was obtained from measurements on the $v=0$ through $v=6$ states.

[b] Different values are reported in reference 282 but are believed to be of lower accuracy and precision.

APPENDIX I. *Variation of dipole moment with vibrational state*—Continued

Compound	Vibrational state	Dipole moment (debyes)	Precision (debyes)	References
$^{35}Cl^{6}Li$—Lithium chloride	$v=0$	7.1195[a]	0.0006	537
	$v=1$	7.2069	0.0008	
	$v=2$	7.2964	0.0012	
	$v=3$	7.3865	0.0018	
$^{37}Cl^{6}Li$—Lithium chloride	$v=0$	7.1192[a]	0.0008	537
	$v=1$	7.2071	0.0012	
	$v=2$	7.2972	0.0014	
ClNa—Sodium chloride	$v=0$	9.002	0.004	473a
	$v=1$	9.060	0.004	
	$v=2$	9.119	0.004	
CsF—Cesium fluoride	$v=0$	7.8750[b]	0.0002	341
	$v=1$	7.9472	0.0002	
$^{19}F^{6}Li$—Lithium fluoride	$v=0$	6.3276[c]	0.0001	527
	$v=1$	6.4151	0.0001	
	$v=2$	6.5034	0.0001	
	$v=3$	6.5933	0.0001	
FNa—Sodium fluoride	$v=0$	8.1558	0.0001	536
	$v=1$	8.2209	0.0001	
	$v=2$	8.2867	0.0001	
FRb—Rubidium fluoride	$v=0$	8.5465	0.0002	591
	$v=1$	8.6135	0.0002	
	$v=2$	8.6810	0.0002	
FTl—Thallium fluoride	$v=0$	4.2282	0.0001	397
	$v=1$	4.2971	0.0001	
	$v=2$	4.3665	0.0004	
HLi—Lithium hydride	$v=0$	5.882	0.003	442
	$v=1$	5.990	0.003	
$^{127}I^{6}Li$—Lithium iodide	$v=0$	7.4285	0.0002	552
	$v=1$	7.5120	0.0002	
OSr—Strontium oxide	$v=0$	8.900	0.003	562
	$v=1$	8.874	0.003	

[a] Slightly different values have been reported in reference 591, but the change with vibrational state is not significantly different.

[b] Calculated from the equation $\mu_v = 7.875 + 0.0722\, v$, which was obtained from measurements on the $v=0$ through $v=4$ states.

[c] Essentially the same values have been reported in reference 591.

APPENDIX I. *Variation of dipole moment with vibrational state*—Continued

Compound	Vibrational state	Dipole moment (debyes)	Precision (debyes)	References
O_2S—Sulfur dioxide	000 010	1.615 1.575	([a])	487b
Carbon compounds:				
COSe—Carbonyl selenide	000 100 010	0.754 0.728 0.730	([b])	199
C_2H_2O—Methylene carbonyl (ketene)	$v=0^c$ $v_7=1$ $v_8=1$ $v_9=1$	1.414 1.430 1.386 1.387	0.010 0.012 0.010 0.010	261

[a] Precision was not stated.

[b] Precision was not stated but is estimated to be about 1 percent. Because of a probable systematic error in calibration, all values are about 3 percent high.

[c] The vibrational assignment has been revised in accordance with A. P. Cox and A. S. Esbitt, J. Chem. Phys. **38,** 1636 (1963).

7.4. Appendix II. Isotopic Dependence of Dipole Moment

This table lists molecules in which isotope shifts in the dipole moment have been accurately measured by microwave or molecular beam techniques. All measurements refer to the ground vibrational state. As in appendix I, only those measurements are included which are felt to be precise enough to give an experimentally significant difference in dipole moments of different isotopic species. This requires that the precision of the measurement be better than 0.01 D. Other cases of measurements on several isotopic species have been reported in the literature, but the uncertainties were too large to give meaningful shifts. Dielectric measurements of *deuterium isotope shifts have been* reported in HCl (128) and NH_3 (096).

The comments on precision and accuracy made in appendix I apply to this table.

APPENDIX II. *Isotopic dependence of dipole moment*

Compound	Isotopic species	Dipole moment (debyes)	Precision (debyes)	Reference
Lithium bromide	$^{79}Br^{6}Li$	7.2680[a]	0.0001	535
	$^{81}Br^{6}Li$	7.2678	0.0001	
	$^{79}Br^{6}Li$	7.2680	0.0002	591
	$^{79}Br^{7}Li$	7.2648	0.0002	
Lithium chloride	$^{35}Cl^{6}Li$	7.1195[a]	0.0006	537
	$^{37}Cl^{6}Li$	7.1192	0.0008	
Lithium fluoride	$^{19}F^{6}Li$	6.3275	0.0002	591
	$^{19}F^{7}Li$	6.3248	0.0002	
Thallium fluoride	$^{19}F^{205}Tl$	4.2282[b]	0.000001	397
	$^{19}F^{203}Tl$	4.2282	0.000001	
Lithium hydride	$^{1}H^{6}Li$	5.884	0.003	442
	$^{1}H^{7}Li$	5.882	0.003	
Carbon compounds:				
Trifluoromethane	$^{12}C^{1}H^{19}F_3$	1.6460	0.001	587
	$^{12}C^{2}H^{19}F_3$	1.6470[c]	0.001	
Fluoromethane	$^{12}C^{1}H_3{}^{19}F$	1.8471	0.001	587
	$^{12}C^{2}H_3{}^{19}F$	1.8583	0.001	
Methyl germane	$^{12}C^{1}H_3{}^{70}Ge^{1}H_3$	0.6425	0.001	587
	$^{12}C^{1}H_3{}^{74}Ge^{1}H_3$	0.6420	0.001	
	$^{12}C^{1}H_3{}^{70}Ge^{2}H_3$	0.6295	0.001	
	$^{12}C^{1}H_3{}^{74}Ge^{2}H_3$	0.6298	0.001	
	$^{12}C^{2}H_3{}^{70}Ge^{1}H_3$	0.6548	0.001	
	$^{12}C^{2}H_3{}^{74}Ge^{1}H_3$	0.6539	0.001	
Methyl silane	$^{12}C^{1}H_3{}^{28}Si^{1}H_3$	0.7351	0.001	587
	$^{12}C^{1}H_3{}^{28}Si^{2}H_3$	0.7236	0.001	
1,1-Difluoroethylene	$^{1}H_2{}^{12}C^{12}C^{19}F_2$	1.385	0.001	587
	$^{2}H_2{}^{12}C^{12}C^{19}F_2$	1.391	0.001	

APPENDIX II. *Isotopic dependence of dipole moment*—Continued

Compound	Isotopic species	Dipole moment (debyes)	Precision (debyes)	Reference
Propyne	$^{12}C^{1}H_3{}^{12}C^{12}C^{1}H$	0.781	0.001	587
	$^{12}C^{1}H_3{}^{12}C^{12}C^{2}H$	0.768	0.001	
	$^{12}C^{2}H_3{}^{12}C^{12}C^{1}H$	0.784	0.001	
	$^{12}C^{2}H_3{}^{12}C^{12}C^{2}H$	0.772	0.001	
Propane	$^{12}C^{1}H_3{}^{12}C^{1}H_2{}^{12}C^{1}H_3$	0.0848	0.001	
	$^{12}C^{1}H_3{}^{12}C^{2}H_2{}^{12}C^{1}H_3$	0.0948	0.001	
	$^{12}C^{2}H_3{}^{12}C^{1}H_2{}^{12}C^{2}H_3$	0.0758	0.001	
2-Methylpropane	$(^{12}C^{1}H_3)_3{}^{12}C^{1}H$	0.1320	0.0006	432
	$(^{12}C^{1}H_3)_3{}^{12}C^{2}H$	0.1406	0.0006	

[a] See also appendix I.

[b] $\mu(^{19}F^{203}Tl) - \mu(^{19}F^{205}Tl) = (33 \pm 3) \times 10^{-6}$ D.

[c] The direction of the isotope shift is felt to be significant.

8. Bibliography

1919

001 Jona, M.:
Physik. Z. **20**, 14–21 (1919).
002 Riegger, H.:
Ann. Physik. **59**, 753–60 (1919).

1921

003 Frivold, O.E.:
Physik. Z. **22**, 603–10 (1921).
004 Weigt, H.:
Physik. Z. **22**, 643 (1921).

1922

005 Falkenhagen, H.:
Physik. Z. **23**, 87 (1922).

1923

006 Frivold, O. E. and Hassel, O.:
Physik. Z. **24**, 82–6 (1923).

1924

007 Zahn, C. T.:
Phys. Rev. **24**, 400–17 (1924).

1925

008 Deleted.
009 Smyth, C. P. and Zahn, C. T.:
J. Am. Chem. Soc. **47**, 2501–6 (1925).

1926

010 Kliefoth, W.:
Z. Physik **39**, 402–14 (1926).
011 Sänger, R.:
Physik. Z. **27**, 165–74 (1926).
012 Sänger, R.:
Physik. Z. **27**, 556–63 (1926).
013 Zahn, C. T.:
Phys. Rev. **27**, 455–9 (1926).

1927

014 Sänger, R.:
Physik. Z. **28**, 455–7 (1927).
015 von Braunmühl, H.-J.:
Physik. Z. **28**, 141–9 (1927).
016 Watson, H. E.:
Proc. Roy. Soc. (London) **A117**, 43–62 (1927).
017 Wrede, E.:
Z. Physik **44**, 261–8 (1927).

1928

018 Estermann, I.:
Z. Physik. Chem. (Leipzig) **B1**, 161–9 (1928).
019 Forró, M.:
Z. Physik **47**, 430–45 (1928).
020 Höjendahl, K.:
"Studies of Dipole Moments," Thesis, Kopenhagen, 1928 (as referred to by *Landolt Bornstein Tabellen*, Parts 142061-3, 6 Auflage, 1951).
021 Mahanti, P. C. and Sen-Gupta, D. N.:
Indian J. Phys. **3**, 181–96 (1928).
022 Mahanti, P. C. and Sen-Gupta, D. N.:
J. Indian Chem. Soc. **5**, 673–81 (1928).
023 Sänger, R. and Steiger, O.:
Helv. Phys. Acta **1**, 369–84 (1928).
024 Sircar, S. C.:
Indian J. Phys. **3**, 197–208 (1928).
025 Stuart, H. A.:
Z. Physik **47**, 457–78 (1928).
026 Stuart, H. A.:
Z. Physik **51**, 490–510 (1928).
027 Zahn, C. T. and Miles, J. B.:
Phys. Rev. **32**, 497–504 (1928).

1929

028 Clark, R. J.:
Proc. Roy. Soc. (London) **A124**, 689–98 (1929).
029 Estermann, I.:
Leipziger Vorträge **17** (1929).
030 Estermann, I.:
Z. Physik. Chem. (Leipzig) **B2**, 287–8 (1929).
031 Ghosh, P. N., Mahanti, P. C. and Mukhergee, B. C.:
Z. Physik **58**, 200–4 (1929).
032 Ghosh, P. N., Mahanti, P. C. and Sen-Gupta, D. N.:
Z. Physik **54**, 711–4 (1929).
033 Miles, J. B.:
Phys. Rev. **34**, 964 (1929).
033a Sänger, R.:
Leipziger Vorträge **29**, 1 (1929).
034 Sänger, R. and Steiger, O.:
Helv. Phys. Acta **2**, 136–44 (1929).
035 Sänger, R. and Steiger, O.:
Helv. Phys. Acta **2**, 411–8 (1929).
036 Deleted.

1930

037 Fredenhagen, K. and Maske, F.:
Z. Physik. Chem. (Leipzig) **B10**, 142–8 (1930).
038 Fuchs, O.:
Z. Physik **63**, 824–48 (1930).
039 Deleted.
040 Keyes, F. G. and Kirkwood, J. G.:
Phys. Rev. **36**, 1570–5 (1930).
041 Kirkwood, J. G. and Keyes, F. G.:
Phys. Rev. **36**, 754 (1930).
042 Mahanti, P. C.:
Physik. Z. **31**, 546–55 (1930).
043 Sänger, R.:
Helv. Phys. Acta **3**, 162 (1930).
044 Sänger, R.:
Physik. Z. **31**, 306–15 (1930).
045 Schwingel, C. H. and Williams, J. W.:
Phys. Rev. **35**, 855–62 (1930).
046 Deleted.
047 Steiger, O.:
Helv. Phys. Acta **3**, 161 (1930).
048 Zahn, C. T.:
Phys. Rev. **35**, 848–54 (1930).
049 Zahn, C. T.:
Phys. Rev. **35**, 1047–55 (1930).

1931

050 Braune, H. and Asche, T.:
Z. Physik. Chem. (Leipzig) **B14**, 18–26 (1931).
051 Deleted.
052 Ghosh, P. N. and Chatterjee, T. P.:
Phys. Rev. **37**, 427–9 (1931).
053 Sänger, R.:
Physik. Z. **32**, 21–6 (1931).
054 Deleted.
055 Steiger, O.:
Physik. Z. **32**, 425 (1931).
056 Watson, H. E., Rao, G. G. and Ramaswamy, K. L.:
Proc. Roy. Soc. (London) **A132**, 569–85 (1931).
057 Zahn, C. T.:
Phys. Rev. **38**, 521–7 (1931).
058 Zahn, C. T.:
Phys. Rev. **37**, 1516–26 (1931).

1932

059 Greene, E. W. and Williams, J. W.:
Phys. Rev. **42,** 119–40 (1932).
060 Knowles, H. L.:
J. Phys. Chem. **36,** 2554–66 (1932).
061 Mizushima, S. and Higashi, K.:
Proc. Imp. Acad. (Tokyo) **8,** 482 (1932).
062 Sänger, R., Steiger, O. and Gächter, K.:
Helv. Phys. Acta **5,** 200–10 (1932).
063 Zahn, C. T.:
Phys. Rev. **40,** 291–8 (1932).
064 Zahn, C. T.:
Physik. Z. **33,** 525–30 (1932).
065 Zahn, C. T.:
Physik. Z. **33,** 686–7 (1932).
066 Zahn, C. T.:
Physik. Z. **33,** 730–1 (1932).

1933

067 Estermann, I. and Fraser, R. G. J.:
J. Chem. Phys. **1,** 390–9 (1933).
068 Estermann, I. and Wohlwill, M.:
Z. Physik. Chem. (Leipzig) **B20,** 195–208 (1933).
069 Deleted.
070 Deleted.
071 Deleted.
072 Grassi, U.:
Nuovo Cimento **10,** 3–20 (1933).
073 Luft, K. F.:
Z. Physik **84,** 767–82 (1933).
074 McAlpine, K. B. and Smyth, C. P.:
J. Am. Chem. Soc. **55,** 453–62 (1933).
075 Smyth, C. P. and McAlpine, K. B.:
J. Chem. Phys. **1,** 60–1 (1933).
076 Smyth, C. P. and McAlpine, K. B.:
J. Chem. Phys. **1,** 190–6 (1933).
077 Deleted.
078 Uhlig, H. H., Kirkwood, J. G. and Keyes, F. G.:
J. Chem. Phys. **1,** 155–9 (1933).
079 Deleted.
080 Wohlwill, M.:
Z. Physik **80,** 67–79 (1933).
081 Zahn, C. T.:
Physik. Z. **34,** 461–2 (1933).
082 Zahn, C. T.:
Physik. Z. **34,** 570–4 (1933).

1934

083 Czerlinsky, E.:
Z. Physik **88,** 515–21 (1934).
084 Groves, L. G. and Sugden, S.:
J. Chem. Soc. **1934,** 1094–8 (1934).
085 Deleted.
086 Scheffers, H.:
Physik. Z. **35,** 425–33 (1934).
087 Schwingel, C. H. and Greene, E. W.:
J. Am. Chem. Soc. **56,** 653–4 (1934).
088 Smyth, C. P. and McAlpine, K. B.:
J. Am. Chem. Soc. **56,** 1697–700 (1934).
089 Smyth, C. P. and McAlpine, K. B.:
J. Chem. Phys. **2,** 499–502 (1934).
090 Smyth, C. P. and McAlpine, K. B.:
J. Chem. Phys. **2,** 571–3 (1934).
091 Stranathan, J. D.:
Bull. Am. Phys. Soc. **9,** No. 2, 7, 10/4 (1934).
092 Stranathan, J. D.:
Phys. Rev. **45,** 741 (1934).
093 Deleted.
094 Watson, H. E., Rao, G. G. and Ramaswamy, K. L.:
Proc. Roy. Soc. (London) **A413,** 558–88 (1934).

1935

095 Braune, H. and Linke, R.:
Z. Physik. Chem. (Leipzig) **B31,** 12–17 (1935).
096 de Bruyne, J. M. A. and Smyth, C. P.:
J. Am. Chem. Soc. **57,** 1203–5 (1935).
097 Groves, L. G. and Sugden, S.:
J. Chem. Soc. **1935,** 971–4 (1935).
098 Kubo, M.:
Sci. Papers Inst. Phys. Chem. Res. (Tokyo) **26,** 242–57 (1935).
099 Kubo, M.:
Sci. Papers Inst. Phys. Chem. Res. (Tokyo) **27,** 65–73 (1935).
100 Mahanti, P. C.:
Phil. Mag. (7) **20,** 274–87 (1935).
101 McAlpine, K. B. and Smyth, C. P.:
J. Chem. Phys. **3,** 55–7 (1935).
102 Ramaswamy, K. L.:
Proc. Indian Acad. Sci., Sect. A, **2A,** 364–77 (1935).
103 Deleted.
104 Smyth, C. P. and McAlpine, K. B.:
J. Am. Chem. Soc. **57,** 979–83 (1935).
105 Smyth, C. P. and McAlpine, K. B.:
J. Chem. Phys. **3,** 347–50 (1935).
106 Stranathan, J. D.:
Phys. Rev. **48,** 538–44 (1935).

1936

107 Fraser, R. G. J. and Hughes, J. V.:
J. Chem. Phys. **4,** 730 (1936).
108 Kubo, M.:
Sci. Papers Inst. Phys. Chem. Res. (Tokyo) **29,** 122–8 (1936).
109 Kubo, M.:
Sci. Papers Inst. Phys. Chem. Res. (Tokyo) **29,** 178–87 (1936).
110 Kubo, M.:
Sci. Papers Inst. Phys. Chem. Res. (Tokyo) **30,** 169–79 (1936).
111 Kubo, M.:
Sci. Papers Inst. Phys. Chem. Res. (Tokyo) **30,** 238–43 (1936).
112 Niini, A.:
Ann. Acad. Sci. Fennicae, Ser. A. II, **A46,** 1 (1936).
113 Ramaswamy, K. L.:
Proc. Indian Acad. Sci., Sect. A, **4A,** 108–33 (1936).
114 Rodenbush, W. H., Murray, L. A. and Bixler, M. E.:
J. Chem. Phys. **4,** 372–6 (1936).
115 Watson, H. E., Kane, G. P. and Ramaswamy, K. L.:
Proc. Roy. Soc. (London) **A156,** 137–43 (1936).
116 Williams, J. W., Schwingel, C. H. and Winning, C. H.:
J. Am. Chem. Soc. **58,** 197–203 (1936).

1937

117 Grassi, U.:
Nuovo Cimento **14,** 461–73 (1937).
118 Groves, L. G. and Sugden, S.:
J. Chem. Soc. **1937,** 158–62 (1937).
119 Groves, L. G. and Sugden, S.:
J. Chem. Soc. **1937,** 1779–82 (1937).
120 Groves, L. G. and Sugden, S.:
J. Chem. Soc. **1937,** 1782–4 (1937).
121 Kubo, M.:
Sci. Papers Inst. Phys. Chem. Res. (Tokyo) **32,** 26–32 (1937).
122 Kubo, M., Morino, Y. and Mizushima, S.:
Sci. Papers Inst. Phys. Chem. Res. (Tokyo) **32,** 129–37 (1937).
123 Linke, R. and Rohrmann, W.:
Z. Physik. Chem. (Leipzig) **B35,** 256–60 (1937).
124 Deleted.
125 Ramaswamy, K. L.:
Proc. Indian Acad. Sci. **6,** 301 (1937).
126 Smits, A., Moerman, N. F. and Pathius, J. C.:
Z. Physik. Chem. (Leipzig) **B35,** 60–8 (1937).
127 Stranathan, J. D.:
J. Chem. Phys. **5,** 828–30 (1937).

1938

128 Bell, R. P. and Coop, I. E.:
Trans. Faraday Soc. **34**, 1209–14 (1938).
129 Brockway, L. O. and Coop, I. E.:
Trans. Faraday Soc. **34**, 1429–39 (1938).
130 Coop, I. E., Davidson, N. R. and Sutton, L. E.:
J. Chem. Phys. **6**, 905 (1938).
131 Coop, I. E. and Sutton, L. E.:
J. Chem. Soc. **1938**, 1269–86 (1938).
132 Coop, I. E. and Sutton, L. E.:
J. Chem. Soc. **1938**, 1869–72 (1938),
133 Fuoss, R. M.:
J. Am. Chem. Soc. **60**, 1633–7 (1938).
134 Deleted.
135 Hugill, J. A. C., Coop, I. E. and Sutton, L. E.:
Trans. Faraday Soc. **34**, 1518–34 (1938).
136 Krieger, F. J. and Wenzke, H. H.:
J. Am. Chem. Soc. **60**, 2115–9 (1938).
137 LeFèvre, R. J. W. and Russell, P.:
Nature **142**, 617 (1938).
138 Mizushima, S. and Kubo, M.:
Bull. Chem. Soc. Japan **13**, 174–81 (1938).
139 Schulz, R. W.:
Z. Physik **109**, 517–37 (1938).
140 Stranathan, J. D.:
J. Chem. Phys. **6**, 395–8 (1938).
141 Stranathan, J. D.:
Phys. Rev. **53**, 323 (1938).

1939

142 Baker, J. W. and Groves, L. G.:
J. Chem. Soc. **1939**, 1144–50 (1939).
143 Coop, I. E. and Sutton, L. E.:
Trans. Faraday Soc. **35**, 505–11 (1939).
144 Deleted.
145 Deleted.

1940

146 Hobbs, M. E., Jacokes, J. W. and Gross, P. M.:
Rev. Sci. Instr. **11**, 126–33 (1940).
147 Linke, R.:
Z. Physik. Chem. (Leipzig) **B46**, 251–60 (1940).
148 Linke, R.:
Z. Physik. Chem. (Leipzig) **B46**, 261–9 (1940).
149 Linke, R.:
Z. Physik. Chem. (Leipzig) **B48**, 193–6 (1940).
150 Smyth, C. P., Grossman, A. J. and Ginsberg, S. R.:
J. Am. Chem. Soc. **62**, 192–5 (1940).

1941

151 Bloom, G. I. M. and Sutton, L. E.:
J. Chem. Soc. **1941**, 727–42 (1941).
152 Deleted.
153 Maryott, A. A., Hobbs, M. E. and Gross, P. M.:
J. Am. Chem. Soc. **63**, 659–63 (1941).
154 Wiswall, R. H., Jr. and Smyth, C. P.:
J. Chem. Phys. **9**, 352 (1941).
155 Wiswall, R. H., Jr. and Smyth, C. P.:
J. Chem. Phys. **9**, 356–61 (1941).

1942

156 Hurdis, E. C. and Smyth, C. P.:
J. Am. Chem. Soc. **64**, 2212–6 (1942).
157 Hurdis, E. C. and Smyth, C. P.:
J. Am. Chem. Soc. **64**, 2829–34 (1942).
158 Watanabe, I., Mizushima, S. and Morino, Y.:
Sci. Papers Inst. Phys. Chem. Res. (Tokyo) **39**, 401–9

1943

159 Hannay, N. B. and Smyth, C. P.:
J. Am. Chem. Soc. **65**, 1931–4 (1943).
160 Hurdis, E. C. and Smyth, C. P.:
J. Am. Chem. Soc. **65**, 89–96 (1943).

1946

161 Coles, D. K. and Good, W. E.:
Phys. Rev. **70**, 979L (1946).
162 Dakin, T. W., Coles, D. K. and Good, W. E.:
Phys. Rev. **70**, 560 (1946).
163 Hannay, N. B. and Smyth, C. P.:
J. Am. Chem. Soc. **68**, 171–3 (1946).
164 Hannay, N. B. and Smyth, C. P.:
J. Am. Chem. Soc. **68**, 244–7 (1946).
165 Hannay, N. B. and Smyth, C. P.:
J. Am. Chem. Soc. **68**, 1005–8 (1946).
166 Hannay, N. B. and Smyth, C. P.:
J. Am. Chem. Soc. **68**, 1357–60 (1946).
167 Hughes, H. K.:
Phys. Rev. **70**, 570 (1946).
168 Townes, C. H.:
Phys. Rev. **70**, 665–71 (1946).

1947

169 Hughes, H. K.:
Phys. Rev. **72**, 614–23 (1947).
170 LeFèvre, R. J. W. and Russell, P.:
Trans. Faraday Soc. **43**, 374–93 (1947).

1948

171 Amphlett, C. B., Mallinger, L. W. and Thomas, L. F.:
Trans. Faraday Soc. **44**, 927–38 (1948).
172 Coles, D. K.:
Phys. Rev. **74**, 1194L (1948).
173 Crain, C. M.:
Phys. Rev. **74**, 691–3 (1948).
174 Golden, S., Wentink, T., Jr., Hillger, R. E. and Strandberg, M. W. P.:
Phys. Rev. **73**, 92–3 (1948).
175 Jelatis, J. G.:
J. Applied Phys. **19**, 419–25 (1948).
176 Oriani, R. A. and Smyth, C. P.:
J. Am. Chem. Soc. **70**, 125–30 (1948).
177 Smith, A. G., Ring, H., Smith, W. V. and Gordy, W.:
Phys. Rev. **74**, 370–2 (1948).
178 Strandberg, M. W. P.:
Phys. Rev. **74**, 1245 (1948).
179 Strandberg, M. W. P., Wentink, T., Jr., Hillger, R. E., Wannier, G. H. and Deutsch, M. L.:
Phys. Rev. **73**, 188 (1948).
180 Townes, C. H., Holden, A. N. and Merritt, F. R.:
Phys. Rev. **74**, 1113 (1948).
181 Townes, C. H., Merritt, F. R. and Wright, B. D.:
Phys. Rev. **73**, 1334–7 (1948).
182 van Itterbeek, A. and de Clippeleir, K.:
Physica **14**, 349–56 (1948).

1949

183 Deleted.
184 Bragg, J. K. and Sharbaugh, A. H.:
Phys. Rev. **75**, 1774–5 (1949).
185 Deleted.
186 Deleted.
187 Coles, D. K. and Hughes, R. H.:
Phys. Rev. **76**, 178 (1949).
188 Dailey, B. P., Mays, J. M. and Townes, C. H.:
Phys. Rev. **76**, 136–7 (1949).
189 Dailey, B. P., Mays, J. M. and Townes, C. H.:
Phys. Rev. **76**, 472 (1949).
190 Gilbert, D. A., Roberts, A. and Griswold, P. A.:
Phys. Rev. **76**, 1723 (1949).
191 Gilliam, O. R., Edwards, H. D. and Gordy, W.:
Phys. Rev. **75**, 1014–6 (1949).
192 Hughes, H. K.:
Phys. Rev. **76**, 1675–7 (1949).

193 Karplus, R. and Sharbaugh, A. H.:
Phys. Rev. **75**, 889, 1449 (1949).
194 Moore, E. M. and Hobbs, M. E.:
J. Am. Chem. Soc. **71**, 411–13 (1949).
195 Oriani, R. A. and Smyth, C. P.:
J. Chem. Phys. **17**, 1174–8 (1949).
196 Roberts, A. and Edgell, W. F.:
J. Chem. Phys. **17**, 742–3 (1949).
197 Strandberg, M. W. P.:
J. Chem. Phys. **17**, 901–4 (1949).
198 Strandberg, M. W. P., Pearsall, C. S. and Weiss, M. T.:
J. Chem. Phys. **17**, 429 (1949).
199 Strandberg, M. W. P., Wentink, T., Jr. and Hill, A. G.;
Phys. Rev. **75**, 827–32 (1949).
200 Strandberg, M. W. P., Wentink, T., Jr. and Kyhl, R. L.:
Phys. Rev. **75**, 270 (1949).
201 Thomas, J. R. and Gwinn, W. D.:
J. Am. Chem. Soc. **71**, 2785–90 (1949).
202 Townes, C. H., Shulman, R. G. and Dailey, B. P.:
Phys. Rev. **76**, 472 (1949).
203 Trischka, J. W.:
Phys. Rev. **76**, 1365–8 (1949).
204 Westenberg, A. A., Goldstein, J. H. and Wilson, E. B., Jr.:
J. Chem. Phys. **17**, 1319–21 (1949).

1950

205 Amble, E. and Dailey, B. P.:
J. Chem. Phys. **18**, 1422 (1950).
206 Barclay, G. A., LeFèvre, R. J. W. and Smythe, B. M.:
Trans. Faraday Soc. **46**, 812–20 (1950).
207 Beard, C. I. and Dailey, B. P.:
J. Chem. Phys. **18**, 1437–41 (1950), *errata* in J. Chem. Phys. **19**, 975 (1951).
208 Coles, D. K., Good, W. E. and Hughes, R. H.:
Phys. Rev. **79**, 224 (1950).
209 Epprecht, G. W.:
Z. Angew. Math. Phys. **1**, 138–47 (1950).
210 Grabner, L. and Hughes, V.:
Phys. Rev. **79**, 819–28 (1950).
211 Deleted.
212 LeFèvre, R. J. W., Mulley, J. W. and Smythe, B. M.:
J. Chem. Soc. **1950**, 290–5 (1950).
213 LeFèvre, R. J. W. and Smythe, B. M.:
J. Chem. Soc. **1950**, 276–83 (1950).
214 Lide, D. R., Jr. and Coles, D. K.:
Phys. Rev. **80**, 911 (1950).
215 Mays, J. M.:
Thesis, Columbia University, (New York, 1950).
216 Senatore, S. J.:
Phys. Rev. **78**, 293–4 (1950).
217 Sharbaugh, A. H., Pritchard, B. S., Thomas, V. G., Mays, J. M. and Dailey, B. P.:
Phys. Rev. **79**, 189 (1950).
218 Sharbaugh, A. H., Thomas, V. G. and Pritchard, B. S.:
Phys. Rev. **78**, 64–5 (1950).
219 Shulman, R. G., Dailey, B. P. and Townes, C. H.:
Phys. Rev. **78**, 145–8 (1950).
220 Deleted.
221 Shulman, R. G. and Townes, C. H.:
Phys. Rev. **77**, 421–2 (1950).
222 Shulman, R. G. and Townes, C. H.:
Phys. Rev. **77**, 500–6 (1950).
223 Smith, D. F., Tidwell, M. and Williams, D. V. P.:
Phys. Rev. **77**, 420–1 (1950).
224 Smith, D. F., Tidwell, M. and Williams, D. V. P.:
Phys. Rev. **79**, 1007–8 (1950).
225 Deleted.
226 Westenberg, A. A. and Wilson, E. B., Jr.:
J. Am. Chem. Soc. **72**, 199–200 (1950).

1951

227 Amble, E.:
Phys. Rev. **83**, 210 (1951).
227a Angyal, C. L., Barclay, G. A., Hukins, A. A. and LeFèvre, R. J. W.:
J. Chem. Soc. **1951**, 2583–8 (1951).
228 Barclay, G. A., LeFèvre, R. J. W. and Smythe, B. M.:
Trans. Faraday Soc. **47**, 357–65 (1951).
229 Burkhard, D. G. and Dennison, D. M.:
Phys. Rev. **84**, 408 (1951).
230 Coles, D. K., Good, W. E., Bragg, J. K. and Sharbaugh A. H.:
Phys. Rev. **82**, 877–8 (1951).
231 Crable, G. F. and Smith, W. V.:
J. Chem. Phys. **19**, 502 (1951).
232 Cunningham, G. L., Jr., Boyd, A. W., Myers, R. J., Gwinn W. D. and Le Van, W. I.:
J. Chem. Phys. **19**, 676–85 (1951).
233 Gibbs, J. H. and Smyth, C. P.:
J. Am. Chem. Soc. **73**, 5115–8 (1951).
234 Hillger, R. E. and Strandberg, M. W. P.:
Phys. Rev. **83**, 575–81 (1951).
235 Hollis, N. R. S. and McIntosh, R. L.:
Can. J. Chem. **29**, 494–7 (1951).
236 Hughes, R. H.:
Bull. Am. Phys. Soc. **26**, 21 (1951).
237 Lawrance, R. B. and Strandberg, M. W. P.:
Phys. Rev. **83**, 363–9 (1951).
238 Lide, D. R., Jr.:
J. Chem. Phys. **19**, 1605–6 (1951).
239 Loomis, C. C. and Strandberg, M. W. P.:
Phys. Rev. **81**, 798–807 (1951).
240 Lovering, W. F. and Wiltshire, L.:
Proc. Inst. Elec. Engrs. (London), Pt. II, **98**, 557 (1951)
241 Luce, R. G. and Trischka, J. W.:
Phys. Rev. **83**, 851–2 (1951).
242 Magnuson, D. W.:
J. Chem. Phys. **19**, 1071 (1951).
243 Magnuson, D. W.:
J. Chem. Phys. **19**, 1614 (1951).
244 Rogers, J. D., Pietenpol, W. J. and Williams, D.:
Phys. Rev. **83**, 431–4 (1951).
245 Shaw, T. M. and Windle, J. J.:
J. Chem. Phys. **19**, 1063–4 (1951).
246 Shoolery, J. N. and Sharbaugh, A. H.:
Phys. Rev. **82**, 95 (1951).
247 Shoolery, J. N., Shulman, R. G. and Sheehan, W. F., Jr.
J. Chem. Phys. **19**, 1364–9 (1951).
248 Shoolery, J. N., Shulman, R. G. and Yost, D. M.:
J. Chem. Phys. **19**, 250–1 (1951).
249 Sirvetz, M. H.:
J. Chem. Phys. **19**, 1609–10 (1951).

1952

250 Angyal, C. L. and LeFèvre, R. J. W.:
J. Chem. Soc. **1952**, 1651–3 (1952).
251 Barclay, G. A. and LeFèvre, R. J. W.:
J. Chem. Soc. **1952**, 1643–8 (1952).
252 Beard, C. I. and Bianco, D. R.:
J. Chem. Phys. **20**, 1488–9 (1952).
253 Birnbaum, G. and Chatterjee, S. K.:
J. Appl. Phys. **23**, 220–3 (1952).
254 Carlson, R. O., Lee, C. A. and Fabricand, B. P.:
Phys. Rev. **85**, 784–7 (1952).
255 Freeman, H. C., LeFèvre, R. J. W. and Maramba, F.:
J. Chem. Soc. **1952**, 1649–51 (1952).
256 Fristrom, R. M.:
J. Chem. Phys. **20**, 1 (1952), corrected in J. Chem. Phys. **26**, 734 (1957).
257 Ghosh, S. N., Trambarulo, R. and Gordy, W.:
Phys. Rev. **87**, 172 (1952).
258 Hawkins, N. J., Cohen, V. W. and Koski, W. S.:
J. Chem. Phys. **20**, 528 (1952).
259 Hrostowski, H. J. and Pimentel, G. C.:
J. Chem. Phys. **20**, 518 (1952).
260 Hughes, R. H.:
Phys. Rev. **85**, 717 (1952).
261 Johnson, H. R. and Strandberg, M. W. P.:
J. Chem. Phys. **20**, 687–95 (1952).
262 Lide, D. R., Jr.:
J. Am. Chem. Soc. **74**, 3548–52 (1952).
263 Lide, D. R., Jr.:
J. Chem. Phys. **20**, 1812–3 (1952).

264 Magnuson, D. W.:
J. Chem. Phys. **20**, 229–32 (1952).
265 Mays, J. M. and Dailey, B. P.:
J. Chem. Phys. **20**, 1695–702 (1952).
266 Myers, R. J. and Gwinn, W. D.:
J. Chem. Phys. **20**, 1420–7 (1952).
267 Smith, D. F. and Magnuson, D. W.:
Phys. Rev. **87**, 226 (1952).
268 Trischka, J. W.:
J. Chem. Phys. **20**, 1811–12 (1952).

1953

269 Andersen, F. A., Bak, B. and Rastrup-Andersen, J.:
Acta Chem. Scand. **7**, 643–51 (1953).
270 Buckingham, A. D., Harris, B. and LeFèvre, R. J. W.:
J. Chem. Soc. **1953**, 1626–7 (1953).
271 Buckingham, A. D. and LeFèvre, R. J. W.:
J. Chem. Soc. **1953**, 3432–5 (1953).
272 Buckingham, A. D. and LeFèvre, R. J. W.:
J. Chem. Soc. **1953** 4169–70 (1953).
273 Conradi, J. J. and Li, N. C.:
J. Am. Chem. Soc. **75**, 1785–8 (1953).
274 Fabricand, B. P., Carlson, R. O., Lee, C. A. and Rabi, I. I.:
Phys. Rev. **91**, 1403–8 (1953).
275 Ghosh, S. N., Trambarulo, R. and Gordy, W.:
J. Chem. Phys. **21**, 308–10 (1953).
276 Deleted.
277 Habgood, H. W.:
Dissertation Abstr. **13**, 296 (1953).
278 Harris, B., LeFèvre, R. J. W. and Sullivan, E. P. A.:
J. Chem. Soc. **1953**, 1622–6 (1953).
279 Hughes, R. H.:
J. Chem. Phys. **21**, 959–60 (1953).
280 Ivash, E. V. and Denninson, D. M.:
J. Chem. Phys. **21**, 1804 (1953).
281 Johnson, R. D., Myers, R. J. and Gwinn, W. D.:
J. Chem. Phys. **21**, 1425 (1953).
282 Lee, C. A., Fabricand, B. P., Carlson, R. O. and Rabi, I. I.:
Phys. Rev. **91**, 1395–403 (1953).
283 Lide, D. R., Jr.:
J. Chem. Phys. **21**, 571 (1953).
284 Luce, R. G. and Trischka, J. W.:
J. Chem. Phys. **21**, 105–9 (1953).
285 Sirvetz, M. H. and Weston, R. E., Jr.:
J. Chem. Phys. **21**, 898–902 (1953).
286 Trambarulo, R., Ghosh, S. N., Burrus, C. A. and Gordy, W.:
J. Chem. Phys. **21**, 851–5 (1953).
287 Tulinskie, A., DiGiacomo, A. and Smyth, C. P.:
J. Am. Chem. Soc. **75**, 3552–4 (1953).

1954

288 Buckingham, A. D., Holland, H. G. and LeFèvre, R. J. W.:
J. Chem. Soc. **1954**, 1646–8 (1954).
289 De More, B. B., Wilcox, W. S. and Goldstein, J. H.:
J. Chem. Phys. **22**, 876–7 (1954).
290 Ferguson, R. C.:
J. Am. Chem. Soc. **76**, 850–3 (1954).
291 Hardy, W. A. and Silvey, G.:
Phys. Rev. **95**, 385–8 (1954).
292 Deleted.
293 Honig, A., Mandel, M., Stitch, M. L. and Townes, C. H.:
Phys. Rev. **96**, 629–42 (1954).
294 Hrostowski, H. T. and Myers, R. J.:
J. Chem. Phys. **22**, 262–5 (1954).
295 Deleted.
296 Javan, A. and Engelbrecht, A.:
Phys. Rev. **96**, 649–58 (1954).
297 Kisliuk, P.:
J. Chem. Phys. **22**, 86–92 (1954).
298 LeFèvre, R. J. W. and Rao, D. A. A. S. N.:
Australian J. Chem. **7**, 135–45 (1954).
299 Lide, D. R., Jr.:
J. Chem. Phys. **22**, 1577–8 (1954).
300 Magnuson, D. W.:
"Microwave Dielectric Constant Measurements in Hydrogen Fluoride Vapor," Union Carbide Nuclear Co. (Oak Ridge, Tenn.), Aug. 9, 1954 (O. R. N. L. Rept. K1180), as reported in Kuipers, C. A., J. Mol. Spectry. **2**, 75 (1958).
301 Massey, J. T. and Bianco, D. R.:
J. Chem. Phys. **22**, 442–8 (1954).
302 Miyagawa, I.:
J. Chem. Soc. Japan, Pure Chem. Sect. **75**, 1162–5 (1954).
303 Miyagawa, I.:
J. Chem. Soc. Japan, Pure Chem. Sect. **75**, 1165–9 (1954).
304 Slayton, G. R., Simmons, J. W. and Goldstein, J. H.:
J. Chem. Phys. **22**, 1678–9 (1954).
305 Sterzer, F.:
J. Chem. Phys. **22**, 2094 (1954), corrected in J. Chem. Phys. **23**, 762 (1955).
306 Tate, P. A. and Strandberg, M. W. P.:
J. Chem. Phys. **22**, 1380–3 (1954).
307 Wilcox, W. S., Goldstein, J. H. and Simmons, J. W.:
J. Chem. Phys. **22**, 516–8 (1954).

1955

308 Barchukov, A. I., Minaeva, T. M. and Prokhorov, A. M.:
Zh. Eksperim. i Teor. Fiz. **29**, 892 (1955).
309 Braunstein, R. and Trischka, J. W.:
Phys. Rev. **98**, 1092–8 (1955).
310 Chau, J. Y. H. and LeFèvre, R. J. W.:
Australian J. Chem. **8**, 562–4 (1955).
311 Chiba, T.:
Bull. Chem. Soc. Japan **28**, 19–24 (1955).
312 Chiba, T.:
Bull. Chem. Soc. Japan **28**, 295–9 (1955).
313 Chiba, T.:
Bull. Chem. Soc. Japan **28**, 505–9 (1955).
314 DiGiacomo, A. and Smyth, C. P.:
J. Am. Chem. Soc. **77**, 747 (1955).
315 DiGiacomo, A. and Smyth, C. P.:
J. Am. Chem. Soc. **77**, 1361–4 (1955).
316 Deleted.
317 Fernandez, J., Myers, R. J. and Gwinn, W. D.:
J. Chem. Phys. **23**, 758–9 (1955).
318 Holland, R. S. and Smyth, C. P.:
J. Am. Chem. Soc. **77**, 268–71 (1955).
319 Howe, J. A. and Goldstein, J. H.:
J. Chem. Phys. **23**, 1223–5 (1955).
320 Kraitchman, J. and Dailey, B. P.:
J. Chem. Phys. **23**, 184–90 (1955).
321 LeFèvre, R. J. W. and Rao, D. A. A. S. N.:
Australian J. Chem. **8**, 140–2 (1955).
322 Madden, R. P. and Benedict, W. S.:
J. Chem. Phys. **23**, 408–9 (1955).
323 Massey, J. T. and Hart, R. W.:
J. Chem. Phys. **23**, 942 (1955).
324 Mockler, R. C. and Bird, C. R.:
Phys. Rev. **98**, 1837–9 (1955).
325 Rogers, M. T. and Pruett, R. D.:
J. Am. Chem. Soc. **77**, 3686–8 (1955).
326 Rogers, M. T., Pruett, R. D. and Speirs, J. L.:
J. Am. Chem. Soc. **77**, 5280–2 (1955).
327 Tuomikoski, P.:
J. Phys. Radium **16**, 347–8 (1955).

1956

328 Barchukov, A. I., Minaeva, T. and Prokhorov, A. M.:
Soviet Phys. JETP. (English Transl.) **2**, 760L (1956).
329 Buckingham, A. D., Chau, J. Y. H., Freeman, H. C., LeFèvre, R. J. W., Rao, D. A. A. S. N. and Tardif, J.:
J. Chem. Soc. **1956**, 1405–11 (1956).
330 Hughes, R. H.:
J. Chem. Phys. **24**, 131–8 (1956).
331 Jache, A. W., Moser, P. W. and Gordy, W.:
J. Chem. Phys. **25**, 209–10 (1956).
332 Deleted.
333 Kwak, N., Goldstein, J. H. and Simmons, J. W.:
J. Chem. Phys. **25**, 1203–5 (1956).

334 Laurie, V. W..
J. Chem. Phys. **24**, 635–6 (1956).
335 Lide, D. R., Jr. and Mann, D. E.:
J. Chem. Phys. **25**, 595 (1956).
336 Magnuson, D. W.:
J. Chem. Phys. **24**, 344–7 (1956).
337 Maryott, A. A. and Birnbaum, G.:
J. Chem. Phys. **24**, 1022–6 (1956).
338 Deleted.
339 Rogers, M. T., Pruett, R. D., Thompson, H. B. and Speirs, J. L.:
J. Am. Chem. Soc. **78**, 44–5 (1956).
340 Tannenbaum, E., Myers, R. J. and Gwinn, W. D.:
J. Chem. Phys. **25**, 42–7 (1956).
341 Trischka, J. W.:
J. Chem. Phys. **25**, 784–5 (1956).
342 Uenishi, R. K.:
Dissertation Abstr. **16**, 1327–8 (1956).

1957

343 Birnbaum, G.:
J. Chem. Phys. **27**, 360–8 (1957).
344 Boggs, J. E., Crain, C. M. and Whiteford, J. E.:
J. Phys. Chem. **61**, 482–4 (1957).
345 Chiba, T., Shimozawa, T., Miyagawa, I. and Morino, Y.:
Bull. Chem. Soc. Japan **30**, 223–7 (1957).
346 Gent, W. L. G.:
J. Chem. Soc. **1957**, 58–62 (1957).
347 Ishiguro, T., Chiba, T., and Gotoh, N.:
Bull. Chem. Soc. Japan **30**, 25–7 (1957).
348 Kilb, R. W., Lin, C. C. and Wilson, E. B., Jr.:
J. Chem. Phys. **26**, 1695–703 (1957).
349 Kilb, R. W. and Pierce, L.:
J. Chem. Phys. **27**, 108–12 (1957).
350 Kojima, T. and Nishikawa, T.:
J. Phys. Soc. Japan **12**, 680 (1957).
351 Kurland, R. J. and Wilson, E. B., Jr.:
J. Chem. Phys. **27**, 585–90 (1957).
352 La Rochelle, J. H.:
Dissertation Abstr. **17**, 46 (1957).
353 Laurie, V. W.:
J. Chem. Phys. **26**, 1359–62 (1957).
354 Lide, D. R., Jr.:
J. Chem. Phys. **27**, 343 (1957).
355 Lide, D. R., Jr., Mann, D. E. and Fristrom, R. M.:
J. Chem. Phys. **26**, 734–9 (1957).
356 Lide, D. R., Jr. and Mann, D. E.:
J. Chem. Phys. **27**, 868–73 (1957).
357 Lide, D. R., Jr. and Mann, D. E.:
J. Chem. Phys. **27**, 874–7 (1957).
358 Magnuson, D. W.:
J. Chem. Phys. **27**, 223–6 (1957).
359 Deleted.
360 Marshall, S. A. and Weber, J.:
Phys. Rev. **105**, 1502–6 (1957).
361 Maryott, A. A. and Kryder, S. J.:
J. Chem. Phys. **27**, 1221–2 (1957).
362 Miyagawa, I., Chiba, T., Ikeda, S. and Morino, Y.:
Bull. Chem. Soc. Japan **30**, 218–22 (1957).
363 Morino, Y., Miyagawa, I., Chiba, T. and Shimozawa, T.:
Bull. Chem. Soc. Japan **30**, 222–3 (1957).
364 Naylor, N. E., Jr. and Wilson, E. B., Jr.:
J. Chem. Phys. **26**, 1057–60 (1957).
365 Siegel, S.:
J. Chem. Phys. **27**, 989–90 (1957).
366 Deleted.
367 Swalen, J. D. and Herschbach, D. R.:
J. Chem. Phys. **27**, 100–8 (1957).
368 Veselago, V. G.:
Soviet Phys. JETP (English transl.) **5**, 513L (1957).
369 Veselago, V. G.:
Zh. Eksperim. i Teor. Fiz. **32**, 620 (1957).
370. Wagner, R., Fine, J., Simmons, J. W. and Goldstein, J. H.:
J. Chem. Phys. **26**, 634–7 (1957).

1958

371 Barchukov, A. I., Murina, T. M. and Prokhorov, A. M.:
Opt. i Spektroskopiya **4**, 521–3 (1958).
372 Barchukov, A. I. and Prokhorov, A. M.:
Opt. i Spektroskopiya **5**, 530–4 (1958).
373 Barchukov, A. I. and Prokhorov, A. M.:
Opt. i Spektroskopiya **4**, 799 (1958).
374 Barrett, A. H. and Mandel, M.:
Phys. Rev. **109**, 1572–89 (1958).
375 Burrus, C. A.:
J. Chem. Phys. **28**, 427–9 (1958).
376 Burrus, C. A. and Graybeal, J. D.:
Phys. Rev. **109**, 1553–6 (1958).
377 Cox, A. P., Thomas, L. F. and Sheridan, J.:
Nature **181**, 1000L (1958).
378 Erlandson, G. and Selén, H.:
Arkiv Fysik **14**, 61–4 (1958).
379 Fritsky, H. G.:
Z. Physik **151**, 351 (1958).
380 Gräff, G., Paul, W., and Schlier, Ch.:
Z. Physik **153**, 38 (1958).
381 Hirota, E., Oka, T. and Morino, Y.:
J. Chem. Phys. **29**, 444–5 (1958).
382 Lew, H., Morris, D., Geiger, F. E. and Eisinger, J. T.:
Can. J. Phys. **36**, 171–83 (1958).
383 Lide, D. R., Jr. and Mann, D. E.:
J. Chem. Phys. **28**, 572–6 (1958).
384 Lide, D. R., Jr. and Mann, D. E.:
J. Chem. Phys. **29**, 914–20 (1958).
385 Lotspeich, J. F.:
Dissertation Abstr. **19**, 340–1 (1958).
386 Millen, D. J. and Sinnott, K. M.:
J. Chem. Soc. **1958**, 350–5 (1958).
387 Pierce, L.:
J. Chem. Phys. **29**, 383–8 (1958).
388 Deleted.
389 Swalen, J. D. and Stoicheff, B. P.:
J. Chem. Phys. **28**, 671–4 (1958).
390 Veselago, V. G.:
Izv. Akad. Nauk SSSR Ser. Fiz. **22**, 1150–3 (1958).

1959

391 Beeson, E. L., Williams, Q. and Weatherly, T. L.:
Bull. Am. Phys. Soc. **4**, 291 (1959).
392 Burrus, C. A.:
J. Chem. Phys. **31**, 1270–2 (1959).
393 Clayton, L., Williams, Q. and Weatherly, T. L.:
J. Chem. Phys. **30**, 1328–34 (1959).
394 Curl, R. F., Jr.:
J. Chem. Phys. **30**, 1529–36 (1959).
395 de Kowalewski, D. G., Kökeritz, P. and Selén, H.:
J. Chem. Phys. **31**, 1438 (1959).
396 Eagle, D. F., Weatherly, T. L. and Williams, Q.:
J. Chem. Phys. **30**, 603–4 (1959).
397 Gräff, G.:
Z. Physik **155**, 433–40 (1959).
398 Kasai, P. H., Myers, R. J., Eggers, D. F., Jr. and Wiberg, K. B.:
J. Chem. Phys. **30**, 512–6 (1959).
399 Kökeritz, P. G. and Selén, H.:
Arkiv Fysik **16**, 197–8 (1959).
400 Krisher, L. C. and Wilson, E. B., Jr.:
J. Chem. Phys. **31**, 882–9 (1959).
401 Laurie, V. W.:
J. Chem. Phys. **30**, 1210–4 (1959).
402 Laurie, V. W.:
J. Chem. Phys. **31**, 1500–5 (1959).
403 Deleted.
404 Lide, D. R., Jr.:
Spectrochim. Acta **1959**, 473–6 (1959).
405 Lide, D. R., Jr. and Mann, D. E.:
J. Chem. Phys. **31**, 1129–30 (1959).
406 Lotspeich, J. F., Javan, A. and Engelbrecht, A.:
J. Chem. Phys. **31**, 633–43 (1959).

407 Maryott, A. A. and Kryder, S. J.:
J. Chem. Phys. **31**, 617–21 (1959).
408 Meschi, D. J. and Myers, R. J.:
J. Mol. Spectry. **3**, 405–16 (1959).
409 Pierce, L. and Krisher, L. C.:
J. Chem. Phys. **31**, 875–82 (1959).
410 Pierce, L. and O'Reilly, J. M.:
J. Mol. Spectry. **3**, 536–47 (1959).
411 Schafer, G. E.:
Dissertation Abstr. **19**, 2631 (1959).
412 Swalen, J. D. and Costain, C. C.:
J. Chem. Phys. **31**, 1562–74 (1959).
413 Tyler, J. K., Thomas, L. F. and Sheridan, J.:
Proc. Chem. Soc. **1959**, 155–6 (1959).
414 Veselago, V. G.:
Opt. i Spektroskopiya **6**, 450–7 (1959).

1960

415 Bhattacharya, B. N. and Gordy, W.:
Phys. Rev. **119**, 144–9 (1960).
416 Boggs, J. E. and Deam, A. P.:
J. Chem. Phys. **32**, 315–6 (1960).
417 Bransford, J. W., Kunkle, A. C. and Jache, A. W.:
J. Inorg. Nucl. Chem. **14**, 159–60 (1960).
418 Chan, S. I., Zinn, J., Fernandez, J., and Gwinn, W. D.:
J. Chem. Phys. **33**, 1643–55 (1960).
419 Dodd, R. E. and Little, R.:
Nature **188**, 737 (1960).
420 Favero, P. and Baker, J. G.:
Nuovo Cimento **17**, 734 (1960).
421 Green, G. W. and Lew, H.:
Can. J. Phys. **38**, 482–94 (1960).
422 Hirota, E. and Morino, Y.:
Bull, Chem. Soc. Japan **33**, 158–62 (1960).
423 Ilias, D. and Boudouris, G.:
Compt. Rend. **250**, 1833–5 (1960).
424 Irisova, N. A. and Dianov, E. M.:
Opt. Spectry. (USSR) (English transl.) **9**, 136A (1960).
425 Kasuya, T. and Oka, T.:
J. Phys. Soc. Japan **15**, 296–303 (1960).
426 Kivelson, D., Wilson, E. B., Jr. and Lide, D. R., Jr.:
J. Chem. Phys. **32**, 205–9 (1960).
427 Kojima, T.:
J. Phys. Soc. Japan **15**, 1284 (1960).
428 Kondo, K. and Oka, T.:
J. Phys. Soc. Japan **15**, 307 (1960).
429 Kwei, G. H. and Hershbach, D. R.:
J. Chem. Phys. **32**, 1270–1 (1960).
430 Le Blanc, O. H., Laurie, V. W. and Gwinn, W. D.:
J. Chem. Phys. **33**, 598–600 (1960).
431 Lide, D. R., Jr.:
J. Chem. Phys. **33**, 1514–8 (1960).
432 Lide, D. R., Jr.:
J. Chem. Phys. **33**, 1519–22 (1960).
433 Deleted.
434 Maryott, A. A. and Birnbaum, G.:
J. Phys. Chem. **64**, 1778 (1960).
435 Millen, D. J. and Morton, J. R.:
J. Chem. Soc. **1960**, 1523–8 (1960).
436 Petersen, D. H. and Pierce, L.:
Spectrochim. Acta **16**, 1272 (1960).
437 Pierce, L. and Petersen, D. H.:
J. Chem. Phys. **33**, 907–13 (1960).
438 Prokhorov, A. M. and Shipulo, G. P.:
Opt. Spectry. (USSR) (English transl.) **8**, 218–9 (1960).
439 Sheridan, J., Tyler, J. K., Aynsley, E. E. and Dodd, R. E.:
Nature 185, **96** (1960).
440 Tyler, J. K. and Sheridan, J.:
Proc. Chem. Soc. **1960**, 119–20 (1960).
441 Weatherly, T. L. and Williams, Q.:
Bull. Am. Phys. Soc. **5**, 228 (1960).
442 Wharton, L., Gold, L. P. and Klemperer, W.:
J. Chem. Phys. **33**, 1255 (1960).

1961

443 Deleted.
444 Barchukov, A. I. and Petrov, U. N.:
Opt. i Spektroskopiya **11**, 129 (1961).
444a Deleted.
445 Boggs, J. E. and Deam, A. P.:
J. Chem. Phys. **35**, 1178–80 (1961).
446 Buckingham, A. D. and Raab, R. E.:
J. Chem. Soc. **1961**, 5511–23 (1961).
447 Deleted.
448 Dixon, W. B. and Wilson, E. B., Jr.:
J. Chem. Phys. **35**, 191–8 (1961).
449 Hirota, E. and Morino, Y.:
Bull. Chem. Soc. Japan **34**, 341–8 (1961).
450 Johnson, R. C., Weatherly, T. L. and Williams, Q.:
Bull. Am. Phys. Soc. **6**, 270 (1961).
451 Johnson, R. C., Weatherly, T. L. and Williams, Q.:
J. Chem. Phys. **35**, 2261–2 (1961).
452 Kojima, T., Breig, E. L. and Lin, C. C.:
J. Chem. Phys. **35**, 2139–44 (1961).
453 Laurie, V. W.:
J. Chem. Phys. **34**, 291–4 (1961).
454 Laurie, V. W.:
J. Chem. Phys. **34**, 1516–9 (1961).
455 Meyer, R. T. and Myers, R. J.:
J. Chem. Phys. **34**, 1074–5 (1961).
456 Mirri, A. M., Gaurnieri, A. and Favero, P.:
Nuovo Cimento **19**, 1189–94 (1961).
457 O'Reilly, J. M. and Pierce, L.:
J. Chem. Phys. **34**, 1176–81 (1961).
458 Pierce, L.:
J. Chem. Phys. **34**, 498–506 (1961).
459 Pierce, L. and Hayashi, M.:
J. Chem. Phys. **35**, 479–85 (1961).
460 Pierce, L. and Jackson, R.:
J. Chem. Phys. **35**, 2240–1 (1961).
461 Deleted.
462 Ramsey, N. F.:
Amer. Scientist **49**, 509 (1961).
463 Rogers, M. T. and Canon, J. M.:
J. Phys. Chem. **65**, 1417–9 (1961).
464 Sage, M. L.:
J. Chem. Phys. **35**, 142–8 (1961).
465 Weiss, R. E.:
Thesis, Mass. Inst. of Tech. (Cambridge, Mass.), 1961.
466 Deleted.

1962

467 Bak, B., Christensen, D., Hansen-Nygaard, L. and Rastrup-Andersen, J.:
J. Mol. Spectry. **9**, 222 (1962).
468 Bak, B., Christensen, D., Hansen-Nygaard, L., Lipschitz, L. and Rastrup-Andersen, J.:
J. Mol. Spectry. **9**, 225 (1962).
469 Bak, B., Christensen, D., Hansen-Nygaard, L. and Rastrup-Andersen, J.:
Spectrochim. Acta **18**, 1421 (1962).
470 Beaudet, R. A. and Wilson, E. B. Jr.:
J. Chem. Phys. **37**, 1133–8 (1962).
471 Beeson, E. L., Weatherly, T. L. and Williams, Q.:
J. Chem. Phys. **37**, 2926 (1962).
472 Davidson, D. W.:
Can. J. Chem. **40**, 1721 (1962).
473 Flygare, W. H., Narath, A. and Gwinn, W. D.:
J. Chem. Phys. **36**, 200–8 (1962).
473a Gold, L. P.:
Thesis, Harvard Univ. (Cambridge, Mass.), 1962.
474 Graybeal, J. D. and Roe, D. W.:
J. Chem. Phys. **37**, 2503 (1962).
475 Hess, W. N., Mather, R. L. and Nobles, R. A.:
J. Chem. Eng. Data **7**, 317–9 (1962).
476 Hirota, E.:
J. Chem. Phys. **37**, 283 (1962).
477 Howe, J. A. and Flygare, W. H.:
J. Chem. Phys. **36**, 650–2 (1962).

478 Jackson, R. H.:
J. Chem. Soc. **1962,** 4585 (1962).

479 Kasuya, T.:
Sci. Papers Inst. Phys. Chem. Res. (Tokyo) **56,** No. 1, 1 (1962).

480 Kim, H., Keller, R. and Gwinn, W. D.:
J. Chem. Phys. **37,** 2748 (1962).

481 Kirchoff, W. H. and Wilson, E. B., Jr.:
J. Am. Chem. Soc. **84,** 334–6 (1962).

482 Deleted.

483 Laurie, V. W., Pence, D. T. and Jackson, R. H.:
J. Chem. Phys. **37,** 2995 (1962).

484 Levine, I. N.:
J. Mol. Spectry. **8,** 276–84 (1962).

485 Levine, I. N.:
Thesis, Harvard Univ. (Cambridge, Mass.), 1962.

486 Lide, D. R., Jr.:
J. Chem. Phys. **37,** 2074 (1962).

487 McLay, D. B. and Mann, C. R.:
Can. J. Phys. **40,** 61–73 (1962).

487a Mizushima, S.:
Advances in Molecular Spectroscopy, Proc. 3, 1167, International Meeting on Molecular Spectra (Pergamon Press, 1962).

487b Morino, Y., Oka, T., Kikuchi, Y., Matumura, C. and Saito, S.:
Symposium on Molecular Structure and Spectroscopy, Part C, 312 (Tokyo, 1962).

488 Mukhtarov, I. A.:
Izv. Akad. Nauk. Azerb. SSR, Ser. Fiz. Mat. i Tekhn. Nauk **No. 4,** 59 (1962).

489 Nugent, L. J., Mann, D. E. and Lide, D. R., Jr.:
J. Chem. Phys. **36,** 965–71 (1962).

490 Pierce, L. and Dobyns, V.:
J. Am. Chem. Soc. **84,** 2651–2 (1962).

491 Pillai, M. G. N.:
J. Phys. Chem. **66,** 178–80 (1962).

492 Rathjens, G. W.:
J. Chem. Phys. **36,** 2401–6 (1962).

493 Regnier, J. F. and Daum, A.:
Compt. Rend. **255,** 247 (1962).

493a Sheridan, J.:
Advances in Molecular Spectroscopy, Proc. 4, 139, International Meeting on Molecular Spectra (Pergamon Press, 1962).

494 Shipulo, G. P.:
Opt. i Spektroskopiya **13,** 593 (1962).

495 Shipulo, G. P.:
Opt. Spectry. (USSR) (English transl.) **13,** 335 (1962).

496 Sobolev, G. A., Shcherbakov, A. M. and Akishim, P. A.:
Opt. i Spektroskopiya **12,** 147 (1962).

497 Tarnawski, A.:
Monatsh. Chem. **93,** 600–5 (1962).

498 Tolles, W. M. and Gwinn, W. D.:
J. Chem. Phys. **36,** 1119–21 (1962).

499 van der Kelen, G. P.:
Bull. Soc. Chim. Belges **71,** 421 (1962).

500 Wharton, L., Kaufman, M. and Klemperer, W.:
J. Chem. Phys. **37,** 621 (1962).

1963

500a Bauder, A., Tank, F. and Gunthard, H. S.:
Helv. Chim. Acta **46,** 1453 (1963).

501 Bauer, R. K. and Lew, H.:
Can. J. Phys. **41,** 1461 (1963).

502 Beaudet, R. A.:
J. Chem. Phys. **38,** 2548 (1963).

503 Blukis, U., Kasai, P. H. and Myers, R. J.:
J. Chem. Phys. **38,** 2753 (1963).

504 Butcher, S. S.:
J. Chem. Phys. **38,** 2310 (1963).

504a Curl, R. F., Rao, V. M. Sastry, K. V. L. N. and Hodgeson, J. A.:
J. Chem. Phys. **39,** 3335 (1963).

505 Dobyns, V. and Pierce, L.:
J. Am. Chem. Soc. **85,** 3553–6 (1963).

506 Ehrenstein, G.:
Phys. Rev. **130,** 669 (1963).

507 Gray, P. and Pearson, M. J.:
Trans. Faraday Soc. **59,** 347 (1963).

508 Hodgeson, J. A., Sibert, E. E. and Curl, R. F., Jr.:
J. Phys. Chem. **67,** 2833–5 (1963).

509 Imanov, L. M. and Kadzhar, Ch. O.:
Opt. i Spektroskopiya **14,** 300 (1963).

510 Kuczkowski, R. L. and Wilson, E. B., Jr.:
J. Chem. Phys. **39,** 1030 (1963).

511 Larkin, M. and Gordy, W.:
J. Chem. Phys. **38,** 2329 (1963).

512 Lide, D. R., Jr.:
J. Chem. Phys. **38,** 2027 (1963).

513 Lide, D. R., Jr:
J. Chem. Phys. **38,** 456 (1963).

514 Muenter, J. S. and Laurie, V. W.:
J. Chem. Phys. **39,** 1181 (1963).

515 Mukhtarov, I. A.:
Dokl. Akad. Nauk SSSR **148,** 566 (1963).

516 Mukhtarov, I. A.:
Dokl. Akad. Nauk SSSR **151,** 1076–8 (1963).

517 Mukhtarov, I. A.:
Opt. i Spektroskopiya **14,** 728 (1963).

518 Mukhtarov, I. A.:
Opt. i Spektroskopiya **15,** 563 – 4 (1963).

519 Nelson, R.:
J. Chem. Phys. **39,** 2382–3 (1963).

520 Poynter, R. L.:
J. Chem. Phys. **39,** 1962 (1963).

521 Stiefvater, O. L. and Sheridan, J.:
Proc. Chem. Soc. **1963,** 368 (1963).

522 Tyler, J. K.:
J. Mol. Spectry. **11,** 39 (1963).

523 Tyler, J. K. and Sheridan, J.:
Trans. Faraday Soc. **59,** 2661 (1963).

524 Varma, R., MacDiarmid, A. G. and Miller, J. G.:
J. Chem. Phys. **39,** 3157–8 (1963).

525 Weiss, R.:
Phys. Rev. **131,** 659 (1963).

526 Wharton, L. and Klemperer, W.:
J. Chem. Phys. **38,** 2705 (1963).

527 Wharton, L., Klemperer, W., Gold, L. P., Strauch, R
Gallager, J. J. and Derr, V. E.:
J. Chem. Phys. **38,** 1203 (1963).

1964

527a Arnold, W., Dreizler, H. and Rudolph, H. D.:
Z. Naturforsch. **19a,** 1428 (1964).

528 Bauer, R. K. and Lew, H.:
Can. J. Phys. **42,** 830–1 (1964).

529 Beaudet, R. A.:
J. Chem. Phys. **40,** 2705 (1964).

530 Boggs, J. E., Coffey, D. and Davies, J. C., Jr.:
J. Phys. Chem. **68,** 2383–4 (1964).

531 Butcher, S. S. and Wilson, E. B., Jr.:
J. Chem. Phys. **40,** 1671–8 (1964).

532 Chan, S. I., Ikenberry, D. and Das, T. P.:
J. Chem. Phys. **41,** 2107 (1964).

532a Dreizler, H. and Dendl, G.:
Z. Naturforsch. **19a,** 512–14 (1964).

533 Esterowitz, L. and Rosenthal, J.:
J. Chem. Phys. **40,** 1986–7 (1964).

534 Freeman, D. E. and Klemperer, W.:
J. Chem. Phys. **40,** 604–5 (1964).

535 Hebert, A. J., Breivogel, F. W., Jr. and Street, K., Jr.:
J. Chem. Phys. **41,** 2368–76 (1964).

536 Hollowell, C. D., Hebert, A. J. and Street, K., Jr.:
J. Chem. Phys. **41,** 3540 (1964).

536a Kuczowski, R. L.:
J. Am. Chem. Soc., **86,** 3617 (1964).

537 Lide, D. R., Jr., Cahill, P. and Gold, L. P.:
J. Chem. Phys. **40,** 156–9 (1964).

538 Lide, D. R., Jr. and Jen, M.:
J. Chem. Phys. **40,** 252–3 (1964).

539 Meighan, R. M. and Cole, R. H.:
J. Phys. Chem. **68,** 503–8 (1964).

540 Muenter, J. S. and Laurie, V. W.:
J. Am. Chem. Soc. **86**, 3901–2 (1964).
541 Mukhtarov, I. A.:
Opt. i Spektroskopiya **16**, 360 (1964).
542 Oka, T., Tsuchiya, K., Iwata, S. and Morino, Y.:
Bull. Chem. Soc. Japan **37**, 4–7 (1964).
543 Powell, F. X. and Lide, D. R., Jr.:
J. Chem. Phys. **41**, 1413–19 (1964).
544 Rao, V. M. and Curl, R. F., Jr.:
J. Chem. Phys. **40**, 3688–90 (1964).
545 Sastry, K. V. L. N. and Curl, R. F., Jr.:
J. Chem. Phys. **41**, 77–80 (1964).
545a Deleted.
546 Tipton, A. B., Deam, A. P. and Boggs, J. E.:
J. Chem. Phys. **40**, 1144 (1964).
547 Tyler, J. K.:
J. Chem. Phys. **40**, 1170–1 (1964).
548 Varma, R., MacDiarmid, A. G. and Miller, J. G.:
Inorg. Chem. **3**, 1754 (1964).

1965

549 Beaudet, R. A.:
J. Chem. Phys. **42**, 3758 (1965).
550 Beaudet, R. A. and Poynter, R. L.:
J. Chem. Phys. **43**, 2166 (1965).
551 Boone, D. W., Britt, C. O. and Boggs, J. E.:
J. Chem. Phys. **43**, 1190 (1965).
552 Breivogel, F. W., Jr., Hebert, A. J. and Street, K., Jr.:
J. Chem. Phys. **42**, 1555 (1965).
553 Butcher, S. S.:
J. Chem. Phys. **42**, 1830 (1965).
554 Butcher, S. S.:
J. Chem. Phys. **42**, 1833 (1965).
555 Butcher, S. S. and Costain, C. C.:
J. Mol. Spectry. **15**, 40–50 (1965).
556 Cox, A. P. and Riveros, J. M.:
J. Chem. Phys. **42**, 3106 (1965).
557 Foster, P. D., Rao, V. M. and Curl, R. F., Jr.:
J. Chem. Phys. **43**, 1064 (1965).
558 Freund, R. S. and Klemperer, W.:
J. Chem. Phys. **43**, 2422 (1965).
559 Hayman, H. J. G. and Weiss, S.:
J. Chem. Phys. **42**, 3701 (1965).
560 Hirota, E.:
J. Chem. Phys. **42**, 2071 (1965).
561 Holmes, R. R. and Carter, R. P., Jr.:
J. Chem. Phys. **43**, 1645 (1965).
561a Huiszoon, C. and Dymanus, A.:
Physica **31**, 1049 (1965).
561b Irwin, T. A. R. and Dalby, F. W.:
Can. J. Phys. **43**, 1766 (1965).
562 Kaufman, M., Wharton, L. and Klemperer, W.:
J. Chem. Phys. **43**, 943–52 (1965).
563 Kim, H. and Gwinn, W. D.:
J. Chem. Phys. **42**, 3728 (1965).
564 Lide, D. R., Jr.:
J. Chem. Phys. **42**, 1013 (1965).
565 Lide, D. R., Jr.:
J. Chem. Phys. **43**, 3767–8 (1965).
566 Lindfors, K. R. and Cornwell, C. D.:
J. Chem. Phys. **42**, 149 (1965).
567 Maryott, A. A., Kryder, S. J. and Holmes, R. R.:
J. Chem. Phys. **43**, 2556–7 (1965).
567a Meighan, R. M.:
Dissertation Abstr. **25**, 4427 (1965).
567b Mukhtarov, I. A.:
Izv. Akad. Nauk. Azerb. SSR, Ser. Fiz. Tekhn., Mat. Nauk **1965**, 71 (1965).
568 Nakagawa, S., Takahashi, S., Kojima, T. and Lin, C. C.:
J. Chem. Phys. **43**, 3583–6 (1965).
568a Phelps, D. H. and Dalby, F. W.:
Can. J. Phys. **43**, 144 (1965).
569 Pierce, L., Nelson, R. and Thomas, C.:
J. Chem. Phys. **43**, 3423–41 (1965).
570 Powell, F. X. and Lide, D. R., Jr.:
J. Chem. Phys. **42**, 4201 (1965).
571 Rao, V. M., Curl, R. F., Jr., Timms, P. L. and Margrave, J. L.:
J. Chem. Phys. **43**, 2557 (1965).
572 Rao, V. M., Yardley, J. T. and Curl, R. F., Jr.:
J. Chem. Phys. **42**, 284 (1965).
573 Saegebarth, E. and Cox, A. P.:
J. Chem. Phys. **43**, 166 (1965).
574 Scharpen, L. H. and Laurie, V. W.:
J. Chem. Phys. **43**, 2765–6 (1965).
575 Tobler, H. J., Bauder, A. and Günthard, Hs. H.:
J. Mol. Spectry. **18**, 239–46 (1965).
576 Tolles, W. M., Handelman, E. T. and Gwinn, W. D.:
J. Chem. Phys. **43**, 3019 (1965).
577 White, M. S. and Beeson, E. L., Jr.:
J. Chem. Phys. **43**, 1839 (1965).

1966

578 Cox, A. P. and Varma, R.:
J. Chem. Phys. **44**, 2619 (1966).
579 Eagle, D. F., Weatherly, T. L. and Williams, Q.:
J. Chem. Phys. **44**, 847 (1966).
580 Krisher, L. C. and Norris, W. G.:
J. Chem. Phys. **44**, 391 (1966).
581 Thomas, E. C. and Laurie, V. W.:
J. Chem. Phys. **44**, 2602 (1966).
582 Bak, B., Nielsen, J. T., Nielsen, O. F., Nygaard, L., Rastrup-Andersen, J. and Steiner, P. A.:
J. Mol. Spectry. **19**, 458 (1966).
583 Dorius, K. L., Britt, C. O. and Boggs, J. E.:
J. Chem. Phys. **44**, 1352 (1966).
584 Freeman, D. E. and Klemperer, W.:
J. Chem. Phys. **45**, 52 (1966).
585 Freeman, D. E., Lombardi, J. R. and Klemperer, W.:
J. Chem. Phys. **45**, 58 (1966).
586 Kim, H. and Gwinn, W. D.:
J. Chem. Phys. **44**, 865 (1966).
587 Muenter, J. S. and Laurie, V. W.:
J. Chem. Phys. **45**, 855 (1966).
588 Powell, F. X. and Lide, D. R., Jr.:
J. Chem. Phys. **45**, 1067 (1966).
589 Salathiel, W. M. and Curl, R. F., Jr.:
J. Chem. Phys. **44**, 1288 (1966).
590 Bak, B., Christiansen, J. J., Kunstman, K., Nygaard, L. and Rastrup-Andersen, J.:
J. Chem. Phys. **45**, 883 (1966).
591 Hebert, A. J.:
Symposium on Molecular Structure and Spectroscopy, Ohio State University, 1966, Paper O–1.
592 Beers, Y. and Russell, T. W.:
IEEE Trans. on Instrumentation and Measurement **IM–15**, 380 (1966).
593 Lafferty, W. J. and Lide, D. R., Jr.:
Private communication.
594 Kirchhoff, W. H. and Lide, D. R., Jr.:
Private communication.
595 Frenkel, L., Smith, W. and Gallagher, J. J.:
J. Chem. Phys. **45**, 2251 (1966).

U.S. GOVERNMENT PRINTING OFFICE : 1967 OL—256-963