International Cooperation on Scientific Nomenclature*

K. L. LOENING
Chemical Abstracts Service, The Ohio State University, Columbus, Ohio 43210

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A brief history of inorganic, organic, bio-, and macromolecular chemical nomenclature is presented. Also, it is shown how these activities are coordinated with nomenclature efforts in other disciplines and various national programs. Suggestions for improving the system are given.

Exactness in communication is essential to effective progress in science, and a good system of nomenclature is a fundamental necessity for exact communication. While science has no nationality, scientists do. And every scientist shares a certain amount of responsibility for the language of his discipline—it is his duty to convey his ideas clearly and unambiguously to the best of his ability.

Obviously, the differences in nationality and language background of scientists represent important barriers to effective communication that must be overcome. Even in the same language the same word may have a number of different meanings. To cite just one example, in English we speak of hard rocks, hard water, and hard acids. In each instance the word "hard" signifies a different property. This is extremely confusing to the uninitiated and a nightmare for the translator. Such situations must be kept to a minimum.

Every science has its own nomenclature and associated nomenclature problems. Chemical nomenclature, to which the main part of this paper will be devoted, has one of the biggest tasks because of the enormous number of compounds already known and the many new ones being prepared each year. The total number of known compounds is variously estimated to be between 3 or 4 million.[1] It is true that chemists frequently communicate about compounds by means of structural formulas and diagrams without using any names at all. Nevertheless, in the over-all picture of chemical communication and documentation it is still necessary to refer to compounds by name. Systematic names, trivial names, trade names, acronyms, laboratory-code designations, etc. are all used for this purpose. It has long been recognized that a systematic nomenclature on an international basis is needed to establish a clear record of identity and continuity of chemical compounds used in research, commerce, and industry throughout the world.

Chemical nomenclature has evolved and continues to evolve in pace with the advancement of chemistry. At present, the development of unified international policies for chemical nomenclature is in the hands of nomenclature commissions of the International Union of Pure and Applied Chemistry (IUPAC) and the International Union of Biochemistry (IUB). Currently, all official nomenclature rules originating from IUPAC are written only in English. The English version then serves as a model from which versions in other languages are prepared. This paper presents some of the achievements and current efforts in international nomenclature in four specific areas of chemistry—inorganic chemistry, organic chemistry, biochemistry, and macromolecular chemistry—and discusses a few activities in other chemical fields.

INORGANIC CHEMISTRY

In contrast to organic chemistry, early developments in systematic inorganic nomenclature were all contributions by individuals. Full credit for making the first attempt toward a rational chemical nomenclature belongs to Guyton de Morveau.[2,3] His pioneer work led to the publication in 1787 of "Méthode de Nomenclature Chimique" by Guyton de Morveau, Lavoisier, Berthollet, and Fourcroy,[4] which is a landmark in the development of chemistry. This work was widely publicized by the use of its nomenclature in Lavoisier's "Traité Elémentaire de Chimie"[5] which appeared in 1789. The earlier chaotic practices were quickly replaced by the new system, the general plan of which is still followed today. Berzelius[6] extended and amplified the system and he adapted it to the Germanic languages. Early English practice followed either the direct translation from French or the Berzelius pattern, but the latter gradually displaced the former. Although the nomenclature system of Guyton de Morveau was designed particularly for oxygen compounds, it soon was recognized that other elements could play much the same role in many compounds as does oxygen in the familiar oxygen salts. These relationships received their maximum systematization in Franklin's concept of systems of compounds.[7-9] A few of the others who contributed to the development of inorganic nomenclature were Werner,[10] who approached the problem of naming ternary and higher-order compounds as complex compounds or coordination compounds; Stock,[11-14] who sought to correct many nomenclature difficulties by introducing the use of Roman numerals in parentheses to designate the oxidation state; and finally Ewens and Bassett,[15] who proposed that instead of the Roman numerals representing the state of oxidation of the central atom, the charge on the ion in Arabic numerals be given in parentheses.

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The first international commission on inorganic nomenclature was established in 1913 by the International Association of Chemical Societies, the precursor of IUPAC. Its efforts were brought to an abrupt end by World War I. Resumption of these efforts in 1921, then under IUPAC, led to a preliminary report written in 1926 by Delépine.[16] As the work of the commission progressed, there were several reports which were followed in 1940 by a comprehensive set of rules[17] that were received and widely followed. After World War II, work was resumed by the IUPAC Commission on the Nomenclature of Inorganic Chemistry. This resulted in the publication of the 1957 Rules,[18] which are the current basis for naming inorganic compounds. This document contains eight major sections dealing with names of elements, formulas and names for compounds in general, ions and radicals, crystalline phases of variable composition, salts and salt-like compounds, coordination compounds, and finally polymorphism.

The remarkable growth of inorganic chemistry during the last 10 years and the elucidation of structure of many inorganic compounds by means of modern techniques of instrumentation has required further nomenclature work in this field. The Commission on Inorganic Nomenclature has continued to expand the 1957 Rules with special attention given to such topics as nonstoichiometric compounds, boron compounds, and coordination compounds. This work will be updated with a revised and much expanded version of the earlier rules in late 1970. In addition, the Commission has issued proposals for the designation of absolute configuration of octahedral complexes,[19] and it is working very closely with its sister Commission on Organic Nomenclature in the area of organometallic compounds. The Commission, in conjunction with the Commission on Atomic Weights, continues to be involved in the question of names and symbols of new elements with the associated problem of establishing initial discovery. Finally, some other topics under discussion by the Commission are pi complexes, zeolites and molecular sieves, and collective names for groups of elements.

ORGANIC CHEMISTRY

Formal international efforts to systematize organic nomenclature began much earlier than those dealing with inorganic nomenclature. Every organic chemist has heard about the Geneva Conference held in 1892, in which 34 chemists from nine different countries participated and adopted the 62 resolutions known as the Geneva system.[20, 21] However, the Geneva rules found only partial acceptance. Furthermore, they were far from complete and related chiefly to aliphatic compounds. And, of course, they did not meet problems raised by subsequent discoveries. The next important step was the "Definitive Report of the Commission on the Reform of the Nomenclature of Organic Chemistry," which was adopted by the Commission and by the Council of the International Union of Chemistry in 1930 in Liège.[22-24] It should be pointed out that, while the Geneva rules recommended only one official name for each compound, this concept was abandoned at Liège and replaced by the idea of unifying existing practice as far as possible by eliminating objectionable names and guiding future naming along desirable lines. There is no necessity to go into further historical detail here, however, a series of excellent papers dealing with the history of organic nomenclature were written by Professor Verkade,[25] who is the present chairman of the IUPAC Commission on Organic Nomenclature.

After World War II the IUPAC Commission continued its work on the codification, revision, and extension of nomenclature rules for organic chemistry. In 1949 it published rules for naming organosilicon compounds as well as rules for radical names with an extended list of examples.[26] The Commission has continued to revise and expand the old definitive rules, and, to date, this has resulted in the following IUPAC documents: Section A, hydrocarbons; Section B, fundamental heterocyclic systems;[27] Section C, characteristic groups containing carbon, hydrogen, oxygen, nitrogen, halogen, sulfur, selenium, and/or tellurium;[28] and, most recently, on a tentative basis, Section E, stereochemistry.[29] At present, the Commission—with the cooperation of the Commission on Inorganic Nomenclature—is trying to complete its works on Section D. This section deals with organometallic compounds and related topics such as organophosphorus, organoboron, and organosilicon compounds.

Other subjects currently receiving attention by the Commission are chains and rings containing hetero atoms, new methods for general organic nomenclature, free radicals, terpenes, and expansion of the rules for stereochemistry. In addition, the Commission has worked very closely over the past few years with the IUPAC/IUB Commission on Biochemical Nomenclature in areas of common interest. This cooperation has resulted in the publication of nomenclature rules for steroids[30, 31] and cyclitols.[32] Joint documents on carbohydrate and carotenoid nomenclature are in preparation and are expected to be issued later this year. Nomenclature rules for other fields of natural products, such as alkaloids and porphyrins, are at the planning stage.

BIOCHEMISTRY

The nomenclature of biochemical compounds is in very large measure a part of organic nomenclature. Yet, it has its peculiar problems, arising partly from the fact that most biochemical compounds must be named before their chemical structure has been determined, and partly from the need for grouping them according to their biological function rather than their chemical class.

The IUPAC Commission on the Nomenclature of Biological Chemistry was established in 1921 along with Commissions for Organic Chemistry and Inorganic Chemistry. It was an active group and always worked closely with the corresponding Organic Commission. Early subjects of concern were carbohydrates (glucides), proteins, enzymes, and fats.[33] In recent times this Commission shared its work with a corresponding IUB Commission. This finally led to the establishment of a combined Commission on Biochemical Nomenclature in 1964.

Since its establishment, the IUPAC/IUB Commission has published 10 sets of tentative rules dealing with the following topics: trivial names,[34] quinones with isoprenoid side chains,[35] folic acid and related compounds,[36] abbreviations and symbols,[37] corrinoids,[38] lipids,[39] and amino acids and peptides.[40-43] In addition to these, there are publications on steroid and cyclitol nomenclature that were issued

jointly with the Commission on Organic Nomenclature, as already mentioned. All these rules are being revised and expanded on a continuing basis.

Other documents in preparation deal with nucleic acids, polynucleotides, vitamin B_6 compounds, conformation of polypeptide chains, and mucopolysaccharides. The Commission is also in the process of updating and expanding the earlier rules for naming enzymes; these rules were developed by a special IUB Commission and published in 1964.[44]

MACROMOLECULAR CHEMISTRY

At present there does not exist any universally accepted systematic nomenclature for polymers. The first attempt to devise and promulgate such a nomenclature, based on the smallest structural repeating unit, was made in 1951 by a Subcommission on Nomenclature of the IUPAC Commission on Macromolecules.[45] The report of this Subcommission covers not only the naming of polymers, but also symbology and definitions. It must be pointed out, however, that the nomenclature recommendations in this report have not received any widespread acceptance.

The 1951 report was followed in 1965 by a report on nomenclature dealing with steric regularity in high polymers.[46] The reason for the long-time interval between these two reports is that this Subcommission was not a standing group but was only reconvened for new business.

In 1967, when the new IUPAC Macromolecular Division was created, it was recognized immediately that a more permanent group was needed to work on macromolecular nomenclature. Consequently, a Commission on Macromolecular Nomenclature was established, which operates in parallel to the other IUPAC nomenclature commissions. Since this Commission is so new, it has not yet published any documents; however, it is presently studying systematic definitions of terms used in polymer science and a new systematic nomenclature for polymers that is based on the structural repeating unit and is more closely related to organic nomenclature practice. The Commission is also taking another look at stereochemical designations for high polymers. Finally, it plans to publish its own list of approved codes and abbreviations for common polymers in view of its objection to certain abbreviations contained in a list recently published by the Plastics and High Polymers Section of the IUPAC Division of Applied Chemistry.[47]

OTHER IUPAC NOMENCLATURE ACTIVITIES

The IUPAC Divisions of Analytical and Physical Chemistry also have nomenclature commissions. In addition, there are other commissions within these two divisions that issue reports on nomenclature, symbols, units, and standards. Recent publications by some of these groups include "Nomenclature, Symbols, Units and their Usage in Spectrochemical Analysis,"[48] "Catalog of Physicochemical Standard Substances,"[49] "Manual of Definitions, Terminology and Symbols in Colloid and Surface Chemistry,"[50] "Recommendations for the Presentation of NMR Data for Publication in Chemical Journals,"[51] and "Recommendations on Ion-Exchange Nomenclature."[52] A revision of the important 1960 "Manual of Physico-Chemical Symbols and Terminology,"[53] has been completed and will be published soon.

The IUPAC Interdivisional Nomenclature Committee should also be mentioned; this group is composed of the chairmen of the various nomenclature commissions. They exchange information and arrange for cooperative efforts and close liaison by such means as the exchange of observers.

Last year at Cortina d'Ampezzo, IUPAC established an Interdivisional Committee on Machine Documentation in the chemical field. While this Committee only met for the first time in early May, undoubtedly it will examine chemical nomenclature from the point of view of computer handling of chemical information.

COOPERATION WITH OTHER INTERNATIONAL NOMENCLATURE ACTIVITIES

Like chemistry, every other science is represented on the international scene by some type of organization. In addition, there are many international bodies that are mission oriented. There is, of course, a great deal of interaction and cooperation, both formal and informal, between all these groups and IUPAC. This is also true at the nomenclature level when there happen to be topics of common interest. To give a complete list of such cooperative undertakings is almost impossible. However, a few examples are cited below.

> At present, members of the International Mineralogical Association and the International Union of Crystallography (IUCr) are cooperating with members of the IUPAC Commission on Inorganic Nomenclature in the development of a nomenclature for zeolites and molecular sieves.
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> Appropriate committees of the Internation Union of Pure and Applied Physics (IUPAP) and the International Standards Organization (ISO) have maintained close liaison with the corresponding IUPAC Commission in the recent revision and updating of the "Manual of Physico-Chemical Symbols and Terminology."[53]
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> In the field of vitamin nomenclature the International Union of Nutritional Sciences (IUNS) was invited by the IUPAC/IUB Commission on Biochemical Nomenclature to present its views and has done so.[54]
>
> Some members of the IUPAC Commission on Organic Nomenclature assist the World Health Organization (WHO) in its program of establishing international nonproprietary names for pharmaceuticals.[55] They supply the systematic chemical names and check the proposed nonproprietary names for conflict with good chemical nomenclature practice.

COORDINATION WITH NOMENCLATURE ACTIVITIES IN THE UNITED STATES

Coordination between nomenclature activities of IUPAC and those of national organizations is essential. The IUPAC national adhering organizations are charged with this responsibility. In the United States the National Academy of Sciences–National Research Council (NAS–NRC) is this organization and serves as the official link between IUPAC and ACS. As part of this mission NAS-NRC established the Office of Biochemical Nomenclature (OBN) in 1965. OBN fulfills the coordinating function in the area of biochemical nomenclature, it seeks to stimu-

late new activities as deemed desirable, and it disseminates information to any interested party.[56]

In other areas of chemistry the principal nomenclature effort in the United States is created in the ACS through its Committee on Nomenclature and the several Divisional Nomenclature Committees. Very close contact between these committees and corresponding IUPAC commissions is being maintained not only through the official channels but also informally by direct exchange of ideas and information. Representative of the ACS contribution to the IUPAC nomenclature efforts are three recent ACS Council approved nomenclature reports, which are the basis of corresponding IUPAC documents now being drafted. These reports deal with the nomenclature of boron compounds,[57] carbohydrates,[58] and polymers.[59]

SOME OTHER CHANNELS OF COMMUNICATION

There is another kind of international cooperation that must be remembered. It is natural for countries sharing the same language to work closely together. Thus, the Chemical Society (London) and the ACS have long cooperated in the field of chemical nomenclature. Mention of this cooperation can be found as early as 1882;[60] in recent times, the Anglo-American Rules for Phosphorus Nomenclature[61] and Carbohydrate Nomenclature[58] are a testimonial to this continuing cooperation. Also noteworthy is the collaboration between the Society of Dyers and Colourists in Great Britain and the American Association of Textile Chemists and Colorists in producing the "Colour Index."[62] Another example of cooperation is that between Canada and the United States in the area of names for pesticides. Canada is represented on the Committee K62 of the American National Standards Institute (ANSI) by Robert E. Carson of the Canadian Standards Association and the Canadian Department of Agriculture.

Important nomenclature symposia with international participation were held in New York in 1951[63] and in Columbus, Ohio, in 1961 in connection with general IUPAC meetings in North America.

Finally, all these channels of communication are, of course, reinforced by informal meetings and correspondence between individuals. In this vein it should be pointed out that the Nomenclature Division at Chemical Abstracts Service answers over a thousand nomenclature queries a year from every part of the world.

FINAL COMMENTS

The development of international nomenclature is rather complex, as is evident from what has been said. Nevertheless, on the whole, the system operates quite well. Naturally, there is always room for improvement, and along that line the following remarks may be helpful.

In science, nomenclature frequently does not follow quickly enough the technical advances. In this age of rapid scientific progress this time lag must be reduced. It should be pointed out that almost all nomenclature work is carried out by volunteers—important men who are busy with many other tasks. An increase in financial support would help to bring about more timely nomenclature recommendations and rules. There is also room for improvement in the dissemination of nomenclature material. IUPAC has recently changed its publication procedure, and this should help. Finally, too often nomenclature rules are stated without an explanation on how or why they were decided upon, even though an extensive debate may have preceded their formulation and adoption. It would be helpful if more of this kind of background material would be presented along with the official rules.

LITERATURE CITED

(1) Tate, Fred A., "Progress Toward a Computer-Based Chemical Information System," *Chem. Eng. News*, **45**, 78–90 (1967).

(2) Guyton de Morveau, L. B., *Ann. Chim. Phys.* [1] **25**, 205 (1789).

(3) Guyton de Morveau, L. B., *J. Physique* **19**, 310 382 (1782).

(4) Guyton de Morveau, L. B., A. L. Lavoisier, C. L. Bertholet, and A. F. Fourcroy, "Méthode de Nomenclature Chimique," Paris, 1787; English trans. by G. Pearson, 2nd. ed., London, 1799.

(5) Lavoisier, Antoine Laurent, "Traité Élémentaire de Chimie," 2 Vols. Paris, 1789; English trans. by Robert Kerr, 1806.

(6) Berzelius, J. J., *J. Phys.* **73**, 258 (1811).

(7) Franklin, Edward C., "The Ammonia System of Acids, Bases and Salts," *Am. Chem. J.* **47**, 285–317 (1912).

(8) Franklin, Edward C., "The Nitrogen System of Compounds," Reinhold, New York, 1935.

(9) Franklin, Edward C., "Systems of Acids, Bases and Salts," *J. Amer. Chem. Soc.* **46**, 2137–51 (1924).

(10) Werner, A., "Neuere Anschauungen auf dem Gebiete der Anorganischen Chemie," 3rd ed., pp. 92–5, Vieweg, Braunschweig, 1913.

(11) Ohman, O., "Der Wert der Stockschen Nomenklatur für den Chemieunterricht nebst Bermerkungen zur Namengebung der Element-Symbol," *Z. Angew. Chem.* **33**(1), 326–7 (1920).

(12) Remy, H., "Rules for Naming Inorganic Compounds," Committee for the Reform of the Nomenclature of Inorganic Chemistry, International Union of Chemistry, 64 pp.

(13) Rosenheim, A., *Z. Angew. Chem.* **33**, 78–79 (1920).

(14) Stock, Alfred, "Einige Nomenklaturfragen der Anorganischen Chemie," *Z. Angew. Chem.* **32**(1), 373–4 (1919).

(15) Ewens, R. V. S., and H. Bassett, "Inorganic Chemical Nomenclature," *Chem. Ind.* **1949**, 131–9

(16) Delépine, Marcel, "Revision of Inorganic Chemical Nomenclature," *Chem. Weekblad.* **23**(6), 86–93 (1926) (Eng.). Published in French in *Bull. Soc. Chim.* **43**, 289–300 (1928) and *Rec. Trav. Chim.* **48**, 652–63 (1929); published in Italian in *Gazz. Chim. Ital.* **58**, 883–91 (1928).

(17) Jorissen, W. P., H. Bassett, A. Damiens, F. Fichter, and H. Remy, "Rules for Naming Inorganic Compounds. Report of the Committee of the International Union of Chemistry for the Reform of Inorganic Chemical Nomenclature, 1940," *J. Amer. Chem. Soc.* **63**, 889—97 (1941). Aslo published in *J. Chem. Soc.* **1940**, 1404–15. Published in German in *Ber.* **A73**, 53–70 (1940).

(18) International Union of Pure and Applied Chemistry, Inorganic Chemistry Section, Commission on the Nomenclature of Inorganic Chemistry, "Definitive Rules for Nomenclature of Inorganic Chemistry 1957," 93 pp., Butterworths, London, 1959. [An American version with comments was published in *J. Amer. Chem. Soc.* **82**, 5523–44 (1969). Extensions to these rules (in English) appear in *Compt. Rend. of IUPAC's 22nd International Conference*, pp. 207–11, and of the *23rd Conference*, pp. 183–7.]

(19) International Union of Pure and Applied Chemistry, Inorganic Chemistry Division, Commission on the Nomenclature of Inorganic Chemistry, "Tentative Proposals for Nomenclature of Absolute Configurations Concerned with Six-

Coordinated Complexes Based on the Octahedron," *Inorg. Chem.* **9**(1), 1–5 (1970).

(20) Pictet, Amé, "Le Congrès International de Genève pour la Réforme de la Nomenclature Chimique," *Arch. Sci. Phys. Nat.* [3] **27**, 485–520 (1892).

(21) Tiemann, Ferd, "Ueber die Beschlüsse des Internationalen, in Genf vom 19. bis 22. April 1892 versammelten Congresses zur Regelung der chemischen Nomenclatur," *Ber.* **26**, 1595–1631 (1893).

(22) International Union of Chemistry, Commission on the Reform of the Nomenclature of Organic Chemistry, "Definitive Report," Liège Meeting, 1930. [Translation with comments by Austin M. Patterson, *J. Amer. Chem. Soc.* **55**, 3905–25 (1933). Published in French or German in *Ber. Deut. Chem. Ges.* **A65**, 11–20 (1932); *Bull. Soc. Chim.* [4], **45**, 973–82 (1929); *Rec. Trav. Chim.* **48**, 641–51 (1929); *Helv. Chim. Acta.* **14**, 868–75 (1931); also in *J. Chem. Soc.* **1931**, 1607–16 (Eng.).]

(23) International Union of Chemistry, Commission on the Reform of the Nomenclature of Organic Chemistry, "Full Text of the New Organic Nomenclature Rules," Reported by Austin M. Patterson, *Science* **87**, 215–6 (1938). [Rules 34 and 49 are given in full.]

(24) Verkade, P. E., "La Revision Récente de la Nomenclature des Combinaisons Organiques," *Rec. Trav. Chim.* **51**(2), 185–217 (1932).

(25) Verkade, P. E., "Études Historiques sur la Nomenclature de la Chimie Organique. I. La Naissance de la Nomenclature de Genève (1892) et des Propositions de Nomenclature de Saint-Étienne (1897) et la Litterature Afférente," *Bull. Soc. Chim. Fr.* **1966**(6), 1807–12. II. Le Développement de la Nomenclature de Chimie Organique Pendant la Période de 1889–1897. *Ibid.*, **1967**(11), 4009–20. III. Faits et Évenéments Relatifs à la Nomenclature de la Chimie Organique Pendent la Période 1897–1911. *Ibid.*, **1968** (4), 1358–67. IV. L'Activité de l'Association Internationale de Sociétés Chimiques Dans le Domaine de la Nomenclature de la Chimie Organique, 1911–1914. *Ibid.*, **1969**(11), 3877–81. V. Activités Individuelles Danes le Domaine de la Nomenclature de la Chimie Organique Pendant la Période de 1914–1930. *Ibid.*, **1969** (12), 4297–308.

(26) International Union of Pure and Applied Chemistry, Organic Chemistry Division, Commission on the Nomenclature of Organic Chemistry, "Changes and Additions to the Definitive Report," Liège Meeting 1930, *Compt. Rend. Conf. Union Intern. Chim. Pure Appl. 15th.*, Amsterdam **1949**, 132–85.

(27) International Union of Pure and Applied Chemistry, Organic Chemistry Division, Commission on the Nomenclature of Organic Chemistry, "Nomenclature of Organic Chemistry 1957, Definitive Rules for Section A. Hydrocarbons; Section B. Fundamental Heterocyclic Systems," 2nd. ed., pp. 1–70, Butterworths, London, 1966. [An American version with comments was published in *J. Amer. Chem. Soc.* **82**, 5545–74 (1960).]

(28) International Union of Pure and Applied Chemistry, Organic Chemistry Division, Commission on the Nomenclature of Organic Chemistry. "Nomenclature of Organic Chemistry 1965, Definitive Rules for Section C. Characteristic Groups Containing Carbon, Hydrogen, Oxygen, Nitrogen, Halogen, Sulfur, Selenium, and/or Tellurium," 260 pp., Butterworths, London, 1965. [Also published in *Pure Appl. Chem.* **11**(1–2), 1–260 (1965).]

(29) International Union of Pure and Applied Chemistry, Organic Chemistry Division, Commission on the Nomenclature of Organic Chemistry, "Nomenclature of Organic Chemistry. Tentative Rules for Section E. Fundamental Stereochemistry," *Biochim. Biophys. Acta* **208**(1), 1–44 (1970).

(30) International Union of Pure and Applied Chemistry, Commissions on the Nomenclature of Organic Chemistry and the Nomenclature of Biological Chemistry, "Definitive Rules for Nomenclature of Steroids," in "Nomenclature of Organic Chemistry," 1957, 2nd ed., p. 71–83, Butterworths, London, 1966. [Also published in *J. Amer. Chem. Soc.* **82**, 5577–81 (1960). (These rules have been updated by the IUPAC-IUB Commission on Biochemical Nomenclature).]

(31) International Union of Pure and Applied Chemistry, Organic Chemistry Division, Commission on the Nomenclature of Organic Chemistry and the IUPAC-IUB Commission on Biochemical Nomenclature, "IUPAC-IUB 1967 Revised Tentative Rules for Steroid Nomenclature," *Biochemistry* 8(6), 2227–42 (1969); *Biochim. Biophys. Acta* **164**(3), 453–86 (1968); *Eur. J. Biochem.* **10**(1), 1–19 (1969); *J. Org. Chem.* **34**(6), 1517–32 (1969); *Steroids* **13**(3), 277–310 (1969).

(32) International Union of Pure and Applied Chemistry, Organic Chemistry Division, Commission on the Nomenclature of Organic Chemistry and the IUPAC-IUB Commission on Biochemical Nomenclature, "Cyclitol Nomenclature," *Arch. Biochem. Biophys.* **128**(1), 269–79 (1968); *Biochem. J.* **112**(1), 17–28 (1969); *Biochim. Biophys. Acta* **165**(1), 1–21 (1968); *Eur. J. Biochem.* **5**, 1–21 (1968); *Hoppe-Seyler's Z. Physiol. Chem.* **350**(5), 523–35 (1969); *J. Biol. Chem.* **243**(22), 2809–19 (1968).

(33) Courtois, J. E., "Work of Commission on Nomenclature of Biological Chemistry," in "Chemical Nomenclature," ACS, Washington, D. C., 1953, pp. 83–94. (*Advan. Chem. Ser.* No. 8).

(34) International Union of Pure and Applied Chemistry and International Union of Biochemistry, IUPAC-IUB Commission on Biochemical Nomenclature, "Trivial Names of Miscellaneous Compounds of Importance in Biochemistry," *Arch. Biochem. Biophys.* **118**(3), 505–7 (1967); *Biochem. J.* **102**, 15–16 (1967); *Biochim. Biophys. Acta* **107**, 1–4 (1965); *J. Biol. Chem.* **241**(13), 2987–8 (1966).

(35) International Union of Pure and Applied Chemistry and International Union of Biochemistry, IUPAC-IUB Commission on Biochemical Nomenclature, "Nomenclature of Quinones with Isoprenoid Side-Chains," *Arch. Biochem. Biophys.* **118**(3), 507–11 (1967); *Biochem. J.* **102**(1), 17–19 (1967); *Biochim. Biophys. Acta* **107**, 5–10 (1965); *J. Biol. Chem.* **241**(13), 2989–91 (1966).

(36) International Union of Pure and Applied Chemistry and International Union of Biochemistry, IUPAC-IUB Commission on Biochemical Nomenclature, "Nomenclature and Symbols for Folic Acid and Related Compounds," *Arch. Biochem. Biophys.* **118**(3), 511–3 (1967); *Biochem. J.* **102**(1), 19–20 (1967). *Biochim. Biophys. Acta* **107**, 11–13 (1965). *J. Biol. Chem.* **241**, 2991–2 (1966).

(37) International Union of Pure and Applied Chemistry and International Union of Biochemistry, IUPAC-IUB Commission on Biochemical Nomenclature, "Abbreviations and Symbols for Chemical Names of Special Interest in Biological Chemistry," *Arch. Biochem. Biophys.* **129**(1), 1–12 (1969); *Arch. Biochem. Biophys.* **115**(1), 1–12 (1966); *Biochemistry* **5**, 1445 (1966); *Biochem. J.* **101**, 1–7 (1966); *Biochim Biophys. Acta* **108**, 1–4 (1965) (Nucleic acid section only); *Bull. Soc. Chim. Biol.* **50**(1), 3–20 (1968) (Fr.); *Eur. J. Biochem.* 1(3), 259–66 (1967); *Hoppe-Seyler's Z. Physiol. Chem.* **348**, 245–55 (1967) (Ger.); *J. Biol. Chem.* **241**, 527 (1966); *Virology* **29**, 480 (1966).

(38) International Union of Pure and Applied Chemistry and International Union of Biochemistry, IUPAC-IUB Commission on Biochemical Nomenclature "Nomenclature of Corrinoids," *Arch. Biochem. Biophys.* **118**(3), 513–6 (1967); *Biochem. J.* **102**(1) 20–2 (1967); *Biochim. Biophys. Acta* **117**(2), 285–8 (1966); *J. Biol. Chem.* **241** (13), 2992–4 (1966).

(39) International Union of Pure and Applied Chemistry and International Union of Biochemistry, IUPAC-IUB Commission on Biochemical Nomenclature, "Nomenclature of

Lipids," *Arch. Biochem. Biophys.* **123**(2), 409–15 (1968); *Biochemistry* **6**(10), 3287–92 (1967); *Biochim. Biophys. Acta* **152**, 1 (1968); *Hoppe-Seyler's Z. Physiol. Chem.* **350**(3), 279–85 (1969) (Ger.); *J. Lipid. Research* **8**(5), 522–8 (1967); *Mol. Biol.* **2**(5), 784–91 (1968) (Russ.).

(40) International Union of Pure and Applied Chemistry and International Union of Biochemistry, IUPAC-IUB Commission on Biochemical Nomenclature "Abbreviated Designation of Amino Acid Derivatives and Peptides," *Arch. Biochem. Biophys.* **121**, 1 (1967); *Biochemistry* **5**(8), 2485–9 (1966); *Biochem. J.* **102**(1), 23–7 (1967); *Biochim. Biophys. Acta* **121**(1), 1–7 (1966); *Eur. J. Biochem.* **1**(4), 375–78 (1967); *J. Biol. Chem.* **241**(11), 2491–5 (1966).

(41) International Union of Pure and Applied Chemistry and International Union of Biochemistry, IUPAC-IUB Commission on Biochemical Nomenclature, "Rules for Naming Synthetic Modifications of Natural Peptides," *Arch. Biochem. Biophys.* **121**, 6 (1967); *Biochemistry* **6**(1), 362–4 (1967); *Biochem. J.* **104**, 17 (1967); *Biochim. Biophys. Acta* **133**(1), 1–5 (1967); *Bull. Soc. Chim. Biol.* **49**, 325 (1967); *Eur. J. Biochem.* **1**(4), 379–81 (1967); *Hoppe-Seyler's Z. Physiol. Chem.* **348**, 262 (1967); *J. Biol. Chem.* **242**(4), 555–7 (1967).

(42) International Union of Pure and Applied Chemistry and International Union of Biochemistry, IUPAC-IUB Commission on Biochemical Nomenclature, "Abbreviated Nomenclature of Synthetic Polypeptides (Polymerized Amino Acids)," *Arch. Biochem. Biophys.* **123**, 633–7 (1969); *Biochemistry* **7**(2), 483–5 (1968); *Biochem. J.* **106**(3), 577–80 (1968); *Biochim. Biophys. Acta* **168**(1), 1–5 (1968); *Biopolymers* **8**(2), 161–6 (1969); *Eur. J. Biochem.* **3**(2), 129–31 (1967); *Hoppe-Seyler's Z. Physiol. Chem.* **349**(8), 953 (1968) (Ger.).

(43) International Union of Pure and Applied Chemistry and International Union of Biochemistry, IUPAC-IUB Commission on Biochemical Nomenclature, "One-Letter Notation for Amino Acid Sequences," *Arch. Biochem. Biophys.* **125**, 1–5 (1968); *Biochemistry* **7**(8), 2703–5 (1968); *Biochim. Biophys. Acta* **168**(1), 6–10 (1968); *Bull. Soc. Chim. Biol.* **50**(10), 1577 (1968) (Fr.); *Eur. J. Biochem.* **5**, 151–3 (1968).

(44) International Union of Biochemistry, Commission on Enzymes, "Enzyme Nomenclature Recommendations (1964)," Elsevier Publishing Co., New York, 1965, 219 pp.

(45) International Union of Pure and Applied Chemistry, Physical Chemistry Division, Commission on Macromolecules, Subcommission on Nomenclature, "Report on Nomenclature in the Field of Macromolecules," *J. Polym. Sci.* **8**(3), 257–77 (1952).

(46) International Union of Pure and Applied Chemistry, Physical Chemistry Division, Commission on Macromolecules, Subcommission on Nomenclature, "Report on Nomenclature Dealing with Steric Regularity in High Polymers." *Pure Appl. Chem.* **12**, 645–56 (1966).

(47) International Union of Pure and Applied Chemistry, Division of Applied Chemistry, Plastics and High Polymers Section, "Recommendations for Abbreviations of Terms Relating to Plastics and Elastomers," *Pure Appl. Chem.* **18**(4), 583–9 (1969).

(48) International Union of Pure and Applied Chemistry, Analytical Chemistry Division, Commission on Spectrochemical and Other Optical Procedures for Analysis, "Nomenclature, Symbols, Units and their Usage in Spectrochemical Analysis," *IUPAC Inform. Bull. Appendices on Tentative Nomenclature, Symbols, Units, and Standards* No. 1, Dec. 1969, 61 pp.

(49) International Union of Pure and Applied Chemistry, Physical Chemistry Division, Commission on Physicochemical Measurements and Standards, "Catalog of Physicochemical Substances," *IUPAC Inform. Bull. Appendices on Tentative Nomenclature, Symbols, Units, and Standards* No. 2, Dec. 1969, 24 pp.

(50) International Union of Pure and Applied Chemistry, Physical Chemistry Division, Commission on Colloid and Surface Chemistry, "Manual of Definitions, Terminology and Symbols in Colloid and Surface Chemistry," *IUPAC Inform. Bull. Appendices on Tentative Nomenclature Symbols, Units, and Standards* No. 3, Jan. 1970, 83 pp.

(51) International Union of Pure and Applied Chemistry, Physical Chemistry Division, Commission on Molecular Structure and Spectroscopy, "Recommendations for the Presentation of NMR Data for Publication in Chemical Journals," *IUPAC Inform. Bull. Appendices on Tentative Nomenclature, Symbols, Units and Standards* No. 4, Jan. 1970, 2 pp.

(52) International Union of Pure and Applied Chemistry, Analytical Chemistry Division, Commission on Analytical Nomenclature, "Recommendations on Ion-Exchange Nomenclature," *IUPAC Inform. Bull. Appendices on Tentative Nomenclature, Symbols, Units and Standards* No. 5, Jan. 1970, 7 pp.

(53) International Union of Pure and Applied Chemistry, Physical Chemistry Section, Commission on Physico-Chemical Symbols and Terminology, "Manual of Physico-Chemical Symbols and Terminology," *J. Amer. Chem. Soc.* **82**, 5517–33 (1960).

(54) International Union of Nutritional Sciences, *Proc. Int. Congr. Nutr. 7th Hamburg 1966* **5**, 861–75 (1967).

(55) World Health Organization, "International Non-Proprietary Names for Pharmaceutical Preparations," Cumulative List No. 2., WHO, Geneva, 1967, 101 pp. [Cumulates lists 1–17 published in the *WHO Chronicle* 1956–1967.]

(56) Cohn, W. E., "The Organization and Functioning of Biochemical Nomenclature," J. CHEM. DOC. **7**(2), 72–3 (1967).

(57) American Chemical Society, "The Nomenclature of Boron Compounds," *Inorg. Chem.* **7**(10), 1945–64 (1968).

(58) American Chemical Society, "Rules of Carbohydrate Nomenclature," *J. Org. Chem.* **28**(2), 281–91 (1963). [This report is the result of a cooperative effort by the Nomenclature Committee of the Division of Carbohydrate Chemistry of the American Chemical Society and the Subcommittee on Carbohydrate Nomenclature of the Publications Committee of The Chemical Society, London. They are sometimes referred to as the "Anglo-American Rules" and were accepted by the Council of the American Chemical Society in 1962.]

(59) American Chemical Society, "A Structure-Based Nomenclature for Linear Polymers," *Macromolecules* **1**, 193–8 (1968).

(60) The Chemical Society (London), "Appendix to Anniversary Meeting, March 1882" [Nomenclature Instructions to Abstractors]. *J. Chem. Soc.* **41**, 247–52 (1882).

(61) American Chemical Society, Nomenclature, Spelling, and Pronunciation Committee, "Organic Compounds Containing Phosphorus," *Chem. Eng. News* **30**, 4513–26 (1952). [Also published in *J. Chem. Soc.* **1952**, 5122.]

(62) The Society of Dyers and Colourists and American Association of Textile Chemist and Colourists, "Colour Index," 2nd ed., Bradford, England; Lowell, Mass., 1965, 4 Vols., 4580 pp. Supplement 1963, 1123 pp.; "Additions and Amendments," No. 1– , 1963– (Quarterly).

(63) American Chemical Society, "Chemical Nomenclature," ACS, Washington, D. C., 1953. 112 pp. [*Advan. Chem. Ser.* No. 8.]