IUPAC Standards and Recommendations*

by Ron Weir

In 1919, the year of the birth of IUPAC, international science was in its infancy. Modern instantaneous communication as we know it had not been born, but a number of scientists foresaw the need for an international organisation with a focus on chemistry to serve as a catalyst, to promote standards, and to facilitate clear, unambiguous communication throughout the world in the rapidly growing discipline. The early founders of the organisation could not have foreseen the explosion of knowledge and instant communication networks available today. However, they did understand the serious ramifications of not having clear, unambiguous communication in science and engineering.

For those individuals who cling to the notion that historic national practices trump safety, practicality, and international trade, please read the following.

Definitions of terms, standard values of quantities, procedures, rules for naming compounds and materials, standardised units, names and properties of elements in the periodic table—all constitute standards that facilitate communication and set international norms. These IUPAC standards and recommendations are internationally binding for scientists in industry and academia, patent lawyers, toxicologists, environmental scientists, legislation, and others working in or for the chemical enterprise. In this column we briefly review the reasons why standards are necessary, how they are created, and how they are updated as new information becomes available.

Q. What purpose is served by the creation of standards and recommendations?

There is more than a single purpose fulfilled by the creation of IUPAC standards and formal Recommendations. All are relevant to society. These are (i) saving resources, (ii) saving money, and (iii) saving lives. Below are three illustrative examples.

Example 1: The American NASA Mars Climate Orbiter in 1999. NASA lost the orbiter due to an incorrect conversion between metric and English (USA) units. While the financial loss amounted to about 150 million US dollars, a price cannot be placed on the loss of scientific data and associated work.

Example 2: Construction of the Laufenburg Bridge over the Rhine between Switzerland and Germany in 2003. Germany used the North Sea level as its standard reference while Switzerland used the Mediterranean Sea as its reference level. The difference in levels is 27 cm. To make matters worse, when the adjustment was made, the signs were applied incorrectly. The total difference applied to the two ends of the bridge was 54 cm, resulting in a costly error.

Example 3: Toxicology and health care. In a patient, blood glucose levels were read on the glucose meter (made in the USA) as 42 $mmol{\cdot}L^{-1}$ (not S.I. approved units) that was assumed by staff to be 42 $mg{\cdot}dL^{-1}$ (approved S.I. units), when it is in fact equivalent to 758 $mg{\cdot}dL^{-1}$! The drastic ramification was a diagnosis of hypoglycaemia, rather than hyperglycemia, nearly costing the patient his life. The problem arose because the glucose meter used did not conform to IUPAC international standards. The USA is one of a few hold-out countries against adopting the metric or S.I. system, even in medical equipment. The International Committee of Medical Journal Editors has demanded that all measurements associated with medicine be reported in metric units, with temperatures given in degrees Celsius. This example emphasises the importance of the adoption of an internationally agreed-upon standard scientific language around the world. For details, see the editorial "S.I. for Dummies" by Dr. Tomaszewski in the *Journal of Medical Toxicology*. [1]

Q. How are the standards and recommendations developed? What level of global consensus is achieved and how is it achieved? Are other scientific bodies involved? What about the general public?

Experts in the various fields of science throughout the world, working together in the IUPAC Divisions and Commissions, develop standards and recommendations. Global consensus is reached through partici-

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pation by international representatives serving on the IUPAC Divisions and Commissions; representatives from the IUPAC National Adhering Organisations (including national chemical societies), representatives from six other scientific organisations serving on IUPAC (the International Union of Crystallography, the International Union of Nutritional Science, the International Union of Pure and Applied Physics, the International Union of Biochemistry and Molecular Biology, the International Bureau of Weights and Measures, and the International Union of Pharmacology), and through a public review period of several months.

Following this extensive consultation, approved feedback, and approved scientific review, it is assumed that each respective community supports the consensus.

The general public is not usually directly involved aside from the public review of Provisional Recommendations, during which time the public can submit comments and suggestions.

National newspaper articles often highlight relevant IUPAC work, such as the discovery of new elements and how they are named. A case in point is the recent announcement by IUPAC of the discovery and naming of four new elements in the periodic table.

Q. What is the usual timeline from start to finish?

After extensive consultation as noted above, an IUPAC Division approves the final text of the proposed standard or recommendation and the manuscript is sent to the IUPAC Interdivisional Committee on Terminology, Nomenclature and Symbols (ICTNS) for further review. In the case of formal Recommendations, the manuscript is posted publically for five months to invite and encourage comments from the general public. In parallel, the manuscript is sent to as many as twenty-five additional expert reviewers. The time to publication in the IUPAC journal *Pure and Applied Chemistry* (*PAC*) is about twenty-four months.

In the case of a Technical Report, which is not a policy document of IUPAC but rather a report on the subject of a specific study, such as critical assessments of methods and techniques, the total time elapsed between Division approval and ICTNS review is about fifteen months. For any changes to the International System of Units (S.I.) itself, the International Bureau of Weights and Measures (BIPM) and its hierarchical structure outside of IUPAC may take several years to achieve consensus. A current example is the ongoing discussion to realign the definition of the mole.

Q. How are the Standards and Recommendations used and valued?

The guidelines for good practice with respect to nomenclature, terminology, units, and symbols are embodied in the IUPAC Green Book, along with other IUPAC Colour Books (see www.iupac.org/what-we-do/books/color-books/). In general, the vast majority of scientists and most scientific journals adhere to the IUPAC Recommendations for international practice. There are some exceptions, usually associated with individuals who cannot adjust to change and with some countries whose political history appears to shun international consensus. The potential impact of not following the standards and recommendations was noted earlier.

In terms of value, a number of peer-reviewed journals will only accept papers that follow IUPAC policy. In addition, UNESCO and EU Customs Union recognise the IUPAC system as their official policy.

Q. How often are the Standards and Recommendations updated?

There is no single simple answer. Whenever an IUPAC Division or Commission believes that an update is required to a Recommendation or a Technical Report, then the changes are made *via* the process described above. As an example, the atomic masses of the elements are updated every one or two years. However, the frequency of the discovery of a new element is rare, but when a discovery is verified, such as was announced at the end of 2015, the update is put in place. For the Colour Books, because sophisticated work is involved, the updates may be done at intervals of five or six years, or even longer.

Q. Other thoughts on what should be communicated?

All the work of IUPAC is done, almost entirely on a volunteer basis, by more than a thousand scientists from around the world, who serve on IUPAC Divisions, Commissions, Standing Committees, and Task Groups.

Reference

1. Tomaszewski, C. *J. Med. Toxicol.* **3**(3):87-88. 2007. http://doi.org/10.1007/BF03160915

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