Ask the Historian

The Origin of the "Delta" Symbol

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Question

What is the origin of the "delta" symbol for fractional charges?

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Answer

One of the important consequences of G. N. Lewis' proposal in 1916 of the shared electron-pair or covalent bond was the possibility, in addition to the conventional integral ionic charges resulting from complete electron transfer, of developing intramolecular partial or fractional charges due to unequal sharing of the electron pair - a possibility succinctly summarized by Lewis in his 1923 monograph on *Valence and the Structure of Atoms and Molecules* (1):

The pair of electrons which constitutes the bond may lie between two atomic centers in such a position that there is no electric polarization, or it may be shifted toward one or the other atom in order to give to that atom a negative, and consequently to the other atom a positive charge. But we can no longer speak of any atom as having an integral number of units of charge, except in the case where one atom takes exclusive possession of the bonding pair, and forms an ion.

Application in the 1920s of Lewis' shared electron-pair bond to the electronic theory of organic reactivity by such British chemists as Christopher Ingold, Robert Robinison, Arthur Lapworth, and Thomas Lowry soon revealed the necessity of introducing a new symbolism in order to differentiate between the use of the + and - signs to indicate net ionic charges, on the one hand, and their use to indicate relative polarity due to fractional charges, on the other. It was with this in mind that the "delta" symbolism for fractional charges was first introduced by Ingold (figure 1) and his wife Hilda in a footnote to a 1926 paper on the electronic theory of aromatic substitution (2):

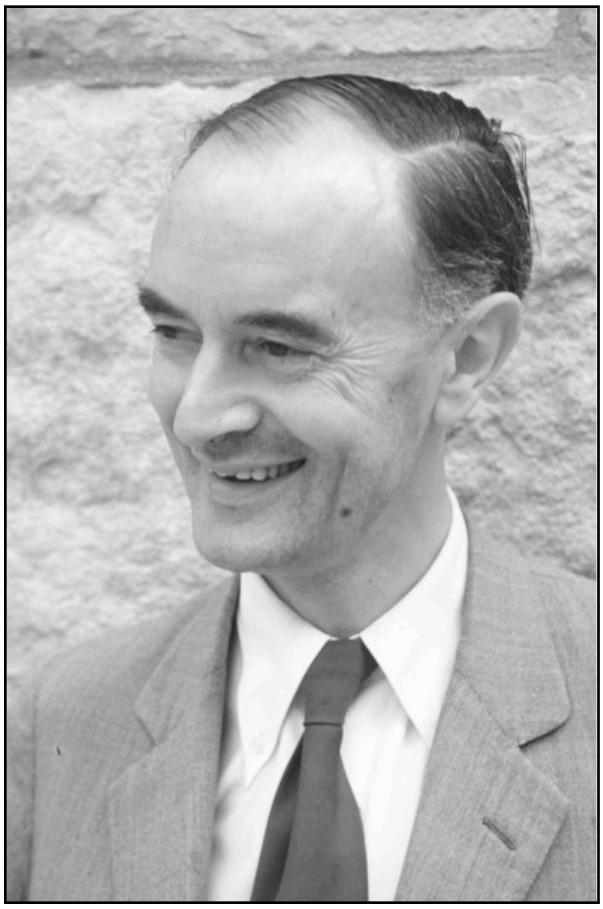

Figure 1. Christopher Kelk Ingold (1893-1970).

In this formula, and those which follow, δ+ and δ- are used to signify small fractions of a unit charge; n represents neutrality, and the signs + and - connote unit charges.

Despite the intense rivalry between Ingold and Robinson, Robinson was, rather surprisingly, one of the first to adopt Ingold's suggestion and employed it in his famous 1932 summary of his own version of the electronic theory of organic reactivity (3, 4). Nevertheless, the symbol was used only sparingly during the 1930s in the monograph literature dealing with the electronic theory of organic chemistry (5, 6), with a

substantial increase in usage not occurring until the 1940s and 1950s (7, 8).

Literature Cited

1. G. N. Lewis, *Valence and the Structure of Atoms and Molecules*, Chemical Catalog Co.: New York, NY, 1923, p. 83.

2. C. K. Ingold, E. H. Ingold, "The Nature of the Alternating Effect in Carbon Chains. Part V. A Discussion of Aromatic Substitution with Special Reference to Respective Roles of Polar and Nonpolar Dissociation; and a Further Study of the Relative Directive Efficiencies of Oxygen and Nitrogen," *J. Chem. Soc.*, **1926**, 1310-1328. Footnote, p. 1312.

3. For details of the Robinson-Ingold controversy, see R. Robinson, *Memoirs of a Minor Prophet: 70 Years of Organic Chemistry*, Elsevier: Amsterdam, 1976, Chap. 11; T. I. Williams, *Robert Robinson: Chemist Extraordinary*, Clarendon: Oxford, 1990, Chap. 7; and K. T. Leffek, *Sir Christopher Ingold: A Major Prophet of Organic Chemistry*, Nova Lion Press: Victoria, 1996, Chap. 6.

4. R. Robinson, *Two Lectures on An Outline of an Electrochemical (Electronic) Theory of the Course of Organic Reactions*, Institute of Chemistry: London, 1932, pp. 20, 36.

5. W. A. Waters, *Physical Aspects of Organic Chemistry*, Van Nostrand: New York, NY, 1936, pp. 161, 440.

6. H. B. Watson, *Modern Theories of Organic Chemistry*, Clarendon: Oxford, 1937, pp. 23, 68.

7. A. E. Remick, *Electronic Interpretations of Organic Chemistry*, Wiley: New York, NY, 1943, pp. 92-93, 99, 104, 107, 118-119, 129-131.

8. C. K. Ingold, *Structure and Mechanism in Organic Chemistry*, Cornell University Press: Ithaca, NY, 1953, pp. 61, 73-78, 102, 232, 238, 244, 248, 457.

Do you have a question about the historical origins of a symbol, name, concept or experimental procedure used in your teaching? Address them to Dr. William B. Jensen, Oesper Collections in the History of Chemistry, Department of Chemistry, University of Cincinnati, Cincinnati, OH 45221-0172 or e-mail them to jensenwb@ucmail.uc.edu