Gilbert N. Lewis “The Atom and the Molecule” (1916)
Història, memòria i identitat

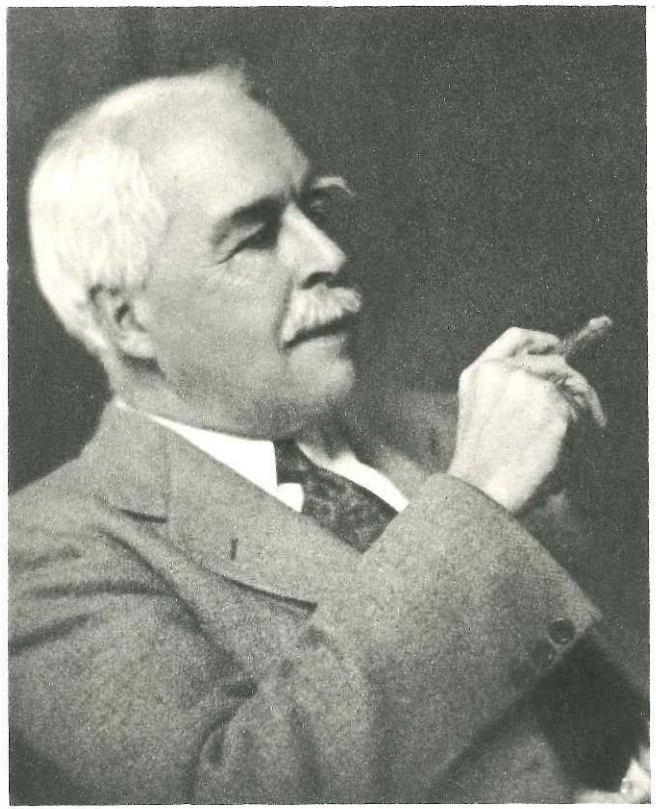
[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF CALIFORNIA.]

THE ATOM AND THE MOLECULE.

BY GILBERT N. LEWIS.

Received January 26, 1916.

Agustí Nieto-Galan
Centre d’Història de la Ciència (CEHIC)
Universitat Autònoma de Barcelona



Camera portrait by John Hagemeyer

GILBERT NEWTON LEWIS

In Honor of

Gilbert Newton Lewis

on his

Seventieth Birthday

Printed by the

University of California Press

Berkeley and Los Angeles

1945

In Honor of Gilbert Newton Lewis on his Seventieth Birthday. Printed by the University of California Press. Berkeley and Los Angeles, 1945, p. 7.

"Few scientists have equaled his breadth of vision and his **keenness of insight into truly fundamental problems**. In both experiment and interpretation he has been the leader in the development of **chemical thermodynamics**….He grasped the significance of **the electron pair in molecular structure and laid the foundation for the modern theory of valence**. He extended our concept of **acids and bases**. He was the first to **isolate heavy hydrogen**. He has added to our understanding of **the color of organic compounds**. He has elucidated the complex phenomena of **phosphorescence**…",

GILBERT NEWTON LEWIS

October 25, 1875—March 23, 1946

1896 Química a Harvard

1899 PhD. Harvard, T.W. Richards (pesos atòmics)

1900-01: Leipzig (W. Ostwald), Göttingen (W. Nernst)

1902: Retorn a Harvard

1905: MIT, Cambridge MA. A. A. Noyes (energia lliure)

1912: Berkeley (Research school), Dean of the College of Chemistry, seminari "Valence"

1916: "The Atom and the Molecule"

1917-18: Chemical Warfare Service, Gas Defense School (París)

1923: *Valence and the Structure of Atoms and Molecules*

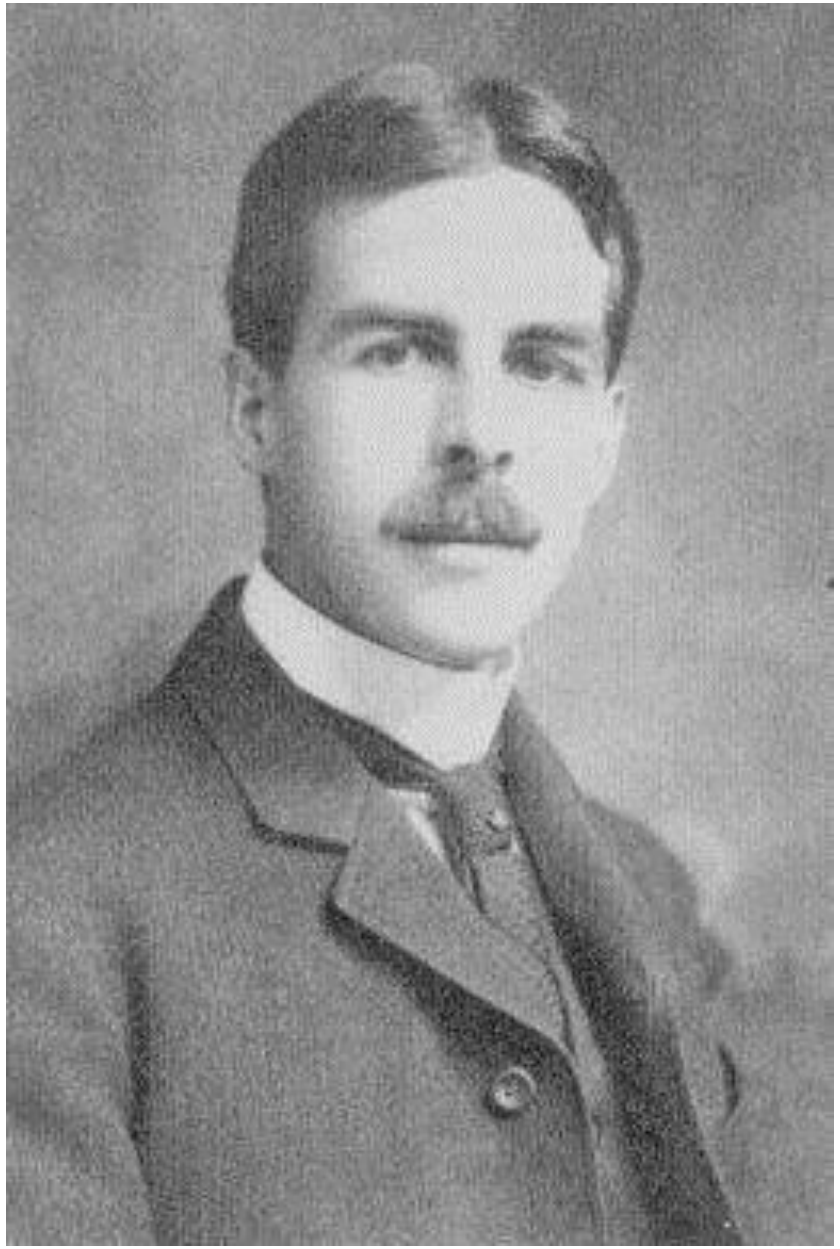
(with Merle Randall) *Thermodynamics and the Free Energy of Chemical Substances*

1926: *The Anatomy of Science*

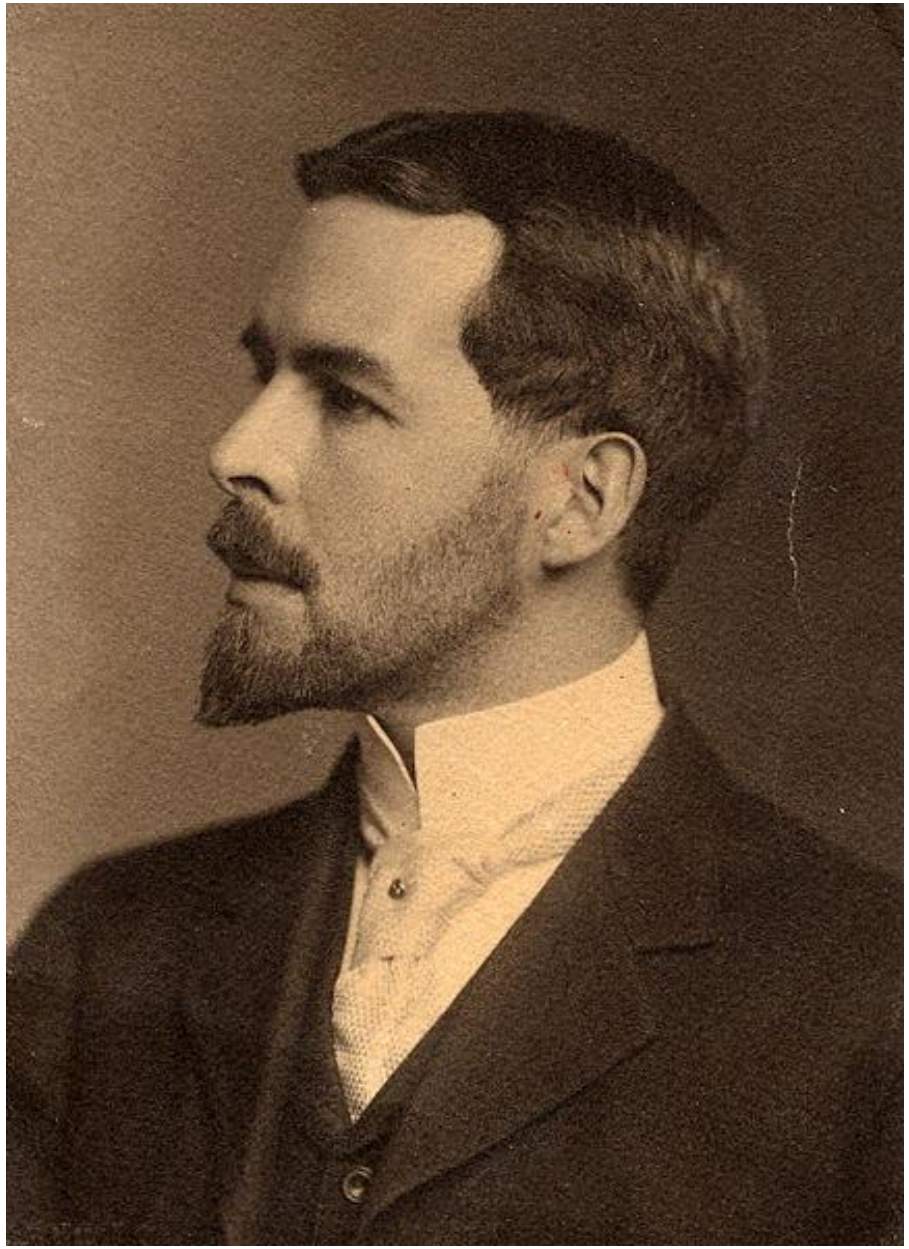
1932-35: Isòtops

1930s: àcids-bases de Lewis

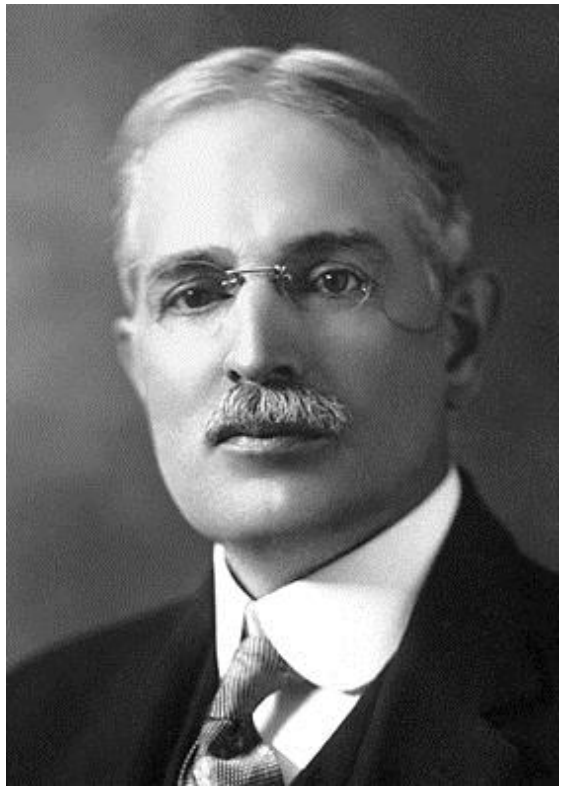
1940s: Fotoquímica



G. N. Lewis, c. 1900



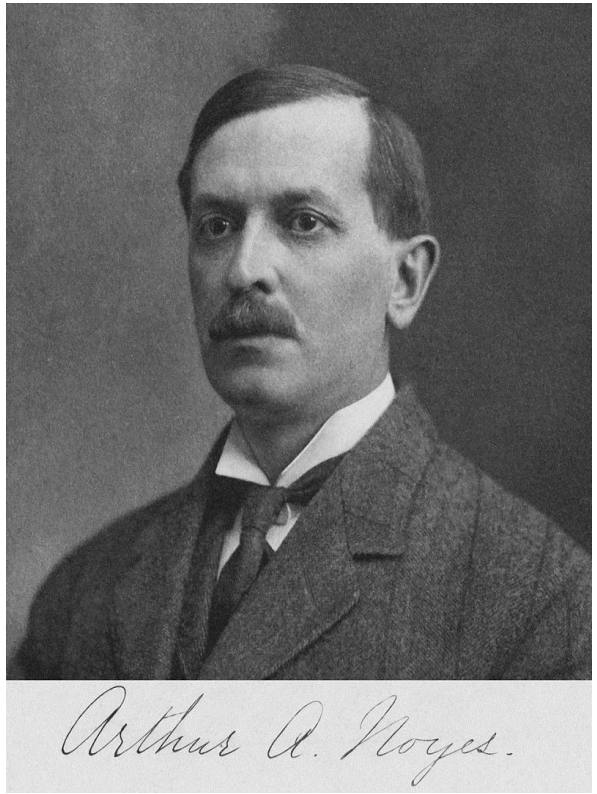
G. N. Lewis, c. 1910



Theodore W. Richards (1868-1928)

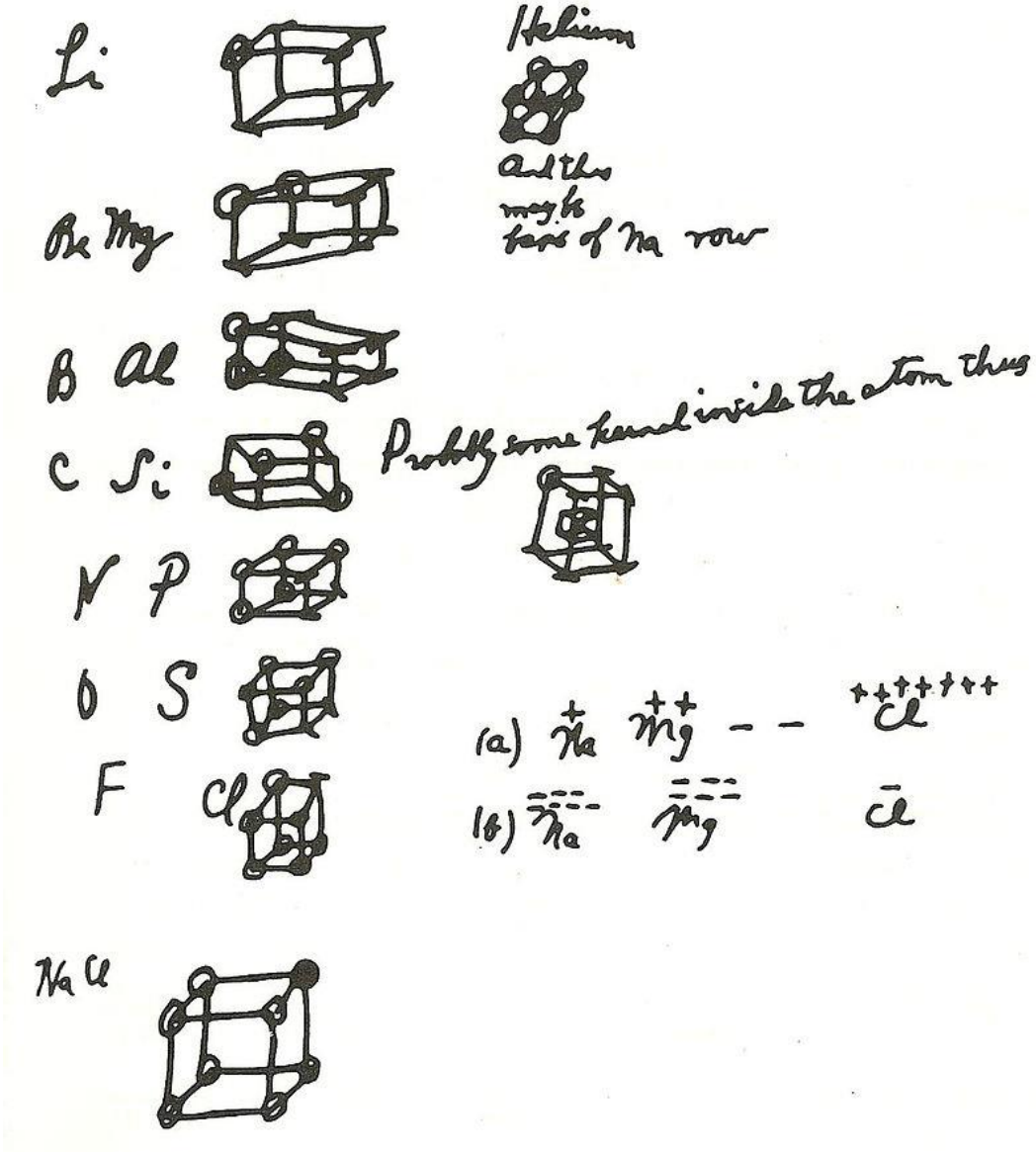
Premi Nobel 1914: Determinació de pesos atòmics
Director del Department de Química a Harvard
Volums atòmics i moleculars

1899: “Some electrochemical and thermochemical relations of Zn and Cd amalgams” (G.N. Lewis, PhD)



Arthur A. Noyes (1866–1936)

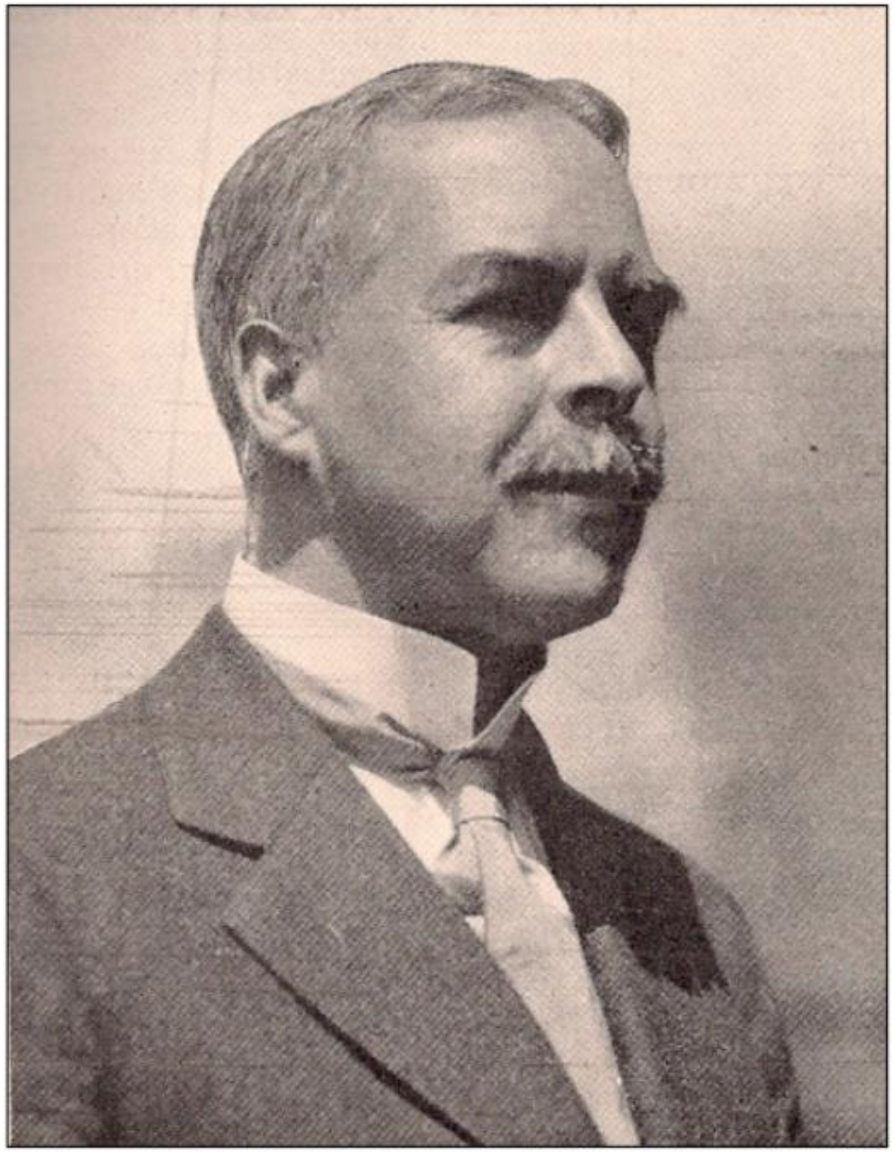
Format amb Ostwald a Leipzig
Director del MIT
Energia lliure, termoquímica
Millora de l’equació de Nerst



Harvard, 1902

Gilman Hall, University of California, Berkeley

University of California College of Chemistry staff members in front of the newly constructed Gilman Hall, 1917. Gilbert N. Lewis is fifth from the left, first row.



Gilbert Newton Lewis

College of Chemistry: l’escola de recerca de Lewis

Llibertat intel·lectual
Especulació
Prioritat en recerca

William Bray, Richard Tolman, Joel Hildebrand,
Merle Randall, Harold Urey, Alfred Parson,
Gleen Seaborg, Willard Libby, Melvin Calvin, etc.

La nova hegemonia nordamericana

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF CALIFORNIA.]

THE ATOM AND THE MOLECULE.

BY GILBERT N. LEWIS.

Received January 26, 1916.

Journal of the American Chemical Society, **38 (1916), pp. 762-785**

1. In every atom is an essential *kernel* which remains unaltered in all ordinary chemical changes and which possesses an excess of positive charges corresponding in number to the ordinal number of the group in the periodic table to which the element belongs.

2. The atom is composed of the kernel and an *outer atom* or *shell*, which, in the case of the neutral atom, contains negative electrons equal in number to the excess of positive charges of the kernel, but the number of electrons in the shell may vary during chemical change between 0 and 8.

3. The atom tends to hold an even number of electrons in the shell, and especially to hold eight electrons which are normally arranged symmetrically at the eight corners of a cube.[1]

4. Two atomic shells are mutually interpenetrable.

5. Electrons may ordinarily pass with readiness from one position in the outer shell to another. Nevertheless they are held in position by more or less rigid constraints, and these positions and the magnitude of the constraints are determined by the nature of the atom and of such other atoms as are combined with it.

6. Electric forces between particles which are very close together do not obey the simple law of inverse squares which holds at greater distances.

The Cubical Atom.

A number of years ago, to account for the striking fact which has become known as Abegg's law of valence and countervalence, and according to which the total difference between the maximum negative and positive valences or polar numbers of an element is frequently eight and is in no case more than eight, I designed what may be called the theory of the cubical atom. This theory, while it has become familiar to a number of my colleagues, has never been published, partly because it was in many respects incomplete. Although many of these elements of incompleteness remain, and although the theory lacks to-day much of the novelty which it originally possessed, it seems to me more probable intrinsically than some of the other theories of atomic structure which have been proposed, and I cannot discuss more fully the nature of the differences between polar and nonpolar compounds without a brief discussion of this theory.

Robert E. Kohler, "G. N. Lewis's Views on Bond Theory: 1900-16", *The British Journal for the History of Science,* Vol. 8, No. 3 (Nov., 1975), pp. 233-239

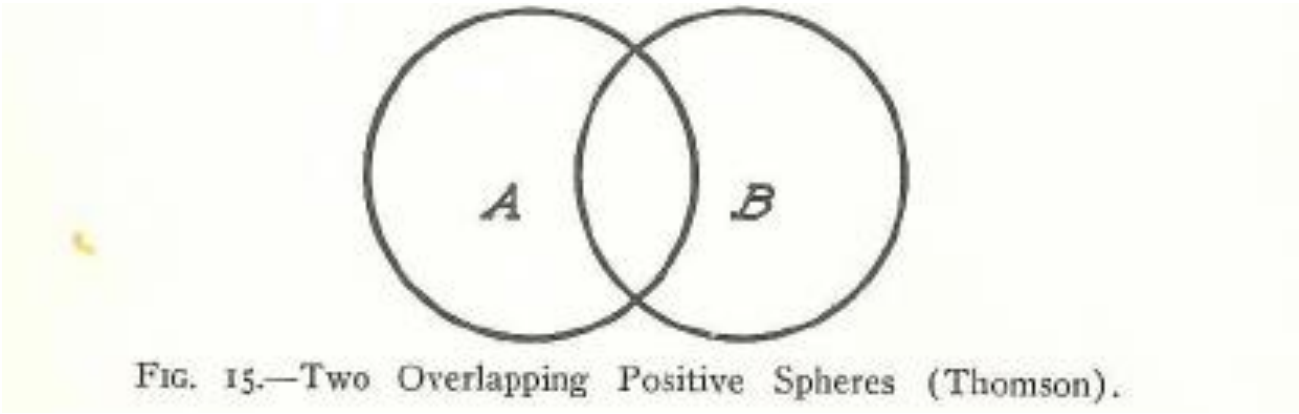
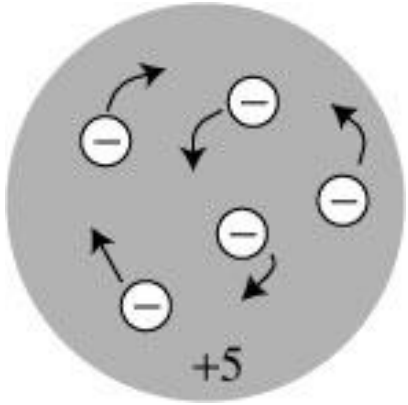
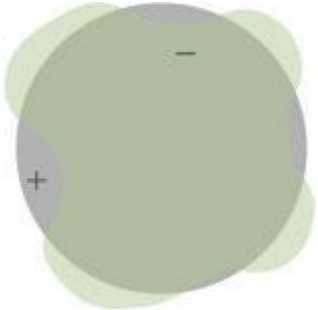


Fig. 15.—Two Overlapping Positive Spheres (Thomson).



J.J. Thomson, "On the structure of the atom: an investigation of the stability and periods of oscillation of a number of corpuscles arranged at equal intervals around the circumference of a circle; with application of the results to the theory of atomic structure," *Phil. Mag.,* 6, (1904), 237-265.



Lord Rayleigh, "On electrical vibrations and the constitution of the atom," *Phil. Mag.,* 11 (1906), 117-123

J. Stark, *Prinzipien der Atomdynamik: Die Elektrischen Quanten*,Leipzig, Verlag von S. Hirsel, 1910

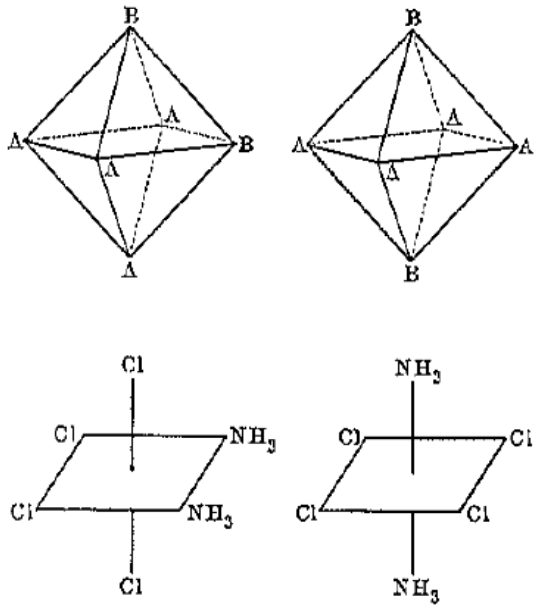


Fig. 14.10. SCHEMATIC REPRESENTATION OF *cis* (left) AND *trans* (right) ISOMERS OF COMPLEX METAL IONS.
(From A. Werner, *New Ideas on Inorganic Chemistry* [1911].)

Alfred Werner (1866 – 1919)

Alfred Werner*, Neuere Anschauungen auf dem Gebiete der anorganischen Chemie* (1905)

Premi Nobel de Química (1913) "in recognition of his work on the linkage of atoms in molecules by which he has thrown new light on earlier investigations and opened up new fields of research especially in inorganic chemistry".

Parson (1915) assumed three distinct types of chemical union. One of these types involved a pair of electrons acting jointly to hold two atoms together, as is shown on the right-hand portion of Figure 21, which reproduces his picture of the hydrogen molecule. On the other hand, he assumes a far more complicated process in the union of two atoms of chlorine, as is shown in the left-hand part of the figure, where the dots represent valence electrons and the shaded circles rep-

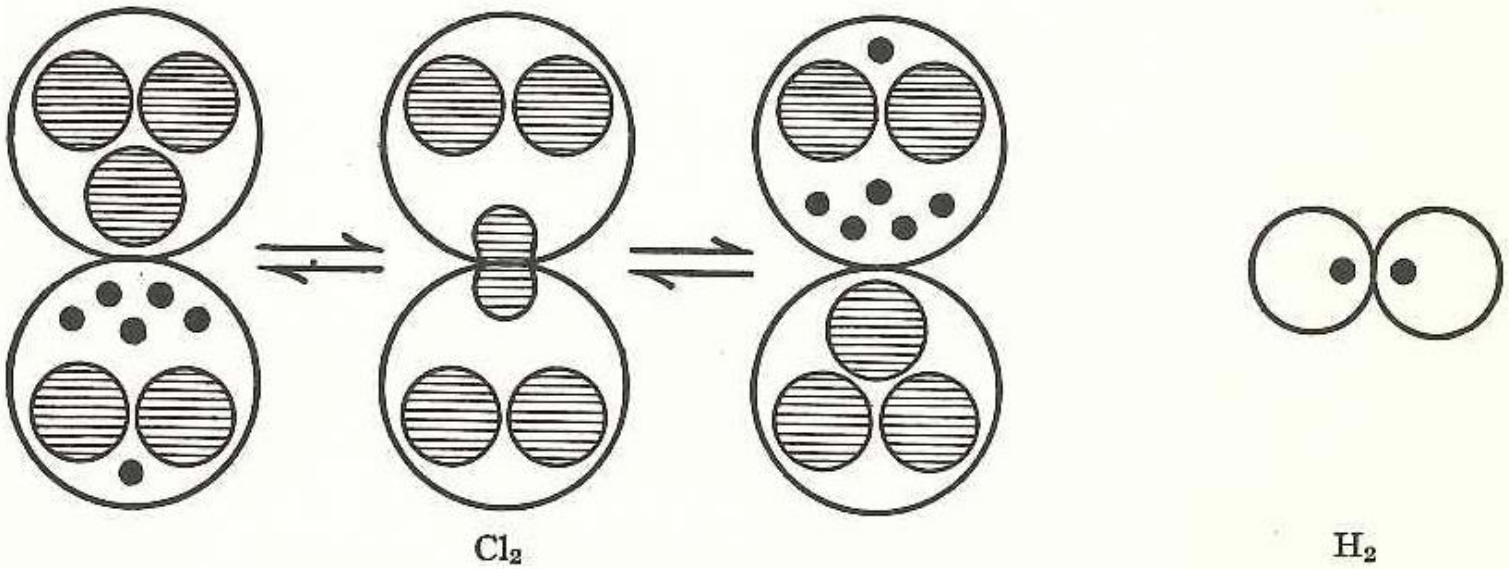


FIG. 21.—Parson's Models of the Chlorine and Hydrogen Molecules.

Alfred L. Parson, "Magneton Theory of the Structure of the Atom," *Smithsonian Miscellaneous Collection*, Pub 2371, 80pp, 2 plates (Nov 29, 1915)

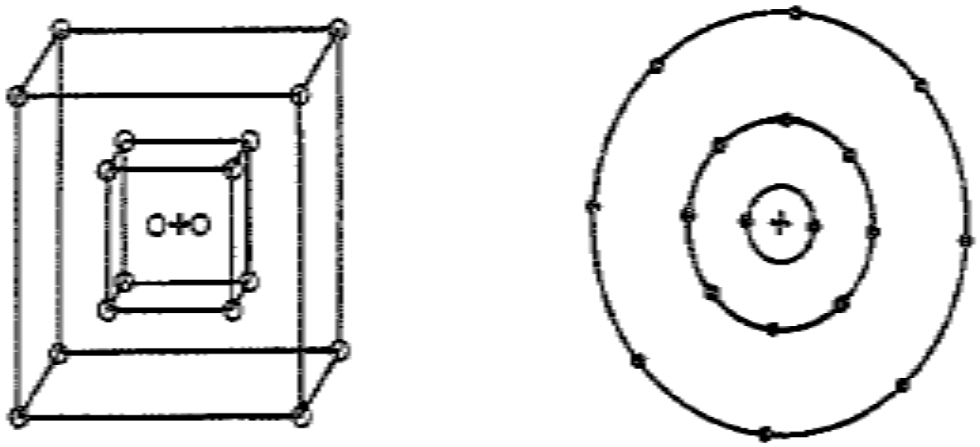
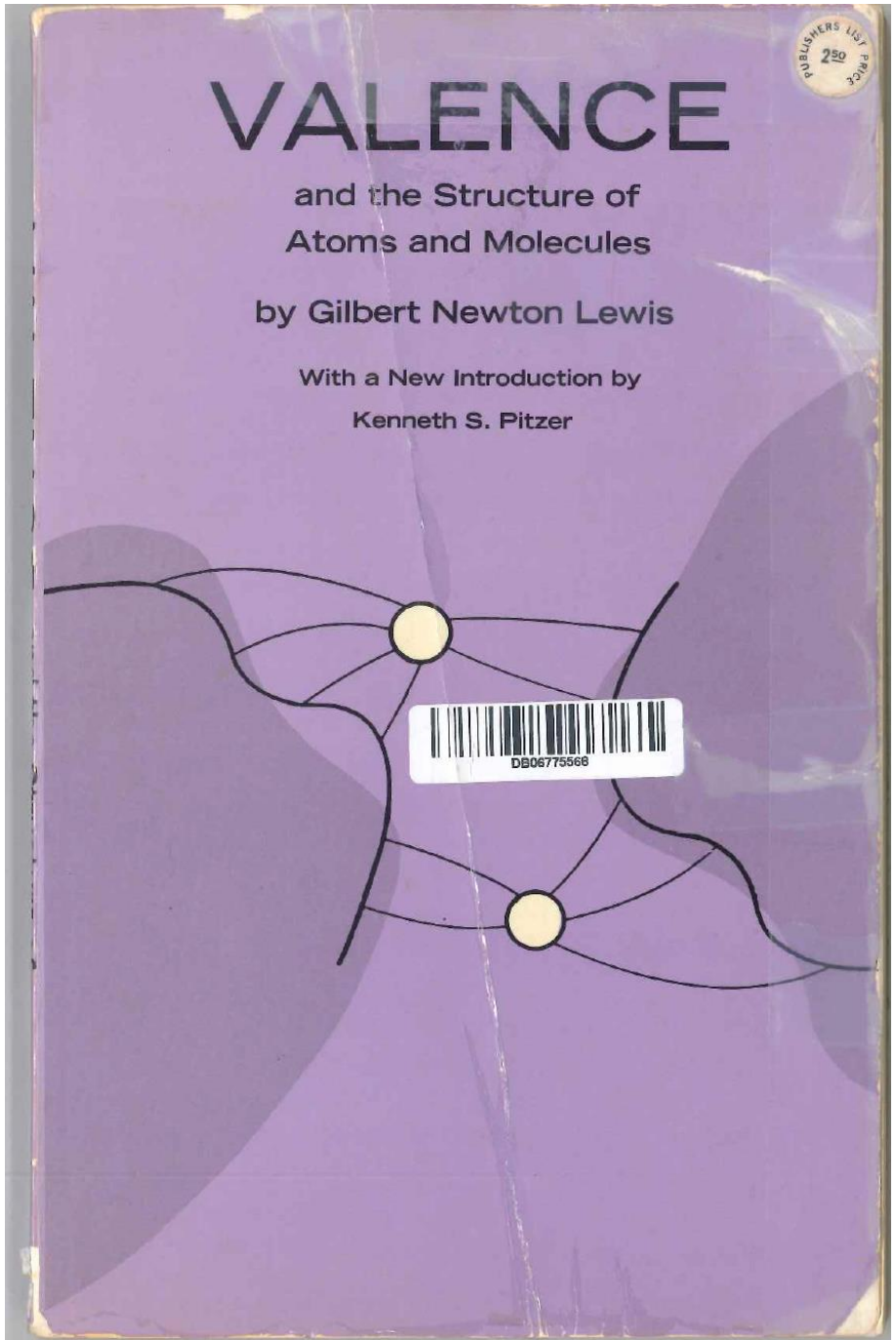


Fig. 20.3. TWO 1916 MODELS OF THE ARGON ATOM.
(From G. N Lewis, *Valence and the Structure of Atoms and Molecules* [1923], with permission of the Reinhold Press.)

Walther Kossel, “Über Molekülbildung als Frage des Atombaus”, *Annalen der Physik*, 49, 229, 1916



Some Atomic Models.

In the year 1902 (while I was attempting to explain to an elementary class in chemistry some of the ideas involved in the periodic law) becoming interested in the new theory of the electron, and combining this idea with those which are implied in the periodic classification, I formed an idea of the inner structure of the atom which,

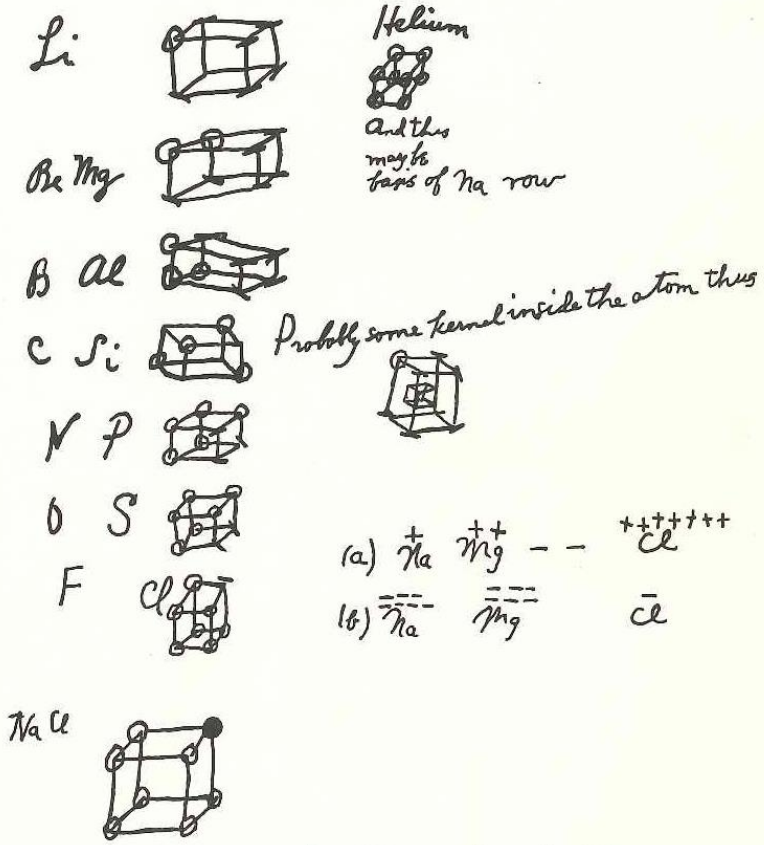


FIG. 3.—Lewis: Memorandum of 1902.

although it contained certain crudities, I have ever since regarded as representing essentially the arrangement of electrons in the atom. In Figure 3 is reproduced a portion of my memorandum of March 28, 1902, which illustrates the theory.

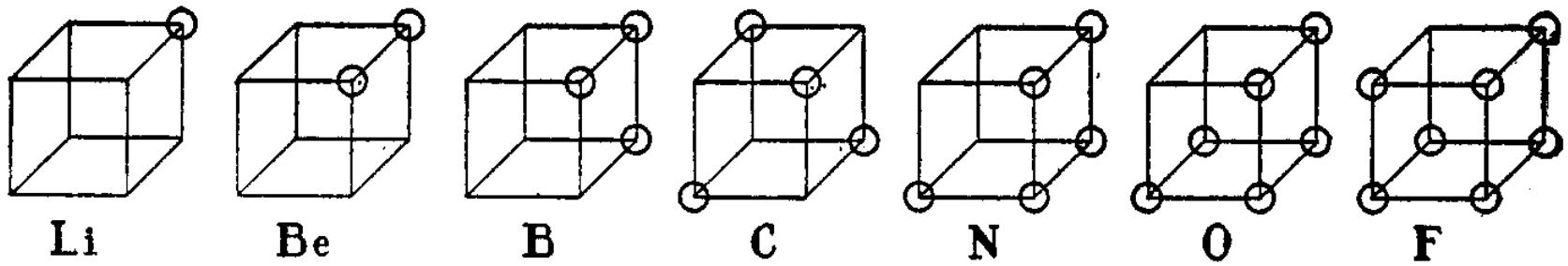


Fig. 2.

The pictures of atomic structure which are reproduced in Fig. 2,[1] and in which the circles represent the electrons in the outer shell of the

[1] These figures are taken from a memorandum dated March 28, 1902, together with the models are notes concerning different types of chemical compounds; the various possible arrangements of electrons in the outer atom and the possibility of intra-atomic isomerism; the relationship between symmetrical structure and atomic volume; and certain speculations as to the structure of the helium atom which we shall see were probably partly incorrect. The date of origin of this theory is mentioned not with the purpose of claiming any sort of priority with respect to those portions which overlap existing theories, but because the fact that similar theories have been developed independently adds to the probability that all possess some characteristics of fundamental reality.

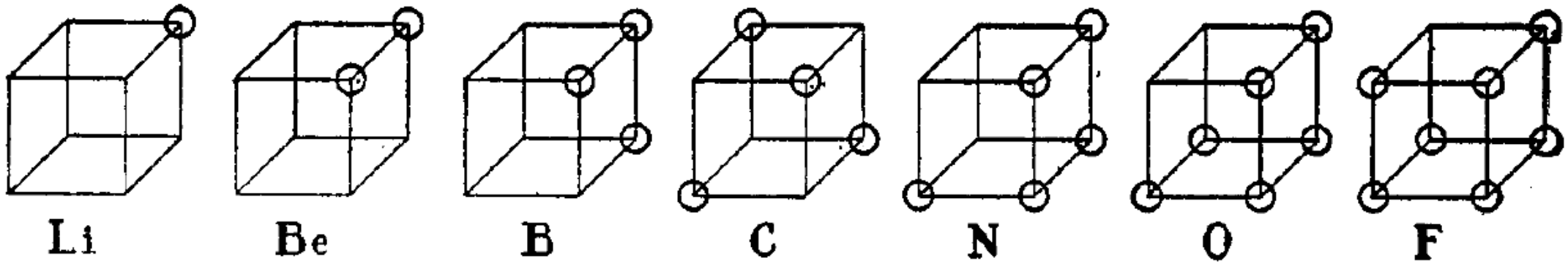


Fig. 2.

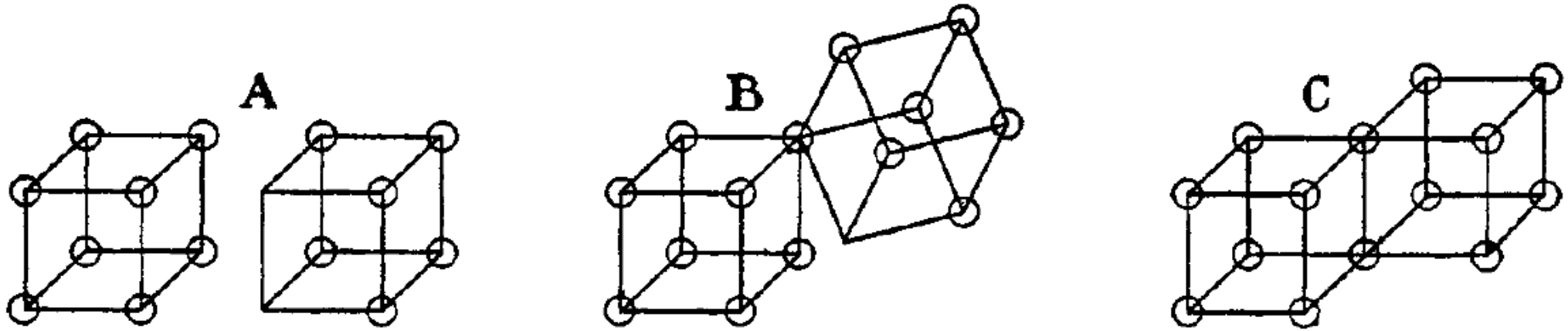


Fig 3.

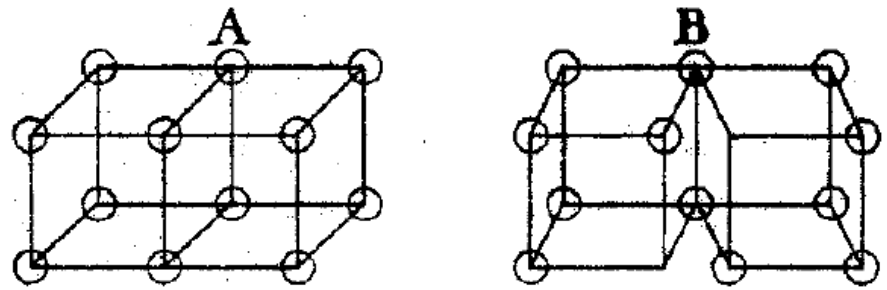


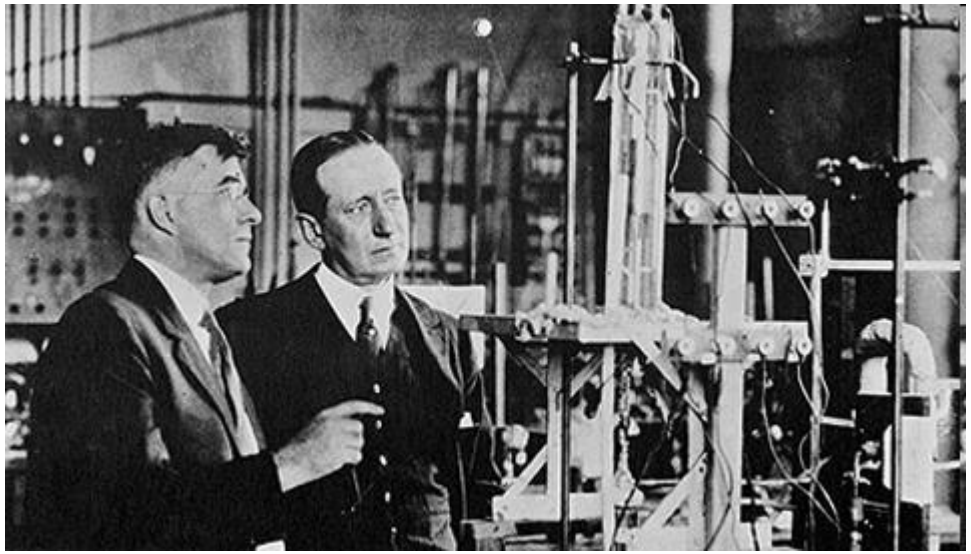
Fig. 4.

Shortly after publication of his 1916 paper, Lewis became involved war work and did not return to the subject of chemical bonding until 1923, when he masterfully summarized his model in a short monograph entitled *Valence and the Structure of Atoms and Molecules*. His renewal of interest in this subject was largely stimulated by the activities of the American chemist, Irving Langmuir, who between 1919 and 1922 popularized and elaborated Lewis' model. Many of our current terms relating to the chemical bond, such as covalent, octet rule, etc., were actually introduced by Langmuir rather than Lewis.

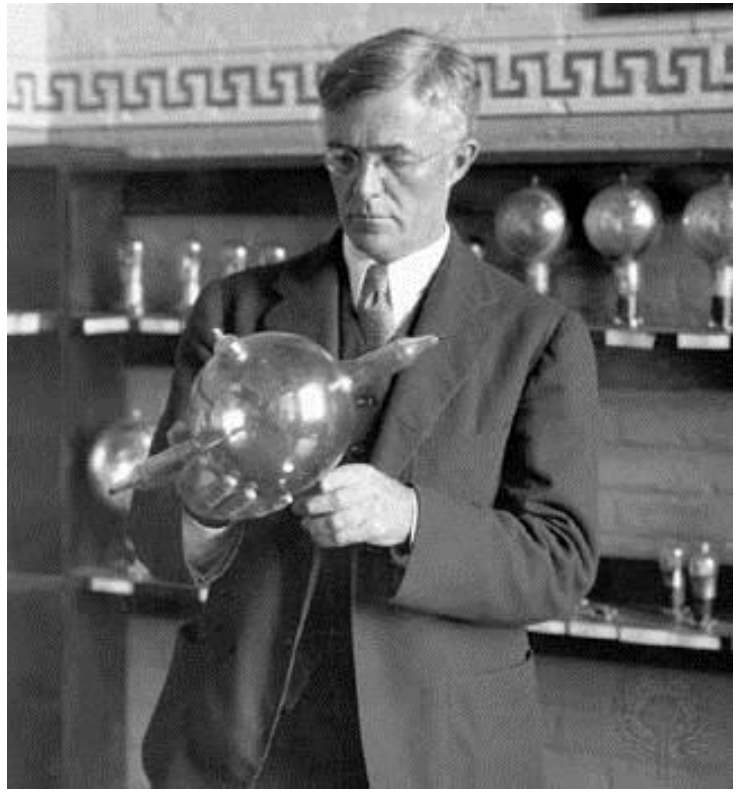
William B. Jensen

Department of Chemistry, University of Cincinnati

Published in *Britannica on Line*, Encyclopedia Britannica: Chicago, IL, 2000.



1922, amb Marconi



Irving Langmuir (1881-1957)
PhD a Göttingen amb W. Nernst
Sobre l'enllaç "covalent": *JACS*, 41, 868, 1919; 1543, 1919
Public Lectures (1919-21): ACS
General Electric Company, Schenectady, NY, USA
Premi Nobel de Química (1932): "for his discoveries and investigations in surface chemistry"

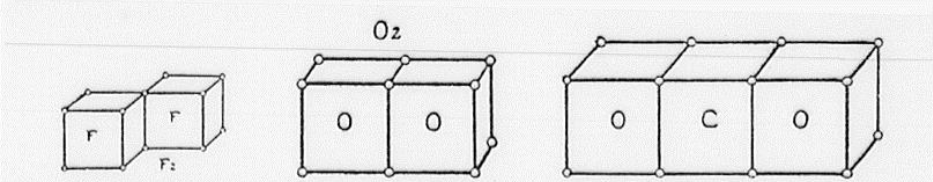
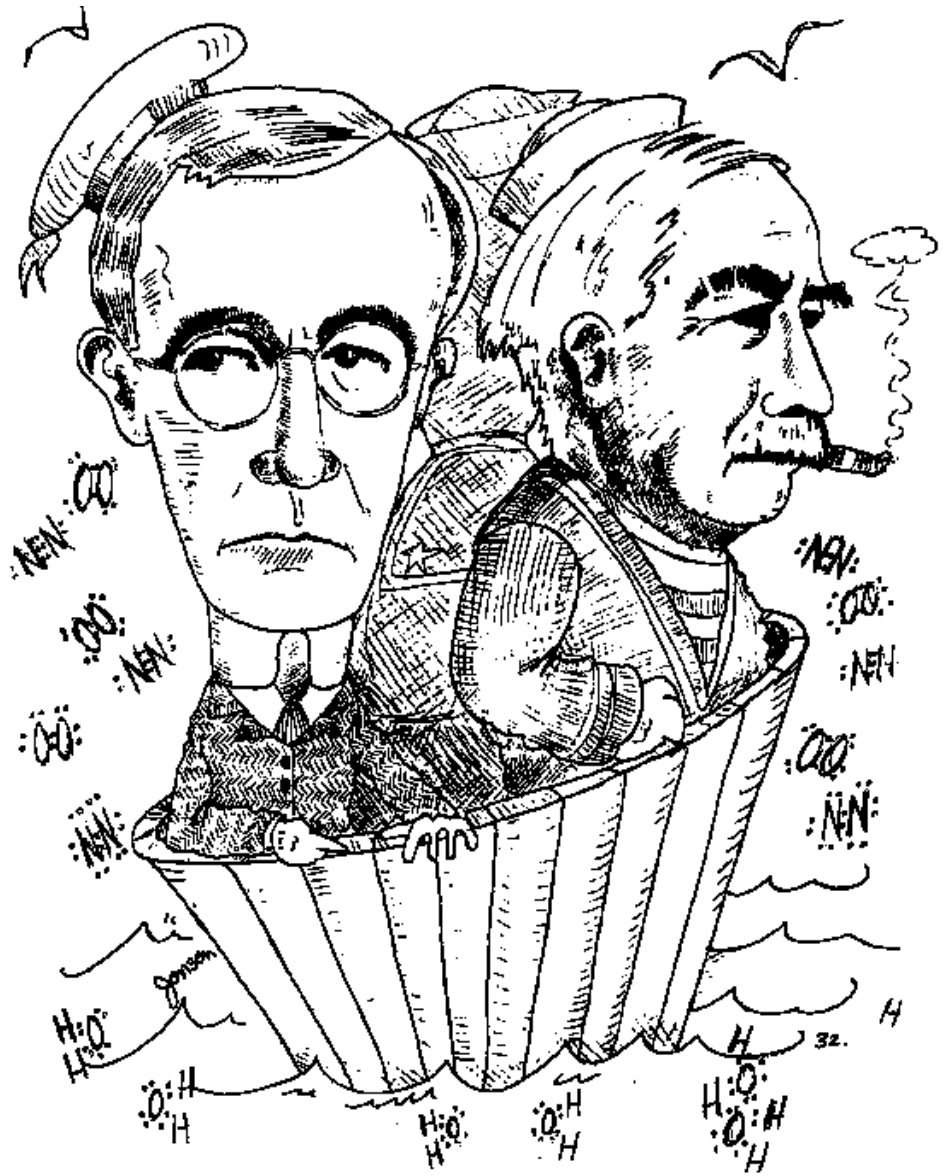
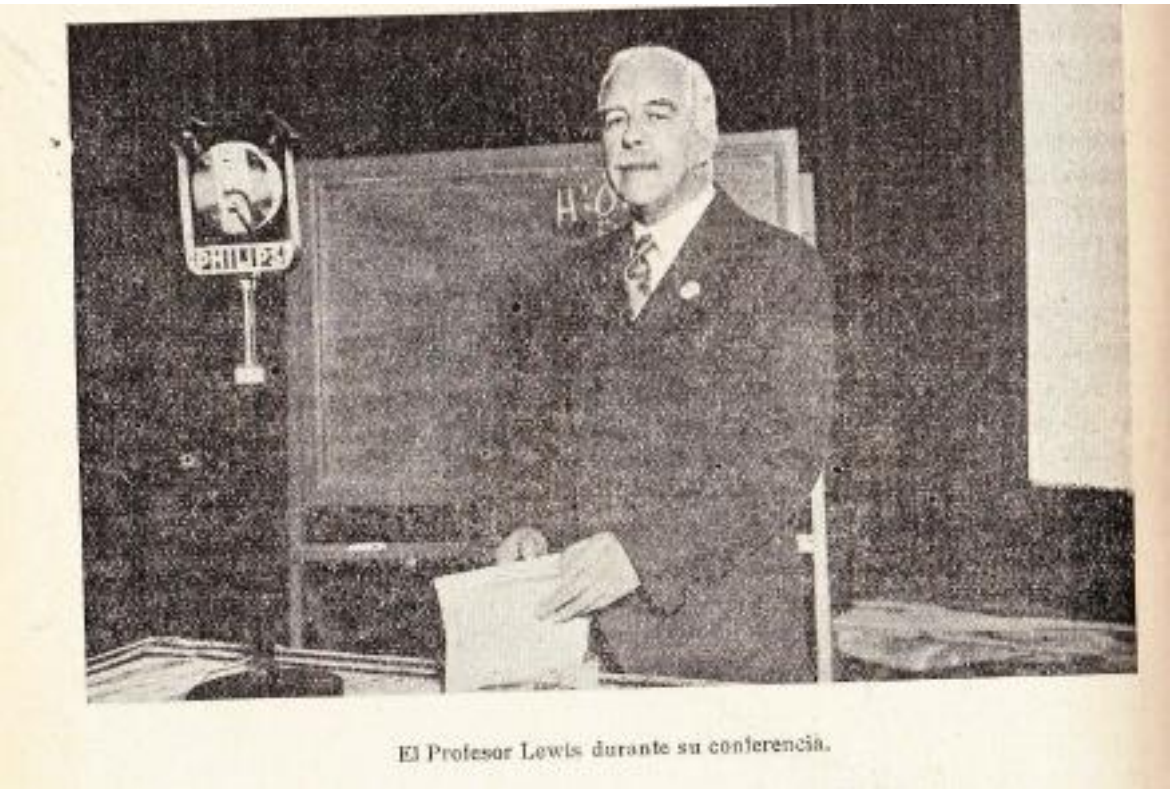


Fig. 20.5. LANGMUIR MODELS OF SEVERAL MOLECULES. (From I. Langmuir, *J. Am. Chem. Soc.* [1919], with permission of the editor.)



http://www.minerva.unito.it/



El Profesor Lewis durante su conferencia.

IX International Congress of Pure and Applied Chemistry (Madrid 1934).

1932 Harorld Urey: descobriment del deuteri

1933: Identificació de l'aigua pesada D_2O

1934: Lewis: "Different kinds of water".

Mètodes de separació dels isòtops de l'hydrogen:

1. Difusió a través de parets metàl·liques calentes
2. Electròlisi fraccionada de l'aigua (Urey)
3. Destil·lació fraccionada

DIFFERENT KINDS OF WATER

by

Gilbert N. Lewis (Berkeley, Cal.)

With my assistant, Dr. Ronald T. Macdonald, to whose devoted interest and skill is due much of the success of the investigations which I am going to describe, I was attempting, about a year ago, the separation of the isotopes of lithium and of oxygen. As this work was slowly proceeding one thought was constantly recurring-how much more interesting it would be to separate the isotopes of hydrogen. Between the compounds of H^1 and the corresponding compounds of H^2 we must expect the greatest of all isotopic differences, but the extremely small concentration of the isotope H^2 seemed to render futile any such objective.

However, it occurred to me that the greater differences in the properties of this pair of isotopes might overcome the great disparity in their amounts, so as to make this the easiest rather than the hardest of isotopic separations. After a few preliminary calculations I was convinced that the rapid fractionation of the hydrogen isotopes could be accomplished by a great variety of methods. Within a few days work was begun on three of these methods, all of which proved feasible, and two of which have been successfully used in the separation of the hydrogen isotopes.

The Method of Separation by Diffusion Through Metals.

AÑO XI - NUM. 124 MAYO 1934

QUÍMICA E INDUSTRIA

REVISTA TÉCNICA INDUSTRIAL

ÓRGANO OFICIAL DE LA CÁMARA NACIONAL DE INDUSTRIAS QUÍMICAS

ADHERIDA A LA ASOCIACIÓN ESPAÑOLA DE PRENSA TÉCNICA

Gran Premio con medalla de oro en la Exposición Internacional de Barcelona 1929
Diploma de Honor en el V Congreso Internacional de la Prensa Técnica y Profesional

Agente exclusivo para la publicidad en Alemania, países sucesores de la monarquía austro-húngara y Suiza «Ala Anzeigen Aktiengesellschaft», Potsdamer Strasse 27 A. Berlín W. 35

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España y América latina: Un año, 15 Ptas.
Otros países: Un año, 25 ptas.

SUMARIO:

El IX Congreso Internacional de Química Pura y Aplicada, por Don Alejandro Lifchuz, Doctor Ingeniero.— *La neutralización de los aceites en pequeña escala*, por Luis Bergues, Ingeniero Químico.— *Revista de Revistas.— Bibliografía. Patentes.— Noticias varias.*

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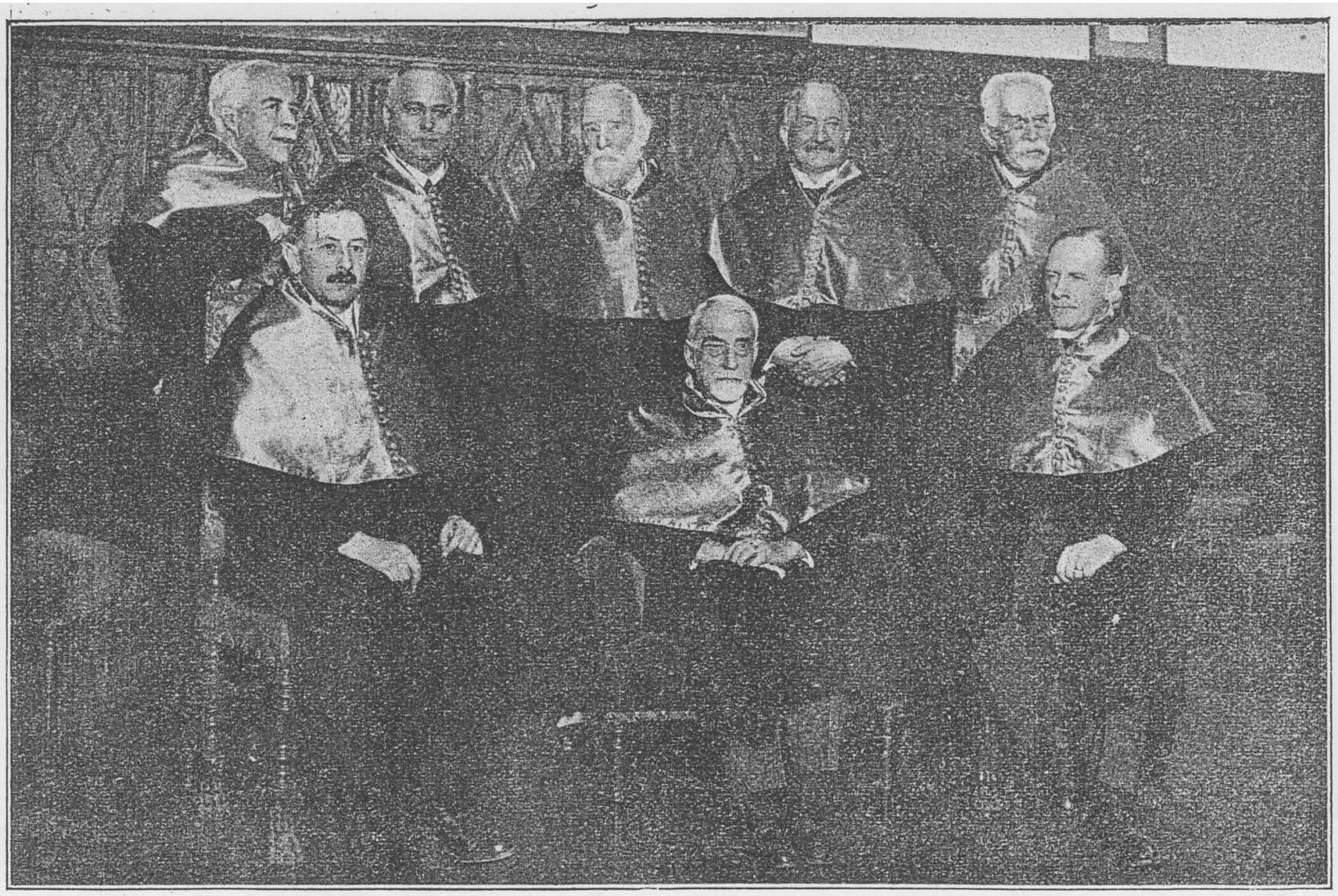
Teléfono 73543
BARCELONA
(España)

QUIMICA TEORICA Y QUIMICA MINERAL

La nota sobresaliente de esta sección la dió **J. N. Lewis** (California) con su conferencia sobre «Las diferentes clases de agua». En el curso de sus trabajos para la separación de los isótopos del litio y de oxígeno, le sedujo la interesante perspectiva de la separación de los isótopos del hidrógeno, donde las diferencias isotópicas debían de ser muy marcadas. Para llegar a ese objeto empleó tres métodos distintos:



Los Doctores «honoris causa» (sentados) Karrer, Fourneau y Róbinson, en Farmacia, y (de pié) los investidos en Ciencias.

G. N. Lewis (Berkeley), N. Parravano (Rome), H. E. Amstrong (London), P. Walden (Rostock), H. Le Chatelier (Paris), Ciències

E. Fourneau (Paris), P. Karrer (Zurich) and R. Robinson (Oxford), Farmàcia

One of the great puzzles of Lewis' career is the absence of a Nobel Prize. It has been suggested that he should have shared the 1934 Nobel Prize in Chemistry with Harold Urey for his contributions to the separation and study of deuterium and its compounds and that, had he lived longer, he most certainly should have shared the 1954 Nobel Prize in Chemistry with Linus Pauling for his contributions to the theory of the chemical bond.

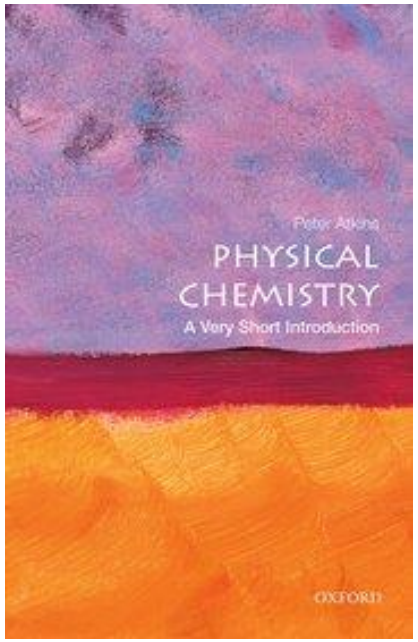
William B. Jensen

Department of Chemistry, University of Cincinnati

Published in *Britannica on Line*, Encyclopedia Britannica: Chicago, IL, 2000.

It is one of the **scandals of intellectual history that Lewis never received the Nobel Prize** despite his several seminal contributions to chemistry and physical chemistry in particular",

Peter Atkins, *Physical chemistry. A very Short Introduction*. Oxford University Press. Oxford 2014, p. 14



Gilbert N Lewis: Nominee in 41 nominations:

Chemistry 1922 by Frederick Donnan
Chemistry 1924 by Theodore Richards
Chemistry 1925 by Victor Lenher
Chemistry 1929 by James Clark
Chemistry 1929 by William Campbell
Chemistry 1929 by James Partington
Chemistry 1929 by Samuel Smiles
Chemistry 1930 by William Campbell
Chemistry 1932 by William Campbell
Chemistry 1932 by Karl Landsteiner
Chemistry 1932 by Wilhelm Palmaer
Chemistry 1933 by Charles Mann
Chemistry 1933 by Cannon Sneed
Chemistry 1934 by Fritz Haber
Chemistry 1934 by Wilhelm Palmaer
Chemistry 1935 by Adolf Deissmann
Chemistry 1940 by Sir Christopher Kelk Ingold
Chemistry 1942 by Sir Owen Richardson
Chemistry 1943 by Sir Owen Richardson
Chemistry 1944 by Louis Plack Hammett
Chemistry 1946 by Sir Christopher Kelk Ingold
Chemistry 1924 by James Clark
Chemistry 1924 by Charles Walcott
Chemistry 1926 by William Campbell
Chemistry 1929 by Arthur Allmand
Chemistry 1929 by William Harkins
Chemistry 1929 by Hermann Irving Schlesinger
Chemistry 1929 by Julius Stieglitz
Chemistry 1931 by William Campbell
Chemistry 1932 by William Foster
Chemistry 1932 by Alan Menzies
Chemistry 1933 by Irving Langmuir
Chemistry 1933 by Wilhelm Palmaer
Chemistry 1933 by Otto Stern
Chemistry 1934 by William Campbell
Chemistry 1935 by Emil Abel
Chemistry 1935 by Max Planck
Chemistry 1941 by Sir Owen Richardson
Chemistry 1942 by Kasimir Fajans
Chemistry 1944 by Norris Hall
Chemistry 1944 by Sir Owen Richardson

https://www.nobelprize.org/nomination/archive/show_people.php?id=5441

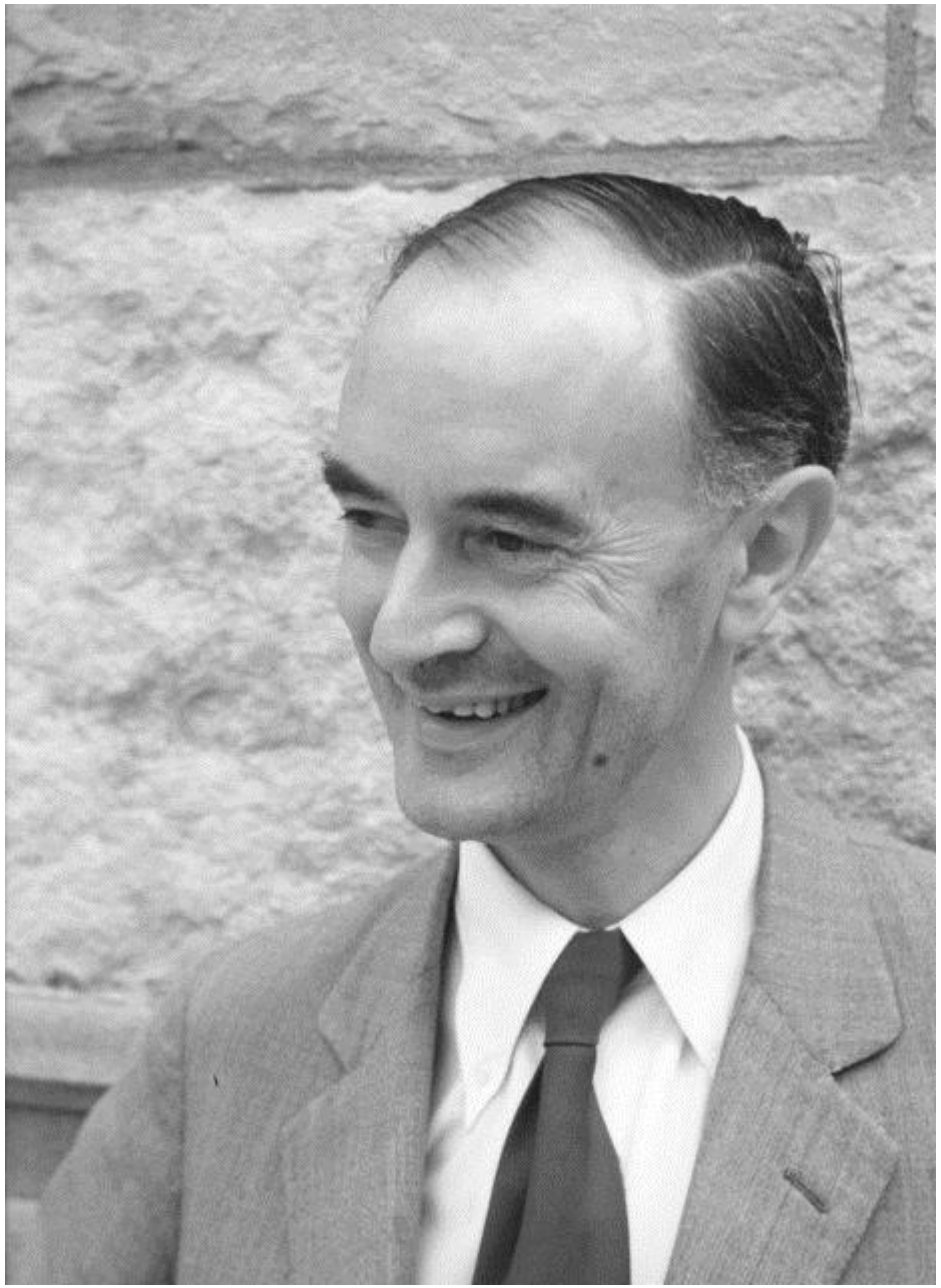
The 1920s saw a rapid adoption and application of Lewis' model of the electron-pair bond in the fields of organic and coordination chemistry. In organic chemistry this was primarily due to the efforts of the British chemists Arthur Lapworth, Robert Robinson, Thomas Lowry, and Christopher Ingold and, in coordination chemistry, to the efforts of the American chemist Maurice Huggins and the British chemist Nevil Sidgwick. Though Lewis occasionally published on his bonding model throughout the 1920s, he stopped writing on the subject after 1933 and left the task of reconciling the model with the newer quantum mechanics of Erwin Schrödinger and Werner Heisenberg in hands of the American chemist, Linus Pauling. Pauling transformed it into the "valence bond model" and made it the subject of his classic book, *The Nature of the Chemical Bond*, first published in 1939.

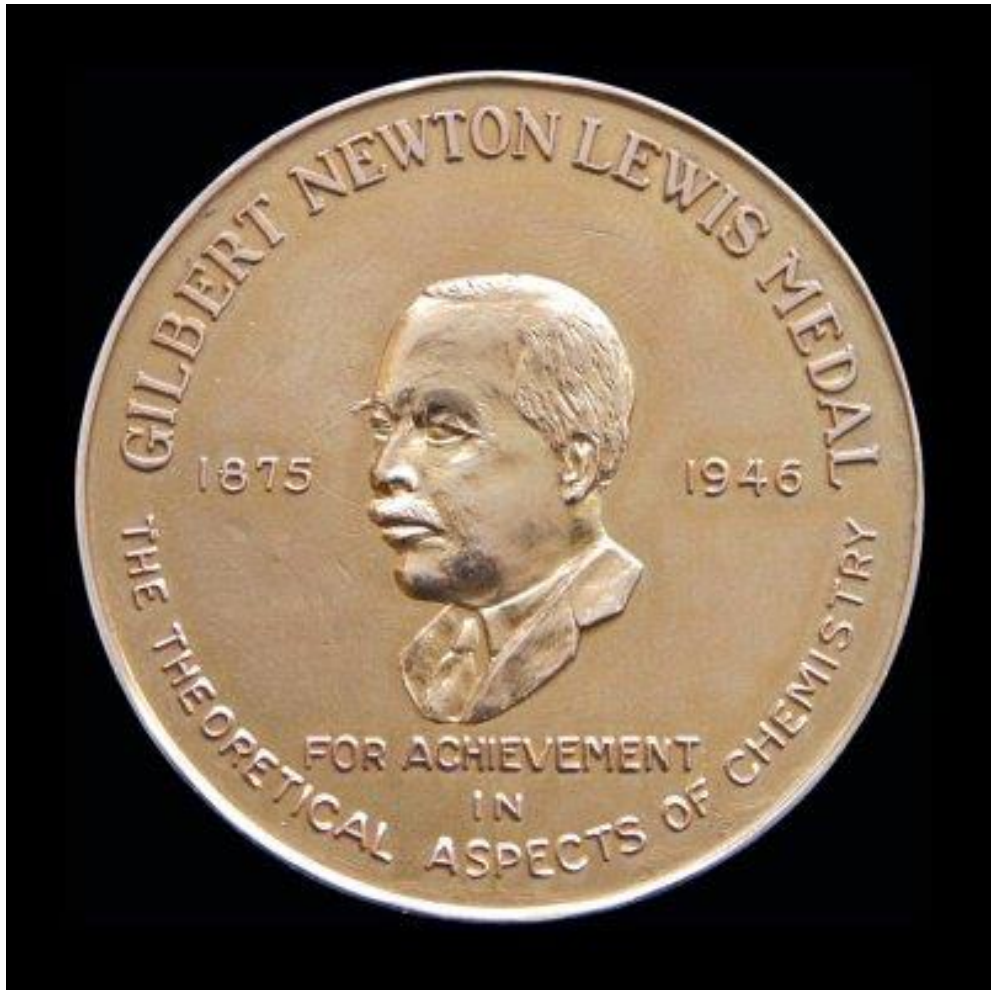
William B. Jensen

Department of Chemistry, University of Cincinnati

Published in *Britannica on Line*, Encyclopedia Britannica: Chicago, IL, 2000.

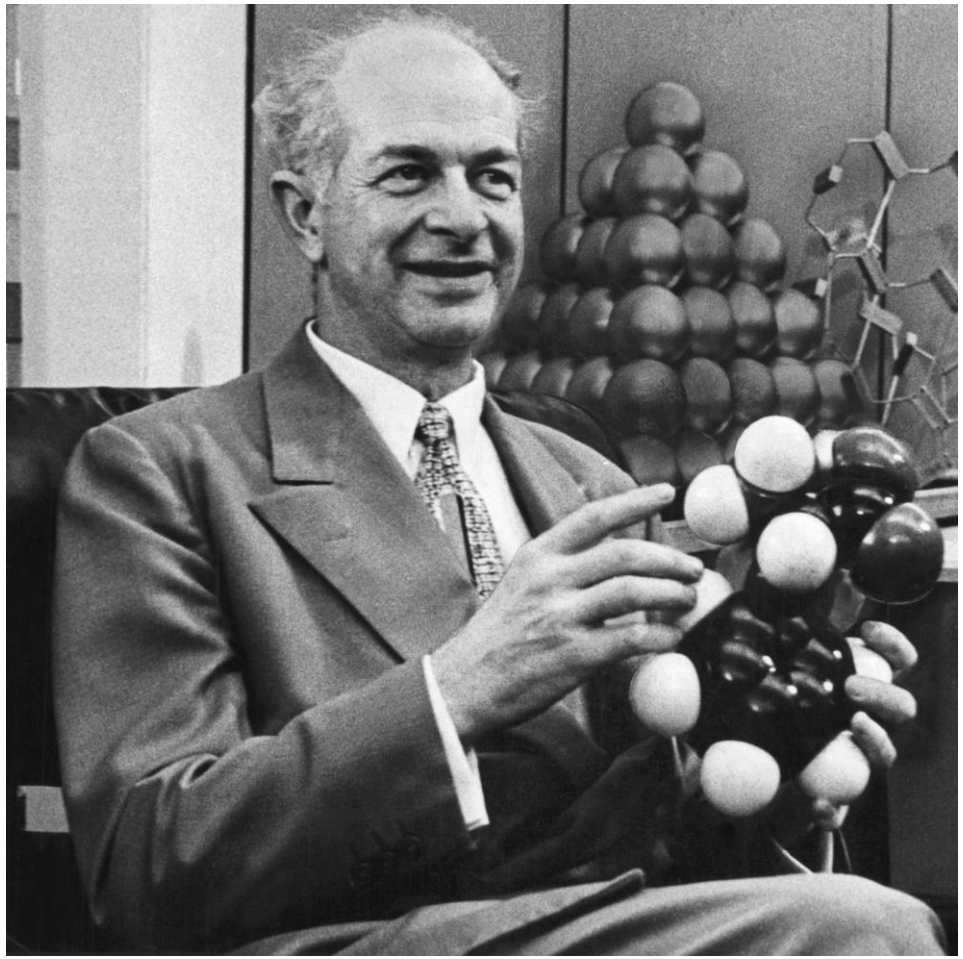
RSC Advancing the Chemical Sciences
National Chemical Landmark
Chemistry Department
University College London
During the period 1930-1970
Professor Sir Christopher Ingold
pioneered our understanding of the
electronic basis of structure, mechanism
and reactivity in organic chemistry,
which is fundamental to
modern-day chemistry.
28 November 2008



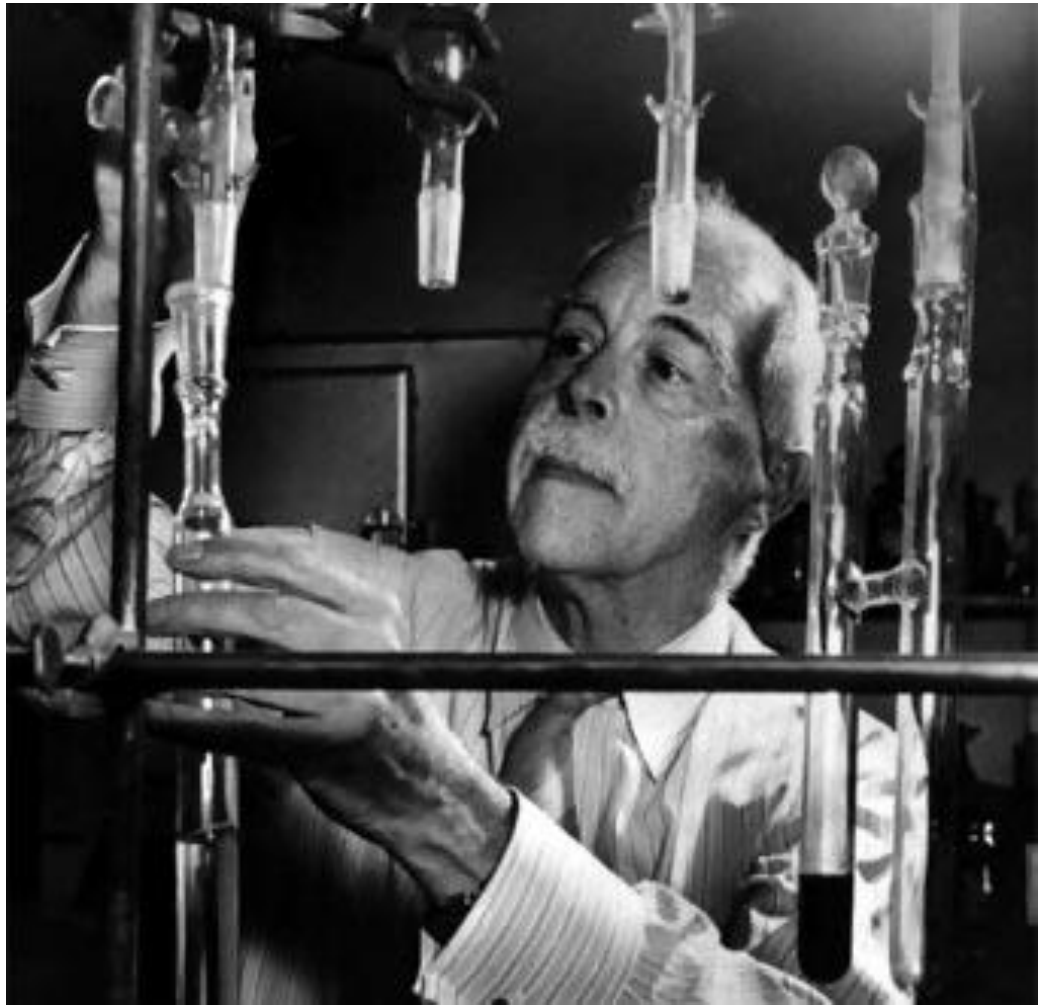

GILBERT NEWTON LEWIS MEDAL
1875
1946
THE THEORETICAL ASPECTS OF CHEMISTRY
FOR ACHIEVEMENT
IN

AWARDED
TO
Linus Pauling
November 27, 1951
BY THE
CALIFORNIA
SECTION
AMERICAN CHEMICAL SOCIETY

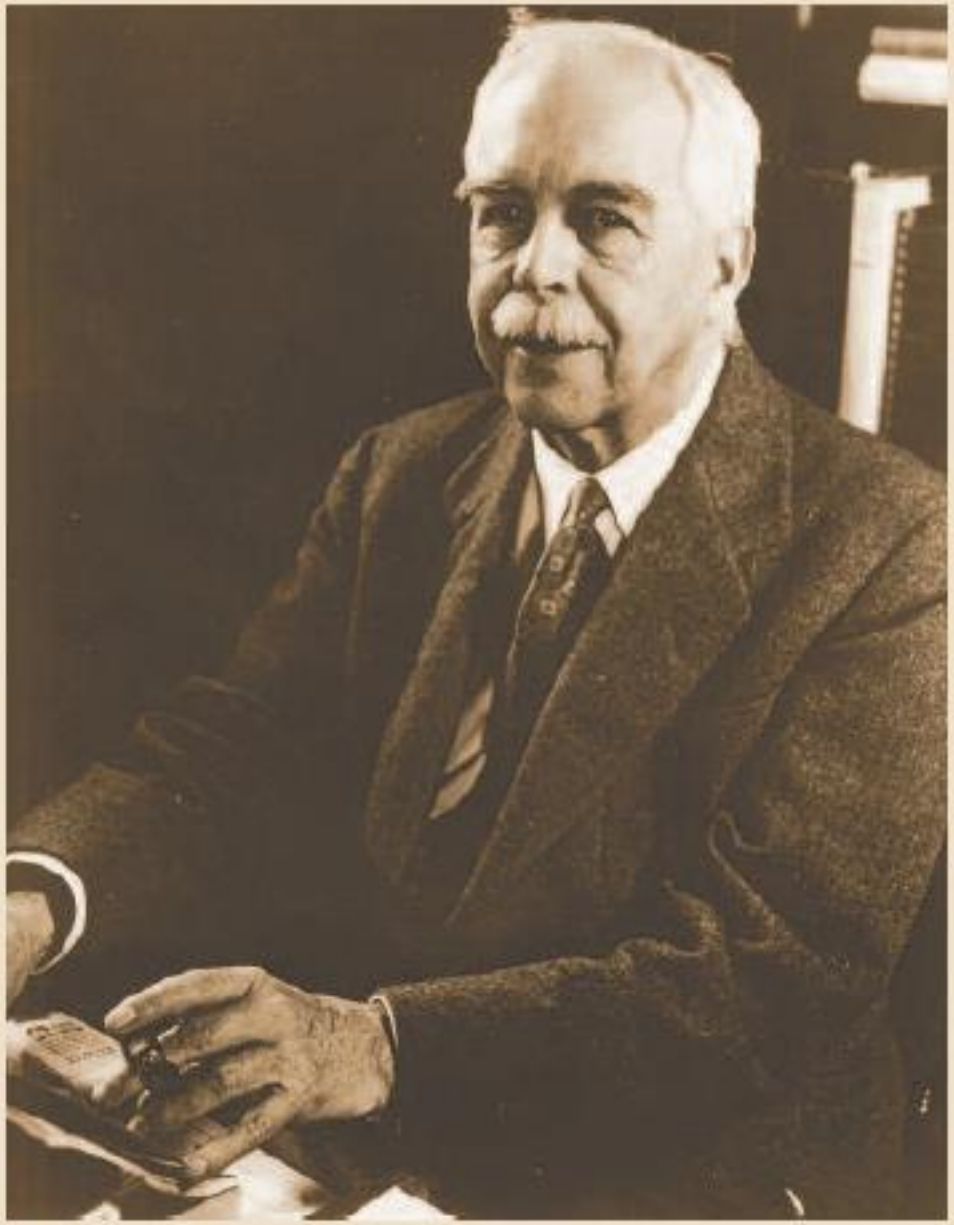
“After the discovery of the electron many efforts were made to develop an electronic theory of the chemical bond. A great contribution was made in **1916 by Gilbert Newton Lewis**, who proposed that the chemical bond, such as the single bond between two carbon atoms or a carbon atom and a hydrogen atom represented by a line in the customary structural formula for ethane, consists of **a pair of electrons held jointly by the two atoms that are bonded together**. Lewis also suggested that **atoms tend to assume the electronic configuration of a noble gas,** through the sharing of electrons with other atoms or through electron transfer, and that the eight outermost electrons in an atom with a noble-gas electronic structure …. Applications of the theory and additional contributions were made by many chemists, including Irving Langmuir and Nevil Vincent Sidgwick.



LINUS PAULING, “Modern structural chemistry”
Nobel Lecture, December 11, 1954

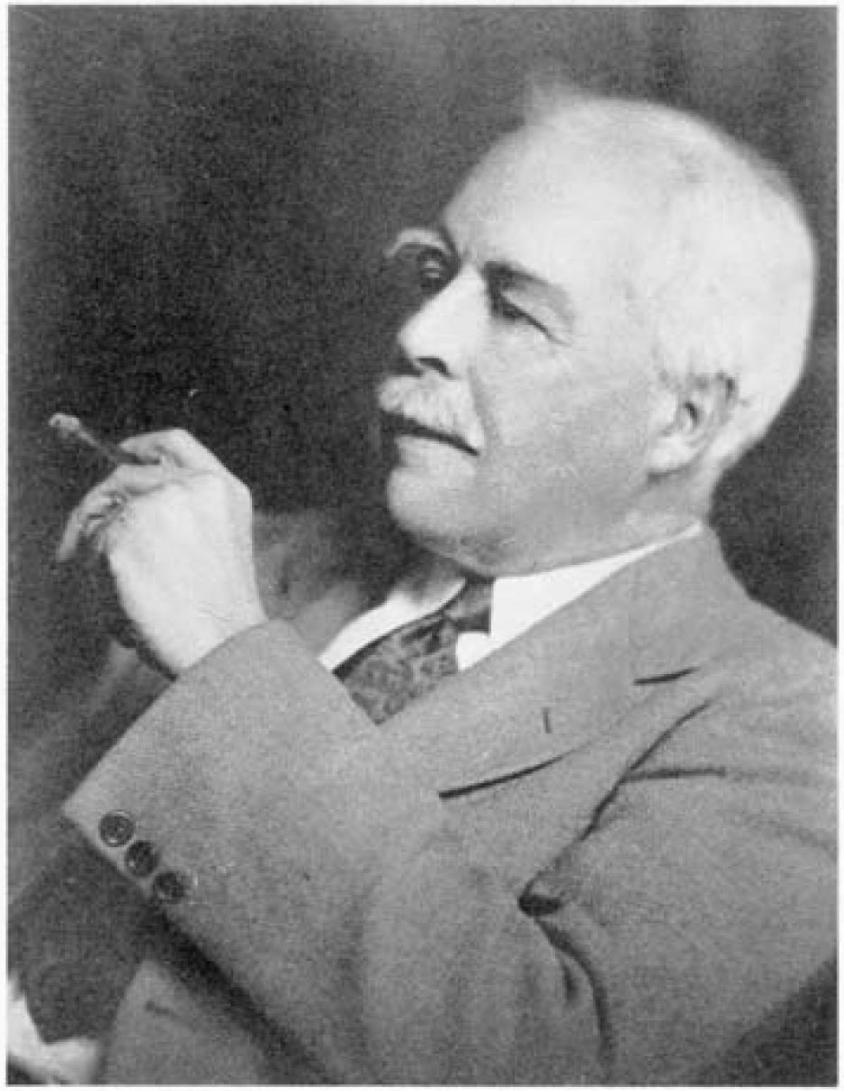


1944

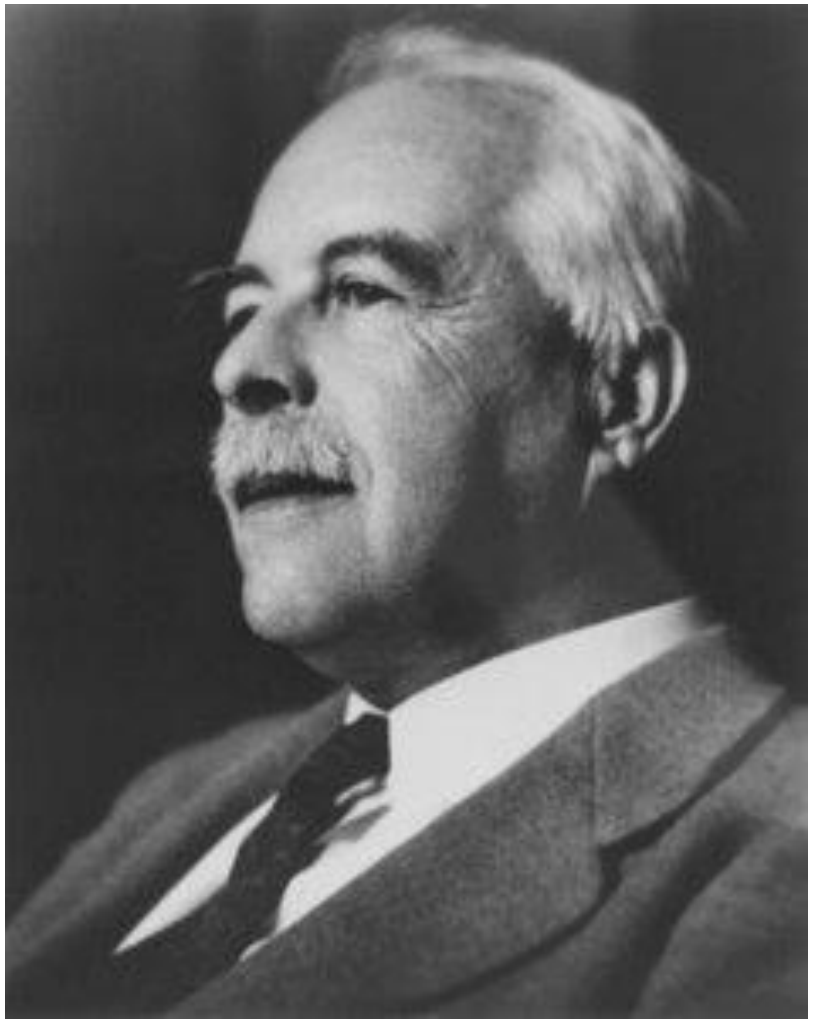


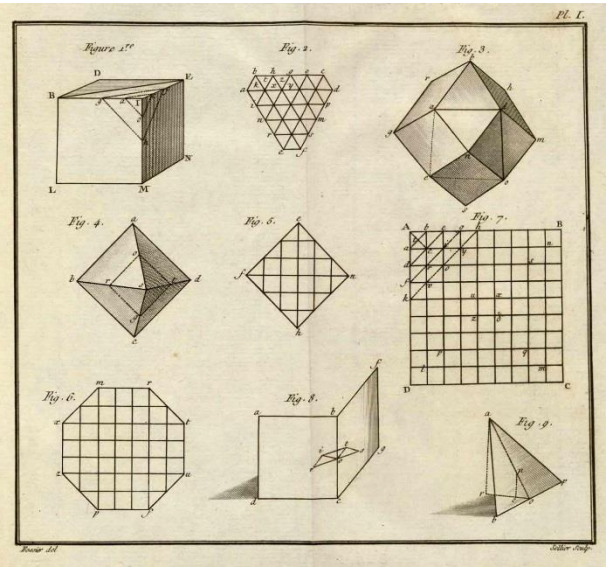
Gilbert N. Lewis with his trademark cigar

1897: Thomson descobreix l'electró
1902: "Memorandum" de Lewis a Harvard
1911: Model atòmic the Rutherford
1913: Model atòmic de Bohr
Moseley: número atòmic
1916: "The Atom and the Molecule"
1919: Articles de Langmuir
1923: *Valence and the Structure of Atoms and Molecules*
Thermodynamics and the Free Energy of Chemical Substances
De Broglie: ona-partícula
1924: Principi d'exlussió de W. Pauli, nombres quàntics
1926: Lewis, *The Anatomy of Science*
1926: E. Schrödinger i la mecànica ondulatòria de l'electró
1931: J. Slater, Linus Pauling: hibridació d'orbitals
1932-35: Lewis sobre isòtops
1934: Harold Urey, Premi Nobel the química *"for his discovery of heavy hydrogen"*
1930s: Àcids-bases de Lewis [resistències protòniques]
1939: Linus Pauling, *The Nature of the Chemical Bond*
1940s: Lewis: Fotoquímica
1946: Mort de Lewis
1953: Christopher Ingold, *Structure and Mechanism in Organic Chemistry*



Gilbert N. Lewis





RENÉ JUST HAÜY, *Essai d'une Théorie sur la Structure des Crystaux*, 1784

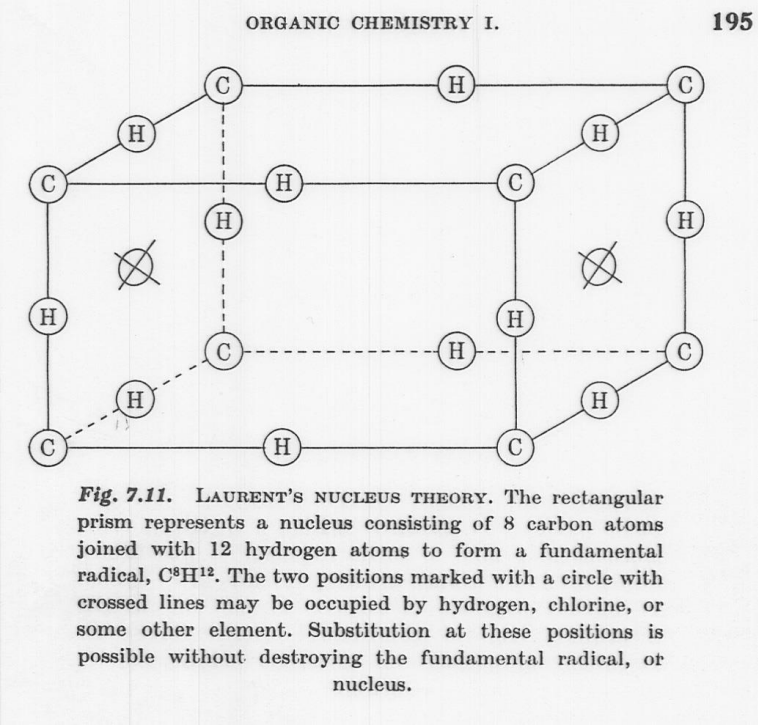


Fig. 7.11. LAURENT'S NUCLEUS THEORY. The rectangular prism represents a nucleus consisting of 8 carbon atoms joined with 12 hydrogen atoms to form a fundamental radical, C^8H^{12}. The two positions marked with a circle with crossed lines may be occupied by hydrogen, chlorine, or some other element. Substitution at these positions is possible without destroying the fundamental radical, or nucleus.

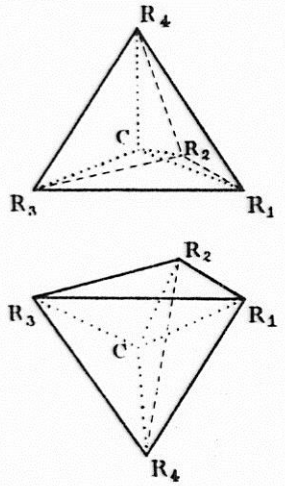
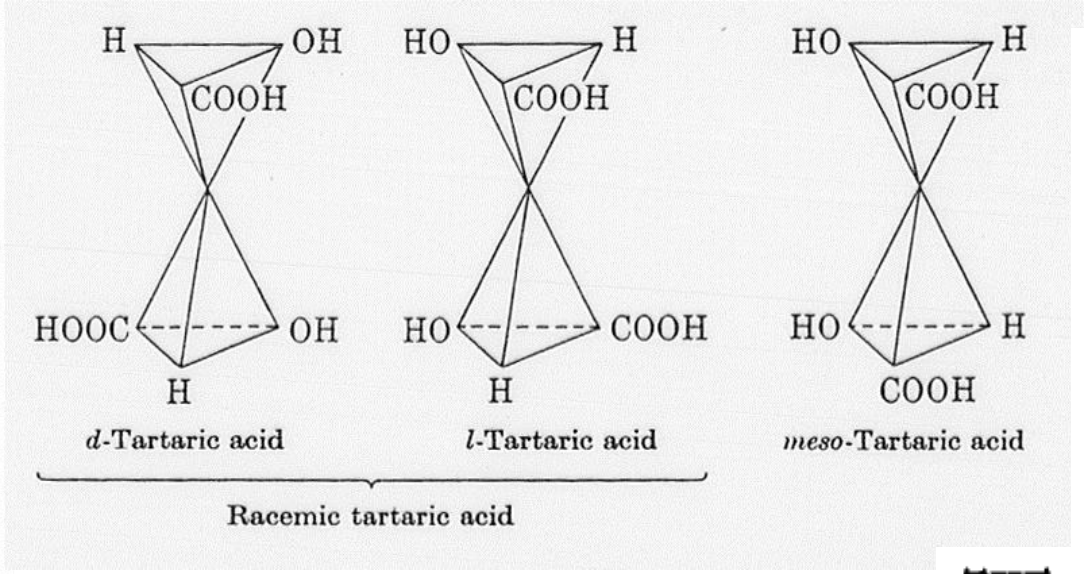


Fig. 12.15. VAN'T HOFF'S TETRAHEDRAL REPRESENTATION OF THE MIRROR-IMAGE RELATIONSHIP.
(From van't Hoff, *La chimie dans l'espace* [1875].)



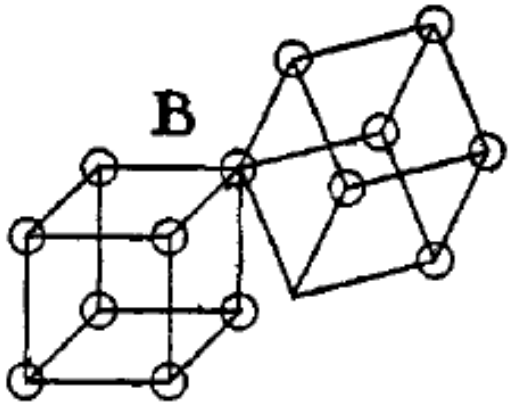


Fig 3.

THE ATOM AND THE MOLECULE.

Lewis, Gilbert Newton

L'Àtom i la molècula

Traducció i introducció a càrrec de Josep Castells i Guardiola

Col·lecció: Clàssics de la química ; 1
2004

"Es pot formular alguna predicció raonable sobre la perdurabilitat interpretativa del parell d'electrons de Lewis?
Paul A. M. Dirac: "acceptada la mecànica quàntica, les qüestions químiques són problemes de matemàtiques aplicades"
…és admissible acceptar que la química pugui anar esdevenint lentament un exercici d'hipersupercomputació [però] …les justificacions o explicacions formulades dins del nivell interpretatiu de la química seran acceptables sempre que no vagin clarament en contra de les bases teòriques de la física…."

"I és aquí on retrobem finalment el parell d'electrons, ja que té un paper important en el **nivell interpretatiu de la química**. **Per tant, em sembla garantida una llarga perdurabilitat del parell d'electrons….de Lewis**!"

(Josep Castells, pp. 22-23)