

The Kekulé Riddle

*A Challenge for Chemists and
Psychologists*

Edited by

John H. Wotiz
Professor Emeritus
Department of Chemistry
Southern Illinois University
Carbondale, IL 62901 USA



Clearwater, FL • Vienna, IL

© Glenview Press* by agreement with Cache River Press, 1993

All rights reserved. This book is protected by Copyright ©. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the copyright owner.

Library of Congress Catalogue Card Number 92-72493
ISBN 0-9627422-2-8

1st edition

Edited by:
John H. Wotiz

Publisher and Distributor:
Cache River Press
Rt 3, Box 239C
Vienna, IL 62595

***Glenview Press, Inc.**
P. O. Box 492
Carbondale, IL 62901 USA

It happens seldom in the life of an historian that he comes across the work of a man who has really produced a great masterpiece and has then been practically forgotten.

This may be more common in art history than it is in the history of science. To give just one example, one of the greatest painters of the 17th century was Jan Vermeer who can truly be considered one of the first impressionists ever. He painted very little, only about 40 works half of which were in the collection of one Delft collector whose estate was sold in 1696. In the 18th and 19th centuries, Vermeer's work was little known, and his paintings were often attributed to other artists. We can well imagine how the great French art historian, Theophile Thoré Bürger, must have felt when he realized that these wonderful works attributed to others were really by one hand, that of Jan Vermeer.

In the history of science this may be rarer, yet it does happen, and in this chapter we would like to discuss one specific example—that of Josef Loschmidt and his *Chemische Studien* of 1861 (1). In each generation since Loschmidt's death in Vienna in 1895, someone has recognized his greatness and has written about it extensively, only to have Loschmidt's name forgotten again.

The first to recognize his greatness was Richard Anschütz (2, 3), a student of Kekulé, who became his biographer and his successor as professor in Bonn. In 1913 he reprinted and annotated Loschmidt's work of 1861 (1). Anschütz's comments speak for themselves. He wrote on page 101 of his reprint (3) "Loschmidt presented his views of the constitution of aromatic compounds four years before Kekulé. If these views had been published in a well-known chemical journal, they would really have created a great deal of stir and would have added substantially to the development of chemistry. Besides that, Loschmidt developed his graphic formulae on the basis of ideas about molecules which even today [1913] deserve careful consideration." Perhaps Anschütz did not ask himself a key question: where could Loschmidt have published his work in 1861? The *Berichte* and the *Monatshefte* did not yet exist. In view of Liebig's (4) devastating attack on Austrian chemistry in general and Loschmidt's teacher, P. T. Meissner, in particular, the *Annalen* was unlikely to have accepted it.

On page 105 of his reprint (3), Anschütz poses the important question whether Kekulé had seen the original of Loschmidt's 1861 work, or whether he had only learned superficially about the graphic formulae through a third party. In a single one-line sentence, he then denies that Kekulé had actually seen Loschmidt's book but asserts that he must have learned about the formulae, in all probability through a good friend, Hermann Kopp, who was not an organic chemist and who had written an abstract of Loschmidt's book in Liebig's *Jahresbericht der Chemie*, in 1861 (5). This review by Kopp might be compared to our reviews nowadays by *Chemical Abstracts*.

Anschütz may have been too kind to Kekulé. Perhaps Loschmidt's little book was better known than he realized. Why was it that just after its publication so many alternative benzene structures appeared?

Time and again the argument has been made (3, 6, 7, 8, 9) that Loschmidt's private publication did not constitute an accepted form of publication. But that is not so. The printing of the book was paid for by Loschmidt, but the book was for sale by the printer for 20 Neugroschen and foreign libraries could and did purchase it (10). Later Anschütz found out (11, p. 305) that Kekulé must have seen the book shortly after its publication, for how else could Kekulé comment on these structures in a personal letter of January 14, 1862 to Erlenmeyer (12) had he not seen the structures—"Loschmidt's Confusionsformeln" he calls them. Did he really find them confusing? Or was this merely a play on words, "Loschmidt's Constitutions Formeln" are just Confusionsformeln (11, p. 305; 13, p. 41). Why, if he had not seen the structures, would he again refer to them, this time publicly in his famous paper presented by Wurtz in Paris on January 27, 1865 and printed in the *Bulletin de la Société Chimique* (14). Gillis (13) recognized that all of Loschmidt's structures considered for benzene [e.g., 181, 182, 184 and 185 in (1) and (3) undoubtedly attracted Kekulé's attention and may have influenced his subconscious.

What a bit of luck that Anschütz came across Loschmidt's name in Kekulé's *French* paper, in which Kekulé said that he preferred his structures to those of Loschmidt and Crum Brown. Surely when a scientist says that he prefers one structure over another, he must know both. However, when essentially that same paper appeared in German in the *Zeitschrift für Chemie*, also in 1865 (15), footnote 2, referring to Loschmidt, was left out. Was that accidental or deliberate? [Editor's note: for a summary of Kekulé's selective memory, see Chapter 17] In a rework (16) of that paper a year later, Loschmidt's name appeared once again, in a slightly modified footnote.

Anschütz's role is a most interesting one. Time and again he recognized Loschmidt's greatness, for instance in acknowledging that he was the first to predict the existence of cyclopropane (3, p. 118), to formulate ozone (3, p. 130), and to depict toluene, benzyl alcohol, phenol and many other aromatic compounds correctly. He also agreed that Loschmidt's presentation of simple molecules like acetic acid is preferable to Kekulé's sausage formula, which he actually illustrated (3, p. 110). Anschütz made an enormous effort to reformat Loschmidt's book and to add many footnotes which help greatly in the understanding of his work which Kekulé had failed to understand and/or acknowledge.

The late Dr. William Wiswesser was first attracted to Loschmidt's work by a review article written by Moritz Kohn in *The Journal of Chemical Education* of 1945 (7). Dr. Wiswesser recognized that Loschmidt's formulae could be regarded as the first line formula notation, "rational formulae" so close to his heart—his *Wiswesser line notation*. Before his death in December 1989, he prepared a great deal of material, collating Loschmidt's work with his notations, and copies of this collation on computer disks are available to the public (17). Wiswesser's article on Loschmidt which appeared in the *Aldrichimica Acta* (18), and the republication of Loschmidt's book and Anschütz's revision have sparked renewed interest in this almost forgotten chemist.

It is interesting to speculate how Loschmidt arrived at his organic formulae. If he is known for anything it is the Loschmidt number, but that is something quite different. Was he an outsider who simply had a lucky break? The answer to that can be found in an important paper of 1878 entitled "The Scientific Goals and Accomplishments of Chemistry"(19). Beginning with Dalton's theory, the author of the paper describes the historical development of the understanding of the molecular construction of organic molecules. He names Avogadro's hypothesis of 1811 as an important step which was not further developed until it was understood that gas particles are identical with chemical molecules. The development of Avogadro's hypothesis led to the Loschmidt number, and so it appears that Loschmidt's studies in gas theory were the source and basis for his extraordinary work in chemistry. One sentence in that 1878 paper (19) is important: "The chemical aspect of atomic theory was substantially broadened approximately 20 years ago through the hypothesis developed *by chemists* [emphasis supplied] which can be called the theory of the chemical valence of atoms."

Now, which chemists developed this hypothesis? One, of course, was Kekulé. But another, the link between Avogadro and molecular construction as it was known in 1878, was Josef Loschmidt. And of course, one may ask who made this important statement without naming Loschmidt? It was none other than August Kekulé in his *Rektoratsantrittsrede* in Bonn (19). Could he have forgotten the chemist's name? It is well known that Kekulé had a marvellous memory (11, p. 468), a photographic memory, and so that is unlikely. He must have known a great deal about Loschmidt's work and deliberately omitted his name in the very passage where he could so easily have acknowledged Loschmidt's contribution (20). Here Kekulé talked of the relationship between physics and chemistry which Loschmidt understood so clearly.

Not only did Loschmidt understand, he was able also to depict on paper representations of molecules which came remarkably close to our present day molecular modeling. No chemist before him, and very few in the 100 years that followed, have depicted molecules as realistically as he. Although he was known mainly as a physicist and was called by some authors (6, 21) an outsider to chemistry, the same scientific experience that led to the Loschmidt number led him also to this outstanding work in organic chemistry. It is Kekulé's speech in Bonn in 1877 (19) which provides the link between Avogadro through Loschmidt to molecular modeling. Loschmidt's studies in gas theory practically predestined him to become the founder of molecular modeling. He did not need a dream (22). The introduction of his tiny book [1] showed how clearly Loschmidt understood the structures of molecules.

The title of Loschmidt's book is interesting. He called it *Constitutions-Formeln der organischen Chemie in graphischer Darstellung*, the title on the cover of the copies in the library of the Technical University in Vienna [shown in (21)], in the British Museum Library, and elsewhere. However, the copy which Aldrich reprinted (lb) from a microfilm supplied by the Austrian National Library bears the title *Constitutions-Formeln der organischen Chemie in geographischer Darstellung*.

Presumably this was a galley proof, and someone may have commented to Loschmidt that *graphic* made more sense than *geographic*. However, it is interesting to note that among the definitions of geography is “a systematic arrangement of constituent elements” (23), and Loschmidt attempted just that. Here again, Loschmidt shows himself to be not only a superb chemist, but one of the great physicists of his time, and in fact, he became the world’s first professor of physical chemistry. Loschmidt’s models were the very first which considered atomic sizes and their relationships within molecules. He would have been ahead of his time even in the 1940s, not to speak of the 1860s when Kekulé came out with his sausage-like representations (24-28).

The following figures show a comparison between the way in which we depict molecules today, Loschmidt’s representations of 1861, Kekulé’s from 1865 on, and the same molecules in molecular modeling. One reaches the inevitable conclusion that Loschmidt was far closer to our molecular modeling than anyone in the 19th century:

Figure 1 compares the simple molecule acetic acid, as represented by Loschmidt, with molecular modeling of today, and with the then accepted sausage formula of Kekulé. The latter has the carbon atom of the carbonyl in direct contact with two hydrogen atoms. On page 110 of his reprint (3) Anschütz points out how superior Loschmidt’s formula is. Figure 1 also shows the situation in 1867. By that time, Kekulé, who in 1865 had preferred his own structures to Loschmidt’s and Crum Brown’s, had abandoned his sausage formula of acetic acid.

Acetone [also Figure 1] is another example of Loschmidt’s clarity. In Kekulé’s textbooks (27, 28) published five and six years later, the oxygen atom is in contact with three carbon atoms.

Cyclopropane [also Figure 1] was first made by Freund in 1882. Loschmidt predicted its existence 21 years earlier. Anschütz (11, p. 302) recognized that this was the first prediction of a carbocyclic structure.

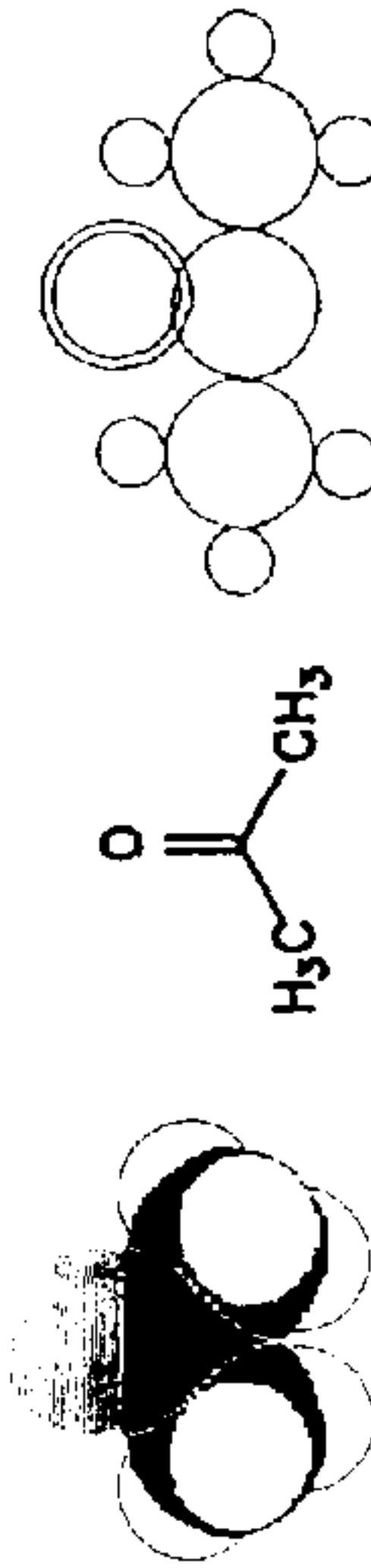
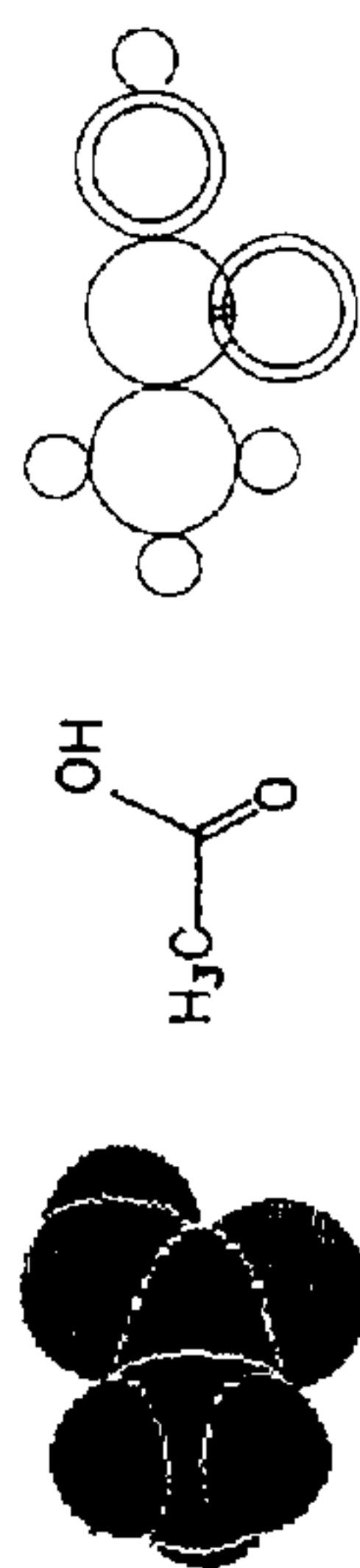
Anschütz (3, p. 110) pointed out that Loschmidt was the first to show double and triple bonds, with the overlaps, as shown with ethylene and acetylene [Figure 2].

Loschmidt, the physical chemist, thought about the sizes of atoms and came close to reality [Figure 3].

Let us now consider some of Loschmidt’s 121 aromatic structures. Figure 4 contains the comparison of Loschmidt’s structure of benzenesulfonic acid with Kekulé’s. In Kekulé’s formula of five years later, the sulfur atom is in contact with three carbon and two oxygen atoms. Yet Kekulé considered his formulae superior to Loschmidt’s. Today this sounds like a joke, since to us Kekulé’s formulations are the *Confusionsformeln*.

Loschmidt used an odd representation for chlorine, as in chlorobenzene [also Figure 4], but surely it is preferable to Kekulé’s, where the chlorine is in contact with three carbon atoms.

ACETONE



Organischen Chemie

Dr. Aug. Kekulé,
a. Professor der Chemie an der Universität zu Berlin



Erstausgabe
Verlag von Ferdinand Enke
KEKULÉ 1861

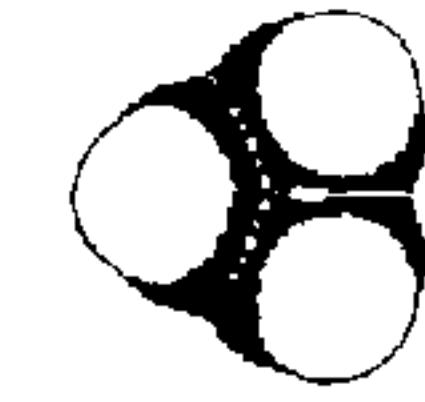
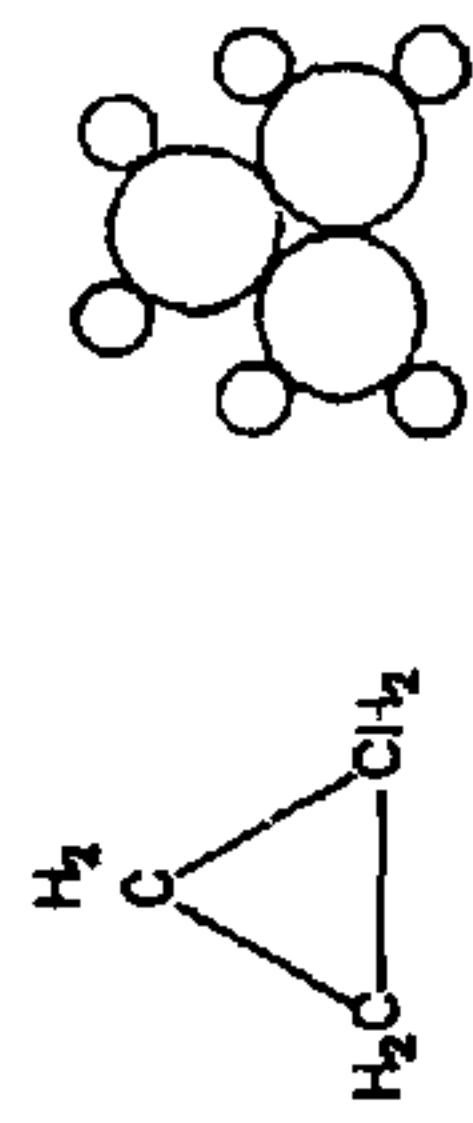
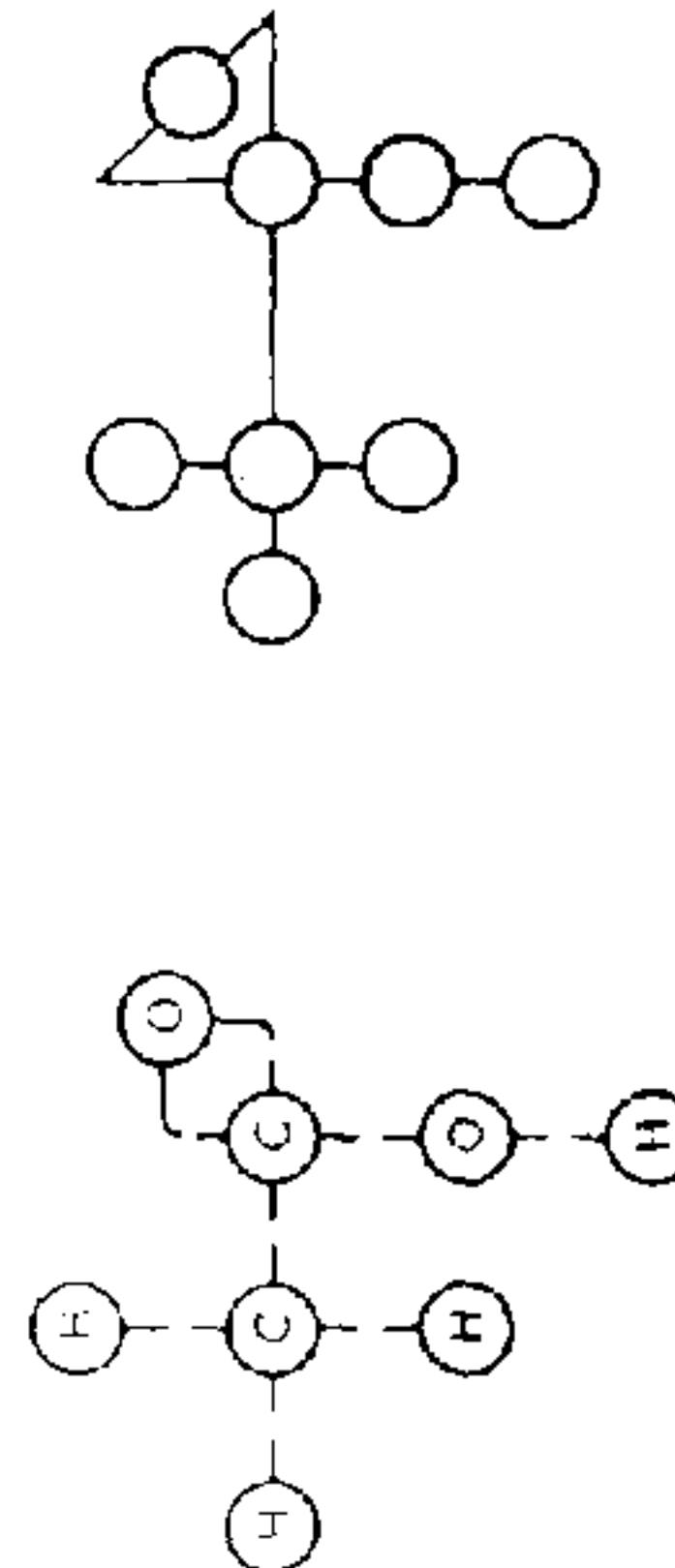
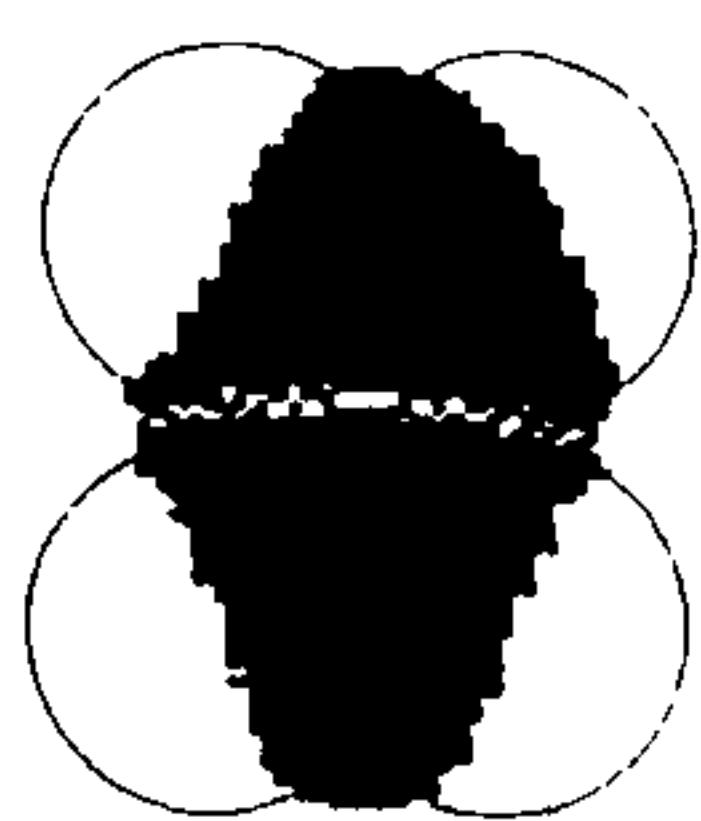
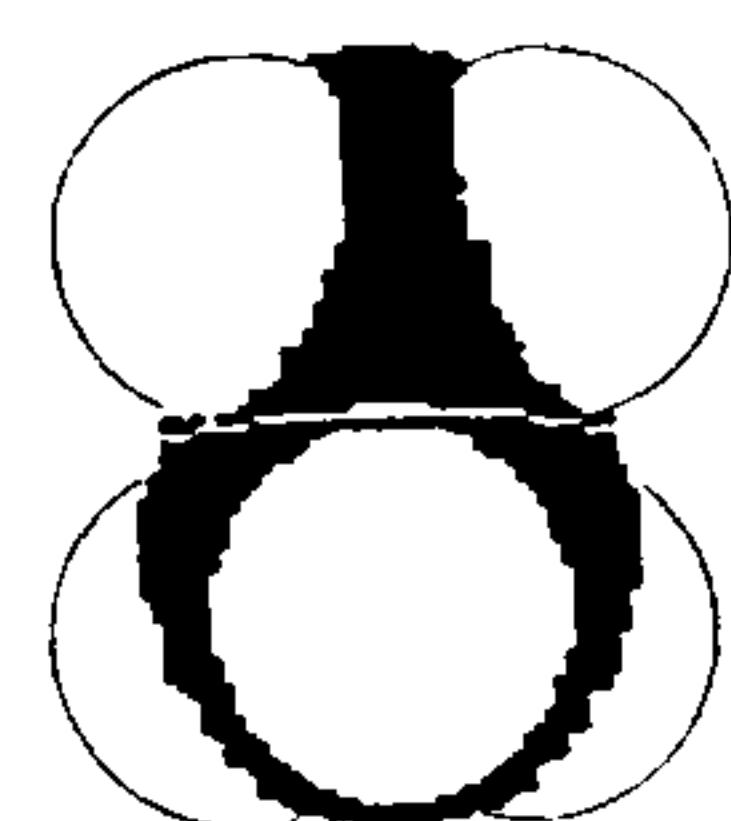
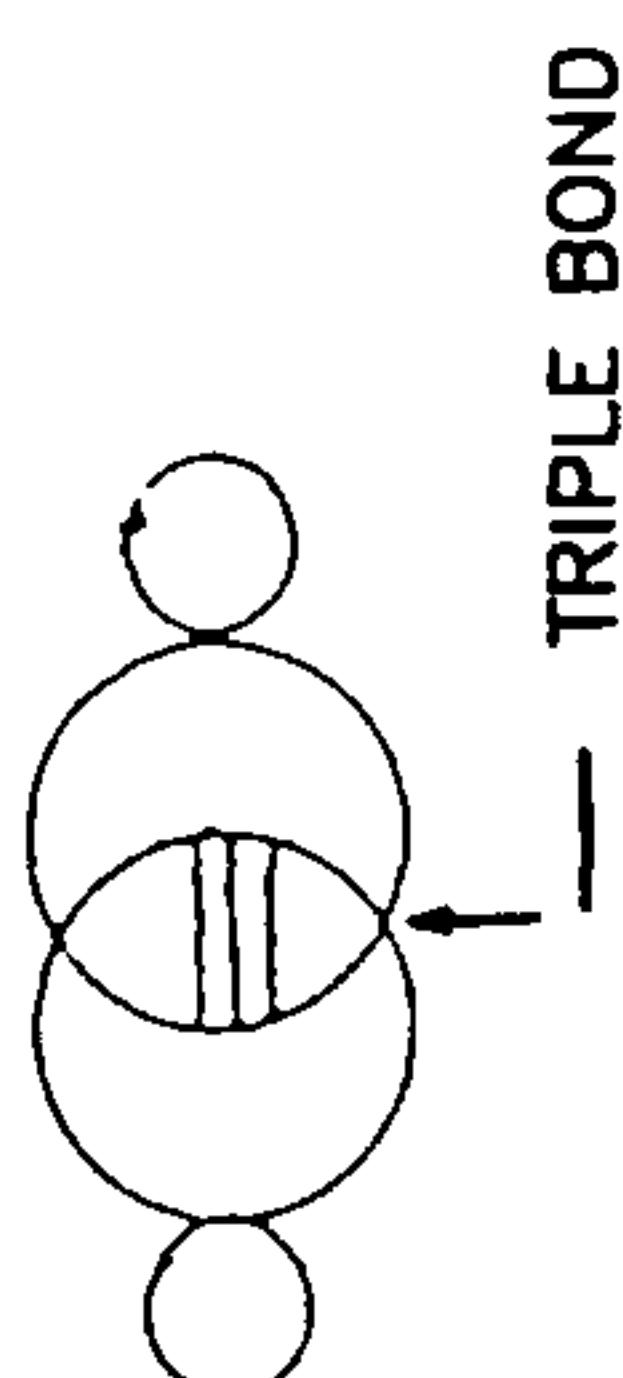
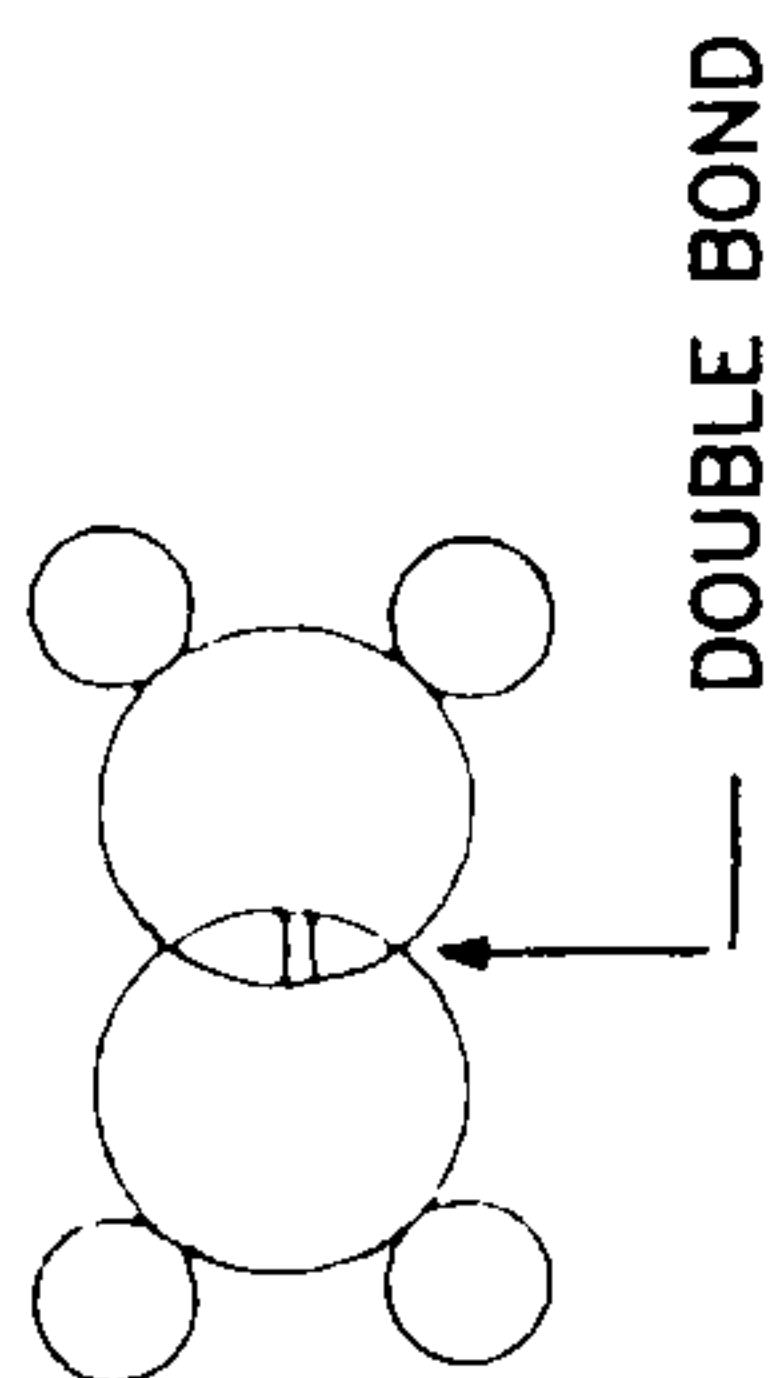
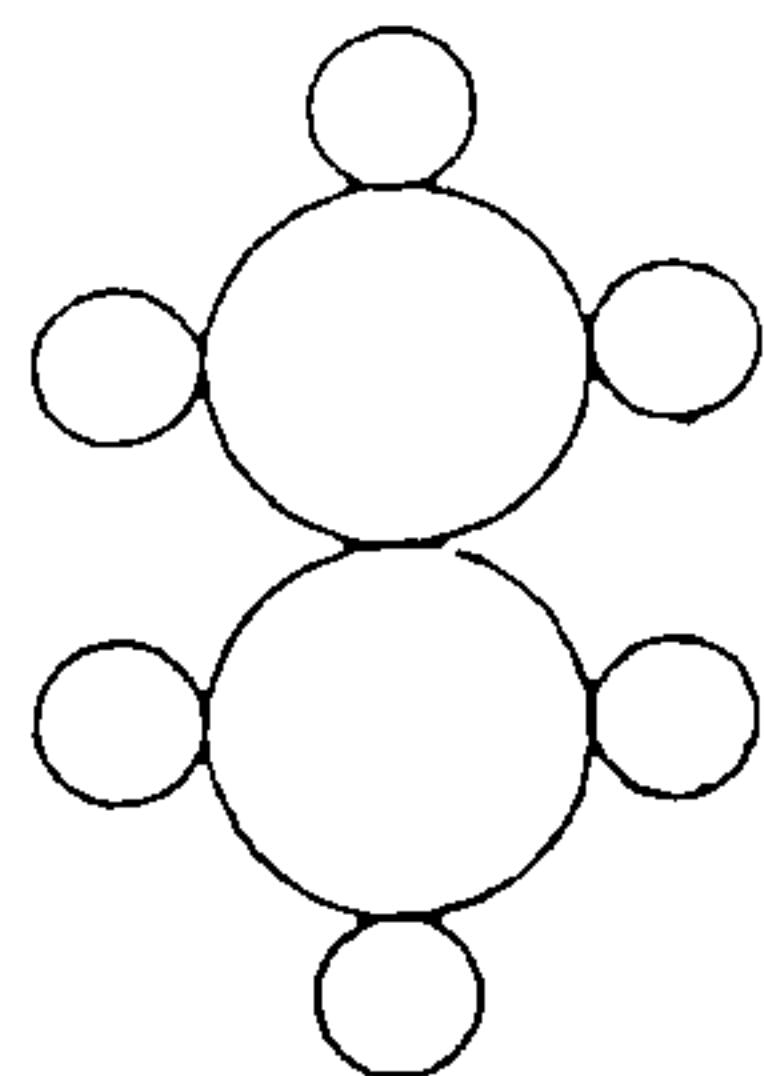


FIG. 1



ETHANE



ETHYLENE

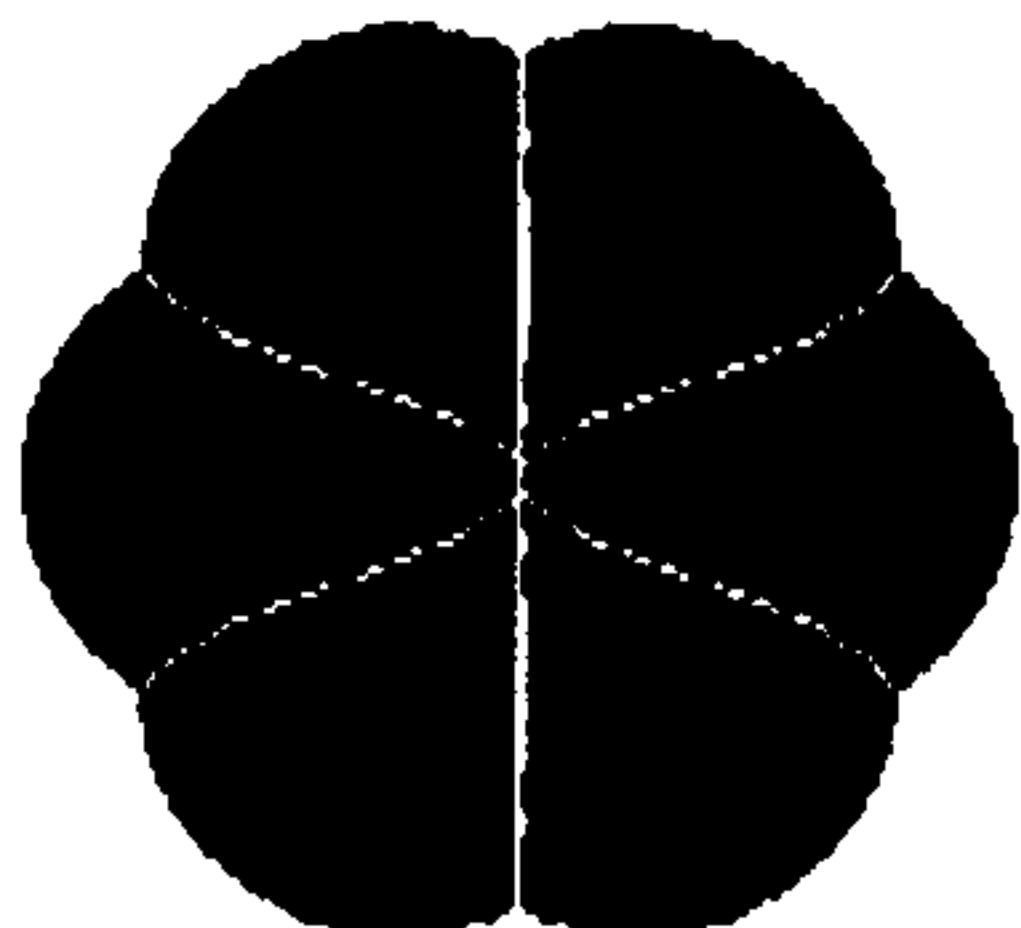


ACETYLENE

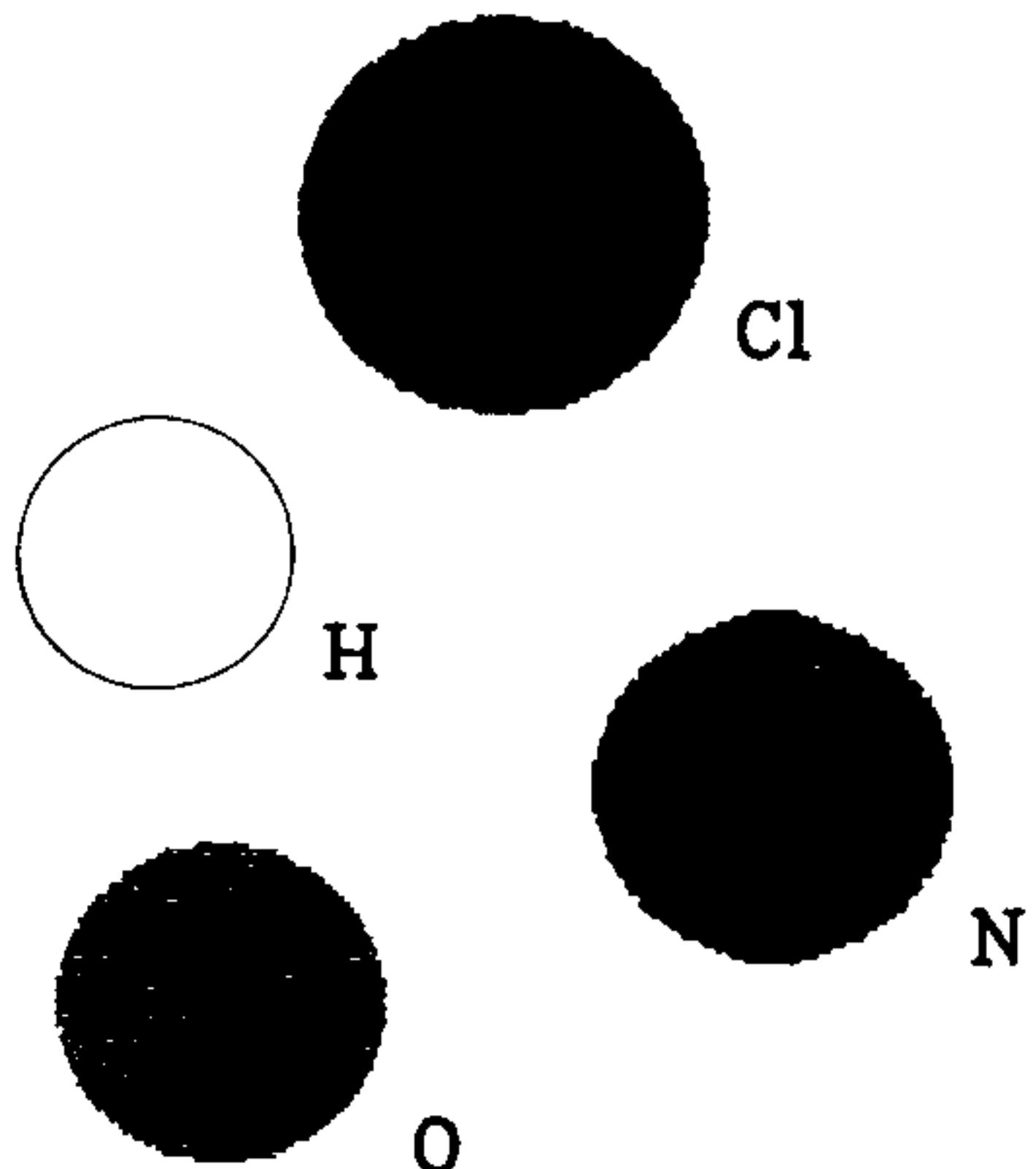


FIG. 2

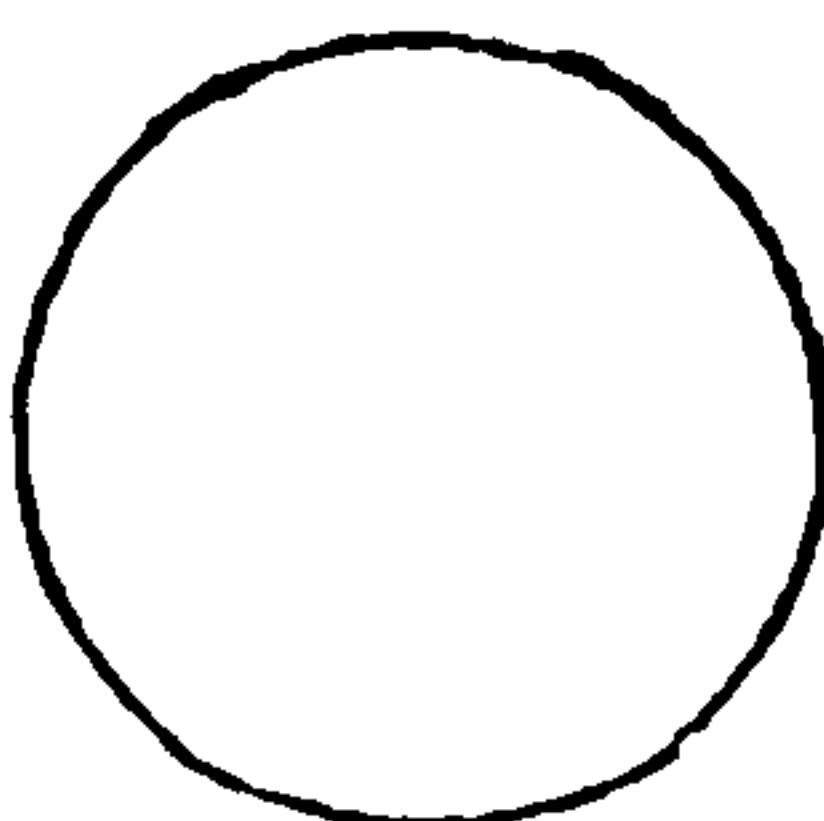
SET OF ATOMIC SIZES



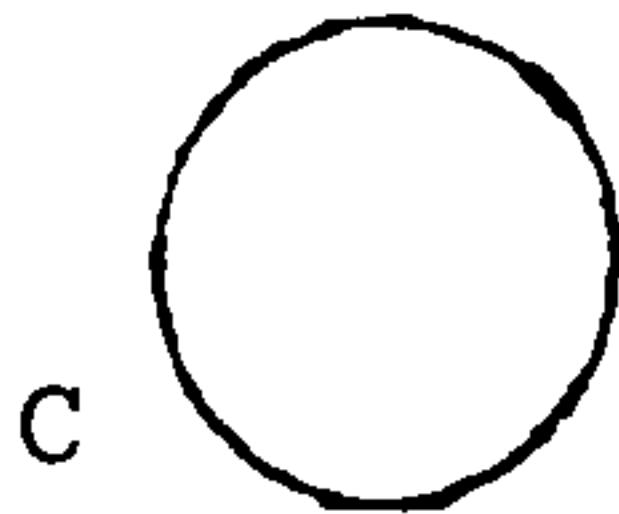
BENZENE



Alchemy II
TRIPOS Associates
St. Louis, Mo.

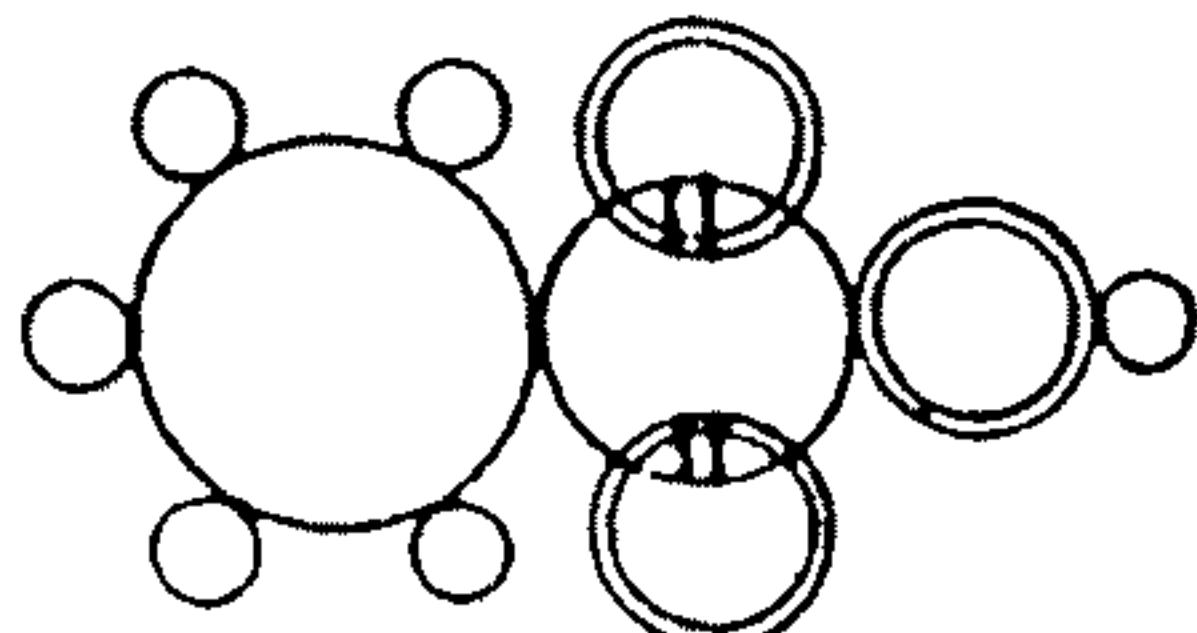


BENZENE

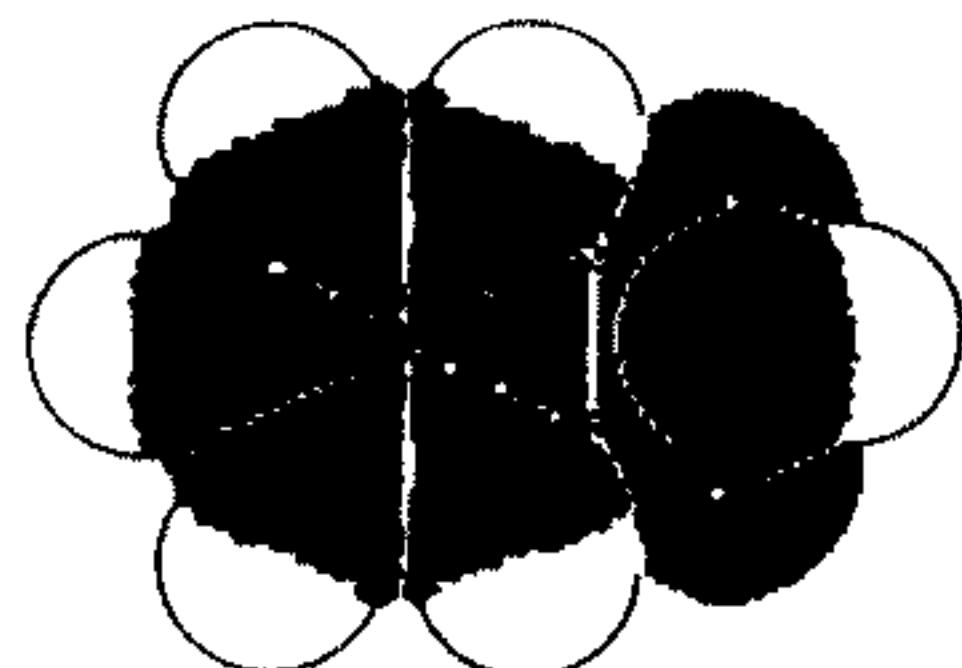
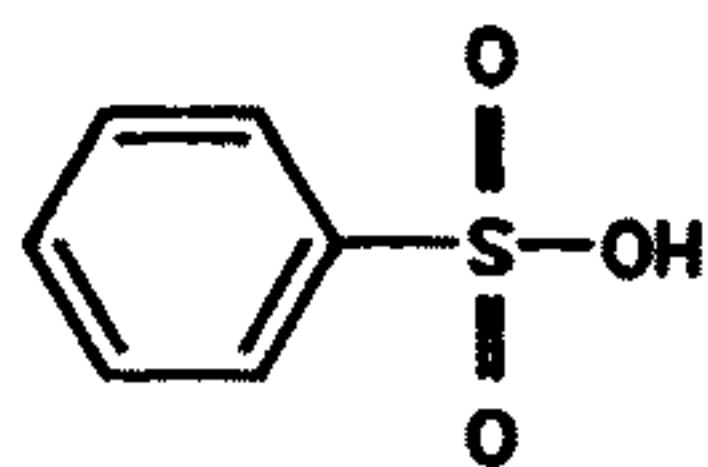


LOSCHMIDT 1861

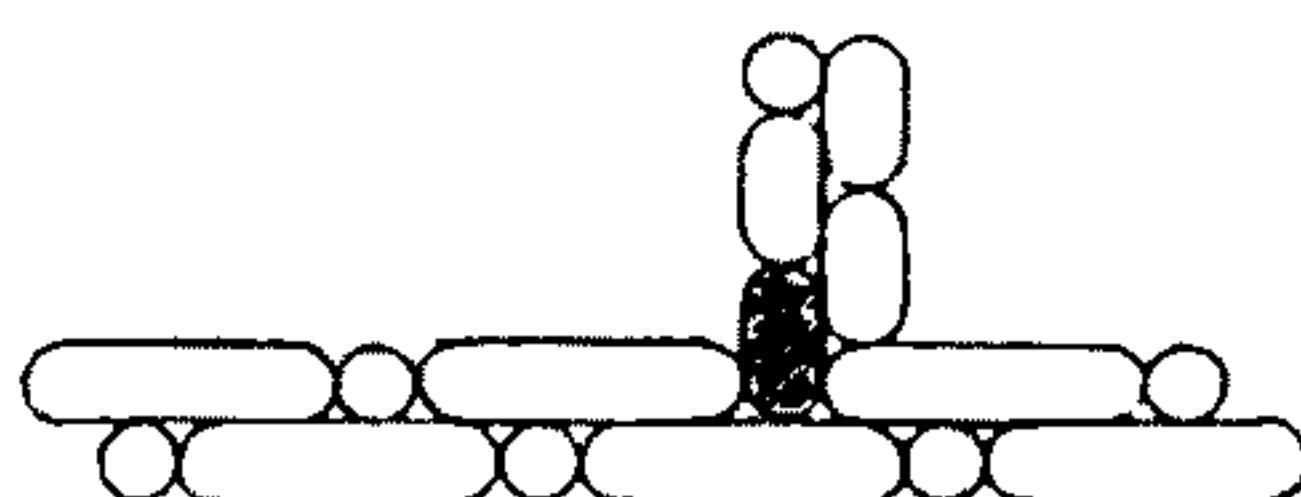
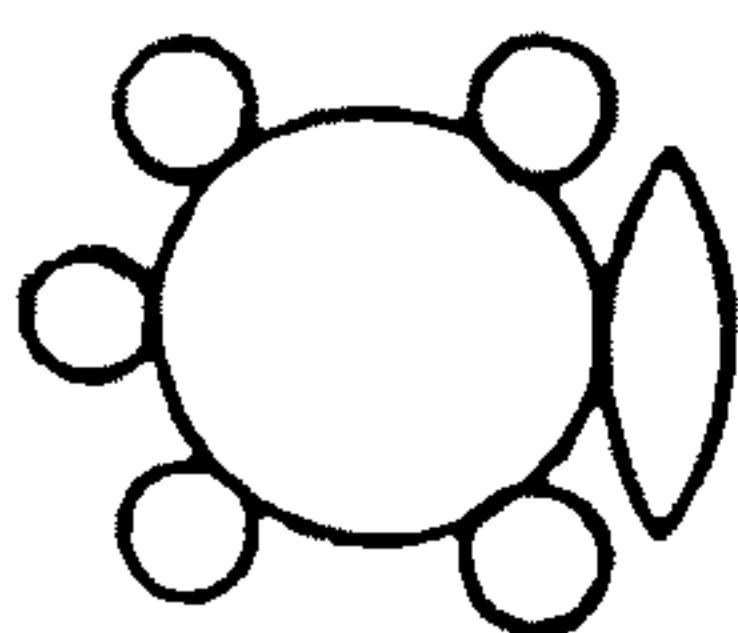
FIG. 3

BENZENESULFONIC ACID

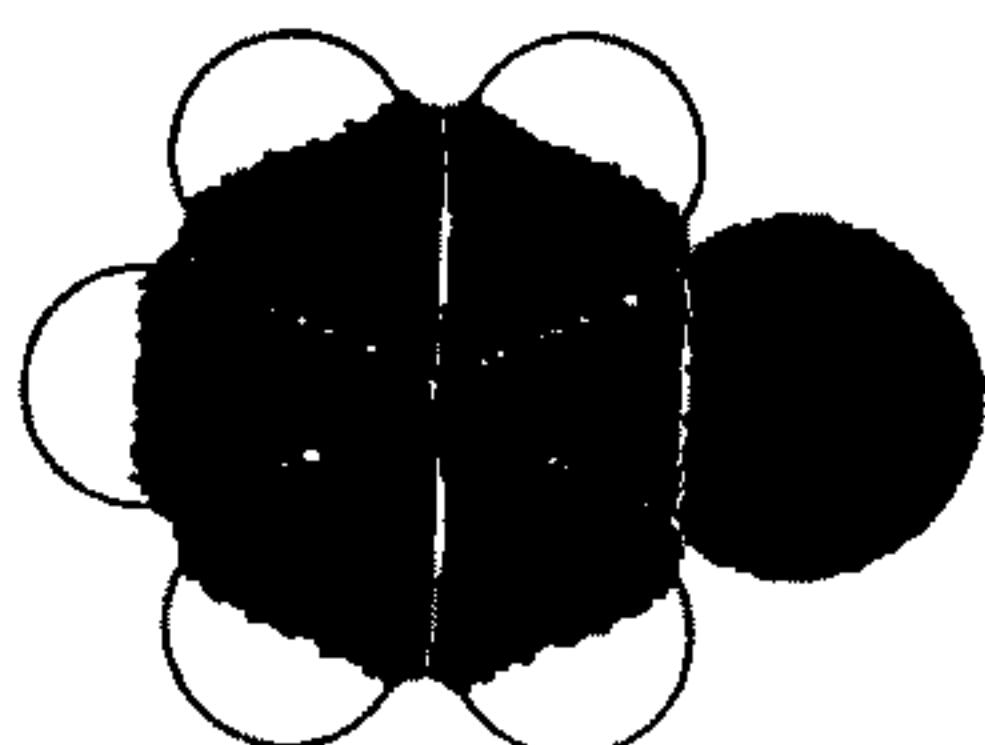
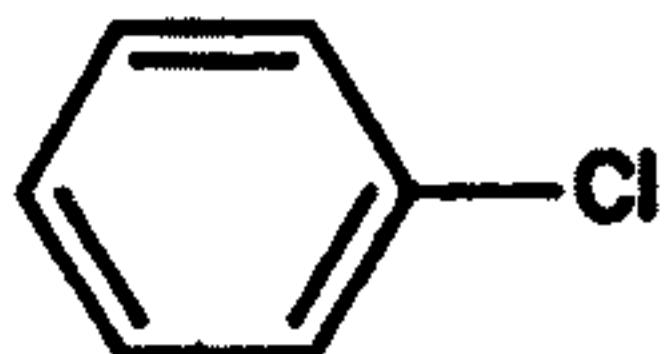
LOSCHMIDT 1861



MOLECULAR MODELLING 1990

A. KEKULÉ, LEHRBUCH DER
ORGANISCHEN CHEMIE 1866
CHEMIE DER BENZOLDERIVATE 1867**CHLOROBENZENE**

LOSCHMIDT 1861



MOLECULAR MODELLING 1990

A. KEKULÉ, LEHRBUCH DER
ORGANISCHEN CHEMIE 1866
CHEMIE DER BENZOLDERIVATE 1867**FIG. 4**

Most textbooks of chemistry state that Kekulé presented his hexagonal structure of benzene in 1865, but in fact his textbook (28) of 1867 still shows these sausage formulae. What has sometimes been overlooked is that in 1867 Kekulé did consider the possibility that benzene might be a hexagon, but with corners of hydrogen atoms, not carbon atoms (28, pp. 22-23)[Figure 5]. Now one can understand why Kekulé presented aniline with the nitrogen atom taking the place of a hydrogen and the benzene ring broken. Only in the 1870s did Kekulé adopt the hexagonal formula with carbon atoms in the corners, long after other chemists had done so. In contrast, Loschmidt correctly depicted many aromatic structures [Figure 6], for instance, cinnamic acid, aldehyde and alcohol with the double bond in the *trans* position, a remarkable achievement in 1861.

The clarity of Loschmidt's structures of triphenylamine and benzidine [Figure 6] is particularly instructive. Kekulé's formula of benzidine is still based on the idea that the corners of the hexagon are hydrogen atoms.

In 1980 Klaus Hafner (29) described the importance of the benzene structure very clearly:

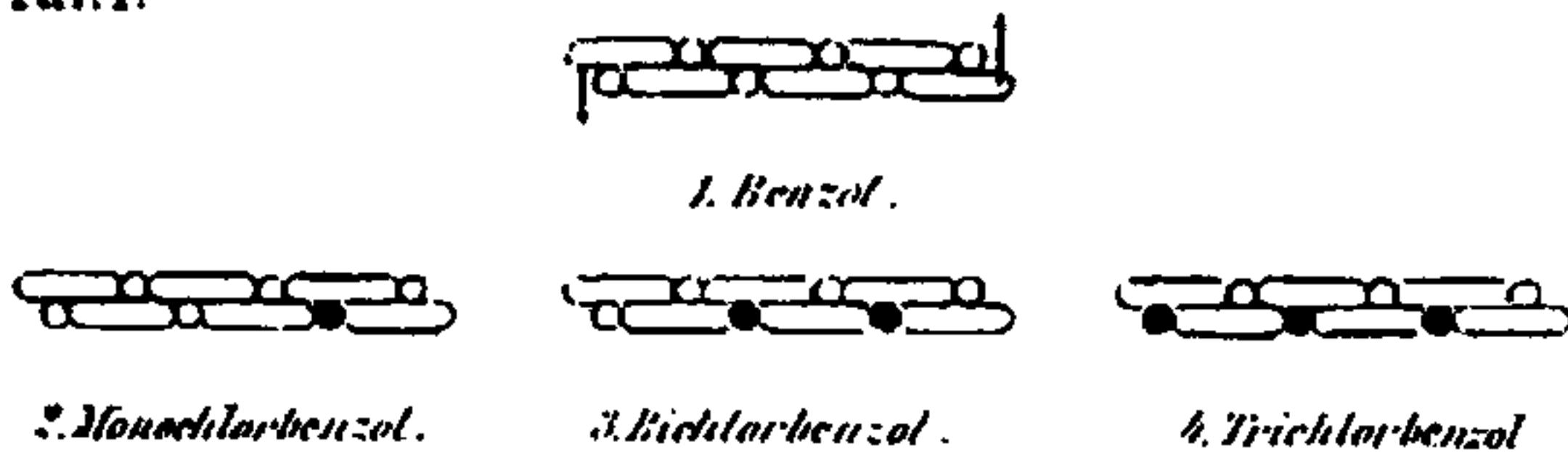
"The drawing of the benzene structure follows logically from structural theory.... From our point of view today this is an obvious conclusion, but more than 100 years ago it was an extraordinary mental leap, comparable with the enormous intellectual effort required before man could exchange the runners of the sled for the wheel. The idea that a hydrocarbon might have a circular structure was beyond the understanding of chemists of that time. The circle was the symbol for the indivisible, the atom." Hafner attributed this extraordinary mental leap to Kekulé, but in 1967, Ferdinand Kirchhof (21) had written:

"The idea that a compound might have a circular structure was outside the understanding of chemists of that time. The circle was the symbol for the indivisible, the atom, and the credit for representing the C₆^{VI} nucleus through the symbol of the circle belongs undoubtedly to Loschmidt." Loschmidt, not Kekulé.

Prof. G. P. Schiemenz [Editor's note: see also Chapter 9] suggested during the Kekulé symposium (30) that, although Loschmidt did indeed use a circle for benzene, this was just a symbol; he did not think of the six carbon atoms as being in a circle. Yet Loschmidt made this very clear (1, pp. 14-15; 3, p. 28) when he commented on the proposed structure of the as yet unknown cyclopropane: "In view of the behavior of other polyvalent atoms, this linking of the carbon atoms is not unlikely; in some cases, as we will see below with phenyl, it is the most **acceptable supposition**" [emphasis supplied].

A frequent argument first advanced by Anschütz (2, 3) and repeated by others (6, 9, 29) seeks to prove the superiority of Kekulé's concept over Loschmidt's by referring to Loschmidt's *in suspenso* passage relating to the structure of benzene (1, p. 30; 3, pp. 58-59). Loschmidt discusses various possibilities, having already stated that he considered the ring the most plausible, and leaves the decision about the details of this ring *in suspenso*, that is pending, because "our structures do not

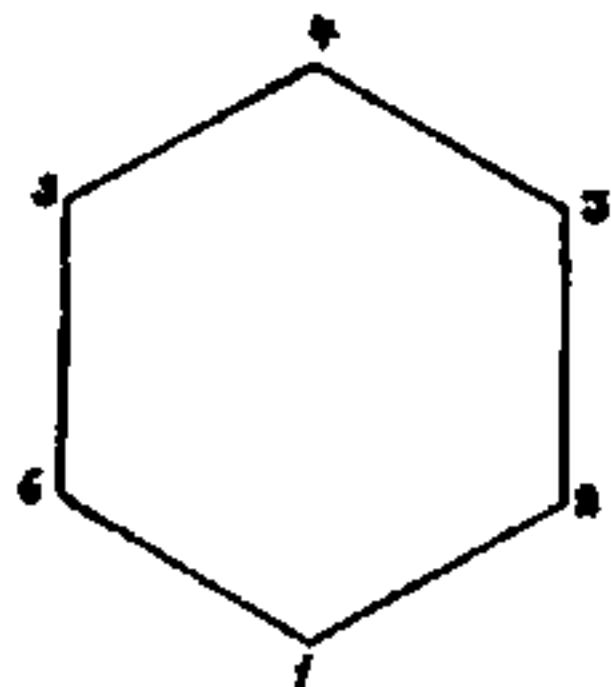
Taf. I.



Wenn man die sechs Kohlenstoffatome des Kerns C_6A_6 (oder des Benzols) in der Weise untereinander gebunden annimmt, wie dies früher entwickelt wurde (§. 1588), so bilden sie eine geschlossene und völlig symmetrische Atomgruppe, gewissermassen einen Ring; die sechs Wasserstoffatome sind dann nicht nur in Bezug auf den Kohlenstoff völlig symmetrisch gestellt, sie nehmen auch im Atomsystem (Molecul) völlig analoge Orte ein; sie sind also gleichwerthig *).

Bei dieser Auffassung könnte man das Benzol durch ein Sechseck darstellen, dessen sechs Ecken durch Wasserstoffatome gebildet sind:

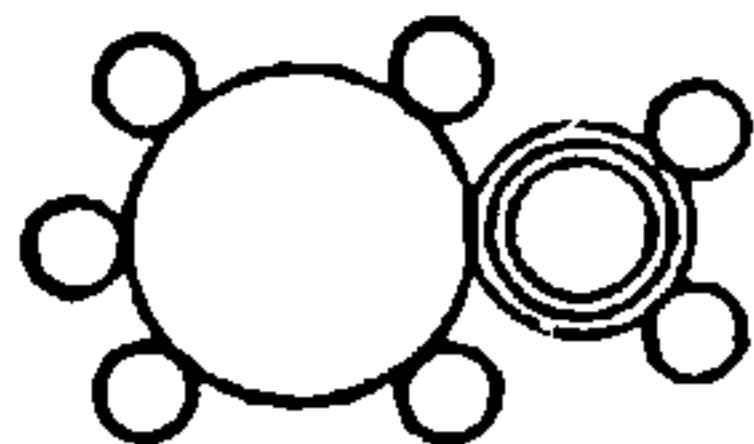
(emphasis supplied)



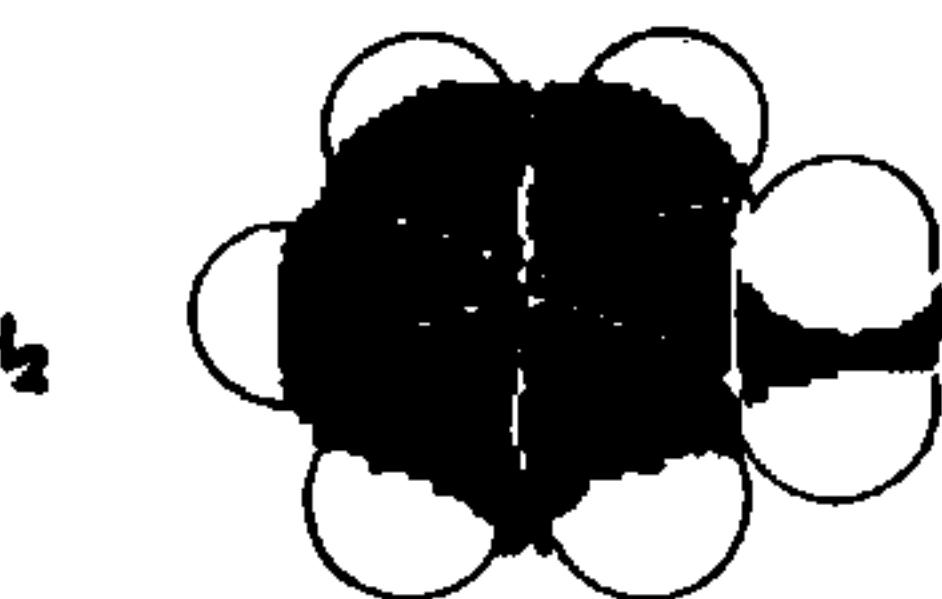
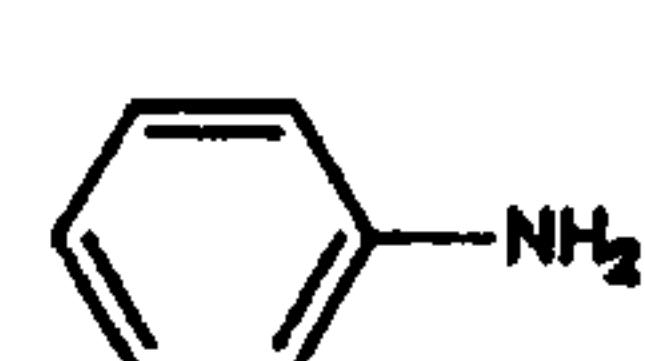
Man sieht dann leicht ein, dass für die durch stets fortschreitende Substitution entstehenden Derivate die folgenden isomeren Modificationen möglich sind.

A·KEKULÉ, CHEMIE DER BENZOLDERIVATE 1867

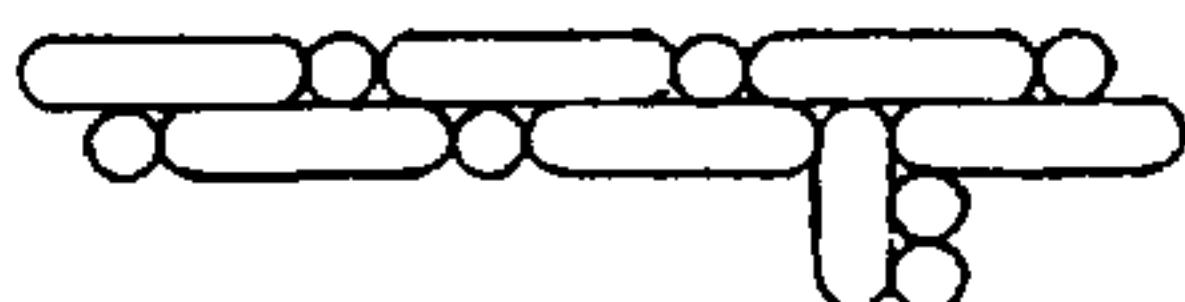
ANILINE



LOSCHMIDT 1861



MOLECULAR MODELLING 1990



A. KEKULÉ, LEHRBUCH DER
ORGANISCHEN CHEMIE 1866
CHEMIE DER BENZOLDERIVATE 1867

FIG. 5

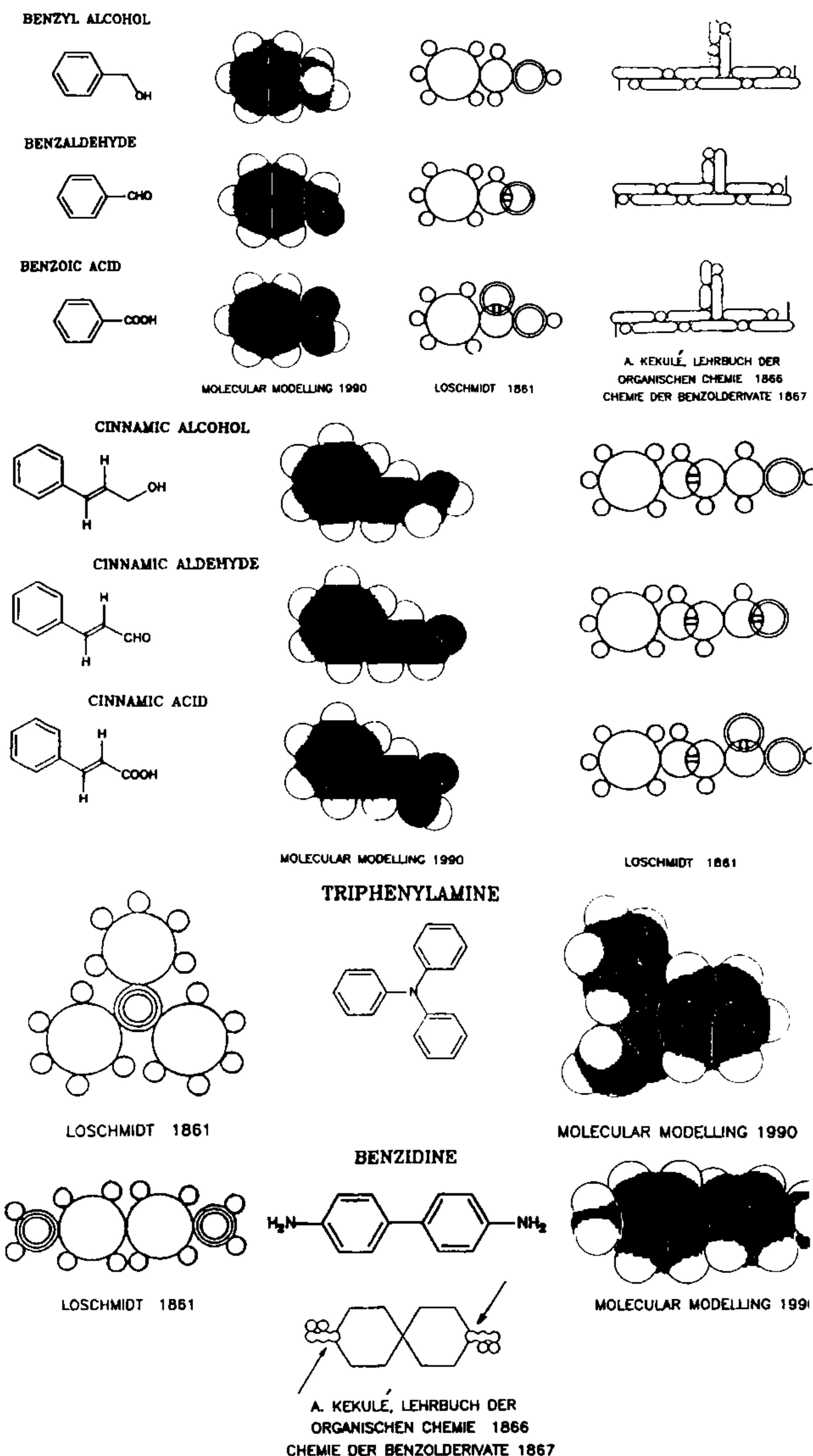


FIG. 6

depend on this. We take for the C_6^{VI} nucleus the symbol 184 [i.e., the ring] and treat it just as if it were a hexavalent element" [Figure 7]. Today, with the benefit of molecular modeling, we note also with admiration how close Loschmidt came in depicting the size of the benzene ring.

In 1865, the year in which Kekulé supposedly first published his benzene formula, in fact the sausage formula predominated; his newly formulated hexagon had hydrogen atoms in the corners, and attempts to combine sausage formulae with the hexagon failed (28). Of course, after twenty years of work in aromatic chemistry, Kekulé's final concept of benzene was superior to Loschmidt's of 1861, although even then his structure was not what we use for benzene today. But as far as scientific priority is concerned, Loschmidt was the first to draw the circular structure of benzene and we have now reverted to the circle to indicate the delocalization of electrons. The suggestion (3, 6, 9) that one cannot use Loschmidt's structure 185 [Figure 7] for benzene to explain the positions of hydrogen, of substituents, and of isomerism is debatable. Some of Loschmidt's 121 aromatic structures were indeed mistaken, but mainly because he lacked experimental facts. Pyrogallic acid, for instance, is shown [structure 191 (1, p. 31; 3, pp. 60-61)] as a 1,2,4-benzenetriol, not 1,2,3-benzenetriol, but in 1861 only one of the three benzenetriols was known, and not a great deal about that. These mistakes are understandable and may be unimportant when considering the total picture. Loschmidt was a brilliant scientist whose molecular models remained the best for decades.

A great deal has been written about Kekulé's dream of a snake biting its tail. Did he have this dream? What difference does it make? Loschmidt's correct formulations preceded Kekulé's by years. Kekulé certainly knew something, and probably a good deal about Loschmidt's work, but only an examination of Kekulé's character [Editor's note: see also Chapters 13, 14 and 17] could have determined whether his silence about Loschmidt was due to ambition or his anti-Austrian feelings (20) or indeed just his failure to understand Loschmidt's work. In 1990 we celebrated 100 years of the Benzofest, a Fest that was in fact four years late and honored a great chemist, Kekulé, but for the wrong reason.

In recent years, fraud and misconduct in science has been much discussed (20). A fraud can take many forms, with acts of commission and omission. Figure 7, from the article on Kekulé by Richard Lepsius, Kekulé's academic grandson, was published in 1965 (31). Kekulé did not look on benzene in 1865 as Lepsius alleges. Nor did Loschmidt look on benzene as is depicted, and to misspell Loschmidt's name is just adding a minor insult to a major injury. Loschmidt said that one might be tempted to think of benzene as Lepsius showed, but that he preferred structure 185 [Figure 7]. Were Kekulé's and Lepsius' acts of commission or omission? We cannot be certain, but we can be certain of the results. Loschmidt must have known of Kekulé's derogatory remarks. Was he discouraged by such a summary dismissal of his work by this great German chemist? Is this why his later work was mainly in

CHEMIKER-ZEITUNG

CHEMISCHE APPARATUR

17. SPRECHER: H. SPRECHER
CHEMIEBORSE / UNFALLSCHUTZ IM CHEMIEBETRIEB

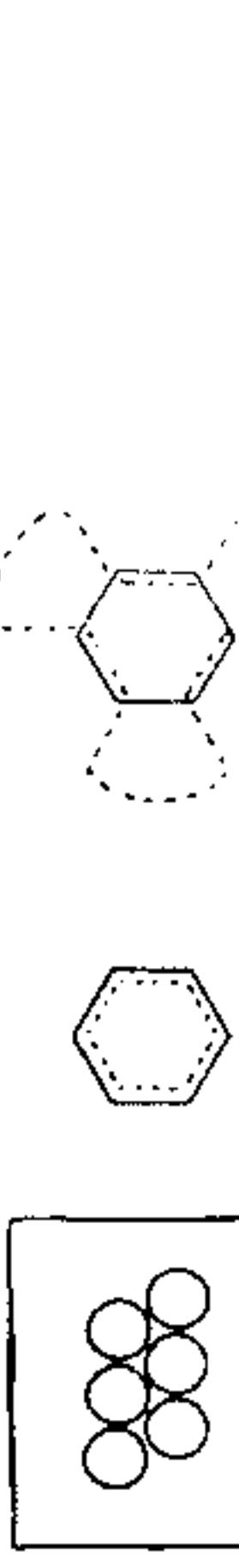
Zu der GDCh-Hauptversammlung und Kekulé-Fest
von 13. bis 18. September 1965 →
Übermitteln den in Bonn Vermummten die herzlichen
Grüße und Wünsche für einen ergiebigen Besuch

R E D A K T I O N U N D V E R L A G
Chemiker-Zeitung / Chemische Apparatur

100 Jahre Benzoltheorie
Friedrich August Kekulé von Stradonitz zum Gedächtnis

Von Richard Lepsius

Unter diesen Un-
ständen könnte man fast versucht sein, die Unvollständigkeit dieser
Kerne nicht sowohl durch Verdichtung, als vielmehr durch Schichtung
der Kohlenstoffatome zu erklären, und dem Kerne C_6 ungefähr das
Schema 182 beizulegen. Dies wäre demnach der doppelte Alkykern,
nach der Variante Sch. 68, und nun könnte zugleich den Kern der
Naphthalinreihe C_{10} , den einzigen unvollständigen Kern von Bedeutung,
den nicht sechs Säulen stehen [der Terpentinkern C_{10} dürfte eher
ähnlich dem Vinylkern C_6 auszusehen], als einen verdreifachten
Alkykern, mehr dem Methylkern C_3 auflassen, und ihm das Sch. 183
geben. Diese Naphtalin würde dann eine dem Methyl-Kenzo betrachteten wer-
den. Jedenfalls ist es auch dem bis jetzt Vorliegenden unmöglich,
hierüber zu einem definitiven Resultat zu gelangen, und wir können
unterer Entscheidung um so mehr in suspense halten, als unsere Con-
struktionen davon völlig unabhängig sind. Wir nehmen für den Kern
 C_6 das Symbol Sch. 184 an, und behandeln denselben ganz so, als
ob er ein archaisches Element wäre.



Die noch heute übliche Kekulésche Formel



Kern C_6 : Phenyl-Rette.

Unter diesen Un-
ständen könnte man fast versucht sein, die Unvollständigkeit dieser
Kerne nicht sowohl durch Verdichtung, als vielmehr durch Schichtung
der Kohlenstoffatome zu erklären, und dem Kerne C_6 ungefähr das
Schema 182 beizulegen. Dies wäre demnach der doppelte Alkykern,

nach der Variante Sch. 68, und nun könnte zugleich den Kern der
Naphthalinreihe C_{10} , den einzigen unvollständigen Kern von Bedeutung,
den nicht sechs Säulen stehen [der Terpentinkern C_{10} dürfte eher
ähnlich dem Vinylkern C_6 auszusehen], als einen verdreifachten
Alkykern, mehr dem Methylkern C_3 auflassen, und ihm das Sch. 183
geben. Diese Naphtalin würde dann eine dem Methyl-Kenzo betrachteten wer-
den. Jedenfalls ist es auch dem bis jetzt Vorliegenden unmöglich,
hierüber zu einem definitiven Resultat zu gelangen, und wir können
unterer Entscheidung um so mehr in suspense halten, als unsere Con-
struktionen davon völlig unabhängig sind. Wir nehmen für den Kern
 C_6 das Symbol Sch. 184 an, und behandeln denselben ganz so, als
ob er ein archaisches Element wäre.



Schem. 182, 183



Schem. 184, 185

FIG. 7

physics where he was appreciated? Other chemists must also have known Kekulé's opinion, but they, like Kekulé, were consciously or unconsciously influenced by Loschmidt's ideas. However, if Kekulé had understood and had publicly recognized the importance of Loschmidt's work, molecular modeling as we now know it would have come much earlier. We, the scientists, have been the losers. [Editor's note: see also Chapter 17].

When Boltzmann (32) wrote in Loschmidt's obituary that Loschmidt's "work forms a mighty cornerstone which will be visible as long as science exists," he understated the facts. Boltzmann clearly did not know Loschmidt's *Chemische Studien* (1), and should have said that Loschmidt's work forms two important cornerstones, one in physics and one in chemistry.

Loschmidt published relatively little and never outside of Austria, nor did he ever go to international meetings to present his views. His works include the one small book of 1861 (1), a few essays, and 17 scientific papers, mostly in physics, presented in the *Sitzungsberichte der Akademie der Wissenschaften* in Vienna between 1865 and 1890. His most famous paper in physics, "Zur Grösse der Luftmoleküle" (33), describes his calculation of the number of molecules in one milliliter of an ideal gas, the *Loschmidt number*.

In 1948, Hubert de Martin submitted a well-written Ph.D. thesis (8) on Loschmidt to the University of Vienna. His discussion of Loschmidt's book recapitulates Anschütz's comments. He refers (8, p. 68) to Loschmidt's greatest work in physics: "Loschmidt's paper 'The Size of Air Molecules' presents in a few pages the solution to a problem which had engaged the world's best minds for millennia—since Democritus and Epicurus..."—his cornerstone in physics. We believe that the few pages, 47 in all, of his 1861 book, where he dealt with organic structures as no one had before, constitute his cornerstone in chemistry.

Loschmidt must have been a truly shy and self-effacing man. It is interesting to know a little about his background. He was born in a small village near Karlsbad [Karlovy Vary] in Bohemia in 1821. His parish priest recognized some of his potential and urged him to go to high school and then to the university in Prague, where he studied first philosophy and mathematics and then the natural sciences, physics and chemistry. Later he studied at the Polytechnic Institute in Vienna, now the Technische Universität, and worked with a number of industrial companies in Lower Austria, Styria, Bohemia, and Moravia. Unfortunately, most of the industrial enterprises failed, and Loschmidt returned to Vienna in the early 1850s penniless, and accepted a job as a private tutor.

He then qualified as a high school teacher in chemistry and physics. He must have been very much of a loner but his keen interest in theoretical questions, coupled with his practical knowledge in all sorts of commercial chemical enterprises, led to his studying some of the most fundamental questions in physics and chemistry of his time. He became the good personal friend of two very able younger Viennese

physicists, Josef Stefan and Ludwig Boltzmann, who appreciated his competence and ingenuity, and Stefan helped him to become *Privatdozent* at the University of Vienna in 1866. A man without a Ph.D. hardly ever reached the position of *Privatdozent*, about the equivalent of an American assistant professor. Two years later, in 1868, he became associate professor after his election to the Royal Academy of Sciences in Vienna the year before. Also in 1868, he founded the *Chemisch-Physikalische Gesellschaft*, a society of chemists and physicists in Vienna which still exists today. In 1869, he received the well deserved honorary degree of Doctor of Philosophy. In 1875 he became the chairman of the Physical Chemistry Laboratory and the first professor of physics in Vienna appointed to include physical chemistry. Two years later he was dean of the faculty of philosophy, and finally in 1885 was elected to the senate of that faculty.

We venture to say that this meteoric advance from a penniless *Hofmeister*, a tutor, to high school teacher, professor, dean and university senator, is unique in the annals of science. However, it is clear that this recognition and the personal respect and admiration of his good friends was based almost entirely upon his important work in physics.

On a personal level, we know of only one woman in his life, Karoline Mayr, with whom he lived for many years. Only when he was 66 and she was expecting his child were they married. Sadly, their one son, Josef Karl, died of scarlet fever just three years after his father's death in 1895. Karoline Loschmidt survived her husband for many years and died of cancer in Vienna in 1930.

Why are we making such an effort with Loschmidt? One of the greatest achievements in the history of western culture is the development of the concept, that matter is constructed of molecules. Only in the last years have we been able to prove, e.g., through X-rays and NMR analyses, that organic molecules really look as the models show—models which have been developed in the last 200 years by many brilliant minds. When we deal with molecular modeling as a matter of course, then for the sake of truth and justice, the father of the correct molecular depictions in organic chemistry, Loschmidt, must be honored.

We hope that not only Austrian and Czech chemists, but chemists around the world will have the good sense to remember Loschmidt in 1995, the 100th anniversary of his death, and that our grandchildren will have another Benzolfest in 2061, the 200th anniversary of the correct formulation of benzene. And of course it will be important to ascertain that authors and editors of textbooks of chemistry acknowledge Loschmidt not just as the first to depict benzene correctly, but also as the true father of molecular modeling.

As Dr. Wiswesser wrote (18), "...that tiny book of 1861 was really the masterpiece of the century in organic chemistry."

Dr. William J. Wiswesser asked us for help with his paper published in the *Aldrichimica Acta* (18) and submitted an abstract of a joint paper to the Boston Benzolfest symposium. Sadly, he died in December 1989 without having been able

to work with us on this paper. We are deeply indebted to him for bringing Loschmidt's work to our attention and sharing his research with us.

References and Notes

- 1a. Loschmidt J (1861) *Chemische Studien*. Wien: Carl Gerold's Sohn
- 1b. Reprinted by the Aldrich Chemical Company, Milwaukee, Wisconsin, 1989, Cat. No. Z18576-0
2. Anschütz R (1912) Ber Deut Chem Ges 45, 539
- 3a. Loschmidt J (1913) Konstitutions-Formeln der organischen Chemie in graphischer Darstellung, herausgegeben von R. Anschütz in: *Ostwald's Klassiker der exakten Wissenschaften*, Nr. 190, Verlag Wilhelm Engelmann, Leipzig
- 3b. Reprinted by the Aldrich Chemical Company, Milwaukee, Wisconsin, 1989, Cat. No. Z18577-9
4. Liebig J (1838) Ann Pharm 25: 339-47
5. Kopp H Liebig's Jahresbericht für 1861, 1, 335
6. Graebe C (1920) *Geschichte der organischen Chemie*, 1. Band, Berlin: Verlag Julius Springer, p. 234 ff., 286 ff.
7. Kohn M, (1945) J Chem Ed 22: 381
8. de Martin H (1948), *Loschmidt J, Sein Leben und Wirken*, Dissertation University of Vienna
9. Wizinger-Aust R (1966) Kekulé A, *Leben und Werk*, Lecture at the Annual Meeting of the Gesellschaft Deutscher Chemiker 1965, Weinheim: Verlag Chemie
10. The British Library copy bears a small sticker affixed to it by the printer, "In Commission bei C. Gerold's Sohn in Wien," i.e., for sale by the printer, who sold books printed there and elsewhere. The British Library still has the invoice by the well known London book dealer, Davit Nutt, dated 30 October 1863, billing the British Museum for twenty Neugroschen
11. Anschütz R (1929) A Kekulé, *Leben und Wirken*, Vol. 1, Berlin: Verlag Chemie
12. Kekulé A, Letter to Erlenmeyer, 4. Jan. 1862 (cited in 11, p. 305; we want to thank Prof. Hafner K. [Kekulé Archives, Technische Hochschule Darmstadt] for sending us a copy of the entire letter)

13. Gillis JB (1966) *Leben und Wirken von Kekulé in Gent*, Lecture at the Annual Meeting of the Gesellschaft Deutscher Chemiker 1965, Weinheim: Verlag Chemie
14. Kekulé A (1865) Sur la constitution des substances aromatiques, Bull Soc Chim (3) 98-110, particularly p. 100
15. Kekulé A (1865) Ueber die Constitution der aromatischen Verbindungen, Z für Chem 8 (1) 176-84, 193, 194
16. Kekulé, (1866) Untersuchungen über aromatische Verbindungen, Ann Chem Pharm 137 (2) 129-97, particularly p. 134
17. Aldrich Catalog Numbers Z20690-3 and Z20691-1
18. Wiswesser WJ (1989) Aldrichimica Acta 22 (1) 17
19. Kekulé A (1878) *Die wissenschaftlichen Ziele und Leistungen der Chemie, Antrittsrede zum Rektorat der Rheinischen Friedrich-Wilhelms-Universität am 18. Oct. 1877*, Bonn: Verlag Max Cohen & Sohn
20. See also chapter 17 by Wotiz and Rudofsky in this book which also deals with Kekulé's selective memory and misconduct in science [Editor's note]
21. Kirchhof F (1967) Josef Loschmidt und die Benzolformel, Chem Ztg Chem Appar 91 (2) 48-51
22. Roberts RM (1989) *Serendipity, Accidental Discoveries in Science*, New York: John Wiley & Sons Inc., p. 75 ff [Editor's note: Also Chapter 17]
23. Webster's Ninth New Collegiate Dictionary, (1983) Springfield, MA: Merriam-Webster Inc
24. Kekulé A (1858) Über die Konstitution und die Metamorphosen der chemischen Verbindungen und über die chemische Natur des Kohlenstoffs, Ann Chem Pharm 106 (2), 129-59. (1904) Neuauflage durch A. Ladenburg: *Ueber die Konstitution und die Metamorphosen der chemischen Verbindungen und über die chemische Natur des Kohlenstoffs. Untersuchungen über aromatische Verbindungen*. In: Ostwald's Klassiker der exakten Wissenschaften. Nr. 145, Leipzig: Verlag Wilhelm Engelmann
25. Kekulé A (1861) *Lehrbuch der organischen Chemie oder der Chemie der Kohlenstoffverbindungen*, 1. Band, Erlangen: Verlag Ferdinand Enke, p. 166-8
26. Kekulé A (1865) Bull Acad Roy Belg 2 (19) 551

27. Kekulé A (1866) *Lehrbuch der organischen Chemie*, 2. Band. Erlangen: Verlag Ferdinand Enke, p. 493-741
28. Kekulé A (1867) *Chemie der Benzolderivate oder der aromatischen Substanzen*, 1. Band. Erlangen: Verlag Ferdinand Enke, particularly pp. 3-5, 22, 23
29. Hafner K (1980) *Darmstädter Schriften* 46. Darmstadt: Justus von Liebig Verlag
30. Wotiz J (1990) Organizer of the Am Chem Soc Boston Kekulé symposium. See also the introductory Chapter 1 in this book
31. Lepsius R (1965) 100 Jahre Benzoltheorie, *Chem-Ztg, Chem Appar* 89 (17) 581-86
32. Boltzmann L (1905) *Gedenkrede auf J. Loschmidt*, Populäre Schriften. Leipzig: Barth
33. Sitzungsberichte der Akademie der Wissenschaften, (1866) Wien, 52, Abt. II, pp. 396-443

ADDENDUM: Collection of Loschmidt Citations

We believe that Loschmidt's *Chemische Studien* (1) is one of the most important works in organic chemistry in the 19th century. Fundamental insights into the structures of organic molecules were formulated for the first time. In view of the vital part which the development of the benzene formula has played in the history of organic chemistry, and considering the undoubted role of Kekulé in the understanding of aromatic chemistry, and also his failure to recognize the significance of Loschmidt's work, we took the occasion of the symposium "Kekulé Benzolfest 100 Years Later" to draw to the attention of interested scientists the importance of Loschmidt, the chemist. Its importance goes far beyond the question of priority for the correct representation of benzene.

This chapter also seeks to establish that:

- 1) *Chemische Studien* (1) was an acceptable publication, known to some of the greatest chemists of its time, including Kekulé, Kopp and Erlenmeyer
- 2) that (1) was the first to depict the circular structures of benzene and many of its derivatives
- 3) that Loschmidt was the first to show many other structures clearly, the first to depict double and triple bonds correctly—in fact, the man who can truly be called the *Father of Molecular Modeling*.

We are certainly not the first to try to highlight the fundamental importance of Loschmidt's work. In fact, over the years there have been several citations and commentaries on *Chemische Studien* (1) expressing views close to ours. Particularly Anschütz (3) and Kirchhof (21) were scientists who spent a good deal of time thinking about Loschmidt. However, each puts forward a rather different explanation why Loschmidt's work was not appreciated.

The following original citations of *Chemische Studien* (1) illustrate the views of previous authors.

A. Kopp H. (5) in Liebig's Jahresbericht, 1861, 1, 335:

"J. Loschmidt hat Konstitutionsformeln der organischen Verbindungen-zur Verdeutlichung, wie die die Verbindung zusammensetzenden elementaren Atome als in einer Ebene geordnet zu denken seien in graphischer Darstellung gegeben, und die Gründe, welche ihm für seine Anschauungsweise sprechen, erörtert."

B. Kekulé's letter to Erlenmeyer, 1862 (12):

"...Ihre Kritik der Erdmannschen ... Theorie habe ich erhalten (besten Dank) und gelesen; ziemlich gleichwertig mit Loschmidt's **Confusionsformeln** [our emphasis]. Ich bedaure, dass Sie mich zu einer Kritik dieser Kritik auffordern; ich hätte natürlich lieber still geschwiegen und ich glaube sogar, ich will trotz Ihrer Aufforderung still schweigen...."

C. Kekulé's A. famous paper "Sur la constitution des substances aromatiques," 1865 (14):

Footnote 2: "Je conserve la forme que j'avais adoptée en 1859 en exprimant pour la première fois mes vues sur la constitution atomique des molecules Elle me parait préférable aux modification proposées par M. M. Loschmidt et Crum-Brown."

D. Kekulé A., German translation of (14) 1865 (15):

Footnote 2 omitted.

E. Kekulé A., Rework of (15), of 1866 (16):

Footnote 2 reappears: "... sie scheint mir vor den neuerdings von Loschmidt und von Crum Brown vorgeschlagenen Modifikationen gewisse Vorzüge darzubieten...."

F. Anschütz R., Republication of (1) 1913 (3):

Je mehr ich mich jedoch in die erste Abhandlung vertiefte, um so mehr wuchs mein Interesse und meine Bewunderung. Denn in ihrem letzten Drittels sprach *Loschmidt* vier Jahre vor *Kekulé* Ansichten über die Konstitution der aromatischen Substanzen aus, die, in einer verbreiteten chemischen Zeitschrift veröffentlicht, sicher allgemeines Aufsehen erregt und zur Entwicklung der Chemie wesentlich beigetragen hätten. Allein auch davon ganz abgesehen, leitete *Loschmidt* seine graphischen Formeln auf Grund von Vorstellungen über den Bau der Moleküle ab, die mir auch heute noch alle Beachtung zu verdienen scheinen....

Um *Loschmidts* Verdienste richtig einzuschätzen, ist es notwendig, daß man sich den Zustand vergegenwärtigt, in dem sich die Chemie der aromatischen

Substanzen zur Zeit der Auffassung seiner Schrift >Chemische Studien< befand....

Und doch war die Wissenschaft schon damals für viel weitergehende theoretische Betrachtungen reif, wie *Loschmidt* beweist.

Loschmidt erkennt die Eigenart der sog. aromatischen Verbindungen darin, daß sie den Kern C_6^{VI} enthalten....

Allein die bis jetzt bekannten Beobachtungen ermöglichen nach *Loschmidt* keine endgültige Entscheidung, deshalb läßt er die Frage nach der Bindungsweise der Kohlenstoffatome im Kern C_6^{VI} >in suspenso< und behandelt ihn ganz so, als ob er ein sechsstelliges Element wäre....

Viel tiefer als *Loschmidts* Benzoltheorie war die drei Jahre später von *Kekulé* entwickelte Theorie der aromatischen Substanzen. Wohl sehen beide im Benzolkern den in allen aromatischen Verbindungen vorhandenen Bestandteil, beide formulieren ihn als ringförmiges Atomgebilde. >Aber während *Loschmidt* die Frage nach der Bindung der sechs Kohlenstoffatome als unwesentlich >>in suspenso<< läßt, legt *Kekulé* seine Benzolformel seiner ganzen Theorie zugrunde. *Kekulé* erklärt wie *Loschmidt* die Isomerie von Benzylalkohol und Kresol. Allein er vermag auch die Isomeren der Di- und Polysubstitutionsprodukte durch die verschiedene Stellung der Substituenten am Benzolkern begreiflich zu machen. Auch stellt *Kekulé* die Annahme auf, >daß ein mehrwertiges Atom nicht gleichzeitig mit mehr als einem Kohlenstoffatom des Benzolkerns verbunden sein kann<.

Jetzt entsteht die wichtige Frage: hat *Kekulé* die *Loschmidtsche* Schrift aus eigener Anschauung gekannt? Oder ist er nur von dritter Seite über *Loschmidts* graphische Formeln oberflächlich unterrichtet worden?

Der Herausgeber verneint die erste und bejaht die zweite Frage.

>*Kekulé* war kein Gelehrter der mit seinen neuen chemischen Betrachtungen Geheimniskrämerei trieb. Ganz im Gegenteil. Es war ihm geradezu ein Bedürfnis, über die ihn bewegenden wissenschaftlichen Ideen sich zu unterhalten. In der Zeit, als er sich mit den Ideen zur Aufstellung der Benzoltheorie trug – er war in seinem Lehrbuch bei den aromatischen Substanzen angelangt–, waren die beiden Freunde des Herausgebers, Dr. *Carl Glaser*, der langjährige Mitdirektor der badischen Anilin- und Soda-fabrik, und Prof. Dr. *Wilhelm Körner*, zurzeit in Mailand Direktor der landwirtschaftlichen Hochschule, seine vertrauten Mitarbeiter. Beiden war *Loschmidts* Schrift unbekannt, beide versicherten dem Herausgeber auf das bestimmteste, daß *Kekulé* mit ihnen niemals über *Loschmidts* Benzolformel gesprochen habe. *Kekulé*s sehr sorgfältig und umsichtig zusammengebrachte Bibliothek enthielt, wie eingangs erwähnt, *Loschmidts* >Chemische Studien< nicht. *Kekulé* hat diese Schrift nie unter Augen gehabt<.

G. Graebe C. 1920 (6):

Vielleicht sind *Kekulé* und *Würtz* [sic] damals noch zu vorsichtig gewesen. Dagegen ist *Loschmidt* 1861 bei der Aufstellung von schematischen Formeln in vielen Fällen über das hinausgegangen, was sich aus den experimentellen Tatsachen herleiten ließ. Hierüber soll weiter unten berichtet werden....

Loschmidt ist von der Vorstellung ausgegangen, daß die Atome dem Mittelpunkt von Kugeln entsprechen. "deren Halbmesser die Distanz bezeichnet, in welcher sich das Atom, wenn es eine chemische Verbindung eingegangen, von der

Gleichgewichtssphäre jedes anderen Atoms, mit welchem es durch eine Atomkraft verknüpft ist, behauptet." Diese Sphären veranschaulicht Loschmidt in seinen schematischen Formeln durch Kreise....

Loschmidt hat seine Konstitutionsbetrachtungen mit großem Geschick und Fleiß über das ganze Gebiet der organischen Chemie ausgedehnt. Unter den 368 graphischen Formeln, die in seiner Schrift enthalten sind, haben sich ziemlich viele später als richtig erwiesen, obwohl damals häufig noch die experimentellen Beweise fehlten; bei anderen hat er sich geirrt.

Wie aus der chemischen Literatur hervorgeht, ist seine Abhandlung so gut wie unbeachtet geblieben, und hat daher auf die Entwicklung der organischen Chemie keinen Einfluß ausgeübt. Es beruht dies wohl zum Teil auf dem Umstand, daß der damals noch unbekannte und später nicht als Chemiker, sondern als Physiker berühmt gewordene Verfasser seine Broschüre nur im Selbstverlag herausgab und keine Untersuchungen zum Beweis seiner Schemata ausführte. Auch hat seine Abhandlung sicherlich auf diejenigen, in deren Hände sie damals gelangte, einen zu hypothetischen Eindruck gemacht. Da sie keine neuen Tatsachen enthielt, wurde im Jahresbericht der Chemie nur das Erscheinen derselben angegeben....

Als einen eigentlichen Vorläufer von Kekulé kann man daher Loschmidt nicht bezeichnen. Er hat weder die Struktur des Benzols aufgeklärt, noch eine Erklärung für die damals bekannten Isomerien, wie z. B. Salicylsäure und Oxybenzoësäure, oder über die Zahl der möglichen Isomeriefälle gegeben....

Zutreffend erklärte Loschmidt den Unterschied von Benzylalkohol und Kresol. Viele seiner Schemata sind aber zu voreilig aufgestellt und verfehlt. So nahm er im Azobenzol eine Gruppe NH an, die zwei Atome Wasserstoff des Benzols ersetzt; und in seinen Schemata für Indigo und Isatin ist Stickstoff vorhanden, der mit drei Kohlenstoffatomen des Benzolkerns verbunden ist. Es konnten daher Loschmidts Schemata, trotz dem großen Fleiß, den er auf deren Aufstellung verwandt hat, keinen Einfluß auf die Erkenntnis der Konstitution aromatischer Verbindungen ausüben.

H. R. Wizinger-Aust 1966 (9):

Längere Zeit nach Kekulés Tod, im Jahre 1912, entdeckte RICHARD ANSCHÜTZ, daß schon vor KEKULÉ ein Forscher für den Benzolkern das Ringsymbol vorgeschlagen hatte. 1861 hatte JOSEPH LOSCHMIDT, damals noch ein ganz unbekannter Chemiker, in Wien eine Abhandlung herausgebracht, betitelt "Constitutionsformeln der Organischen Chemie in graphischer Darstellung." Diese Schrift enthält 368 graphische Formeln; 121 betreffen aromatische Verbindungen. Der Benzolkern ist durch einen großen Kreis symbolisiert, die Wasserstoffatome durch kleine, die mehrwertigen Elemente durch etwas größere Kreise. Die Formelbilder wirken geradezu frappierend. Auf den ersten Blick möchte man meinen, es sei KEKULÉ alles vorweggenommen. Es besteht aber doch ein wesentlicher Unterschied. LOSCHMIDTS Kreis symbolisiert lediglich die Zusammenballung der sechs Kohlenstoffatome zu einem einheitlichen Ganzen, das sich wie ein sechsstelliges Element verhalte. Über die Anordnung der Kohlenstoff- und damit auch der Wasserstoffatome und Substituenten sagt er nichts aus:

“Jedenfalls ist es nach dem Vorliegenden unmöglich, hierüber zu einem definitiven Resultat zu gelangen, und wir können unsere Entscheidung umso mehr in suspenso halten, als unsere Constructionen davon völlig unabhängig sind.” Im Gegenstanz zu KEKULÉ konnte LOSCHMIDT mit seinem unbestimmten Modell die Isomerieverhältnisse der Substitutionsprodukte nicht erfassen. Aber LOSCHMIDT stand an der Schwelle der richtigen Erkenntnis, und es unterliegt keinem Zweifel, daß seine Abhandlung großes Aufsehen erregt und zur Entwicklung der aromatischen Chemie damals schon geführt haben würde, wenn sie in einer verbreiteten chemischen Zeitschrift veröffentlicht worden wäre. LOSCHMIDT aber hatte sie auf eigene Kosten drucken lassen. So fand sie keine Verbreitung. Auch in Universitätsbibliotheken war sie nicht vorhanden....

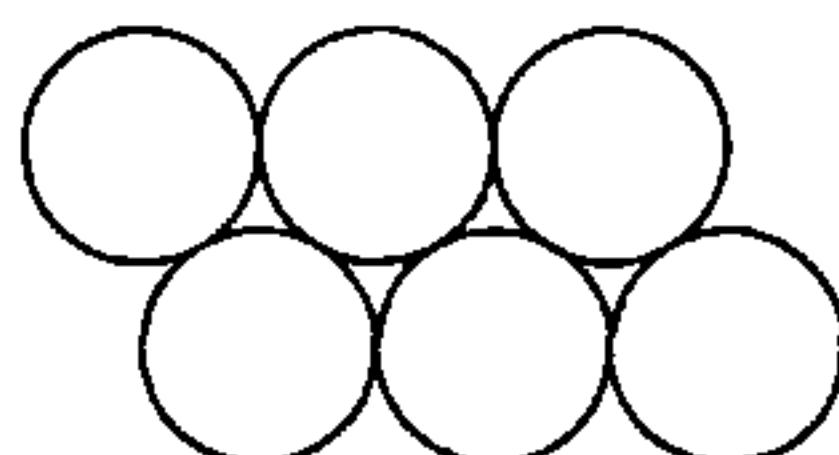
In seiner großen Bescheidenheit hat LOSCHMIDT auf seine wertvolle Arbeit auch später nie aufmerksam gemacht, sondern KEKULÉS Verdienste neidlos anerkannt.

I. Gillis J.B. 1966 (13):

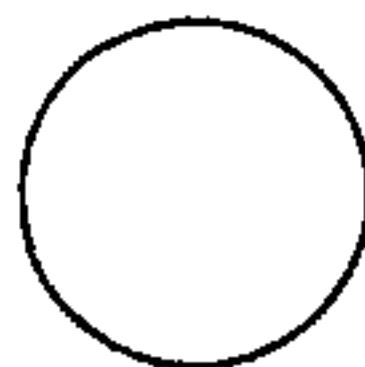
Erst ab 1861-1862 veranlaßte jedoch die Lückentheorie KEKULÉ, die Existenz von Doppelbindungen auch in ungesättigten Molekülen zuzulassen. Zur gleichen Zeit las er das Buch “Chemische Studien” von LOSCHMIDT, das 1861 in Wien erschienen war. Gezwungenermaßen überflog er die sieben großen Tabellen mit 368 graphischen Formeldarstellungen, darunter 121 für aromatische Verbindungen. Er war mit ihnen gar nicht einverstanden und nannte sie in einem Schreiben an ERLENMEYER vom 4. Januar 1862 sogar “Confusionsformeln.” Indessen dürften sowohl der von LOSCHMIDT für die



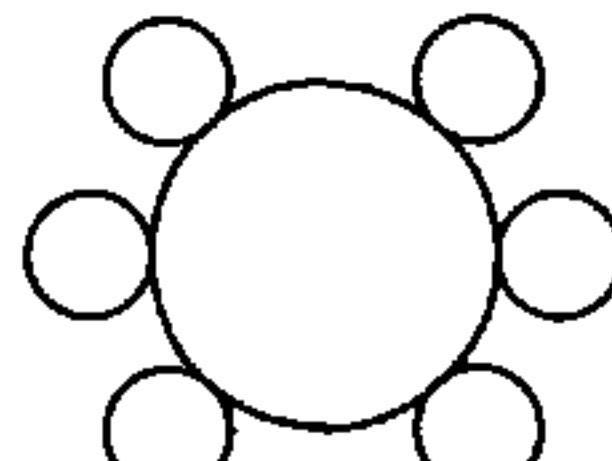
Schema 181.



Schema 182.



Schema 184.



Schema 185.

Phenylreihe vorgeschlagene Kern C_6^{VI} , als auch die Darstellungen Nr. 181, 182, 184 und 185 zweifellos seine Aufmerksamkeit erregt und vielleicht sein Unterbewußtsein beeinflußt haben.

J. Kirchhof F. 1967 (21):

Diese Arbeit ist nicht nur für den Chemiehistoriker interessant zu lesen, man könnte sie geradezu als eine kurzgefaßte Konzeption einer "Theoretischen Chemie" bezeichnen. Schon der erste Absatz der Einleitung mutet fast modern an und verrät die physikalische Einstellung dieses Chemikers, wenn er schreibt: "Die Chemie hat seit Liebigs Vorgange die Annahme acceptiert, daß das Volum des Materiellen, selbst in einem festen oder flüssigen Körper, verschwindend klein sei, gegen die leeren Zwischenräume, welche die kleinsten Teile der Materie von einander trennen, und daß daher dieselben—die Atome—nur per distans durch Anziehungs- und Abstoßungskräfte auf einander wirken. Man hat diese Constitution sinnreich mit der unseres Sonnensystems verglichen, in welchem die interplanetaren Räume in einem ähnlichen Verhältnisse zu dem Volumen der Sonne und der Planeten stehen....

Die Vorstellung, eine Verbindung könnte kreisförmige Struktur haben, lag dem Bewußtsein der Chemiker jener Epoche völlig fern. Der Kreis war das Symbol für das Unteilbare, für das Atom, und das Verdienst, den C₆^{VI}-Kern durch ein Kreissymbol zu kennzeichnen, gebührt zweifellos *Loschmidt*....

Was den vermuteten Einfluß der *Loschmidtschen "Constitutionsformeln"* auf die Gestaltung der Benzolformel betrifft, so mag es sein, das *Kekulé*, ein ausgesprochener Augenmensch, durch die Fülle der 14 Seiten im Format 22 mal 35 cm umfassenden, mit Kreissymbolen bedeckten Tafeln verwirrt war, wie es auch dem Referenten erging, und sich ungehalten über die "Confusionsformeln" äußerte. Immerhin mögen diese zahlreichen kleinen und großer [sic] Kreise eine nachhaltige Wirkung gehabt und seine Phantasie mehr oder minder zwangsläufig auf das Kreissymbol des Benzols geführt haben. Hätte sich *Loschmidt* auf die wenigen, in Abb. 2 herausgegriffenen Kreissymbole beschränkt, so hätten diese vielleicht eine imponierendere Wirkung auf *Kekulé* ausgeübt....

So sehen wir, wie dieses wohl am meisten umstrittene Symbol der organischen Chemie im Laufe einer mehr als 100 jährigen Entwicklung allmählich die heutige Gestalt angenommen und schließlich seine resonanz-energetische Deutung gefunden hat. Generationen bedeutender Chemiker mehrerer europäischer Länder haben sich an diesem Werdegang mit Fleiß und Hingabe beteiligt, an ihrer Spitze wohl *August Kekulé* mit zahlreichen Schülern und Mitarbeitern, aber auch einige Vorläufer und Außenseiter, wie *J. Loschmidt*.

K. Hafner K. 1980 (29):

Wiederum gelang Kekulé der große Wurf. Sein unwiderstehliches Bedürfnis nach Anschaulichkeit und seine ungewöhnliche Vorstellungskraft kamen ihm dabei erneut zu Hilfe. Die Aufstellung der Benzolformel ist im Grunde eine logische Folgerung aus der Strukturlehre. Aus unserer heutigen Sicht eine selbstverständliche Erkenntnis, vor mehr als hundert Jahren jedoch ein außergewöhnlicher Gedankensprung, etwa mit dem eminent geistigen Aufwand vergleichbar, der einst notwendig war, bis der Mensch die Schlittenkufen mit dem Rad vertauschen konnte. Die Vorstellung, eine Kohlenstoffverbindung könnte ringförmige Struktur besitzen, war dem Bewußtsein der Chemiker jener Epoche entzogen. Der Kreis war das Symbol für das Unteilbare, das Atom....

Mit seiner wiederum erst nach einer mehrjähriger Phase des Abwägens und Prüfens 1865 der Pariser Akademie vorgelegten Mitteilung "Sur la Constitution des Substances Aromatiques" (72) und seiner darauffolgenden Annalen-Arbeit "Untersuchungen über aromatische Verbindungen" (73) präzisierte er seine Theorie von der Struktur des Benzols u.a. mit dem lapidaren Satz: "Diese Thatsachen berechtigen offenbar zu dem Schluß, daß in allen aromatischen Substanzen eine und dieselbe Atomgruppe, oder, wenn man will, ein gemeinschaftlicher Kern enthalten ist, der aus sechs Kohlenstoffatomen besteht." Eine Erkenntnis," die sich bereits vier Jahre vorher in Überlegungen Joseph Loschmidts (1821-1895)(74) anbahnte, ohne jedoch bei diesem zu klareren Vorstellungen über den Bau dieses Kerns zu führen.

Vitae

DR. CHRISTIAN R. NOE was born in Schärding/Austria in 1947; he studied at the Technical University in Vienna from 1965 to 1972 and obtained his doctorate with a dissertation directed by Prof. Hromatka. He also studied pharmacy and received his M.Sc. from the University of Vienna in 1979. Following one year as a postdoctorate fellow with Prof. Albert Eschenmoser at the ETH in Zurich in 1977-8 he became *Universitätsdozent* in organic chemistry at the Technical University in Vienna in 1982. Since 1985 he has been in charge of the laboratory for enantioselective synthesis at the Technical University in Vienna, and in 1989 he became director of that university's Christian Doppler Laboratory for Chiral Compounds. In 1991, he was appointed to the Karl Mannich Chair in Pharmaceutical Chemistry at the Johann Wolfgang GOETHE University in Frankfurt. His main research interests have been in the field of chiral recognition as well as the development and use of chiral reagents to effect efficient syntheses of biologically active compounds.

ALFRED BADER was born in Vienna in 1924 and was educated at Queen's University in Kingston, Ontario (B.Sc. in engineering chemistry, 1945, B.A. in history, 1946, and M.Sc. in organic chemistry, 1947) and at Harvard University (Ph.D. under Prof. Louis F. Fieser, 1949). In 1950 he was a research chemist and then group leader in organic chemistry at the Paint Division of the Pittsburgh Plate Glass Company. He started the Aldrich Chemical Company in Milwaukee, Wisconsin in 1951, serving as its president until 1975 when Aldrich merged with the Sigma Chemical Company in St. Louis. He then became the president of the Sigma-Aldrich Corporation and was elected chairman in 1980. In 1991 he became chairman emeritus. He has long been interested in the history of chemistry and in art history, particularly biblical iconography.