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<thead>
<tr>
<th>Liquids</th>
<th>Temperature of Exposure</th>
<th>Hours of Exposure</th>
<th>Effects of Exposure on Filler</th>
<th>Liquid</th>
<th>Vapor</th>
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<tr>
<td>Glacial Acetic Acid</td>
<td>100°C</td>
<td>1265</td>
<td>None</td>
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<td>20.24% Hydrochloric Acid</td>
<td>100°C</td>
<td>1265</td>
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<td>Nitric Acid Concentrated</td>
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<tr>
<td>Sulphuric Acid</td>
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<tr>
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<td>Xylenes</td>
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<thead>
<tr>
<th>Range C</th>
<th>Length mm</th>
<th>Price Ea.</th>
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<tr>
<td>15 to 110</td>
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<td>0 to 205</td>
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<tr>
<td>0 to 405</td>
<td>381</td>
<td>3.60</td>
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<th>Lots of 12</th>
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<tr>
<td>Less 10% 15%</td>
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<td></td>
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Perhaps it is the approach of Election Day; anyway, something brings back to my mind and attention some remarks that were made by Mr. Frank W. Abrams at the graduation exercises at Lehigh University last June, and which were reported in full in The Lamp. I do believe that some of these remarks can be quoted here without their being criticized as political propaganda; at least, by the time they appear, the political “kettle” will have stopped boiling.

Mr. Abrams is speaking about “The Individual in a Group Society”:

The American people have proved that there is a direct relation between their accomplishments and their free political and economic institutions. It has been shown in this country of ours that freedom is the best way to assure the full release of human energies—that the good of all is best served when each individual is free to fulfill himself.

But there is more to it than that. When we let others take over a job we should do ourselves we hand over one of the great joys of living—the satisfaction of personal accomplishment. A person who has no urge to meet his own problems of living and feel at the end pride in their solution has failed to make use of the great privilege of having been born free.

It strikes me that our forefathers paid us a great compliment when they established the United States of America. They founded our government on the expectation that we would be fit to govern ourselves. And in so doing they set up many safeguards to protect the individual against the tyranny of authority, including the tyranny of the majority. But in so doing they made an important assumption, which was that in exercising the privileges of freedom each of us would have a strong sense of responsibility to other individuals, and to society as a whole, as the price of our privileges. Freedom without the continued performance of the duties that go with it cannot long be preserved.

How well have we remembered and practiced this fundamental truth? If we have reason to be anxious about a dwindling concern for the individual in society, perhaps it is due as much to the failures of individuals as to the great impersonal forces like “population growth” and “science and technology.”

The conditions which these forces have created are not in themselves a threat to our freedoms. The threat is in ourselves. What you and I do, or don’t do, about the circumstances we face is what counts...

Obviously, our society has need of various types of voluntary groups. Business corporations, labor organizations, educational groups, professional organizations, and all the other forms of group action can accomplish some things no individual can do so well by himself. But we must be constantly aware that there is a tendency in all group action to subordinate the individual. A net contribution to individual freedom will be made by these groups only if they are administered so as to enlarge the opportunities for expression and action by their members. At the same time, unless restraint characterizes the relationship of these voluntary groups among each other, the long-term result may be harmful both to the groups themselves and to the individuals who compose them.

There are two basic safeguards, it seems to me: one is the “law of the land”; the other is the restraints that these voluntary groups impose upon themselves when, like individuals, they act with a full sense of responsibility. Too much legal restraint or control by central authority of any kind leads to loss of liberty. The other way is a hard and demanding way, but it is the way of democracy. For what is democracy but the willingness of individuals, and groups of individuals, so to conduct themselves that a minimum of legal restraint and central authority is required?...

I cannot tell any one of you how to preserve your own individuality in the years to come, except to repeat that it has to be earned through your own efforts. I may perhaps suggest that you examine group standards and values critically before accepting them. You yourself must decide what to give up or not to give for money, position, power, or security. You must decide when to conform and to what extent, or when to walk the long, difficult, and often lonely road which the free individual sometimes must take.

Editor's Outlook
It has been known for some time that monovalent aluminum compounds exist under the conditions prevailing in the electrical discharges used in exciting spectra, but it is only in the last decade that these molecules have become more than a curiosity. Recently studies have been made of their application to new methods for producing and refining aluminum. This work has resulted in a closer characterization of the properties of the compounds already known from spectra, and in the discovery of other univalent aluminum compounds. This paper outlines our present knowledge of these unusual compounds.

**DISCOVERY**

It would seem that the discovery of monovalent aluminum should be credited to W. Jevons (1, 2). In 1913 while studying the spectra of silicon tetrachloride in a discharge between aluminum electrodes he discovered the spectrum of aluminum monochloride, and in 1924 he identified it. The same spectrum was observed when hydrogen chloride was subjected to a high voltage discharge between aluminum electrodes. A discharge in aluminum trichloride was necessary to produce a strong enough band structure for determination. Among the workers in this field we may cite Mahanti (3) for his work on monobromide, Miescher (4) on monochloride, bromide and iodide and Rochester (5) on monofluoride.

Much earlier chemical evidence for the existence of aluminum subcompounds had been obtained. In the period 1876 to 1897 the preparation of subfluorides, chlorides, bromides, and sulfides of aluminum were claimed (6). It is doubtful that the claims were valid.

---

**THEORETICAL APPROACHES**

Before continuing with the experimental developments it may be well to consider this problem from a more theoretical viewpoint. The chief paper of note in this field is that of F. Irnann (10). In the introduction to his paper some qualitative arguments are given. Considering the periodic table, it can be seen that aluminum falls in the same family as gallium, indium, and thallium, all of which have compounds of valence one or two (11). Further, silicon, the element with one more electron than aluminum, commonly forms aluminum monochloride and the method of Victor Meyer to determine its vapor density. Assuming a dissociation into aluminum monochloride and chlorine they calculated the following results.

<table>
<thead>
<tr>
<th>Temperature, °C.</th>
<th>Dissociation, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>835</td>
<td>3</td>
</tr>
<tr>
<td>943</td>
<td>2</td>
</tr>
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<td>1117</td>
<td>14</td>
</tr>
<tr>
<td>1244</td>
<td>15</td>
</tr>
<tr>
<td>1260</td>
<td>14</td>
</tr>
</tbody>
</table>

The percentages of dissociation are too high by a factor of about $10^6$ and in view of the method used it is doubtful that the results have any meaning.

Definite chemical evidence for a subchloride was obtained in 1930 by Frommer and Polanyi (8). They found that when chlorine reacted with aluminum in the presence of copper a luminescence ascribable to cuprous chloride bands occurred. It was known that strong reducing agents, such as hydrogen atoms, produced the emission in the following way.

$$\text{CuCl} + \text{H} = \text{HCl} + \text{Cu} + \text{luminescence} \quad \text{(Reaction 1)}$$

They postulated that in the case of aluminum the strong reducing agent was aluminum dichloride. Their scheme can be modified to the following correct one.

$$\text{Cl}_2 + 2\text{Al} = 2\text{AlCl} \quad \text{(Reaction 2)}$$
$$\text{Cl}_2 + \text{Cu} = \text{CuCl}_2 \quad \text{(Reaction 3)}$$
$$\text{AlCl} + 2\text{CuCl} = \text{AlCl}_3 + 2\text{Cu} + \text{luminescence} \quad \text{(Reaction 4)}$$

The next advance in the field may be credited to Willmore (9). He found that if impure aluminum or compounds containing aluminum (e.g., aluminum carbide, alumina, and carbon) were mixed intimately with a fluoride (such as aluminum or magnesium fluoride, or cryolite) and heated to the neighborhood of 1000°C in vacuum or an inert gas stream, pure aluminum was produced. Willmore did not specify the mechanism by which this transfer occurred. It has since been proved, as will be shown later, that aluminum monofluoride was the agent.

---

1 Based on a talk presented at Aluminium Laboratories Limited, Arvida, Que., May 24, 1951, before a group of technical employees from Aluminium Laboratories Limited and the Aluminum Company of Canada, Limited.
has a valency of four, but also has well-defined compounds in which its valence is two, while phosphorus, the next in line, exhibits a similar phenomenon with valences of five and three. Aluminum, silicon, and phosphorus have, beyond the inert gas configuration, two s shell electrons each, and one, two, and three p shell electrons, respectively. Thus for each element the higher valence results from the loss of both s and p electrons, while the lower results from the loss of p electrons only. Finally the ionization potential of aluminum varies as given in Table 1.

<table>
<thead>
<tr>
<th>Ion produced</th>
<th>Electron(s) lost</th>
<th>Ionization potential kg.-cal.</th>
<th>I. P./ion charge, kg.-cal.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al^+</td>
<td>3p</td>
<td>139.5</td>
<td>139.5</td>
</tr>
<tr>
<td>Al^{2+}</td>
<td>3p, 3s¹</td>
<td>435.6</td>
<td>217.8</td>
</tr>
<tr>
<td>Al^{3+}</td>
<td>3p, 3s², 3s³</td>
<td>657.4</td>
<td>219.1</td>
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<tr>
<td>Al^{4+}</td>
<td>3p, 3s⁴, 3p⁶</td>
<td>2767.9</td>
<td>691.5</td>
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</table>

The fairly large difference between the first and second ionization potentials, and the analogical arguments given above, tend to make the existence of monovalent aluminum much more credible.

The bulk of Irmann's paper is concerned with the calculation of the heats of formation at 298°K. of the mono- and divalent halides of aluminum. Calculations were performed for both the solid and gaseous state, the Born-Haber cycle being the method used. Constants were so chosen that agreement with known values resulted. His results are shown graphically in Figures 2 and 3. His conclusions may be summarized as follows:

1. The order of stability for all halides is given by AlCl₃ > AIX > AIX₃.
2. Solid AIX is only slightly less stable than solid AlX₃, the degree of instability being about the same for all halides.
3. The stability of gaseous AIX relative to gaseous AIX₃ decreases in the order fluoride, chloride, bromide, iodide.
4. Gaseous AIX is stable at higher temperatures.

Irmann made no attempt to calculate values for the liquid state, but he considered that conclusions reached for solids should be valid for the liquids.

Several workers (12–15) have determined the equilibrium constant for the reaction

\[ 2Al + AlCl₃ \rightleftharpoons 3AlCl \]  

Values have been determined experimentally and calculated from spectroscopic and thermodynamic data. Agreement between experimental and theoretical figures and between various workers is reasonable. Gross, Campbell, Kent, and Levi give the value of \( \Delta F^\circ \) as 95.000–59.567. Russell, Martin, and Cochrane represented their results graphically, and Figure 4 is a reproduction from their paper.

GASEOUS HALIDES

Willmore's patent (9) created an interest in the field, and further work soon resulted. It is interesting to note that an earlier set of patents (16, 17) granted to Mitterbiller and Frühwein, had not been as stimulating. These patents, granted in the early thirties, claimed that aluminum could be produced according to the following process.

\[ AlCl₃ + Al₂O₃ \rightleftharpoons high \text{molecular} \text{halide} \]  

Under the conditions specified the reaction is quite impossible, for the monohalide must be formed at the higher temperature, and decomposed at the lower. A recent Swiss patent (18) confirms this fact. Using the same materials as Mitterbiller employed it was found that reaction 6 went at 1300°C. and 30 mm. of mercury pressure and reversal occurred when the temperature was lowered.
R. SchuZe (19) confirmed Willmore’s results and assumed that the gaseous carrier was aluminum monofluoride. He also found that Willmore’s intimate mixing of the solid reactants was not necessary, but that all the aluminum could be extracted from a heated column of iron-aluminum alloy by passing gaseous fluoride through it. He also proposed a method of production for sodium metal wherein one reacted aluminum with sodium fluoride (see reaction 12 below). His results are summarized in the following reactions:

\[ \text{NaAlF}_{3} + 2\text{Al} = 3\text{AlF} + 3\text{NaF} \]  
\[ \text{MgF}_{2} + 2\text{Al} = \text{Mg} + 2\text{AlF} \]  
\[ \text{AlF}_{3} + 2\text{Al} = 3\text{AlF} \]  
\[ \text{SiF}_{4} + 4\text{Al} = 4\text{AlF} + \text{Si} \]  
\[ \text{NaF} + \text{Al} = \text{AlF} + \text{Na} \]  
\[ \text{AI}_{2}\text{C}_{3} + 2\text{AlF}_{3} = 6\text{AlF} + 3\text{C} \]

Bauermeister (20) also checked Willmore’s work, but it remained for Klemm and Voss (21) to prove, in 1943, that the lower aluminum fluoride was a true monofluoride. This they did by the reaction of aluminum fluoride with aluminum, and by repeatedly resubliming the product with more aluminum. The ratio of aluminum to fluoride in the distillate rapidly approached 1:1; using X-ray methods they could detect only aluminum and aluminum trifluoride in the product. They concluded that the gaseous product of reaction was (AlF)_x and that ratios of Al:F less than 1:1 resulted from codistillation of trifluoride. Klemm and his co-workers (22), using methods similar to those developed in their work with fluoride, also proved the existence of monochloride, bromide, and iodide. In the process of their investigation these workers demonstrated the interesting reactions given below:

\[ \text{AgX} + \text{Al} = \text{Ag} + \text{AlX} \]  
\[ \text{MnX}_{2} + 2\text{Al} = \text{Mn} + 2\text{AlX} \]  
\[ 2\text{Al} + \text{X}_{2} = 2\text{AlX} \]

A considerable advance in subhalide knowledge and art was revealed in a patent granted to Gross (23). Previous workers had produced subfluorides by the reaction of solid mixtures of aluminum-bearing material with relatively non-volatile salts. Unstable or volatile halides were considered undesirable since they could be lost from the reaction zone before a temperature was reached at which monohalide formation took place. In Gross’s process the volatile halide is vaporized separately, and then brought into contact with the heated aluminum-bearing material. It was shown that this system utilized the halide more efficiently than did the mixing of solids. Schulze (19) had arrived at this idea also, at approximately the same time and for somewhat similar reasons—i.e., economy in use of the halide and ease in handling the aluminum material—but he used only fluorides. Gross’s truly radical departure lay in his use of other halides, chiefly chlorides but also bromides. By using such low-boiling materials as aluminum chloride and bromide he was able to achieve a condensation of aluminum separately from the salt. Chlorides or bromides, according to the patent, could either be condensed in a zone other than that used for the aluminum or recirculated to the reactor. This was a considerable improvement, since fluoride materials such as cryolite or sodium fluoride condensed with the aluminum, and the latter had to be separated from the salt matrix by mechanical picking or remelting. Gross surmised that the transfer agent was a monohalide in each case, thus anticipating the work of reference 22. The patent covers the use of fluorides, chlorides, and bromides of alkali and alkaline earth metal and of aluminum, for use in distilling aluminum from impure metal, alloys, and compounds such as AlFe and aluminum carbide. Weiss (24) convinced field investigators that he was developing a similar process in Germany during the last war.

HALIDES

**Liquid.** Between 1943 and 1945 Pedersen and Bauck (25) worked on a process wherein aluminum is separated from accompanying impurities by dissolving it in a solution composed of aluminum chloride and the chloride of an alkali or alkaline earth metal. Solution was claimed to occur at 500°C., and pure aluminum could be precipitated from the solution at a temperature some 5 to 50°C. lower. In 1942 a Norwegian patent (26) was issued for the production of aluminum from alloys. In this it was claimed that while mercury alone would not dissolve aluminum from, say, an aluminum silicon alloy, an amalgam of mercury and aluminum could be produced if aluminum trichloride was added to the mixture. Reaction temperatures were between 360 and 650°C. In 1949 a British patent (27) was issued in which it was surmised that the solubility of aluminum in fused halide mixtures of aluminum chloride and alkaline earth chlorides resulted from the formation of a subhalide, e.g., ACl. Other patents (28, 29) for methods similar to the above have been granted. In all cases the aluminum dissolves in a liquid halide-containing phase and presumably by subhalide formation. The solubility is not, however, as high as that predicted by Irmann’s theoretical considerations.

**Solid.** Schumb and Rogers (30) have reported the isolation of a solid which is apparently AlI. An electrodeless discharge in aluminum triiodide gave a product which was by analysis AlI₂. The evidence of various physical and chemical tests indicated a new compound and they concluded that it was aluminum monoiiodide.

OXIDES

In 1939 a group (31) at I. G. Farben was studying the distillation of aluminum. They used aluminum vessels and found that both aluminum and alumina distilled at an unexpectedly low temperature. They proposed reaction 17, although their results coincided more closely with the stoichiometry of reaction 18, the correct one.

\[ \text{Al}_{2}\text{O}_{3} + \text{Al} = 3\text{AlO} \]  
\[ \text{Al}_{2}\text{O}_{3} + 4\text{Al} = 3\text{AlO} \]
Some nine years later a further study of this reaction was made (32). In addition to the reaction of aluminum with alumina, alumina was treated with ferrosilicon. The distillate from this latter system condensed in two zones, in the cooler of which the distillate had the composition SiO and in the hotter Al₂O₃. By using just the amount of silicon predicted by reaction 19 they were able to distill all the alumina and prove the correctness of their proposed reaction. The work was done in a vacuum at 1800 to 1900°C.

\[
\text{Al}_2\text{O}_3 + 2\text{Si} = 2\text{SiO} + \text{Al}_2\text{O}_3 \quad \text{(Reaction 19)}
\]

Recently a very complete study of the aluminum-alumina oxide system has been made (33). The work constituted a study of the vapor pressure of alumina, aluminum, and mixtures of the two. To explain the observed volatility of alumina, five possible ways in which the evaporation could occur were considered.

\[
\begin{align*}
\text{Al}_2\text{O}_3(\text{liq.}) &= \text{Al}_2\text{O}_3(\text{g}) \\
\text{Al}_2\text{O}_3(\text{liq.}) &= 2\text{Al}(\text{g}) + 3\text{O}(\text{g}) \\
\text{Al}_2\text{O}_3(\text{liq.}) &= 2\text{AlO}(\text{g}) + \text{O}_2(\text{g}) \\
\text{Al}_2\text{O}_3(\text{liq.}) &= \text{AlO}_2(\text{g}) + \text{O}_2(\text{g}) \\
\text{Al}_2\text{O}_3(\text{liq.}) &= \text{AlO}_2(\text{g}) + 2\text{O}(\text{g})
\end{align*}
\]

Of these, equation (20) represents a mode in which the volatility requirement would be much less than that expected, and equation 21 one in which the heat requirement is too high. One of the latter three equations must then be correct, and all involve suboxide compounds.

Turning to the system alumina-aluminum, we find that the same three suboxide compounds could occur as follows:

\[
\begin{align*}
\text{Al}_2\text{O}_3 + \text{Al} &= 3\text{AlO} \\
2\text{Al}_2\text{O}_3 + 2\text{Al} &= 3\text{Al}_2\text{O}_3 \\
\text{Al}_2\text{O}_3 + 4\text{Al} &= 3\text{Al}_2\text{O}_3
\end{align*}
\]

In further narrowing the field, Brewer and Searcy reported that entropy requirements and the observed variations in vapor pressure with composition indicate that the same subcompound is not involved in both systems. The relative concentrations of gaseous oxides above a system of alumina or aluminum plus alumina will depend on the concentration of aluminum gas in equilibrium with them, and the major gaseous constituent above alumina alone must therefore contain aluminum in a higher state of oxidation than it would have in the gas above a mixture of alumina and aluminum. These facts give us the following possible pairs of oxides above the two systems.

![TABLE 2](https://example.com/table2)

The authors point out, however, that the heat of dissociation for the reaction \( \text{Al}_2\text{O}_3 = 2\text{AlO} \) (26) would be greater than 140 kg.-cal., and that this is an unusually high value for such a bond. It is, thus, most probable that number 2 in Table 2 represents actuality.

Brewer and Searcy reported that they had made a literature survey for other possible suboxide compounds of aluminum. They found some slight evidence for the existence of a solid suboxide near 2300°C.

### CHALCOGENIDES

The subchalcogenides of aluminum were investigated by Klemm and his associates (34). In general the method used was to prepare \( \text{Al}_2\text{Y}_3 \) (where \( Y \) is taken to include sulfur, selenium, and tellurium), to place a given amount of this trivalent aluminum compound in a crucible and cover it with aluminum, and then to heat the mixture in a vacuum. A blank was run on each of the components to determine its volatility. The composition of the distillate was determined and X-ray methods were applied to determine the components present. They were able to prove the existence of aluminum(I) sulfide and aluminum(I) selenide, but with tellurium no result was obtained since aluminum(III) telluride had a high vapor pressure at the reaction temperature. The following equations summarize their results.

\[
\begin{align*}
\text{Al}_2\text{S}_3 + 4\text{Al} &= 3\text{Al}_2\text{S}_3 \\
\text{Al}_2\text{Se}_3 + 4\text{Al} &= 3\text{Al}_2\text{Se}_3
\end{align*}
\]

Reaction 27 proceeded at 1300°C, and reversed at lower temperatures, while reaction 28 went at 1100 to 1200°C, and reverted to the reactants on cooling.

Kohlmeier and Retzlaff (35) investigated the system aluminum-sulfur at temperatures up to 1600°C. Above 1200°C, hence in the liquid state, \( \text{Al}_2\text{S}_3 \) reacted with aluminum to yield liquid AIS. The equilibrium

\[
\text{Al}_2\text{S}_3 + \text{Al} = 3\text{Al}_2\text{S}_3
\]

shown in reaction 29 resulted. Increasing temperatures and aluminum concentrations shifted the equilibrium to the right. The subsulfide was characterized quite closely and a phase diagram for the system aluminum-sulfur was given. They found that neither the monosulfide nor the trisulfide were volatile at 1600°C, and atmospheric pressure. They commented that the relationship between their subsulfide and that of Klemm (see reaction 27) should be investigated.

### MONOVALENT IONS BY ANODIC OXIDATION

Davidson and his co-workers (36, 37) have produced transient monovalent aluminum ions by electrolysis with aluminum anodes. The apparent valence of aluminum dissolved by electrolysis into an acetic acid solution of acetates is 2.4. This phenomenon has been known for some time, but these workers were the first to ascribe it to the formation of \( \text{Al}^+ \). In liquid ammonia solutions of mixed nitrate-bromide electrolytes initial valence numbers as low as 1.5 were found. No monovalent aluminum could be found at the end of the electrolysis but nitrogen was formed.
from the nitrate in a quantity sufficient to account for oxidation of the dissolved monovalent ion to the trivalent state. They point out that it is apparently not fortuitous that in electrolytes not containing the reducible nitrate ion the aluminum always dissolved from the electrode in the trivalent state.

In summary we may say that the existence of a good number of monovalent aluminum compounds has been demonstrated. Others may well occur. For instance, it can be shown thermodynamically that in the system aluminum—hydrogen at one atmosphere pressure and 2400°K the equilibrium pressure of aluminum monohydride is 0.2 atmosphere. Whether or not many of these unusual compounds are yet undiscovered much work is yet to be done in characterizing those already known.

LITERATURE CITED

ELECTRONEGATIVITIES IN INORGANIC CHEMISTRY

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ALONE of the diverse branches of chemical science, inorganic chemistry holds the responsibility and the promise of integrating the myriad, miscellaneous facts about the properties of all the elements into a composite whole, from which a thorough understanding of all of chemistry may be derived. Therefore, inorganic chemistry ought to be the best organized, most fundamental specialization within the whole broad field of chemistry. At present it is not. Instead, despite numerous and sometimes successful efforts toward unification, inorganic chemistry is still too much a collection of incompletely assorted data.

Probably the greatest progress toward organizing these data into a semblance of a unified science came about through the recognition of the periodicity of the elements. The later correlation with atomic structure appeared to establish the periodic system as a framework for organizing the knowledge of inorganic chemistry on a firm, fundamental basis. The many contributions of several branches of physical science toward our present concepts of the nature of the chemical bond have added greatly to the unification of inorganic chemistry. Nevertheless, there is still much to be accomplished.

Teachers of inorganic chemistry should be, and are (1), particularly concerned with the present status of their science, because the competition of other specializations for the humanly limited space in the minds of the students is becoming increasingly acute. The need to teach more facts in less time calls for maximum efficiency in learning. Maximum efficiency in learning calls for maximum organization and correlation of the facts to be learned, on the basis of fundamental principles which promote understanding rather than mere memorization. The existence of the periodic table gives the superficial impression that such organization and correlation have largely been achieved. Actually, all serious students of inorganic chemistry must recognize that the remarkable individuality of the separate elements has hardly been disguised by placing them in an orderly arrangement on paper, and that many of the most ordinary chemical phenomena are not yet understood.

A familiar concept, and one of greatest potential value as an aid to understanding common chemical phenomena, is that of "electronegativity," or "the power of an atom in a molecule to attract electrons to itself" (2). Yet this concept has until recently been used chiefly for qualitative description, or as a basis for estimating the "ionic character" of a bond. A theory has recently been proposed (3, 4) which permits a much broader application of the concept of electronegativity to interpreting many of the facts of chemistry. It gives a readily visualizable explanation of a possible cause of electronegativity, relating this property to differences between atoms possessing it and atoms of the inert elements. It suggests how the electronegativity changes in the process of chemical combination, and gives a means of evaluating the electronegativity of an atom in a molecule. It also presents a means of estimating the power of a group of atoms, or of an ion, to attract electrons. By these means it affords a basis for explaining in a consistent manner many facts which at present seem anomalous, and provides new insight as to the causes and consequences of chemical reactivity.

This is the first of a short series of papers intended to demonstrate the application of this broadened concept of electronegativity toward explaining chemistry. It is hoped that these papers may accomplish the following purposes:

(1) Direct attention to the need for a more thorough understanding of common chemical phenomena.

(2) Suggest some relatively simple explanations which may help to achieve such an understanding.

(3) Stimulate interest in the general problem of interpreting the facts of inorganic chemistry.

The basis for broadening the electronegativity concept may be considered to be composed of two separate parts. The first is a new method of calculating electronegativities. The second is a new method of applying electronegativities. In case the first part is not entirely acceptable to those who insist on complex mathematics as basic for any chemical theory, it is emphasized that the second part is quite independent of the first.

Although the major purpose of these discussions is to show how many chemical facts can be explained consistently and logically by expanding the use of electronegativities, it is desirable first to describe and justify the new method of assigning electronegativity values to atoms.

ELECTRONEGATIVITIES OF ATOMS

Average Electronic Densities of Active Elements. Atomic radii have long been used in correlating chemical properties. However, a much more useful property appears to be a function of atomic radius and atomic number, namely, the "average electronic density (ED)." It is determined simply as the average number of electrons per Å²: ED = Z/4.19r². Z is the electronic number and r is the nonpolar covalent radius or the ionic radius. The ED is a representation of the average degree of compactness of the electronic sphere.
about an atomic nucleus. There is abundant evidence that the actual atom is an exceedingly complex electrical system defying simple graphical description. There is no intent to imply that the ED represents the actual electronic density at any particular point within the electronic sphere; it is merely a useful number for purposes of comparison.

Within a principal quantum shell, the average electronic density changes much more uniformly with atomic number than does the atomic radius. This can be seen in Figure 1, which depicts this change for the first period of eight: the ED appears to be linear with atomic number for the addition of s and p electrons within any principal quantum shell.

![Figure 1. Change in Electronic Density and Radius with Atomic Number](image)

When ED values, calculated from the best available nonpolar covalent radii of atoms of the active elements, are compared, it is observed that the highest ED’s (5-6 electrons/Å*) are those of the most active nonmetals, and the lowest (one or less electron /Å*) are those of the most active metals. In other words, those elements whose atoms have most compact electronic spheres, whose electrons on the average are closer together, are the ones with greatest tendency to take on electrons, or greatest electronegativity. Now remember that whenever an atom or ion takes on electrons, its electronic sphere expands, which diminishes the average electronic density. Thus, the dominant chemical tendency of highly electronegative elements is to expand toward a lower ED. Certainly the suggestion seems worth consideration for the increased stability acquired by an electronegative atom as it takes on surplus negative electricity may be, partly at least, the result of the expansion of its electronic sphere.

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Average Electronic Densities of Inert Elements. To investigate this possibility, it is of especial interest to compare the ED values of active elements with the ED’s of the inert atoms. If, as indicated, the ED is related to the electronegativity or chemical reactivity of the elements, then the ED values for the inert atoms should be very significant.

Actually, there are, of course, no covalent bonds formed by the atoms of the inert elements, and therefore no nonpolar covalent radii to be determined from observed internuclear distances. However, it is possible to assign reasonable values of “nonpolar covalent radii” to these atoms. The van der Waals radii of the inert atoms, the alkali metals, and the halogens have been determined, and those of the inert elements have been found to be intermediate, as shown in Table 1.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Van der Waals Radii</th>
</tr>
</thead>
<tbody>
<tr>
<td>F^-</td>
<td>Ne 1.60</td>
</tr>
<tr>
<td>Cl^-</td>
<td>A 1.92</td>
</tr>
<tr>
<td>Br^-</td>
<td>Kr 1.97</td>
</tr>
<tr>
<td>I^-</td>
<td>Xe 2.17</td>
</tr>
<tr>
<td>F</td>
<td>Br 1.14</td>
</tr>
<tr>
<td>Na+</td>
<td>K 1.86</td>
</tr>
<tr>
<td>He</td>
<td>A 1.74</td>
</tr>
<tr>
<td>H</td>
<td>Xe 2.09</td>
</tr>
<tr>
<td>Li</td>
<td>Na 1.54</td>
</tr>
<tr>
<td>Li^-</td>
<td>Br 1.95</td>
</tr>
<tr>
<td>Ne</td>
<td>Rb 2.44</td>
</tr>
<tr>
<td>H^-</td>
<td>Cs 2.62</td>
</tr>
</tbody>
</table>

It is therefore logical to expect the “nonpolar covalent” radii of the inert atoms similarly to be intermediate between those of alkali metals and halogens. Pauling has assigned radii to the inert atoms determined by interpolation of “univalent crystal radii” of isoelectronic ions (5), and his values were used in the work reported earlier (3, 4). However, for various reasons it has seemed better to use the more practical “crystal ionic radii” (5) for the determination of inert atomic radii. These give somewhat higher values, as mentioned earlier, which are listed together with the calculated ED values, in Table 2. Also tabulated are the ionic and nonpolar covalent radii of the alkali metals and halogens, to show that the chosen inert atomic radii are in all cases intermediate in value.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Assigned “Nonpolar Covalent” Radii and ED’s of Inert Atoms (Other Radii (Å) for Comparison)</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>ED r</td>
</tr>
<tr>
<td>H</td>
<td>0.37</td>
</tr>
<tr>
<td>Li</td>
<td>0.60</td>
</tr>
<tr>
<td>He</td>
<td>0.93</td>
</tr>
<tr>
<td>Li^-</td>
<td>1.34</td>
</tr>
<tr>
<td>H^-</td>
<td>2.08</td>
</tr>
<tr>
<td>F^-</td>
<td>0.72</td>
</tr>
<tr>
<td>Na+</td>
<td>0.95</td>
</tr>
<tr>
<td>Ne</td>
<td>1.31</td>
</tr>
<tr>
<td>H</td>
<td>1.36</td>
</tr>
<tr>
<td>Na</td>
<td>1.54</td>
</tr>
</tbody>
</table>

Based on these radii for the inert atoms, which are believed to be reasonable in order of magnitude but are of necessity somewhat arbitrary, the ED values are found, as shown in Table 2, to vary for the different inert elements. That means that if these particular values are to be considered as representing or in any way
way related to the unique stability of the inert elements, the change of ED with atomic number must be taken into account.

Stability Ratios and Electronegativities. For purposes of comparing the relative compactness of electronic shells of atoms of different atomic number, a “stability ratio (SR)” has been devised (5, 4). This is the ratio of the ED of an atom or ion to that (ED) of an isoelectronic inert atom, real, or hypothetical and determined by interpolation between real values: SR = ED/ED0. It is postulated that an average electronic density corresponding to a stability ratio of one represents maximum stability.

It is pertinent to inquire immediately what justification there is for assuming that the particular degree of compactness of the inert atoms represents maximum stability. Perhaps the most direct evidence, aside from the obvious fact that the inert atoms do appear to possess maximum stability, comes from a consideration of the polarizabilities of atoms. The polarizability of an atom is a measure of the tightness with which the electrons are held. Other factors being approximately equivalent, the closer the electrons are held to each other the more tightly they must be held, and the greater the resistance the electronic sphere should offer to deformation by an outside force. It is therefore not surprising that so far as the polarizabilities of atoms are known, atoms or ions of low average electronic density are most easily deformed and the polarizability decreases with increasing ED. According to the radii assigned to the inert atoms, the electronic spheres of these atoms are much less compact than those of the nearest halogens. One would therefore expect the inert atoms to be more polarizable. This expectation is not realized. On the contrary, as shown in Table 3, the inert atoms are less polarizable than the adjacent halogen atoms, although the electrons of the latter are packed, on the average, much closer together.

Moreover, there is much chemical evidence that there is a particular ED value for each atomic number that represents maximum stability, or chemical unreactivity, is indirect, but it is abundant.

Supposing the concept to be essentially correct, it is of interest to speculate whether a plausible physical picture accounting for this maximum stability at a particular average electronic density can be imagined. According to currently accepted theory, the electrons of an atom are not symmetrically located or evenly spaced throughout the electron shell, but are distributed, in terms of most probable locations, throughout various energy levels described by certain permissible combinations of quantum numbers. The various orbitals of the atom differ from each other in their relationship to the nucleus and to each other. It does not seem reasonable to expect these orbitals, with their electrons, to maintain a constant relationship to each other and to the nucleus throughout the expansion or contraction of the electronic sphere. More likely, the relationships will change. If this is so, we may then imagine that for a given number of electrons, one particular fixed combination of electronic interrelationships may represent maximum inner symmetry or balance of forces, such that the complex electrical system as a whole offers maximum resistance to outside forces. Either expansion or contraction of the sphere from this point will then upset the inner symmetry so that the system becomes susceptible to outside influences and may achieve better balance and therefore greater stability by uniting with some other system. It is only natural to assume that the average electronic densities representing maximum stability are those exhibited by the atoms of the inert elements.

<table>
<thead>
<tr>
<th>Inert</th>
<th>Vol/atom/electron</th>
<th>Polarizability (Å²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>0.17</td>
<td>0.56</td>
</tr>
<tr>
<td>Ne</td>
<td>0.94</td>
<td>0.38</td>
</tr>
<tr>
<td>Ar</td>
<td>0.24</td>
<td>2.28</td>
</tr>
<tr>
<td>Kr</td>
<td>1.22</td>
<td>1.65</td>
</tr>
<tr>
<td>Br</td>
<td>0.18</td>
<td>3.40</td>
</tr>
<tr>
<td>I</td>
<td>0.79</td>
<td>2.45</td>
</tr>
<tr>
<td>I</td>
<td>0.19</td>
<td>5.82</td>
</tr>
<tr>
<td>Xe</td>
<td>0.71</td>
<td>4.13</td>
</tr>
</tbody>
</table>

This seems to indicate that the electrons of the inert atoms are held more firmly than the electrons of the halogens, even though in the former they are farther apart. In other words, there seems to be some feature of the particular degree of compactness exhibited by an inert atom which gives the atom maximum resistance to such outside forces as might cause the formation of a chemical bond.
Whatever the correct interpretation may be, the fact is that the stability ratios calculated for the different elements have proved to be extremely useful. In Table 4 atomic nonpolar covalent radii, ED’s, the ED’s representing maximum stability for the same atomic number, and the SR’s for many of the elements are given. Any one of the radii selected for these calculations might become the subject of a long and inconclusive controversy. Rather than attempt to support each number, therefore, I shall merely list them, with the statement that they are selected chiefly from compilations by Pauling (6) and Gordy (7), with some corrections made, as in the case of boron, on the basis of the observed linearity of ED with atomic number for series of elements in which s and p electrons are being added to the outermost principal quantum shell. Anyone preferring to use other radii may easily do so. It must be pointed out that in addition to some uncertainty as to the best values of nonpolar covalent radii, particularly for such elements as the transition metals, there is at present no way of knowing whether linear interpolation of ED; values is reliable for determining the stability ratios of elements having atomic numbers far removed from those of the inert elements. It is believed, therefore, that while the SR values given in Table 4 for the transition elements probably are of the right order of magnitude in most cases, the most dependable SR values are those of the “8-shell” and “18-shell” type of elements.

An inspection of the SR values of Table 4 will reveal the following major facts. The highest values are those of the most active nonmetals, fluorine, oxygen, and chlorine leading in that order. The lowest values are those of the most active metals, the alkali and alkaline earth metals. The elements whose average electronic densities are farthest removed from the values postulated as representing greatest stability are the most active nonmetals.

It appears that the active elements tend to react chemically in such a manner as to approach, if possible, the inert elements not only in electronic number but also in average electronic density (unit stability ratio).

Although this is reasonable, it is not absolutely es-

---

**TABLE 4**

<table>
<thead>
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<th>Element</th>
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* Estimated empirically.
sential to the utility of the concept that the explanation be correct. If, in fact, the most compact atoms always react in the direction of becoming less compact, this fact can be very useful even without establishing a proved relationship between compactness and stability. However, when it further becomes evident that the electron affinities of the halogens are directly proportional to their stability ratios, as shown in Figure 2, the reasonableness in assuming the particular degree of compactness to be of significance becomes even more apparent. Most important of all, it is found, as shown in Figure 3, that the stability ratios of the elements are closely related to the electronegativity values determined by Pauling (8) on the entirely different basis of bond energies. It would seem unreasonable not to take advantage of this relationship and see what it can contribute toward an understanding of chemistry, whether its fundamental or theoretical significance happens to be clearly understood or not.

In the discussion to follow the electronegativity is the attraction for electrons as evaluated by the stability ratio. The general ideas are, of course, equally applicable whatever the derivation of the electronegativity values, and therefore not dependent on the validity of the stability ratio concept.

A Possible Explanation of Electronegativity. Two aspects of electronegativity may be considered. One is the idea that every atom (or ion) possessing this property has an inherent attraction for electrons. The other is the fact that by taking on electrons, such an atom (or ion) becomes chemically more stable. An explanation of electronegativity must therefore tell both why the atom attracts electrons in the first place, and also why the gain increases its stability.

A crude explanation of the attraction for electrons which is inherent in electronegative atoms may be derived from the fact that an atom is electrically neutral in effect only at distances which are very large relative to its radius. Even though the total charge of the electronic cloud about the nucleus exactly balances the nuclear charge, the distribution of negative charge is such that at any point on the periphery of the atom, the nuclear charge is not completely neutralized. Any atom may therefore be considered as having at any point of its periphery, an attraction for foreign electrons which is proportional to the nuclear charge and inversely proportional to the radius and to the repulsion of the electronic sphere of the atom. The stability ratio, as a measure of average electronic density, gives an idea of the magnitude of this attraction, for if electrons are held close together despite their mutual electrostatic repulsion, the attraction must be large, and vice versa. Therefore the electronegativity is roughly proportional to the average electronic density and is measured by the stability ratio.

The concept of maximum stability at unit stability ratio helps to explain the increase in stability when electrons are attracted. The acquisition of a partial negative charge results in expansion of the electronic sphere, which is considered to bring about a better balance of forces within the atom, and also reduces the electronegativity.

Metals and Nonmetals. These ideas of electronegativity help to clarify the meaning of the frequently misunderstood concept of "electropositivity." Most texts apply the term "electropositive" to the more active metals, and the usage is such that the student easily gets the impression that these metals inherently tend to get rid of electrons. It is true that the electrical properties of metals indicate that certain of their electrons are very mobile and can flow easily through the metal crystal. However, the flow of electrons, involving a continual and immediate replacement of any electrons which move away from a given nucleus, is quite different from the chemical removal of electrons which leaves the metal atom with an electron deficiency. The latter requires the input of a relatively large amount of energy, even for the most active of metals. This is indicated by the ionization potential of 3.893 electron volts, or 89.7 kg.-cal./mol, for cesium (9), which is the lowest value for any of the elements. Chemically, an electropositive element is merely an element of low electronegativity. Its atoms contain certain electrons which offer definite but relatively low resistance to removal. Since most of its reactions are therefore with elements greater in electronegativity, it usually becomes the relatively positive partner in polar bond formation.

The idea of electronegativity therefore makes it difficult if not impossible to define a metal on the basis of its chemical properties. It is extremely convenient in the teaching of elementary chemistry to divide the elements into metals and nonmetals and describe their chemical characteristics by saying that metals tend to lose electrons and nonmetals tend to gain electrons. However, a study of the electronegativity values as determined from electronic densities shows that some elements whose physical properties identify them beyond question as metals are more electronegative than some elements whose physical properties identify them as nonmetals. It would seem preferable, therefore, to emphasize that the distinguishing characteristics of a metal are largely physical properties. The elements of highest electronegativity never, and the elements of lowest electronegativity always, show the physical properties of metals, but the elements of intermediate electronegativity may be either metallic or nonmetallic or borderline depending on their atomic weight, state of aggregation, and other factors.

Applications of Electronegativities. The most important application of electronegativities of atoms, of course, is to the nature of the bonds formed in chemical combination, and the effect on the properties of the compounds. As is well known, bonds between atoms initially different in electronegativity are expected to be polar, the negative end of the bond dipole being the atom which initially was more electronegative. Methods of estimating the degree of polarity of such bonds, sometimes termed the extent of "ionic character," cannot be discussed in the present paper.
When Herman Mark came to the Polytechnic Institute in 1940 at the age of 45, he quickly gathered about him a group of workers including Goldfinger, Fankuchen, Stern, Hohenstein, Alfrey, Doty, and Zimm, to study the structure of macromolecules and their behavior in solution. With only a minimum of space and equipment this group transformed itself within five years into the present Institute for Polymer Research. This institute attracts students and research workers from all over the world and has had a profound influence on research and applications of high polymeric molecules in the United States and abroad.

To understand the impetus which Mark gave to this branch of chemistry, we must trace out his varied career and the contributions which he has made to science. After the first world war, when Mark, then a young lieutenant in the Austrian Army, was released from a prisoner of war camp in Italy, he enrolled as an organic chemistry major at the University of Vienna. His university career was brilliant and was perhaps rivaled only by that of his schoolmate, Richard Kuhn. Receiving his doctorate in 1921 under Schlenk with highest honors, he then went to the University of Berlin as an instructor and after one year moved to the Kaiser Wilhelm Institut für Faserstoffe. This institute was the first to study the structure of natural high polymers by means of X-rays. Here Mark carried out X-ray diffraction studies of polymers with Polanyi and others and worked out the structure of graphite with Hassel. Mark then made fundamental studies with Kollman and Ehrenburg of the optical properties of X-rays—the dispersion, refraction, and reflection of X-rays and the Compton effect.

In 1926 Mark joined the staff of the research laboratories of I. G. Farben in Ludwigshafen where he carried out his classical studies with K. H. Meyer and others on the structure of cellulose and other natural high polymers. Their collaborative research is contained in their famous book "Der Aufbau der hochpolymeren organischen Naturstoffe." During the same period he collaborated with Wiel in applying the then new electron diffraction technique to molecules. They were the first to obtain interatomic distances in molecules by electron diffraction.

In 1932 he was appointed Director of the First Chemical Institute at the University of Vienna where he stayed until 1938. The work at that institute was concerned with three main aspects of high polymer chemistry. First, there was the work with Raff and Dostal on the kinetics of addition polymerization. Second, there was the work with Guth on the statistics of rubber-like molecules and the mechanical properties of rubber, and third, there was the work with Simha, Guth, and Eirich on the hydrodynamics of high polymeric molecules in solution.

After his dismissal by the Nazis, Mark went to Canada to become Research Manager of the National Paper Company in Ontario. At that time he initiated the series of monographs on high polymers for the Interscience Publishers commencing with the collected works of W. H. Carothers.

In 1940 Mark left Canada for the United States and joined the faculty of the Polytechnic Institute of Brooklyn. Since the war he and his group at the Institute have continued studies on polymerization kinetics, copolymers, catalysts, and the properties of polymers in solution. He is co-editor with Doty of the Journal of Polymer Science and is active in organizing numerous conferences on high polymers for the Polytechnic Institute of Brooklyn, the American Chemical Society, and the Gordon Research Conferences. He carries on an extensive correspondence with scientists the world over and is always available for students as well as advanced research scientists to advise and to suggest ideas which might be helpful.

Mark has always taken a strong interest in students, both undergraduate and graduate. He once served on the Board of Education of the City of Vienna and is very active within the Chemistry Department of the Polytechnic Institute of Brooklyn. His lectures on polymer chemistry and the history of chemistry are extremely popular with the students. In the latter course he examines the researches which led to modern concepts in chemistry. He is able to do this with authority since he himself has promoted many of these advances or was in personal contact during the past quarter century with many of the scientists while they were carrying out their classical researches.

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(1) See, for example, the Symposium on the Place of Inorganic Chemistry in the Undergraduate Curriculum, J. CHEM. EDUC. 27, 437–57 (1950).

AN ION EXCHANGE EXPERIMENT FOR PHYSICAL CHEMISTRY

Thomas H. Roberts, B. R. Willeford, Jr., and Robert A. Alberty
Bucknell University, Lewisburg, Pennsylvania, and University of Wisconsin, Madison, Wisconsin

Of all the many recently developed applications of the new synthetic ion exchange resins, none is of more far-reaching importance for fundamental research than their use for separating various substances. This technique has in many cases provided a relatively simple means for effecting separations which previously could be carried out only laboriously and with considerable difficulty. Though many applications in the field of organic chemistry have been made (see for example references 1–4), probably the most striking separations have been those of the lanthanides (5) and the actinides (6–8). For this reason, a student experiment which closely parallels the procedure by which the rare earths were separated and which illustrates the separation of cations by elution with complexing agents from a resin column would be a valuable addition to a laboratory course in physical chemistry. Several student experiments with ion exchange resins have been proposed (9–11), but none of these involves separations that closely resemble that of the rare earths.

In several recent reviews (12–15) on ion exchange separations, the theory and factors affecting the degree of separation when complexing reagents are employed have been considered. While these are good reference material for students in physical chemistry, they do not supply the information required for a specific laboratory experiment. Such an experiment should not require expensive materials nor analytical techniques involving instrumentation not normally found in student physical chemical laboratories. Therefore, in planning a practical student experiment, nickel and cobalt were chosen as the ions for the column, since the ionic radii of the rare earths are approximately the same, just as the valence of the ion. Thus, two different metal ions close in valence might then be separated by taking advantage of this difference in the affinity of the two ions for the resin. Although this difference is sometimes quite small it may be accentuated by use of a complexing agent (such as citrate buffer or tartrate buffer) which effectively removes metal ions from the solution and competes with the resin for the cations. The speed with which a given ion moves down the resin column is then dependent upon two things: the affinity of the resin for the ion and the extent to which the ion is complexed by the complexing agent.

Let us consider the reactions which take place when a solution of ammonium citrate of a pH at which nickel citrate complex ions are formed is passed through a resin column on which nickel ion has been adsorbed at the top. The following reversible reaction results:

\[ \text{Ni}^{2+} + 2\text{NH}_3\text{R} \rightleftharpoons \text{NiR}_2 + 2\text{NH}_3 \]  

(1)

where R represents the insoluble macromolecular resin anion. The “capacity” of a resin is the number of equivalents of cation which may be bound on 1 g. of resin. If a resin of sufficiently high capacity is used, all the Ni\(^{2+}\) and Co\(^{2+}\) ions will be adsorbed in a relatively narrow band at the top of the column.

The strength of the metal-resin bond depends upon two things, the radius of the hydrated ion and the valence of the ion. Thus, two different metal ions will be held by the resin with different tenacities. A separation of the two ions might then be achieved by taking advantage of this difference in the affinity of the two ions for the resin. Although this difference is sometimes quite small it may be accentuated by use of a complexing agent (such as citrate buffer or tartrate buffer) which effectively removes metal ions from the solution and competes with the resin for the cations. The speed with which a given ion moves down the resin column is then dependent upon two things: the affinity of the resin for the ion and the extent to which the ion is complexed by the complexing agent.

At the same time the citrate anion of average charge \(-m\) (represented by \(\text{A}^{m-}\)) reacts with the Ni\(^{2+}\) ion as indicated by the following reversible reaction:

\[ \text{Ni}^{2+} + x\text{A}^{m-} \rightleftharpoons \text{NiA}_{x-m}^{2-} \]  

(4)

where \(x\) is the number of anions which complex with each nickel ion. The fraction of the total nickel found in each form, \(\text{Ni}^{2+}\), \(\text{NiR}_2\), and \(\text{NiA}_{x-m}^{2-}\), is determined by the equilibrium constants for reactions (3) and (4). A similar set of two reactions occurs for the Co\(^{2+}\) ion. If these two equilibrium constants for the nickel reactions are sufficiently different from those for the cobalt reactions, a separation may be achieved.

The process which occurs in the column may be visualized as follows for the nickel ion. When the nickel chloride solution is poured on the column the nickel is adsorbed in a narrow band at the top as indicated by equation (1). When the ammonium citrate
buffer is passed into the column the free Ni\textsuperscript{2+} ions are complexed according to equation (4) to a large extent so that the equilbrium for reaction (1) is shifted to the left. The nickel in solution moves down the column to a region of "fresh" resin (NH\textsubscript{4}R). This amounts to increasing the concentration of NH\textsubscript{4}R which shifts the equilibrium of reaction (1) to the right again, i.e., the Ni\textsuperscript{2+} ion is readsoorbed. Thus, as the solution passes down the column, the Ni\textsuperscript{2+} is successively adsorbed and desorbed in a process similar to fractional distillation in which a substance is successively vaporized and condensed. The same process is going on with the Co\textsuperscript{2+} ions. Thus the small differences in equilibrium constants operate many times, with the result that a better separation is achieved by column operation than in a batch experiment. When citrate buffers of higher pH are used reaction (4) is displaced to the right, and the metals are eluted more rapidly from the column.

PRELIMINARY INVESTIGATION

There are many factors which affect the degree of separation which can be achieved. Among these are length of resin bed, flow rate of eluent, pH of eluent, temperature, resin particle size, column loading, and resin exchange capacity (\textsuperscript{13}). It was desired to find conditions under which nickel and cobalt may be satisfactorily separated on a column within the time limits imposed. Among these are the most significant values for the flow rate and pH of the eluent that would give the best separation within the time limits imposed. Using the experimental procedure given in the following section, 29 runs were made under various conditions of flow rate and pH of eluent. The most significant of these runs are summarized in the table. It can be seen that, in general, the best separations were obtained under conditions of slow flow rate and low pH of eluent. These conditions also require longer times for the separation to be accomplished. Of the various conditions studied, a flow rate of 5.1 ml./cm.\textsuperscript{2}/min. and a pH of 3.24 seem to be most satisfactory.

The results of five runs made under these conditions are given in the last lines of the table. They show that an average of 94 per cent of the nickel was recovered free of cobalt contamination in an average time of 3\frac{1}{2} hours. It can be seen that the reproducibility of the experiment is quite satisfactory. The elution curve for Run 32 is shown in Figure 1.

DIRECTIONS

Apparatus. Ion-exchange column filled with Dowex 50 W resin (60-100 mesh), citrate buffer, stock solutions of NiCl\textsubscript{2} and CoCl\textsubscript{2}, two 25-ml. graduates, test tubes and corks, photoelectric colorimeter.

Preparation of Resin Column. Because of its high exchange capacity, Dowex 50 resin was chosen. It is pretreated with 6 N hydrochloric acid to remove ionic impurities. An aqueous suspension of the resin is slurried into a glass column 60 cm. in length and 1.2 cm. in diameter which has a sintered-glass plate at the bottom to support the resin and a piece of rubber tubing and a screw clamp for controlling the flow rate. Alternatively the resin may be placed in an ordinary stopcock buret (11) in the bottom of which a small plug of glass wool has been placed. The resin is allowed to settle to a height of 30 cm. and is washed with distilled water. A solution of ammonium chloride is then passed through the column to convert the resin to the ammonium form. The conversion may be considered complete when the column effluent is basic to methyl orange. After washing with several column volumes of distilled water, the column is ready for use. To conserve time the hydrochloric acid and ammonium chloride treatments may be made previously on large batches of resin using large columns.

![Figure 1. Elution of Nickel and Cobalt](image-url)
Preparation of Eluting Solution. Fifty grams of citric acid monohydrate and 1 g. of phenol (added as a mold growth inhibitor) are dissolved in a liter of water. Concentrated aqueous ammonia is then added to the solution until a pH of 3.24 (as indicated on a pH meter) is reached.

Stock Solution. In order to conserve laboratory time it is desirable to prepare in advance a stock solution of the nickel and cobalt chlorides. This solution should be of known concentration. It is suggested that it be prepared so that each 10-ml. portion of the solution contains 200 mg. each of Co\textsuperscript{++} and Ni\textsuperscript{++}.

Procedure. A quantity of the stock solution containing 200 mg. each of Co\textsuperscript{++} and Ni\textsuperscript{++} is poured into the column, care being taken not to disturb the particles at the top of the resin bed. If distilled water is then poured carefully into the tube, it will layer above the salt solution and there will be adequate head to force the solution through the column. A narrow adsorption band, brown in color is formed at the top of the resin bed. A siphon is connected to the column and about 100 cc. of distilled water is allowed to flow through. If the washings are colorless they are discarded.

The stock solution of the eluent is now connected to the column by a siphon. This solution is passed through the column at a rate of 5 ml./cm.\textsuperscript{2}/min. After a few minutes the brown band can be seen to begin to break up into two bands, the green nickel band being below the pink cobalt band. The effluent is collected in approximately 150-ml. portions until the nickel complex ion is near the bottom of the column. Ten-milliliter fractions are collected during the elution of the nickel and 25-ml. fractions during the elution of the cobalt. For each fraction, the volume and time are recorded (the flow rate may be checked from these data) and a test tube full of the solution is saved for analysis.

Analysis of Samples. The fractions may be analyzed by a photoelectric colorimeter. A Fisher Electrophotometer with a micro attachment was used for the runs reported here. Calibration curves were prepared using citrate solutions containing known amounts of cobalt and nickel. They are reproduced in Figure 2. It is seen that while the interference of nickel with the analysis for cobalt at 525 mu is negligible, the cobalt complex absorbs sufficiently at 650 mu to make necessary a correction for its presence.

Calculations. The concentration of each metal in milligrams of metal per milliliter of solution in each fraction is read from the calibration curves. The concentrations are plotted versus the total volume of effluent to give the elution curves. The quantities of nickel and cobalt recovered from the column are calculated from the concentrations and volumes of the fractions. The per cent recovery is obtained. The percentage of each metal recovered without contamination by the other is calculated.

Suggestions for Further Work. The results obtained may be compared with those predicted from the "plate" theory by following the directions given by Tompkins.

The influence of pH of eluent, of flowrate, of different weight ratios of cobalt to nickel, or of the ratio of the weight of metals to weight of resin may be investigated.

This experiment is now in use in these laboratories. Satisfactory performance of the experiment on photoelectric colorimetry (16) is a prerequisite to this experiment. If the student has studied the light absorption of nickel and cobalt chlorides in citrate buffer in the regular colorimetry experiment, these data may be utilized in the analysis of the column fractions. Alternatively, the students may be provided with calibration curves for the analysis of the fractions.

ACKNOWLEDGMENT

We wish to express our appreciation to Dr. Edward R. Tompkins for his many helpful suggestions, and to the students in the physical chemistry laboratory course who cooperated with us so well in working out this experiment. To the Dow Chemical Company also goes our thanks for supplying the resin.

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FRAGMENTS OF CHEMISTRY

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7. BORON

Reactions of Trialkyl and Arylboranes. With ammonia and the amines, the alkyl and aryl boranes form rather stable complexes of the type R₂B-NH₃. When these compounds are treated with alkali metals in liquid ammonia, hydrogen is evolved and the resulting amide ion complexes with boron. Reaction takes place according to the equation:

\[ K + R₂B-NH₃ = R₂B-NH₂K + \frac{1}{2}H₂ \]  

(1)

Compounds of the type R₂BHN₄M are strong electrolytes and are surprisingly stable. Thus, the compound Ph₂BHHK is fairly stable in air although Ph₂B oxidizes readily and KNH₂ oxidizes explosively. It may be noted that the boranes form stable complex compounds with salts of several small ions such as OH⁻, F⁻, etc. Thus, tetrabutylammonium triphenylborofluoride Bu₄N⁺BF₄⁻ is quite stable in air.

Dibutylboron Bromide. The dialkyl or aryl boron halides, R₂BBr, amonolize in liquid ammonia. Therefore, they cannot be reduced by means of the alkali metals in that solvent. However, they may be reduced by means of sodium-potassium alloy in ether solution. It is, perhaps, more accurate to say that dibutylboron bromide may be so reduced; similar reactions with other dialkyl or aryl boron halides, while they probably would occur, have not been studied.

The reduction of dibutylboron bromide by means of Na-K alloy takes place in two stages; in the first stage, reaction occurs according to the equation:

\[ (C₄H₉)₂BBBr + M = (C₄H₉)₂B + MBr \]  

(2)

In the second stage we have:

\[ (C₄H₉)₂B + M = MB(C₄H₉)₂ \]  

(3)

Dibutylboron and metal dibutylbordide are both soluble in ether.

If, after reaction (2), the solvent is evaporated and the tube containing the product is exhausted at higher temperatures, and the volatile products are condensed and collected, the butylboron disproportionates according to the equation:

\[ 2(C₄H₉)₂B = (C₄H₉)₂B + C₄H₄B \]  

(4)

The monobutylboron, C₄H₄B, is a solid and is doubtless highly polymerized. In all likelihood, dibutylboron also exists as a polymer of some sort.

In one experiment, a small quantity of a difficulty volatile material was obtained whose composition corresponded closely to that of dibutylboron. It would be of much interest to obtain dialkylboron in the pure state. However, it would be advantageous to work with a compound of one of the lower alkyls, such as the methyl or ethyl derivatives. With a more volatile compound, it might be possible to volatilize the dialkyl boron without decomposition.

The product of reaction (3), MB(C₄H₉)₂, yields a red colored solution; therefore, it is a simple matter to determine the end point of reaction (2). The product of reaction (3) cannot well be isolated and studied. However, its existence may be established by its reactions.

On adding methyl iodide to the product of reaction (3), we should expect to obtain methylidibutylboron in accordance with the equation:

\[ MB(C₄H₉)₂ + CH₄I = CH₄(B(C₄H₉)₂) + MI \]  

(5)

The expected compound is obtained with a 67 per cent yield. Only two-thirds of the dibutylboron reacts in accordance with equation (3). Other observations and reactions indicate that reaction (3) is not quantitative. Seemingly, dibutylboron exists in two (probably polymeric) forms only one of which is reduced to MB(C₄H₉)₂ by sodium-potassium alloy. While there is no question as to the formation of the metal boride to the extent of approximately 67 per cent, it seems equally certain that the dibutylboron, as initially formed, is not all of the same kind. Further investigation is required to establish the nature of the products of reaction (2). By all means, the reaction of more volatile dialkylboron compounds should be investigated. At the same time, it would be of interest to investigate the reduction reactions of diphenylboron halides. The reaction of compounds of the type MBR₄ with the halides of different
Our knowledge of the chemistry of the organo-gallium compounds is very limited. These compounds are studied rather more readily than the corresponding boron compounds because the dialkylgallium halides do not ammonolyze in liquid ammonia. Sodium triphenylgermanide reacts readily with boron trichloride in ether. Seemingly, the reaction is straightforward; no hexaphenylgermane is formed nor is there evidence of a product other than one of boron and germanium. However, the excess of sodium, 2.82 milimols of hydrogen were collected from 5.64 millimols of GaMe₃, or, precisely, one half atom per mol of gallium in accord with equation (8). After discharging the blue color of the excess sodium by addition of ammonium bromide, no hydrogen was evolved on further addition of bromide. In another experiment, carried out with a dilute sodium solution and 6.5 millimols of GaMe₃, 1.70 milimols of hydrogen were evolved according to reaction (8) and 1.64 milimols of hydrogen were evolved according to the reaction:

\[ \text{Na}_2(\text{GaMe}_3)_2 + 2\text{NH}_3\text{Br} = 2\text{NaBr} + 2\text{GaMe}_3 + 2\text{NH}_3 + \text{H}_2 \] (10)

Approximately two-thirds of the gallium reacted according to equation (8) and one-third according to equation (9).

The reaction of trimethylgallium with lithium in ethylamine seems to be similar to that with sodium in ammonia. The lithium salt, Li₂Me₃Ga.GaMe₃, is formed in the sense of equation (9). However, in place of reaction (8), we have

\[ \text{Me}_3\text{Ga.C}_2\text{H}_5\text{NH}_2 + \text{Li} = \text{Me}_3\text{GaC}_2\text{H}_5\text{NHLi} + 1/2\text{H}_2 \] (11)

One molecule of gallium is associated with one mol of lithium ethylamide and one atom of hydrogen is evolved per mol of compound.

The product of reaction (9) is not stable when the ethylamine is evaporated; one atom of hydrogen is evolved per atom of lithium in the compound Li₂(GaMe₃)₂. Evidently, reaction takes place with the amine somewhat as follows:

\[ \text{Li}_2(\text{GaMe}_3)_2 + 2\text{C}_2\text{H}_5\text{NH}_2 = 2\text{LiC}_2\text{H}_5\text{NH.GaMe}_3 + \text{H}_2 \] (12)

In one experiment, 2.06 milimols of lithium were added to 2.06 millimols of Me₃Ga in ethylamine. On completion of the reaction, 0.82 milimols of hydrogen had been evolved. On evaporating the solvent, 1.26 milimols of hydrogen was evolved. On condensing ammonia on the residue and adding ammonium bromide, no hydrogen was evolved. Thus a total of 2.08 milimols were evolved. Of this, 39.4 per cent resulted from reaction (11) and 60.6 per cent from reaction (12); the total hydrogen corresponds to the amount of lithium used within the experimental error.

Dimethylgallium. Dimethylgallium chloride dissolves in liquid ammonia without ammonolysis. On treating its solution with sodium we have the reaction:

\[ \text{Me}_2\text{GaCl} + \text{Na} = \text{Me}_2\text{Ga} + \text{NaCl} \] (13)

Dimethylgallium is soluble in liquid ammonia, its...
solutions having a yellow to orange color, depending on concentration. When the solution is concentrated, a brownish colored compound precipitates. This compound seems to be a complex with ammonia. Hydrogen is evolved slowly at $-33^\circ$ and rapidly at room temperature. One atom of hydrogen is produced per atom of gallium according to the equation:

$$\text{Me}_2\text{Ga} \cdot \text{NH}_3 = \text{Me}_2\text{GaNH}_2 + \frac{1}{2}\text{H}_2 \quad (14)$$

The amino compound, Me$_2$GaNH$_2$, is a solid which may be sublimed in vacuo at 100$^\circ$; it may be melted at higher temperatures. The compound dissolves slowly in water; it is necessary to heat to 60$^\circ$ to effect complete solution. Analyses for nitrogen and gallium correspond closely to the requirements of the formula above.

Dimethylgallium is not acted upon by sodium in liquid ammonia. Its reaction toward oxygen has not been examined. Gallium compounds containing other organic groups have not been investigated.

**Methylgallium.** Methylgallium dichloride reacts with two equivalents of sodium in liquid ammonia according to the equation

$$\text{MeGaCl}_2 + 2\text{Na} = 2\text{NaCl} + \text{GaMe} \quad (15)$$

Methylgallium is soluble in ammonia yielding a solution of brick red color. Methylgallium appears to be complexed with two molecules of ammonia and little hydrogen is evolved at room temperature. This compound requires further study.

With three equivalents of sodium, methyl gallium dibromide reacts slowly in the last stage and approximately one equivalent of hydrogen is evolved. Sodium amide is formed which complexes with the methylgallium. Again, further study is called for.

There is little doubt that numerous compounds may be prepared containing two or three of the elements boron, germanium, and silicon. It would be of interest to know what reaction products would be formed if alkyl aluminum and alkyl indium halides were reduced by means of metals in liquid ammonia. Dimethylalumnum bromide and methylaluminum dibromide are readily prepared and they may be handled with comparative ease. Altogether, we have an extensive field of investigation in connection with the organic derivatives of these third group elements.

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**PURE AND IMPURE**

In a recent issue our distinguished contemporary, Discovery, expressed concern about the position of pure or fundamental research. The really great advances all spring from discoveries made in pure science. Those initial discoveries may sometimes be no more than chance by-products of an 'academic' investigation, yet they can lead to great new departments of technology and industry. The antibiotics and the growth-regulating substances of agriculture are examples within our own time. Research in applied science is certainly important and most of us realize that it was insufficiently encouraged before the war; but it is a form of long-term matricide for efforts in applied science. A balance between the two kinds of efforts must be judiciously maintained.

One of the most dangerous factors operating against pure scientific research today is its high cost. The facilities needed, especially equipment, require more and more money. This is not simply a matter of inflation though rising costs certainly play a significant part. Far more serious is the fact that increasingly complex apparatus is now required to push the front of science further ahead. Thus if $500 per annum as a grant secured so much effort ten years ago, the same sum today cannot secure even half the effort. The proportion is more likely to work out at a quarter or less; or, conversely, it requires $2000 today to support the amount of pure research that $500 would have supported formerly. The scientist with a genuine capacity for research is in a similar situation to the poet or writer of Elizabethan times—he must find a rich patron. That patron must be the State, a university (whose funds in any case mainly derive from the State), or industry in the shape of a large company or an industrial association.

In recent years there has been a praise-worthy expansion in all these pipelines of economic patronage but with greater public investment in research a tendency for greater control of the research worker has not unnaturally arisen. Yet for pure research pure freedom is essential. The exploratory journey cannot be charted and timetabled in advance. The first-class worker must be free to switch his effort and interest from an initial target to some sudden and unexpected development that seems more important; and he, above all, must be the principal judge of the wisdom in making such diversions. However much it may be feared that such complete freedom for the individual will lead to wastage, to blind alleys, or to the overlapping of efforts by different workers, the desire of fund-awarding committees to lay down fixed programs must be suppressed. Their task is to pick the right men to support, to support them adequately, and thereafter to let research follow its own directions. Not every investment in research pays a dividend. Sometimes the dividend is long deferred. But those dividends that accrue from a few projects are so huge in relation to their capital cost that the "losses" from the others can be cheerfully written off. There is no executive place for the accountant in research; indeed, if accountancy were fully applied, many a pure research worker of the past should have died a millionaire (at the expense of the public purse) and not a comparatively poor man!—From *The Chemical Age*, Oct. 27, 1951.
FINDING AND FOUNDED FUTURE CHEMISTS

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The special success of Monmouth College in starting men on the road to the degree of Doctor of Philosophy in chemistry [See Lewis, H. F., "The role of the liberal arts college in the professional training of chemists," J. Chem. Educ., 28 104-7 (1951)] has led to numerous inquiries into our procedures. It therefore seemed advisable to offer, in this article, an account thereof to a journal of national circulation. The present writer is qualified to present the facts, since he has been closely associated for many years with the prime developer of these results here, but was not himself that developer.

The stimulus starting our activity was a criticism leveled at this school, near the time of World War I, for its lack of productivity of graduate students. W. S. Haldeman (now emeritus) was then the sole member of our chemistry staff. (He taught physics in alternate years also, during his spare time!) He decided to induce some of his students, if possible, to take graduate work in chemistry. He began by watching his first-year students carefully. A system of almost daily tests soon began to differentiate them. He singled out particularly young men of superior scholarship in his courses. With such he became specially well acquainted. He would let them know that their good work was noted and appreciated. Signs of dereliction from the path of achievement—an occasional poor grade, obvious overloads of paid work or other extra-curricular activity—were as duly noted and as frankly discussed. This supervision continued through the upper classes. By the time a student became a sophomore and had declared his intention to major in chemistry, he realized that our department had certain important hopes attached to him. His registration was guided each semester. All his grades were sharply watched. If he had financial or other personal problems he knew he could bring them into the chemistry office for an airing, and often did. An assistantship would usually be found for him, if his record was good, often even in his sophomore year. Students who could not stand the discipline were helped to find a department where they could invest at higher interest.

When the senior year was started, two things, the student knew, had to be put in order. One was his application for his Bachelor of Science degree, a paper which demonstrated that all the requirements were fulfilled. During each preceding registration, Haldeman or the additional staff which later joined him, would have checked to see that the courses would also serve as bases for graduate study. German and French, for instance, rather than less useful languages, were included; and at least two years of college mathematics and a year of physics.

The other matter was about the next year: graduate school or job? The decision was the student's; the staff's hopes were toward graduate study. If the student wavered or wondered, it was explained to him that the higher long-range profits were offered by the graduate program, in spite of the immediate job-pay. When graduate study was elected, careful thought was given to "where." The student's affection for a particular
division of chemistry was weighed against general reputations and publication records. Scholarships and assistantship stipends and living expenses were discussed. Again, the student made the final choice.

Then the applications were prepared. A letter, usually from Haldeman, to the university or universities in question, would let them know we had a prospect, and would bring the application forms. Filling in the latter was minutely and personally supervised by Haldeman. If a letter from the applicant was in order, he had to write a trial draft for criticism from our staff. (It is surprising to see how much otherwise good students need to learn about the art of writing an application.) A photograph was taken, and with the applicant wearing a business suit rather than a turtle-neck sweater! Appropriate recommendations were solicited in writing. Forms were made for the student's convenience in doing this, so that the prospective recommender could know where and to whom the letter should go; if it should be separately mailed or sent with other materials; and when it should be on its way. Telegraph, telephone, and personal interviews were used when expedient.

Recommendations were realistic. It is axiomatic among students that Haldeman inclines to generosity with his money, but stinginess with undeserved recommendations. This policy is sometimes hard on an individual laggard student, but is better for the employer, and for the next good student that might be moved in that direction. An item in the recommendations was, where possible, cooperative-test percentiles. These we thought to be even more meaningful than local grades. Class rank as well as grade in a chemistry course was usually provided. Personal qualities, honesty, etc., were emphasized. Withdrawals of all unaccepted applications were made immediately after acceptance of one.

Financial considerations were frankly faced. Very often a problem of this nature was solved by a personal loan of money from Haldeman to the student in the early days of this program. By the time the student had reached this stage, Haldeman knew him thoroughly and felt competent to judge his reliability; and the judgment was entirely in Haldeman's hands, free of the inevitable confusions of a bureaucratic disbursement of scholarships. By putting in all his liquid assets, plus some money which he himself borrowed, Haldeman had at one time as much as $6000 out in long-time low-interest loans. As the first borrowers repaid, and as graduate stipends became larger, this circulating fund shrank, finally to nothing. The amount of money, though large for one college teacher, is not large for an institution, and perhaps some foundations, existing or prospective, may find useful information in the results of this experience. All Haldeman's loans were repaid, and some with truly remarkable promptness.

Very often the value of a laboratory experiment is lost because there is no writeup. From the first and through the years, careful writeups were maintained in this continuing experiment in human chemical engineering. A modest annual newsletter has evolved into a neatly printed pamphlet, issued now at about five-year intervals, stating where each chemical alumnum is for whom he is working, and telling briefly of his family. Summaries indicate the variety of jobs held, publications made, graduate stipends offered, war activities. The names are indexed. The booklet is sent to each alumnus of the department. Previous to each revision, a questionnaire is sent also to each, and followups made if necessary. Every available avenue is used to get information about those who fail to reply. Painstaking care is expended to make the book accurate, and it has been found, by the way, to be a useful document to include with recommendations; it gives an idea of the caliber of the work of the person recommended, to a person who may not have heard of our school. The directory is supplemented by mimeographed newsletters, sent out annually.

Although the original discussion centered about men who become Ph.D.'s in chemistry, there are other types of students among our majors, and these are given equally careful attention. The above-mentioned alumni directory tabulates especially medical degrees. Women graduates are represented in a variety of technical situations.

Moreover, students are taken to meetings of convenient sections of the American Chemical Society, and the State Academy of Science. They are also taken in fairly large groups to centers of chemical industry within a two-hundred mile radius. Alumni and other friends volunteered to finance these travels. To them we owe much, as well as to the vast aggregate of courtesy and cooperation from the host institutions and industries.

A bulletin-board display of career opportunities [See Chem. & Eng. News, 28, 1274 (1950)], and career conferences are part of our present stimulation program.

In summary, Monmouth's method, developed by Haldeman and carried through today essentially on lines he laid down, stresses individual contact, personal acquaintance, systematic stimulation, and help of whatever sort may be needed in the particular situation.

It is evident that all of the items in this program are reproducible, except possibly the financial situation. Graduate appointments were fewer, and less remunerative in relationship to the standard of living, when Monmouth was laying the foundation for the success indicated in Lewis' (loc. cit.) Table 4. Also, Haldeman was willing to risk his own personal saving entirely on the venture. In later years, the main ingredients of the Monmouth program have been: (a) early alertness for promising material, (b) persistent presentation of the opportunities to students, (c) careful and frequent counselling, involving personal as well as technical factors, (d) pushing the candidate to initiate action and follow through, as needed, and (e) keeping records and disseminating information about placements to the alumni themselves, and others.
A LABORATORY SAFETY PROGRAM

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Watch it!

Don't Let it Happen to You

DURING the spring semester of 1948-49 our laboratory safety program lost effectiveness. The frequency of minor accidents increased and more than the usual portion of the laboratory periods had to be devoted to safety instruction. The following year one of our senior students, a laboratory assistant, designed a series of picture stories for our bulletin boards. Interest in these photographs was much greater than in the usual poster series which are available. Accidents dropped in number and the time necessary for safety instruction during the laboratory periods gradually returned to normal. Interest in the photographs was probably due to the fact that most of the students were personally acquainted with the people in the pictures.

The photographs were thumbtacked to the bulletin board with caption cards written in longhand in order to give the display an informal, personal aspect. Students flocked around the pictures each time a new series appeared.

Of course, increased safety consciousness among the instructors may have had something to do with the improved safety record.
HYPERCONJUGATION: AN ELEMENTARY APPROACH

HENRY CONJUGATION, first suggested by Baker and Nathan seventeen years ago (1) is seldom mentioned in the introductory organic chemistry classes, although others equally "advanced" and not less difficult subjects have won their places in these same courses. This is unfortunate since a knowledge of the principal features of the hyperconjugation effect is essential to the understanding of a number of facts in the chemistry of the unsaturated hydrocarbons. At the advanced level there are detailed reviews of the subject (2, 3), which has been treated by the molecular orbital method by Mulliken and his co-workers (4, 5). However, apparently there is not in the literature an elementary approach to the subject and we believe that the following treatment may be useful to many organic chemistry teachers who wish to introduce the concept of hyperconjugation together with that of "normal" resonance to their sophomore or junior students.

Possibly the best manner to teach the concept of hyperconjugation to the beginner student is to give an account of its experimental basis. For didactic reasons the empirical evidences of hyperconjugation may be divided into three categories, namely, kinetic, thermochal, and spectroscopic evidences.

KINETIC EVIDENCE

In 1935 Baker and Nathan (1), studying the following bimolecular reaction between p-substituted benzyl bromides and pyridine with dry acetone as solvent,

\[
\begin{align*}
X-C=\overset{\text{Br}}{\text{C-Br}} + N-C=\overset{\text{H}}{\text{C=H}} & \Rightarrow \\
[\text{X-C-\overset{\text{H}}{\text{C=H}}}]^{\text{Br}} & 
\end{align*}
\]

found that the reaction rate increases in the order \( X = \text{NO}_2 < H < \text{alkyl radicals}, \) that is, with the increasing electron release tendency of the substitute group. It is a firmly established fact that the electron-release tendency of the alkyl radicals due to the inductive effect alone follows the order \( \text{Me} < \text{Et} < \text{iso-Pr} < \text{ter-Bu}. \) Rather surprisingly, however, Baker and Nathan found that the rate of this reaction increases in the order \( X = H < \text{ter-Bu} < \text{iso-Pr} < \text{Et} < \text{Me}. \)

We may explain this apparently anomalous behavior as follows:

1 This behavior is described in the literature as the "Baker-Nathan effect."
of the available system of structure constituents:

**SPECTROSCOPIC EVIDENCE**

It is found experimentally that a compound with conjugated double bonds absorbs light of a longer wavelength than a similar compound with isolated double bonds. Furthermore, as the number of conjugated double bonds increases, the absorption shifts to progressively longer wave lengths. For instance, the extreme ethylene absorption band is 1900-2000 Å, that of 1,3-butadiene is 2100 Å and that of 1,3,5-hexatriene is 2350 Å (10,11). Mulliken, R. S., and C. A. Rieke, and W. G. Brown, J. Am. Chem. Soc., 63, 41 (1941).

The evidence for hyperconjugation from dipole moment measurements (12) is not conclusive and recently has been disproved. This refers to the fact that although the dipole moments of the saturated hydrocarbons and of ethylene are zero, this is not the case with some alkyl-substituted mono- and di-olefins (see Table 2).

These dipole moments could be attributed to two factors, namely, hyperconjugation involving the C—H bonds of the methyl groups or charge transfer due to the difference in the electronegativity of a saturated carbon (sp<sup>3</sup> hybridization) and an unsaturated carbon (sp<sup>2</sup> hybridization). In the last few years it has been shown by theorerical calculations that the inductive effect alone is responsible for the dipole moments of these substances (16).

Since hyperconjugation represents a stabilizing influence it plays an important role in the thermodynamics of certain reactions of the mono- and poly-olefins. An interesting and simple account of the applications of the concept of hyperconjugation to these subjects has recently been published by Baker (17).

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15. Hughes, E. D., and C. P. Smyth, ibid., 64, 2212 (1942).
COLLEGE AND UNIVERSITY RESEARCH IN CHEMISTRY

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Massachusetts Institute of Technology, Cambridge, Massachusetts

TWO out of three chemists on the faculties of American colleges and universities now have one or more research projects underway. These studies—and the graduate-level teaching and administration associated with them—take at least half the time of those faculty members involved. A full-time research staff of over 1300 senior workers would be needed to equal the research effort this represents.

Yet there remains room for still more research without sacrificing teaching in the chemistry departments at most educational institutions. Today, with an urgent need for all scientific and technical studies, the problem is to find and fill the holes in this national pattern of chemical research activity.

A survey of American college and university research resources by the Engineering College Research Council shows a total of 3711 faculty and full-time senior research staff members in chemistry at 476 institutions. Of these, 89 per cent are considered by their institutions to be qualified for research, and 73 per cent of these potential researchers have projects underway.

There are 6949 graduate students and junior staff members now engaged in research in chemistry, and they, too, spend about half time on their projects.

The Engineering College Research Council survey covered all physical and engineering sciences. Chemistry ranked at the top of the list, with more faculty members and graduate students—and more research underway—than in any other of the fields surveyed. In all, over 24,000 faculty members and an equal number of graduate students were reported. Chemists numbered 15 per cent of the total in both categories.

The survey project was undertaken by the Engineering College Research Council, a unit of the American Society for Engineering Education, at the suggestion and with the cooperation of the Department of the Army, Navy, and Air Force. It was completed under the direction of the Research Council’s Committee on Relations with Military Research Agencies, of which Dean A. F. Spilhaus of the University of Minnesota is chairman. The first report of results was made

1 Members of the Committee, in addition to Dean Spilhaus, are Dr. A. P. Colburn, University of Delaware; Dean W. L. Everitt, University of Illinois; Professor F. B. Farquharson, University of Washington; Dr. C. W. Good, University of Michigan; Dr. Paul E. Klopsteg, Northwestern University; President J. R. Van Pelt, Montana School of Mines; and Dean Eric A. Walker, Pennsylvania State College. Dr. Gerald A. Rosselot, Georgia Institute of Technology, is chairman of the Council.

by Dean Spilhaus at the 1951 annual meeting of the A.S.E.E.2

To compile a national inventory of college and university research potential, the Committee sought data from all four-year educational institutions on the numbers of faculty available, their present research commitments, and their special interests and qualifications. Though aware of the shortcomings of the questionnaire process, the Committee adopted that method as being the only possible way to meet the recommended time schedule and to yield data suitable for mechanical processing and comparison.

Only 250 of the nation’s 1000 four-year colleges and universities failed to make specific reports on personnel, present research commitments, and special interests. An informal review of this list of schools from which no replies were received suggests to the committee that “substantially all” of the national potential for research in colleges and universities in the physical and engineering sciences is reported.

Of the 750 colleges replying, 513 listed personnel qualified for research in one or more of the physical and engineering sciences. The remaining 237 replied that their staffs were not active in these fields. The totals, from the 513 schools, are shown in Table 1. In summary, they show:

1. Nearly 25,000 faculty members in all physical and engineering sciences.
2. Of these, 20,000 are considered qualified to participate in research.
3. At least 12,700 of these are now active in research.
4. An average of 27 per cent of all faculty time is spent on research.
5. At least 45 per cent of this research time is already devoted to defense projects—studies sponsored by military agencies, the Atomic Energy Commission, or their industrial contractors.

Putting these figures another way,” Dean A. F. Spilhaus of the University of Minnesota pointed out, “of the 25,000 faculty members reported, one-half are active in research; these spend about one-half of their time in research, and one-half of this is devoted to military research. This means that one-eighth of the total college effort in these fields of engineering and physical sciences is already devoted to defense research.”

More research is now underway in chemistry than in any other of the engineering and physical sciences. Chemists are second only to physicists in their contribution to defense research. Together, chemistry and physics account for one-third of the defense research total; nearly one-half is in the three areas of chemistry, physics, and electronics. "This," the Committee report notes, "is convincing evidence that colleges and universities are maintaining emphasis on the fundamental sciences. They must continue to resist the temptations to undertake extensive assignments in applied research and development."

SUBSTANTIAL CHEMISTRY RESEARCH RESOURCES

The Engineering College Research Council's figures show 3711 faculty members and full-time senior research personnel in chemistry in 476 schools. Of these 3711 faculty members and full-time senior research personnel in chemistry in 476 schools. Of these 3711 faculty members and full-time senior research personnel in chemistry in 476 schools. Of these 3711 faculty members and full-time senior research personnel in chemistry in 476 schools. Of these 3711 faculty members and full-time senior research personnel in chemistry in 476 schools. Of these 3711 faculty members and full-time senior research personnel in chemistry in 476 schools. Of these

TABLE 1

The table below shows the distribution of chemistry research resources.

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Number of faculty</th>
<th>Number of (A) considered qualified to do research</th>
<th>Number of (A) now engaged in research</th>
<th>Number of full-time research workers to which (C) is equivalent</th>
<th>Number of graduate students and assistants engaged in research to which (D) is equivalent</th>
<th>Number of full-time research workers to which (F) is equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeronautical engineering</td>
<td>652</td>
<td>597</td>
<td>437</td>
<td>289.7</td>
<td>236.8</td>
<td>566</td>
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<tr>
<td>Astronomy</td>
<td>279</td>
<td>247</td>
<td>100</td>
<td>105.3</td>
<td>95.5</td>
<td>225</td>
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<tr>
<td>Ceramics</td>
<td>216</td>
<td>200</td>
<td>156</td>
<td>106.8</td>
<td>42.0</td>
<td>215</td>
</tr>
<tr>
<td>Chemical engineering</td>
<td>735</td>
<td>701</td>
<td>564</td>
<td>279.8</td>
<td>99.4</td>
<td>1,699</td>
</tr>
<tr>
<td>Chemistry</td>
<td>3,711</td>
<td>3,320</td>
<td>2,436</td>
<td>1,316.1</td>
<td>506.2</td>
<td>6,949</td>
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<tr>
<td>Civil and sanitary engineering</td>
<td>1,698</td>
<td>1,429</td>
<td>654</td>
<td>313.6</td>
<td>112.1</td>
<td>936</td>
</tr>
<tr>
<td>Chemical engineering</td>
<td>1,448</td>
<td>1,322</td>
<td>964</td>
<td>452.4</td>
<td>172.0</td>
<td>2,086</td>
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<td>1,497</td>
<td>1,238</td>
<td>602</td>
<td>285.1</td>
<td>219.1</td>
<td>1,125</td>
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<td>Electrical engineering</td>
<td>1,119</td>
<td>1,032</td>
<td>626</td>
<td>387.2</td>
<td>313.8</td>
<td>1,107</td>
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<tr>
<td>Food technology</td>
<td>755</td>
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<td>420</td>
<td>272.6</td>
<td>52.6</td>
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<tr>
<td>Industrial engineering</td>
<td>536</td>
<td>421</td>
<td>173</td>
<td>77.1</td>
<td>14.1</td>
<td>352</td>
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<td>Marine engineering</td>
<td>78</td>
<td>71</td>
<td>35</td>
<td>17.7</td>
<td>12.5</td>
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<td>Mathematics</td>
<td>3,297</td>
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<td>570.0</td>
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<td>716</td>
<td>327.1</td>
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<td>964</td>
<td>821</td>
<td>425</td>
<td>215.3</td>
<td>119.3</td>
<td>557</td>
</tr>
<tr>
<td>Metallurgical engineering</td>
<td>488</td>
<td>458</td>
<td>349</td>
<td>187.6</td>
<td>131.7</td>
<td>757</td>
</tr>
<tr>
<td>Mining engineering</td>
<td>136</td>
<td>129</td>
<td>82</td>
<td>44.4</td>
<td>11.0</td>
<td>129</td>
</tr>
<tr>
<td>Petroleum and fuels engineering</td>
<td>209</td>
<td>195</td>
<td>112</td>
<td>72.7</td>
<td>12.5</td>
<td>97</td>
</tr>
<tr>
<td>Physics</td>
<td>2,628</td>
<td>2,272</td>
<td>1,546</td>
<td>866.6</td>
<td>609.3</td>
<td>3,392</td>
</tr>
<tr>
<td>Psychology and human resources</td>
<td>2,432</td>
<td>2,029</td>
<td>1,242</td>
<td>554.7</td>
<td>227.1</td>
<td>3,162</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>24,881</strong></td>
<td><strong>21,038</strong></td>
<td><strong>12,866</strong></td>
<td><strong>6,744.8</strong></td>
<td><strong>3,290.8</strong></td>
<td><strong>24,786</strong></td>
</tr>
</tbody>
</table>

320 are judged qualified to participate in research projects, and 2436 of them are now engaged in research. This effort is equivalent to the work of a full-time research staff of 1316 and of these "equivalents" 506 would be engaged in defense projects for military agencies or their contractors.

These figures seem to show that research accounts for slightly more than one-fifth of the total college effort in chemistry; of this research nearly 40 per cent is devoted to studies for defense. This means that, on an average, 14 per cent of today's total college effort in chemistry is expended on defense research. In some schools with heavy defense assignments this figure is far higher—perhaps to the detriment of effective teaching.

A total of 6949 graduate students and assistants in chemistry research was reported by the survey, equivalent to the full-time work of 3468 junior research staff members. The ratio of junior to senior staff, 6949 to 3711, is considerably higher in chemistry than in most of the engineering and physical sciences covered.

A broad range of chemical fields is represented by this research manpower. Schools surveyed were asked to indicate areas in which one or more faculty were experienced and qualified, and the full report of the project identifies the schools and details the personnel resources reported by each. Organic chemistry, physical chemistry, analytical chemistry methods, and inorganic chemistry—in that order—were the most popular categories.

THE DISTRIBUTION OF CHEMISTRY RESEARCH

Where are these chemistry research resources?

Research now underway in chemistry shows a distribution which is typical of that found in all the physical and engineering sciences. Expansion of research to meet new national needs seems to depend on effective decentralization.

Of the 3711 chemistry faculty and senior research workers, 2070 (56 per cent) are at 104 large universities; institutions with extensive professional and graduate schools. Nine out of ten of these teachers are considered qualified to do research, and nine out of ten of these qualified faculty members have research underway. According to the institutions' reports, those teachers who have research underway spend nearly 60 per cent of their time on these studies, almost half of which are

3 Copies of this full report, entitled "University Research Potential," are available from the Secretary of the Engineering College Research Council at Room 7-304, 77 Massachusetts Avenue, Cambridge 39, Massachusetts, at $1.00 each.
sponsored by defense agencies, as shown in Table 2. At 372 other schools—including smaller universities, teachers colleges, and liberal arts colleges—are 1641 chemistry faculty members. Nine out of ten of these teachers, too, are considered qualified for research, but fewer than half of those qualified have any research in progress. Those who do have research underway devote only 27 per cent of their time to it, and less than one-third of this work is for defense needs.

To summarize: Three-quarters of the college and university chemistry research are at 104 major universities, in the hands of just over half of the nation's total of qualified faculty members. The other half of the qualified chemistry teachers, at 372 smaller schools, share the remaining one-quarter of all research. The chances appear to be nine in ten that a qualified chemist in a large university will have research opportunities as a part of his academic work. At a smaller institution, a similarly qualified teacher has only an even chance of getting research underway.

TABLE 2

<table>
<thead>
<tr>
<th>Total number of faculty and full-time research personnel</th>
<th>Number of (A) qualified to do research</th>
<th>Number of (A) now engaged in research</th>
<th>Number of full-time research workers to which (C) is equivalent</th>
<th>Number of &quot;equivalents&quot; in (D) now engaged in defense research</th>
<th>Proportion of qualified faculty (B) with no research in progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nine universities with most defense research in progress</td>
<td>324</td>
<td>297</td>
<td>291</td>
<td>177.0</td>
<td>132.0</td>
</tr>
<tr>
<td>Ninety-five other major universities</td>
<td>1746</td>
<td>1591</td>
<td>1381</td>
<td>798.3</td>
<td>282.2</td>
</tr>
<tr>
<td>Total at 104 major universities</td>
<td>2070</td>
<td>1888</td>
<td>1672</td>
<td>975.3</td>
<td>414.2</td>
</tr>
<tr>
<td>Total at 93 smaller universities</td>
<td>644</td>
<td>564</td>
<td>549</td>
<td>161.8</td>
<td>21.5</td>
</tr>
<tr>
<td>Total at 279 liberal arts colleges</td>
<td>997</td>
<td>868</td>
<td>415</td>
<td>70.5</td>
<td>52.7</td>
</tr>
<tr>
<td>Total at 476 colleges and universities</td>
<td>3211</td>
<td>3320</td>
<td>2436</td>
<td>1316.1</td>
<td>506.2</td>
</tr>
</tbody>
</table>

Where there are many graduate students, the research of these students in meeting their advanced degree requirements involves faculty members. This research is "research time" though it is well within any definition of teaching duties. Despite these reservations, however, there is obviously an uneven distribution of chemistry research opportunities weighted in the direction of the larger institutions.

LOCATION OF UNTAPP ED RESEARCH RESOURCES

The Engineering College Research Council's survey was prompted by the growing scarcity of research talent to meet the needs for more fundamental research. These needs became acute shortly after the Korean war, and since then research and development in the physical and engineering sciences have been limited not by available funds but by available research manpower. According to Research and Development Board figures, the total military research and development budget has risen from $500 million before Korea to $1.3 billion in 1952. Colleges and universities were responsible for 9 per cent of the 1951 research and development total; they must have at least this same share of the considerably larger 1952 effort. "Fully effective use of college and university resources," the Engineering College Research Council Committee predicted, "may considerably raise the ceiling placed on research and development progress."

According to the survey's figures, there are 3380 chemists in colleges and universities who are not qualified for research. Of these, 884 have no research in progress. If each of these "unemployed" chemistry faculty takes on one-third time research, the total of chemistry research in these schools will be increased by the equivalent of 295 full-time workers, a growth of 22 per cent.

Where is this potential for increased service? In the "big nine" universities with the largest share of defense research only six qualified faculty members have no studies underway. In 104 large universities including this "big nine" group, are 216 faculty members with no research in progress.

4 The nine are University of Minnesota, Massachusetts Institute of Technology, Carnegie Institute of Technology, University of Illinois, University of Michigan, Ohio State University, University of California (Berkeley), Johns Hopkins University, and Oregon State College.

bers qualified but not now active in research. This is less than 12 per cent of the total number of qualified faculty members in these schools.

At 93 smaller universities and technical schools—four-year institutions where there is little emphasis on graduate degrees—only 349 out of 564 qualified faculty members have research in progress. The 215 faculty available here represent 38 per cent of the potential at these institutions.

The 279 liberal arts and teachers colleges which contributed to the Research Council's inventory reported 888 qualified faculty members, of whom 453 have no studies underway. Here more than half of the available total remains to be put into research service. Not all these scientists are equally qualified. It is natural that contractors, both military and industrial, who are particularly concerned with getting, at minimum effort, every value for their research dollar have turned first to the largest institutions where talents in widest variety are available. But today's shortage of research manpower suggests revision of this approach; the Engineering College Research Council figures indicate that would-be contractors may profitably make a more careful search through the rosters of the smaller faculties.

The lack of certain specialized equipment may also limit the research undertakings at smaller schools. But manpower is the most critical need; where manpower is available, the Research Council committee believes that necessary equipment to implement research can probably be supplied. And it is far better to move research equipment than to move research scientists—particularly when moving the scientists disrupts their teaching programs.

The national interest clearly lies in expanding and broadening the research opportunities at all educational institutions—subject only to the important reservation that the colleges' first purpose and responsibility are their teaching programs. If overemphasized, research can become the tail that wags the dog, pulling teachers out of classrooms and away from their students. Within sensible limits, and properly integrated into academic life, research has important benefits for teachers and their students. Chemists need no itemized list of these gains: research helps schools give more interesting opportunities and better salaries to competent faculty; students benefit directly from an acquaintance with research problems and methods, and indirectly from the faculty's new outlooks which inevitably are the result of research activity.

College and university research is an investment that returns double dividends: While the research results contribute to fundamental knowledge, the projects in progress strengthen the teaching programs and promise more and better-qualified scientific manpower for the future. Today's critical needs provide a remarkable opportunity to broaden college and university research experience and so to capitalize on the benefits it bestows.
THE PARAGON OF COLLEGE CHEMISTRY TEACHERS

EDWARD C. FULLER
Champlain College, Plattsburgh, New York

Our nation is faced with a crisis in scientific man power. Charles E. Wilson, Director of Defense Mobilization, has said: "The supply of scientific and engineering graduates in 1951 is less than half that needed to fully man our economic and defense program. Present indications are that the number of scientifically trained graduates will steadily decrease at least until 1954 while demands of essential civilian and defense programs, in the same period, will continue to increase."

One of Mr. Wilson's recommendations for attacking the problem is for colleges to encourage more students to major in science. A college chemistry teacher who excels both as a chemist and as a teacher is the strongest magnet for attracting into our profession the young people we need. Every chemist—whether he be working in industry, college, university, or for the government—has a vital stake in finding the best ways to prepare more and better chemists.

A survey conducted by the author in the fall of 1951 indicates that during the last few years about 9 per cent of the men and women who received Ph.D. degrees from departments of chemistry in 30 universities accepted positions as college teachers of undergraduates. Another 12 per cent accepted positions in universities where considerable research activity is expected of the teaching staff. (There are wide variations in percentages reported by different universities. The figures on college teachers range from 0 to 27 per cent with the median at 9 per cent; on university teachers from 3 to 30 per cent with the median at 12 per cent).

Should the graduate experience of the small percentage of candidates for the Ph.D. degree who will become college teachers contain some basic instruction in teaching? If so, how should this instruction be given? It may help us to find some answers to these questions if we consider what the person who aspires to be a college chemistry teacher should know.

The college chemistry teacher has two principal, equally important, and intimately related jobs to do: (1) He must teach chemistry, (2) He must teach students. He must have mastery of chemistry and deep, human understanding of young people. What knowledge, skills, and attitudes must our paragon of college chemistry teachers possess as a chemist?

Knowledge of Chemistry. He must be thoroughly grounded in the fundamentals of inorganic, organic, analytical, and physical chemistry. To achieve this background he must be proficient in mathematics up through the level of the calculus and in physics up to intermediate college courses in this field. If he is to teach courses more advanced than general chemistry he must be especially proficient in at least one of the four basic areas of chemistry mentioned above or in an interdisciplinary field such as biochemistry, geochemistry, chemical physics, etc. He must have a reading knowledge of scientific French and German. He must be thoroughly familiar with the literature of chemistry.

Chemical Skills. He must be able to handle chemical apparatus with dexterity in order to carry out chemical processes efficiently. He must be skillful in translating experimental observations into rational—often mathematical—concepts and conclusions. He should be able to design and construct special apparatus for particular purposes. He must be able to search chemical literature systematically and rapidly.

Attitudes as a Chemist. He must have an interest in research. He should carry on some research. If no space or funds are available in his college for laboratory research he should keep up to date with the experimental work others are doing along the lines of his special interest. He must have sufficient interest in chemical books and periodicals to scan many of them and read some intensively. Though he may never have the time to make an important original contribution to chemical knowledge, he must keep his mind as alert and as open to new ideas as the minds of chemists whose chief activity is research. He must have pride in his profession as a chemist and must participate to the limit of his resources in the national, regional, and local activities of the American Chemical Society.

What knowledge, skills, and attitudes must our paragon of chemistry teachers possess as a teacher?

Knowledge of teaching. To teach with maximum effectiveness every teacher must have a thorough knowledge of the learning process. How do people learn? Why do they learn? Do they learn some things by one process and others by another? How can the learning process be accelerated? What impede learning? What is the fundamental role of the teacher in the learning process? How can laboratory work be

* Presented at the 121st Meeting of the American Chemical Society, Buffalo, New York, March, 1952.
In his role as coach, the chemistry teacher has four primary functions:

(1) To bring to the attention of his students the best printed sources of knowledge with which a particular course is concerned. In selecting these sources he must consider both the accuracy and complexity of the knowledge they present as well as the clarity of presentation. He must choose accurate material which

organized most effectively to stimulate learning? These are but a few examples of broad questions every chemistry teacher needs to answer for himself.

The teacher can only catalyze the rate of learning by his students; he cannot do their learning for them. As chemists we know that catalysts can have either positive or negative effects—that they may accelerate or inhibit reactions. As teachers we want to be accelerators but we all know instances in which students have learned effectively without teachers—in some cases in spite of poor ones.

A chemistry teacher must know not only what he teaches but why he teaches it. He must have a clear idea of the function his course fulfills in the professional development of his students. Not all courses have identical objectives—nor should they. The teacher of freshman chemistry must modify his aims and methods when he deals with seniors. The chemistry curriculum should be thought of as a whole, each separate course making not only a general but a particular contribution to the growth of the embryonic chemist.

The teacher must recognize the dual function he has to perform. He is both the coach and the referee as his team of students engages in the strenuous game in which Learning must beat Ignorance. He must do all he can to help his students learn but he must also rate their performance as objectively as possible. He must be sympathetic with his students as they struggle to learn but he must grade their achievements with detached impartiality.

The confusion that often exists in students' minds about the teacher's dual role is aptly illustrated by what a college student once said to me. "I can't understand my English teacher," said this young man. "In class he rewrites all my themes for me and then never gives himself a grade that's better than a C!"

Teaching Skills. In his role as referee, the chemistry teacher must be thoroughly familiar with many different devices for evaluating students' progress. He must recognize the usefulness of the short quiz as a spur to stimulate study as well as to measure achievement. He must understand how evaluations of students' achievements obtained from objective tests differ from and complement those based on essay examinations. He must distinguish the different functions of different kinds of laboratory reports. He should discern the advantages—and the drawbacks—of examining his students by standardized tests with national norms like the American Chemical Society Cooperative Tests in Chemistry. He should recognize the contribution that students' term papers and oral reports can make to his judgments of their progress.

In his role as coach, the chemistry teacher has four primary functions:

(1) To bring to the attention of his students the best printed sources of knowledge with which a particular course is concerned. In selecting these sources he must consider both the accuracy and complexity of the knowledge they present as well as the clarity of presentation. He must choose accurate material which

will neither confound the student with its difficulty nor bore him with its simplicity.

(2) To condense or amplify the knowledge set forth in these sources in order to give his students perspective in the field of study. The teacher must help each student build a growing intellectual framework to incorporate new knowledge with that already learned.

(3) To give chemistry on paper new dimensions in the laboratory. The teacher must help his students to bridge the difficult gap between talking about chemistry and "doing" it. Conversely, the teacher must help the student to translate his experience with things into clear thinking about phenomena.

(4) To stir the student's imagination and broaden the horizons viewed with his mind's eye. The paragon of chemistry teachers will nurture youth's curiosity and enthusiasm which are so precious for the development of good chemists.

What skills must a chemistry teacher cultivate as he progresses paragonward? Obviously he must be able to read critically, to write lucidly, and to listen understandingly. He must know how to ask questions as well as how to answer them. He should be able to lecture effectively and to lead small groups of students in their own answers to their questions. He must be able to help students learn the arts of laboratory experimentation without doing this work for them. He should be skillful in guiding students toward optimum development of their potentialities. In all his teaching, he should inspire within his students a love of chemistry and a desire for high achievement in it.

Attitudes as a Teacher. The alert chemist is eager to improve his knowledge and skills in chemistry. The alert teacher is eager to improve his knowledge and skills in teaching. Our paragon of chemistry teachers will continually improve in both fields.

Because chemistry is a rapidly growing science, he will have to work hard just to keep abreast of forward progress in his field, be it inorganic, organic, analytical, or physical. Like Alice and the Red Queen, he must run faster and faster just to keep up with the scenery. He who doesn't run soon becomes an antiquary. While published articles which are the staff of life for the research chemist may not be so for the chemistry teacher, the latter must have a regular ration of reading in periodicals which offer articles outlining broad developments in his field. The Journal of Chemical Education and Chemical and Engineering News should be two of the staples in his reading diet. New textbooks written primarily for graduate courses and some A. C. S. Monographs are sources of intellectual nourishment he should not overlook. The growing number of books and articles devoted to critical summaries of knowledge in particular phases of chemistry are especially helpful to the teacher. More of these are greatly needed. Perhaps the Society's Division of Chemical Education and its Journal can become increasingly helpful in sponsoring such publications.

While the criteria by which a chemistry teacher
selects books and periodicals for his technical library will necessarily differ from those of the research chemist, the teacher’s contacts with new ideas in chemistry must be rich and varied. Love for learning is an attitude indispensable above all others for the man who would be teacher.

Because teaching is an art—and the artist’s growth in stature depends more upon exercising his talent than on increasing his technical knowledge—our paragon must continually refine his teaching skills. Only by constant practice will he approach perfection in them. To become a really fine teacher, he must be as ruthlessly critical of his artistry as the painter or the musician. The best teacher is frequently less satisfied with his work than the mediocre man who fails to recognize his own shortcomings.

While recognizing, as an artist, the need to improve his teaching skills, our paragon will also be on the alert for any major developments in knowledge about the learning process. New knowledge may bring new means for more effective teaching. New devices may be found to lighten the teacher’s load. An attitude of open-mindedness toward new ideas in education is an asset to any college chemistry teacher.

A genuine, friendly interest in the intellectual growth of his students is the sine qua non for our paragon of college chemistry teachers. That this interest might well encompass their emotional, social, and even spiritual growth would be denied by few and endorsed by many. A man teaches best when the light of his mind is suffused with the warmth of his soul.

The paragon of teachers grows constantly in understanding of what he teaches, whom he teaches, how and why he teaches. We can hardly improve on a description of him written more than five hundred years ago by Geoffrey Chaucer:

Of study took he utmost care and heed,
Not one word spoke he more than was his need;
And that was said in fullest reverence;
And short and quick and full of high good sense.
Pregnant of moral virtue was his speech;
And gladly would he learn and gladly teach.

• REORIENTATION FOR TRAINING CHEMISTS AS TEACHERS

The problem of the preparation of college chemistry teachers is actually a multiple one. With the widespread development in recent years—particularly in certain regions such as my own state of Texas—of junior colleges or “community” colleges, one can recognize at least three reasonably distinct types of college chemistry teacher for whom training must be provided:

1. Those who may spend essentially full time in teaching courses on the freshman and sophomore levels such as are commonly provided in the junior colleges. They may on occasion handle adult classes or “on-the-job” training units, but in general these also are comparable to the introductory college level.

2. Those who may spend full time in teaching undergraduate courses, but in programs such as offered by the smaller “senior” or “four-year” colleges which cover the entire undergraduate range through physical chemistry and into certain of the more specialized branches of chemistry.

3. Those in the larger senior colleges and the universities, whose duties include both classroom teaching at the undergraduate level and participation in graduate programs. The latter often involves some teaching in advanced courses on specialized topics but usually places major emphasis on research, both as an active personal program and in the training of graduate research students. In discussing this group, “teaching” will be used in reference to this training of research students as well as classes. Proper training in research—helping a student to learn to tackle his own problems in the laboratory, without simply directing him to answers—requires teaching of high caliber and is a problem of major importance for graduate faculties. It is likely to be particularly difficult at present, when these problems are so often interlinked with “contract” research and the accompanying time schedules.

I would like in this paper to center attention primarily on the problem of preparation of teachers of this last group, those who become members of a university-type faculty.

However, as a matter of possible general interest, I will summarize briefly two programs for training teachers which are being developed at the University of Texas. One is a program for a B.S. in Education degree planned especially for science teachers. It includes a core of education courses (24 semester hours) plus a major program in science (57–9 semester hours). The remainder of the 126 semester-hour program is made up of general requirements such as English, mathematics, humanities, social sciences, and certain electives. The work in education includes the usual basic training and practice teaching. The science courses may be so chosen as to give the student an introduction to a number of branches of science or so as to emphasize

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closely related fields such as physics, mathematics, and chemistry. In the latter case, the student may be graduated with a background in science actually stronger than that provided by the Bachelor of Arts degree with a major in chemistry. In the senior year, in conjunction with practice teaching, the student participates in a seminar with representatives from the various science faculties, in which his problems and difficulties in teaching science may be discussed in detail with experienced teachers.

The bachelor's degree itself is planned for high-school science teachers, but it also serves admirably for those who have opportunity later to enter a college faculty. This happens frequently in the districts in which small colleges are located. The undergraduate program also gives an excellent background for a Master's degree and even further graduate work either in education or in a field such as chemistry.

The second program is still under discussion and has not yet been put into practice. This is an attempt to offer reasonable training for teachers, especially in the junior colleges, who need a thorough understanding of advanced phases both of science and education but who do not have opportunity or any real need for the research and thesis which we require for the Master's degree. It is proposed to use for this purpose a two-year graduate course of study, with work roughly equally divided between the science field and advanced courses in education. Such work could be fitted eventually into a Ph.D. program if the student so desired.

One of the major difficulties, of course, is the question of whether such a two-year program should have a distinctive degree title so that appropriate recognition in rank and salary might be given for the additional professional background.

It may be noted that the goal of the Ph.D. degree is frequently mentioned in discussing these programs. For all college teachers—whether junior college or university—there is increasing economic and professional pressure to take graduate work toward a Ph.D. degree. It is common practice, even a matter of law in many states, to expect a high-school teacher to have a master's degree in order to obtain regular professional status and higher salary brackets. The implication is strong, of course, that a Ph.D. degree and the doctorate title should qualify one for even higher salary levels. It is naturally to be expected, then, that college teachers should probably have some higher degree than those in high school, and the Ph.D. is the obvious possibility. This viewpoint does not take account of the fact that requirements for the degree of Doctor of Philosophy presumably place unique emphasis upon individual attainments in research or creative activities—attainments which may have no particular significance as background for the teaching duties involved. Nonetheless, the viewpoint is well established and widely held, and this has been a factor of importance in altering our graduate programs so that we grant an extensive series of individual doctorate degrees in professional fields rather than a "Doctor of Philosophy" degree.

A second factor of even more weight in this alteration has been the steadily increasing number of industrial and governmental opportunities in research, development, and engineering. Here also it is common to base starting rank and salary scales on the bachelor's, master's or doctor's degree, with no great amount of attention paid to the correlation between the type of job and the original significance of the degree.

In all these fields, education, industry, and government, the need for a reasonably simple and workable classification has outweighed the original concepts behind the degrees as indicated in the titles. This is a real and practical need, and a practical solution has been evolved by taking over the degree titles—and in some measure their accompanying programs—as designating essentially three levels of training and experience for a particular field; but this practical solution to the problem of classification has created for us serious new problems in the preparation and recruiting of college chemistry teachers in our third group, whose professional needs include both teaching and research.

For this group, the Ph.D. in chemistry is normally assumed to be necessary preparation. For teaching students at advanced levels, the teacher must assuredly have both a comprehensive and profound knowledge of his subject.

The specifications of our own Committee on Professional Training, for example, are simple and clear-cut. The specified requirement for a person doing graduate teaching is simply "the doctor's degree in chemistry from an institution recognized for its training in chemistry."

In an earlier day this specification alone was adequate. If we use the term philosophy as embodying a broad knowledge and understanding of phenomena and their causes—which must include human nature and conduct as well as phenomena in inanimate systems or simple plants or animals—one who has attained the degree of Doctor of Philosophy with chemistry as his major field of interest should have an excellent background for teaching in the field. When faculties and graduate enrollments were small, departmental lines were not clearly drawn and programs were likely to be broad in scope. Furthermore, graduate students commonly assisted with laboratory sections or other teaching activities and were thrown into close association from day to day with men whose major interests were in teaching, in aiding students either at graduate or undergraduate levels, and in other fields as well as chemistry. The candidate for the doctorate usually served an effective apprenticeship in teaching as well as in his major field.

Today this pattern is possible, but not probable. The Ph.D. program is still an individual one and can be very broad in scope, but it is most likely to be limited to chemistry and closely related fields such as physics, mathematics, and certain biological sciences.

The student has little encouragement to vary this pattern markedly. The heavily departmentalized organization which is characteristic of most of
tially good teacher because his graduate program gave him little teaching experience, but we do have a serious responsibility to those students with whom he must work while he gains that experience.

Such a program of training can be highly effective. Any of us must have had to start somewhere in assuming charge of a class or a course with at best no more experience than that of two or three years as a part-time teaching fellow. With reasonable assistance, interest and willingness to work can quickly compensate for lack of that minimum initial experience.

The specific nature of the training must vary with the individual and can readily be handled on a reasonable, casual basis. There is, for example, no need to create a corps of "supervisors" to haunt our teachers. This post-doctorate "training" may involve information on such basic points of every-day teaching as classroom and grading procedures, acoustical vagaries of different lecture rooms, techniques of public speaking, etc. It must certainly include broad information on and discussion of departmental curriculum and possible development of new courses. Attendance at professional meetings, symposia, etc., which offer challenging ideas in the broader fields of teaching should be encouraged, as well as those related to specific research problems. Positive recognition, in advances in rank or salary, must be given on the basis of teaching activities and abilities, as well as in the individual's own line of research. (It is assumed, of course, that activities in research will be encouraged as they are at present.)

Basically, such a program involves recognition by the individual as well as the faculty that the responsibilities of a university for the continuing advancement of knowledge involve more than the compilation of laboratory data. Certain aspects of our teaching, such as the continual re-examination and re-evaluation of facts and theories for new research students or new classes and the reactions of such new students to our hypotheses and generalizations, are actually an integral part of that advancement of knowledge. Investment of time and effort to prepare an individual to participate effectively is highly justifiable.

It must be recognized, of course, that this training problem is not one of concern to the universities alone. There have been many discussions of the economic pressures, the ease of recognition for a new compound or a new synthesis as contrasted to a group of students well trained, and other competing factors which tend to discourage our younger teachers. I believe that this problem will be one of concern to our universities and colleges, and the adequacy of preparation of new young chemists for their faculties will determine our future progress in this phase of chemistry.

Actually, these suggestions with regard to training of our larger schools makes it difficult in general for a graduate student in chemistry to work much outside the science departments and their immediate neighbors. The unfortunate schism which so commonly exists between the Colleges of Education and the "subject-matter" departments, the fact that "teacher training" has come to have so much connotation of emphasis on techniques of presentation without real concern for any knowledge or information to be taught—these factors make it particularly difficult to combine fields such as chemistry and education.

A graduate student can still assist in teaching, but large enrollments and more complex class organizations have decreased very materially his opportunities to develop any breadth of vision and understanding of teaching problems. Economic pressures are commonly such that, after teaching a semester or two, he is likely to shift to a research appointment. There, he may still be under the direction of a major professor who is at least a part-time faculty member, but his contacts in his work from day to day are largely limited to persons whose full-time interest is devoted to rather highly specific problems or materials.

The doctorate in chemistry can be a program for training a student both as teacher and as chemist, but in practice our graduates are now, in large majority, trained only as chemists.

Any faculty or department head who has had occasion to interview applicants for teaching positions recently is probably well aware of this. There are many able applicants who have clear—and good—ideas for laboratory research, but who have thought very little of what they might teach effectively. It can be very difficult to evaluate an applicant for a position which involves, for example, some teaching in a beginning course. This applicant may sincerely believe he is quite willing to teach freshmen, and yet may quite obviously have no realization at all of what such teaching actually entails.

One solution to this problem is that we should try to arrange programs specifically for preparing such applicants more adequately. I would not minimize in any way the importance of each graduate faculty searching out and helping in every way possible those students who wish to enter university work. Nonetheless, it seems that the number of beginning graduate students who can declare such an intent will always be small. Many of the most promising young prospects for university faculties must come from those students who discover in the course of their own graduate research a deep interest in fundamental investigation. Such interests will develop late in the graduate program.

The problem of preparation of college teachers for university-type work must, therefore, be met also by a reorientation in our viewpoints to recognize the changed patterns of the Ph.D. degree. Administrative officers and faculty must cooperate more closely in taking positive action to meet what is effectively a need for teacher training on a post-doctorate, 'on-the-job' basis. Opportunity should not be denied to a poten-
our college teachers differ in some respects very little from present-day practice. Such things may often be done, but it is largely in haphazard fashion. Surely no college science department has any objection to a young man making of himself a good teacher, nor would there be any obstacles consciously placed in his way (but he may be subject rather frequently to indirect pressure to give attention to other things). The attitude in general is likely to be that a newcomer can “sink or swim” insofar as teaching is concerned. This is not enough. We must recognize that the background of present-day graduates includes little training or experience as teachers and must face the fact that this places upon the departments and colleges responsibility for making positive efforts to assure reasonably good teaching of all types.

**EFFECTIVE LEARNING IN COLLEGE**

**ORDWAY TEAD**

Board of Higher Education, New York, New York

Any useful discussion of the improving of graduate instruction in order to assure greater competence in teaching has to take account of the nature of the learning process. Unless this process is clearly understood in the light of contemporary psychological research, little progress can be achieved. For the new insights here are capable of yielding aids to teachers which promise fruitful results in fuller and faster learnings as permanent assets to the individual.

I shall therefore not attempt any critical discussion of present methods of college teacher training. I am, however, hopeful that what I shall have to say may throw light by implication both on present deficiencies and on programs of improvement which faculties could adapt in their own ways. This paper will therefore, first, discuss the nature of learning; second, consider what valuable assets we are basically trying to teach; third, consider the ways of developing intelligence as throwing light on how to learn; fourth, make a number of specific suggestions about the activities of teaching as forwarding good learning; and, fifth, consider the bearing of my conclusions upon the objectives and methods of science instruction, including, of course, the training of science teachers.

If you think that I am not distinguishing sharply enough as between undergraduate and graduate, and as between general and professional education, you will be in some part correct. But my central purpose is to set the problem in its widest frame and to leave the particularities of professional scientific education to those who know far more about it than I.

**NATURE OF LEARNING**

I shall define learning as the over-all result in the person of thinking, feeling, acting, and expressing, appropriately to the demands of a situation, or the solution of a problem, or the resolution of a felt difficulty. Learning is evidenced by the successful coping with identified needs, coping with desires or drives pressing for expression. It can yield the several satisfactions of present adjustments, of progressing toward established goals, of a clarifying of directions and purposes in living, or the satisfying of disinterested curiosity or wonder. Learning is the residual outcome of specific experiences which so modify the organism that it thereafter behaves differently.

The needs to be coped with may be immediately and obviously urgent; they may be acquired through prior learnings; they may relate largely to the future in which motives of “preparation” have play, even though the theory of education as preparation for some future good or goal is now invoked far more than seems validly justified.

Each individual is thus the center, focus, and occasion of his own learning activity. It is his felt concern that has to be resolved; it is his promptings, urges, difficulties, interests, curiosity or wonder, which touch off his learning effort. The person in some felt need is the unit of learning concern. Learning is thus not so much “student centered” in some individualistic sense as it is life centered in its regard for knowledge, attitudes, skills, and commitments as these are all affected by individual differences. Learning is thus learning to use,—a truth obvious enough when one is trying to pass the driving test for a motorist’s license, but hard to grasp with respect, for example, to the subject-matter of a course in European history, in philosophy, or in general science. But the difference between the two types of experience is one of teaching effectiveness and not of some generic difference of learning method, intention, or result.

Indeed, it is largely in the middle years of the educational process that we are pedagogically most confused on this score of method. For the nursery school at one end and a good number of professional schools at the other both utilize instructional procedures which in method and outcome largely equate learning with ability to use what is learned. “That only” said Coleridge, “is genuine knowledge (i.e., learning) which...
returns to us in power." And a similar meaning is conveyed by the sentence, "no occurrence is an event for us until it has some bearing on our purposes."1

Kilpatrick has a famous phrasing of the same truth which, were it taken seriously by college teachers, would work a literal revolution in present college teaching methods. For he has said:2

Learning is the tendency of any part or phase of what one has lived so to remain with the learner as to come back pertinently into further experience. When such a tendency has been set up, learning has to that extent been effected. To accept anything less... than to expect learning to tend so to remain and come back relevantly into experience seems indefensible... We learn what we live, we learn each item we live as we accept it, and we learn it to the degree that we accept it.

The implications of my own definition merit further explicit mention, even though such analysis is misleading because the learning experience is always a unified reality. Learning in its thinking phase requires method. This embraces grasp of methods of reasoning, of memorizing, of selecting relevant factual knowledge to draw upon.

Learning as feeling requires appropriate emotive responses of eagerness, warmth, desire, pleasantness, cheerfulness, some glow of mastery—a general sense of the desirability of the experience.

Learning as acting requires skill in execution and successful performance. Without this as one result there is lacking one vital criterion of a valid experience.

Learning as expressing entails the ability to communicate clearly in receiving, and also in conveying ideas and feelings clearly to others.

And until all these concomitant attributes of the four necessary facets are present, complete learning has not occurred. There has usually only been a little "learning about" at a rather ephemeral level.

A further aspect of the process to which I can only allude without suggesting its significance is that the aspect of saluting would seem to be an experiential factor present in good learning. The individual is inherently making for himself value-judgments as his learning experience goes on. "Is all this any good, and why, and how, and how much?"—this is the question each person is constantly putting to himself as learning experience moves on. Even our perceptions derive largely from what we are accustomed to perceive in an already established frame of values.

Another interesting way to characterize the real learning experience is to consider it as an assimilative process or as a kind of symbiosis of learner and subject-matter. Subject and object lose their sharp identity as true learning proceeds. The means and ends of learning become merged into the unity of an assimilated resource—as an incorporation into self of added insights, competences, and wisdom. The learner by taking thought does add a cubit to his total intellectual and emotional stature.


There are, therefore, several familiar aphorisms and epigrams about learning which are clearly untrue. Learning is not the sheer accumulation of unexamined raw experience; nor is it critical or uncritemicized "trial and error" activity; nor is it the sheer verbal memorizing of book material or the encyclopedic storing away of more and more facts. There are no muscles of the mind which by exercise on "hard" subject matter can be strengthened for use in other intellectual areas.

"Mental discipline" is not a general but a particular project and one which is only slightly transferable, if we omit reference to the development of a habitat of vigorous mental attack, which habit it seems possible to learn and transfer.

In short, a competent sense of learning realities has always to hold in view the situation of the learner in terms of responsiveness, attractive appeal, persuasive motive, internalized self-propulsion, outcomes which have some generative dynamism. And until teachers of every subject are willing to look at the methods and their teaching content through the neophyte's eye, they have no reason to expect response to the stimulus, or to the field situation presumably evoked, or to the "gestalt" designed to have emotive power, which they have from their point of view constructed for the student's experiential edification.

**BASIC ASSETS**

A second broad area of inquiry deserves more attention than we usually accord it, no matter what we teach. This area is comprehended in the answers to the question: What are the broader values or attributes of capacity and character which we desire as accompaniments of formal, subject-matter learning experience? I do not minimize the factual and informational as vital aspects of the capacity the teacher is helping to enlarge. Indeed, I am taking this for granted as the usual teacher goal—even though I may seem to de-emphasize it to a degree that some would call into question. But even on this score, the right conclusion seems to me to depend largely on the degree of intensive or specialized use the student is likely to make of the facts.

But my considered judgment is that in so far as education for nonprofessional students is concerned, the values, objectives, or purposes sought are not technical or methodological in nature. And even for preprofessional and graduate students, there is always the danger of going too far with technical subject matter, as opposed to efforts to get breadth of comprehension along with technical skill.

I submit that we want the following out of general education even as it relates itself to scientific experience, and we should seek the same end in graduate study to a greater extent than we do.

(1) We want ability and disposition to think and keep on thinking in whatever are the rewarding ways affecting a given discipline. Continuously enlarging grasp of the methodology of rational deliberation in both its inductive and deductive phases is crucial; and...
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this should include ability to distinguish which kinds of problems are properly approached by one method or the other or by both in proper sequence.

(2) We want ability to achieve fresh insight toward coping with life situations out of rational deliberation prompted by emotive needs and desires more or less common to us all.

(3) We cannot go far without the conscious cultivating of sensitive awareness to beauty, joy, exuberance, including also an awareness of the need deep in our natures to acknowledge wonder, awe, and reverence, as aspects of these insights which are profound.

(4) Acknowledgment has to be made of a field newly stressed in its present vocabulary, namely, that of handling the human relations of life with individuals and groups in a more than "common sense" way.

(5) The total learning experience as it unfolds for the individual should develop through satisfying outcomes a certain confidence and assurance about one's sustained attack on living and striving, on growing and suffering, on all truth-seeking and problem-solving efforts. And a final notable attendant value which merits greater stress is ability to see human affairs over the centuries in some realistic perspective.

Scholars in the natural sciences may, perhaps, tend too readily to exclude consideration of these more fundamental values and purposes from their instruction. But I submit that beyond mastery in all departments of subject matter these attendant learnings are not only possible but essential both to the students' intellectual and spiritual breadth and depth, and at levels undergraduate and graduate. Scientific scholarship, in other words, is not belittled or temporized by looking at its effort in part through the spectacles of general, humanistic purposes. Rather is it true that the inclusion of broader objectives enhances and enriches that scholarship in its every facet. This effort, as it reaches the student's awareness, tends to give rational, esthetic, vocational, and evaluational richness to the content being studied. And it would seem that the major way for the teacher toward such end results will have to be for him to incorporate them into his intention, method, and treatment as he moves through his subject matter. We first have to have the broadened intention and desire; given these, imaginative thinking about applications will produce the results in varying ways with various teachers.

Thus, I would underscore what I have so briefly hinted by a brief recapitulation. Students of scientific subjects especially are in need of protection against: (1) thinking scientifically in too narrow a range of interests; (2) being "intuitive," "visionary," or imaginative in too limited a range of subject matter; (3) being insensitive to the esthetic aspects of their experience, whether in science or beyond it; (4) being insensitive to the importance of human relations in contemporary institutions and in the nuances of the necessary dealings of man with man in personal and corporate dealings; (5) ignoring some underlying philosophic outlook which begins to orient them meaningfully and purposefully to their world; as well as (6) suffering from lack of historic perspective as to how, why, and when transitions in the flux of the human scene may be expected, may be more or less counted upon, and may have to be coped with.

INTELLIGENCE

One more conceptual discussion of the conditions of good learning should be helpful toward the necessary, heightened self-consciousness required of the teacher who would assure good learning. I am indebted to Dr. George D. Stoddard's "The Meaning of Intelligence" for suggestions along the following lines which I have adapted from his discussion of intelligence.

Certain component conditions seem important as offering a number of criteria toward characterizing the learning process in any field at the college level. There must be a sense of the difficulty to be faced; a true complexity in the material confronted; an ability to abstract or conceptualize the raw data; economy in the hypotheses or explanations brought forward; the effort works toward some identifiable goals; the total experience has some recognizable social value; energy has to be concentrated on the pursuit of solutions; there has therefore to be resistance to emotional states which might deflect from objective reflection; and out of it all some freshly original result emerges for the learner.

The problem for the teacher, therefore, is to ask how he organizes his over-all presentation to bring to focus at one time or another these several aspects and requirements which are especially relevant in scientific learning. This is a total effort which each teacher has to make in his own unique way. Again here, the intention and desire are basic. And beyond a limited point, method has to be evolved in individual practice.

Assure the presence of student desire; challenge and disturb; confront with relevant evidence; relate meaningfully to present comprehensions; encourage and inspire to persistent effort; and assure that some reasonably satisfying outcome is obtained in terms of the student's acknowledgments. This summarizes a familiar and essential sequence of steps which have tested usefulness in bringing new learning mastery to pass.

SPECIFIC ACTIVITIES

Let me next in all too summary form offer a few suggestions about some steps in a program looking to instructional improvement in the classroom, basing these on the general definitions already set forth.

(1) Relate departmental and individual course objectives organically to the stated objectives of the institution.

(2) State departmental and course objectives in written form in the college catalogue for student consumption after faculty acceptance, and review these each year with one's colleagues interdepartmentally.

(3) Let each teacher be sure that he is on occasion supplying effective answers for his students to such
questions as: Why should you study this course? What intellectual relation has it to other courses? What vocational and avocational implications may it have? What secondary purposes are being sought beyond mastery of subject matter? What intellectual methods have to be employed for competent understanding here? What are the likely and desirable outcomes for the students? Am I, by sufficient variety of instructional methods, making this course a challenging, relevant, and zestful experience for the student?

(4) Let each teacher be sure that every course, and every session of every course, are carefully planned with a beginning, a middle, and an end. And let him engage in self-scrutiny at the end of each day's work to see how class or laboratory performance is really progressing in relation to the plan.

(5) Let each teacher seek the criticism of his peers as being more effective as a teacher through classroom visitation. The notion that each teacher's classroom is sacrosanct and that he has the right to work in splendid uncriticized isolation has to be abandoned.

(6) As to one's attack on teaching methods, remember the dictum of Henry Adams, "Whatever else you do, never neglect trying a new experiment every year."

(7) Watch the problem of the tempo of students in their learning. There should be good digestion and mastery of material before the teacher moves forward to new material.

(8) Realize that the teacher, like the actor, has to project himself "over the footlights." There is a reasonable extent of showmanship which is legitimate and essential. There have to be some vibrancy and phosphorescence in the class-hour performance—some manifest excitement about the things of the mind and spirit. The teacher should be the exemplar of all this.

(9) Let the teacher realize that periodic recognition of student success or victory is invaluable; and to assure this requires something more personalized than the marking system. Similarly, there is need for specific personal encouragement of the discouraged and the failing.

(10) A final and inclusive question needs to be self-posed. Do I know the basic preconceptions, beliefs, and convictions with which I approach my professional labors? Do I distinguish the premises of my science from the premises, beliefs, and methods in other areas of human experience? Have I, in short, some philosophy of life and of science which places my teaching in some larger frame of reference and significance?

This last set of questions is, of course, critical and fundamental to the whole effort and success of teaching. And I believe it needs far more extensive shared reflection by science teachers as they assemble together in the next few years. I wish the time were available to pursue this further in the present discussion.

SCIENCE TEACHING
This brings me finally to instruction in the sciences as such. And here I at once enter a disclaimer of special ability or fitness. I only know that the citizen has the right to join with the teachers of science in considering what it is the community decides it wants out of science instruction, leaving questions of methodology to be decided when desired objectives are established, and ends and means can be carefully integrated.

Because of my sense of personal limitation I am taking the liberty of quoting from a memorandum which has grown out of a series of science interdepartmental conferences being held by the faculty of Hunter College during the current winter under the chairmanship of Professor Abraham Raskin, who has recently come to the college from the University of Chicago. The aim of these conferences has been the discovery of an acceptable plan for a general science course. I am sure this formulation of the underlying aims of science instruction is regarded by the committee as exploratory and not final. But it does seem to me to have the great value of focusing attention on the newer approaches to science instruction as to which we are all exercised. And again I say this has pertinence for graduate no less than undergraduate education.

(1) An understanding of the nature of science. Many introductory and survey courses deal largely with the results of scientific investigation. We hope to stress the understanding of science rather than the memorization of undigested information. This aim may be achieved by a thorough study of a few, very carefully selected, problems in science, by the case history method, by results of many observations; how he distinguishes between different types of evidence; how he identifies and formulates hypotheses; and how he recognizes when necessary and sufficient data are available to support a conclusion. This aim can probably best be achieved through experiences in the laboratory, by case history demonstrations, and by studying how certain outstanding scientists have formulated and attempted to solve specific problems.

(2) An awareness of the fact that the boundaries of the category sciences are largely artificial. As scientists attack more and more fundamental problems, they uncover large numbers of relationships which transcend regular subject matter boundaries. New sciences arise from these relationships between and among the older sciences as the latter's concepts and techniques are refined and extended. This creates an increasing need for specialization and its most modern development, group research, in which teams of investigators representing different areas work on a single problem from individual approaches.

(3) An appreciation of the unity of purpose in a program of general education. Our fundamental aim is to develop in our students the values, attitudes, knowledge and skills that will equip them to live rightly and well in a free society. We cannot achieve this aim by the teaching of science alone. We must emphasize the fact that the intellectual values so useful in science are not the only values necessary to one's full development as an individual

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and as a member of society. Our students must develop also an appreciation and understanding of the larger areas of human endeavor—the humanities and social studies.

(6) An active concern regarding the application of their knowledge of science and its methods in the solution of some of the problems which face the citizens of a free society. For this purpose, our students will need to understand the relationship between the social and technology in society. Society generally sets a problem by expressing a need or a wish. Applied science or technology, applying the fruits of basic science, attempts to find a solution which most effectively satisfies the need or desire of society. The citizens of a free society, with well-developed attitudes, habits, and powers of evaluation, should be concerned that science and technology be directed toward constructive ends.

(7) An ability to view science in relation to its own past and to general human history. This, together with the presentation of the humanities and social studies, should result in developing in our students a more complete picture of the origins, current status, and trends of our civilization. We can contribute to the realization of this aim by including in the integrated science course some consideration of how the cultural, social, and philosophical climates have influenced and been influenced by the scientific endeavors of man in various stages of his history.

(8) An effective power of communication in science. The integrated course can contribute to this general aim of the curriculum by helping our students attain a degree of scientific literacy; by emphasizing the importance to the growth of science of prevision in the description of phenomena and in other ways.

(9) An appreciation of the pleasure that can come from an understanding of the beauties and forces of nature.

It is obviously not for me to attempt to amplify this impressive statement of principles into terms of curricular organization, or class or laboratory methods. But surely when the sights of teachers of science, or other disciplines, and of general educators, can all be trained upon goals of this broadened type, a long step ahead will have been taken both on behalf of undergraduate and graduate education.

If and when all students can truly learn something of the nature and scope of the sciences, of their truth-seeking passions, of the several ways of scientific thinking, of the nature and scope of the sciences, of their truth-seeking passions, of the several ways of scientific thinking, of the social results scientific applications have brought, of the benefits and dangers of universalizing those results to use in parts of the world now not industrialized—if these gains of understanding can be assured, the larger utility of education in the sciences will be established beyond question and with immense gains in the body politic.

Of course, one distinguishes and stresses the special educational and intensive outcomes of the science teacher's education. But the academic world is already so preoccupied with these aims that I hardly need to emphasize them further. However, I reiterate in conclusion that there remain those other aspects of learning, of attitude and outlook which simply cannot be ignored. They are the aspects that bear on the relation of the pursuit of science to the living of life, both for the scientist as person and also as citizen, community member, and responsible participant in shaping the future of the social scene. If and when all students can truly learn something of the social results scientific applications have brought, of the benefits and dangers of universalizing those results to use in parts of the world now not industrialized—if these gains of understanding can be assured, the larger utility of education in the sciences will be established beyond question and with immense gains in the body politic.

In sum, my point is that we are charged to educate the man in his wholeness first and the scientist in his intellectuality second.

That this is not a novel thesis nor an impossible demand, that the efforts of a variety of educational experiments seem to me clearly to establish. I wish there were time for me to discuss the instructional developments at Harvard under President Conant's personal guidance, at Lehigh under Dean Doan, at Carnegie Tech as prompted by Provost E. D. Smith and the late President Doherty, at M. I. T. with its admirable recent report on the relation of the social studies and the humanities to the scientific curriculum, and at a number of other undergraduate institutions where the generalized approach is showing the science teachers themselves that they have more to teach than they appreciate and more to learn than their own discipline may encompass. In other words, we have today the encouraging advantage that we have started in earnest to ask the right questions about scientific education. The ties that bind college to graduate instruction will refuse to be loosed. And the germinal influences of all this will increase and multiply.

Our scientific education has yielded social results which are the marvel of the world. But they are also the terrorizing Frankenstein of all too many beyond our borders. Our very successes have become excesses if we will make a global appraisal. The good has been the enemy of the better. All that has to be changed in our educational aim and emphasis from here on out.

We profess on this occasion to be discussing the training of science teachers. Actually, we are considering how it is that the forces and consequences of science and a scientific outlook relate themselves with spiritual productivity to the fulfillment of a democratic tradition in a society committed to elevating the welfare of men as individuals with souls. Scientists stand in need of associating themselves afresh with that central human impulse which would relate the individual to those forces of law and order and meaning and power and awareness, as these transcend the specific scientific

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See in this connection, for example, "Education for Professional Responsibility" (Proceedings of Inter-Professions Conference), Carnegie Press, Carnegie Institute of Technology, 1948.

An increased interest in programs for training graduate students for college teaching is becoming evident. Two tendencies particularly in chemistry may be responsible for this interest. On the one hand, we have the attractive opportunities for scientists to accept industrial and government positions drawing potential good teachers away from academic careers. A young man, married, and thinking about creating a home has to have some of the inspiration of the missionary to choose college teaching today. On the other hand, we have the increasing tendency on the part of college administrators and of agencies concerned with teaching to stress better teaching. This tendency takes the form of teacher-evaluation charts given to students who rate their instructors on the various factors listed. Alumni are often asked who their good teachers were. The American Council of Education (1, 2) and the U. S. Office of Education have sponsored conferences on the improvement of college teaching. Some excellent reports have been prepared by these conferences, but unfortunately those people who should read and benefit from such reports ordinarily do not see them—they go only to presidents, deans, and department heads. Also unfortunately, some of the younger men who would benefit most by these conferences do not have the opportunity to mingle with the older, experienced teachers from all fields to get the inspiration that comes from such sessions.

The Committee on Graduate Instruction of the Council on Graduate Work of the Land-Grant College Association (3) has been studying the problem of preparing college teachers. Last fall this Committee sent a questionnaire to 86 subject-matter departments in 25 member institutions and 83 answers were received. Departments to which the questionnaires were sent were those granting five or more Doctor of Philosophy degrees during the five years 1946-50. Departments of botany, chemistry, economics, English, history, mathematics, and zoology were polled.

Eleven departments, 13 per cent of the total, reported that their students take courses concerned with training for college teaching, or that courses are available for them.

Twenty departments, 24 per cent of the total, reported that seminars dealing with training for college teaching are available. Seven universities offer an opportunity to take courses dealing with training for college teaching; 12 provide an opportunity to participate in seminars. In some universities both courses and seminars are available, with 13 offering these facilities.

Ninety-nine per cent of the departments afford an opportunity for at least some of the graduate students to have predoctoral teaching experience. For laboratory departments, it is experience in laboratory and recitation sections. Ninety per cent of the departments reported that the predoctoral teaching is supervised, and 60 per cent reported that the teaching load of the supervisor was decreased to permit time for supervision. Teaching performance is observed in 80 per cent of the departments, but several departments are very emphatically opposed to such a practice.

Each person answering the questionnaire was asked to indicate which one of the three following statements best describes how he personally feels about the question of training graduate students for college teaching.

(a) Systematic training for college teaching should be required for all Ph.D. students who expect to enter a teaching career—13 replies or 16 per cent.
(b) Training opportunities for college teaching should be available for those who plan to engage in teaching but should not be required for the Ph.D. degree—53 replies or 65 per cent.
(c) The usual program leading to the Ph.D degree is in itself sufficient training for college teaching—15 replies or 20 per cent.

Referring particularly to chemistry, twenty-four questionnaires were sent out and twenty-three were returned. Twenty-two of these departments stated that opportunities are available for predoctoral teaching experience as teaching assistants for laboratory and/or recitation sections.

All departments reported that teaching is supervised, and twenty-one that teaching is observed. Only one department reported that special attention was given to the preparation of teachers of beginning chemistry.

Two departments (Louisiana State and Oregon State) reported courses in training for college teaching. Louisiana State offers courses in the History of Chemistry and the Use of Demonstrations in Chemistry, and seminars are available for those Ph.D. students who plan to enter a teaching career.
The courses are not required but 80 per cent of the students take them. They are taught by members of the chemistry department. Oregon State has four courses, dealing with the training of college teachers, entitled 'The College Student, College and University Teaching, The American College and University, and the Construction and Use of Objective Examinations.' The courses are not required for students who plan to enter college teaching and are not in addition to the regular doctorate program. Two of the 43 doctorate candidates chose the courses in 1950-51. The courses, available to students in all fields, are taught by the faculty of the School of Education.

Four departments reported the availability of seminars. In each case, the seminar is conducted by the Department or School of Education. The seminar is elective for doctorate candidates at Massachusetts, Missouri, and Oregon State, but required of students registered for the Ph.D. degree in college teaching at Michigan State College.

At Oregon State College, a graduate minor in college teaching is available. It is based upon the following considerations:

1. A department in which students may qualify for advanced degrees has the responsibility of preparing students for teaching as well as for research in the specific field.
2. Programs for preparation for college teaching are properly worked out in terms of higher education.
3. The graduate school gives leadership in the development of standards for teacher preparation and the coordination of the activities of departments in a common function.

Five basic courses constitute the graduate minor. The first three courses are prerequisite to all the others. Graduate standing is prerequisite for all. The first three courses are called "The College Student," "College and University Teaching," and "The American College and University." These courses are designed to consider: (1) the college student as the central factor in teaching, (2) the dynamic process by which the university or college affects changes in the student, and (3) the situation in which the teaching takes place.

The other two courses are "Teaching Procedures Seminar" and "College Teaching Studies." In the "Teaching Procedures Seminar" the students observe, study, and demonstrate procedures in their fields. In the "College Teaching Studies," done in connection with an actual college teaching assignment, the students work out some concrete aspect of teaching aims, procedures, or evaluation.

Whereas the program at Oregon State College provides a minor to be coordinated into a doctorate program, the program for the Doctor of Philosophy degree for College Teachers at Michigan State College is defined as a minor to be coordinated into a doctorate program. Two of the 43 doctorate candidates chose the courses in 1950-51. The courses, available to students in all fields, are taught by the faculty of the School of Education.

The usual rules for the publication of a doctoral thesis apply to this work in this field. A final oral examination is held about a month before the end of the second year of the candidate's doctorate program. The candidate must pass examinations before a representative of the Department of Foreign Languages, demonstrating his ability to read German and French.

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quarter under the direction of a committee consisting of the Head of the Basic College Department, an experienced and competent teacher in that department, a representative from an upper-school department, and a representative from the Division of Education.

The guidance committee mentioned above shall include the director of the appropriate upper-school division, heads of appropriate upper-school departments, the head of the Basic College department representing the area in which the candidate is working, or their representatives, and such other persons as the student's program may require. At least three upper-school departments must be represented, except in cases where a department administers two or more recognized subject-matter fields such as sociology and anthropology.

Not over 50 per cent of the course credits earned beyond the bachelor's degree may be in any one department, except credits in research courses upon which the thesis is based, which may be allowed in excess of this 50 per cent.

Candidates who complete their degree requirements under one of these special programs will be awarded in addition to the regular diploma a certificate indicating the completion of a program in teacher-training.

One person has chosen this program with a major in chemistry, one with a major in physical science, and one with a major in biological science. The weakness in this program at Michigan State College is that the student must take too many courses in the fields designated to serve as adjunct fields. Accordingly, the course program is "top-heavy," forcing the candidate into a longer time of study than is usually required for a doctorate degree.

College and university scientists should strive in a graduate program toward three aims which are basically the activities of all scientists.

1. Scientists must be students, in order to increase their own knowledge.
2. They must be teachers, to transmit science to their students and to train future teachers of science.
3. They must be investigators, to advance science and its practical applications.

For a given individual it is not necessary that all three of these factors be equal in importance. For some of them the second aim should be of greater importance, because the responsibility of training and educating the oncoming generation is great. This scientist must know how to present science subject matter in the finest manner possible. He must know about good teaching materials and the methods of using them. He must demonstrate to students, colleagues, and administrators that he is not only a scientist but that he also knows how to "sell" his science to his audience.

A young scientist starting out on his teaching career is a freshman in experience. His only experience in handling large groups of people has been to note how others behave when before large groups. Maybe he will learn from the mistakes, the mannerisms, and the awkwardness of other speakers, but very likely he will not. Maybe his supervisor has taught him the fine points of handling groups of individuals, and of organizing material for presentation. Maybe someone has pointed out to him that he says, "ah, and, uh," and connects all sentences with "and and." More probably he hasn't had any practical suggestions. Should this young science teacher be helped? I firmly believe he should. How can he be helped? He can be by some teacher-training from experienced good teachers.

It is therefore proposed by the author that prospective young teachers have the opportunity of some training as part of their graduate program. Such training need not be a large number of credit hours. A brief indoctrination about the nature of the college student, the American college and university, and college teaching would be very valuable. Six semester credits would be sufficient if the material were properly organized. A description of the important points and not a collection of fancy words is all that would be needed. More important, however, is the need of good guidance in actual teaching, either by a brief course in teaching procedures or by an apprentice-type of teaching, properly supervised. In other words, a good course on the teaching of chemistry is essential. This latter can be brought about by one, two, or three department staff members devoting some of their time and energy to teacher-training problems, methods of demonstration, and to the communication of scientific ideas both to the future teachers of science and to the students.

Whose duty is it to lead in this teacher-training? It is the duty and the responsibility of the scientist to grasp this problem and to solve it. Who are we chemists must be active and vigorous in developing teaching methods or the professional educators will tackle the problem. If the latter group assumes the leadership there will be more and more emphasis on how to teach and less on actual teaching. We chemists will have no one to blame but ourselves if we find it necessary to follow laws and requirements which qualify persons for becoming college instructors but which disregard whether the instructor knows his subject matter or not. We as chemists must assume that a graduate school and a department of chemistry have a responsibility for preparing both research scientists and science teachers. It also behooves us to take the latter responsibility very seriously by including a good background for prospective teachers, or other agencies will.

LITERATURE CITED


3. RUSSELL, WALTER C. (Chairman), Report of the Committee on Graduate Instruction of the Council on Graduate Work of the Land-Grant College Association, Houston meeting, November 13, 1951.
Many years ago there were some characters of questionable motive who were attempting to change lead into gold so that they would not have to work for a living. They were also seeking a philosopher’s stone so that they could have everlasting life to enjoy their ill-gotten wealth. These men were known as alchemists. When they began to reform their ways of life they wished to conceal their shady beginning, and they changed their name from alchemists to chemists. Today, the chemist is a fairly respectable fellow of reasonably good standing in his community.

Many years ago there were some other characters of questionable motive who were attempting to predict the future of a client by the status of the stars at the time of his birth. They were prepared to say which are your lucky days and on which days you should have stayed in bed. These men were called astrologers. When they began to reform their ways they also wished to conceal their shady beginning, therefore they changed their name from astrologers to astronomers. The present day astronomer is also a fairly respectable fellow.

Thus, the chemists and the astronomers have a very similar history. How about their present day activities? The chemist spends his working hours peering into a tube. The astronomer also spends his working hours peering into a tube. The only difference is that the tube of the chemist is entirely of glass and is called a test tube, while the tube of the astronomer is made only partly of glass and is called a telescope.

Because of this great similarity between the men who use the watch glass and the men who use the spy glass, it is only natural that the astronomer should turn to the chemist to help him gain a better understanding of the nature of the universe.

Identification of Matter in Stars. One of the most useful tools to the astronomer is spectroscopy, a phase of science begun by the chemist Bunsen and his physicist friend Kirchhoff.

If you have a gas stove in your kitchen it is very easy to carry out an experiment at home which demonstrates spectroscopy. Turn on a gas burner and then sprinkle some salt into the flame. The flame will turn a beautiful yellow color for a few seconds. If you sprinkle pepper into the flame you will see some incandescent sparks as the pepper burns but there will be no change in the color of the flame. When the chemist Bunsen investigated this phenomenon very carefully he found that each chemical element, when heated, gave off a characteristic color by which it may be identified. The chemical element which is responsible for the yellow color is sodium.

When the spectroscopists developed their science further, they paid less attention to color and more attention to the precise wave-length position of the various lines which a heated element or simple compound emits. The sun is very hot and each chemical element in it produces characteristic spectroscopic lines. Altogether there are thousands of these lines. By analyzing these we can find out what chemical elements are in the sun. This task is still incomplete. There remain a thousand lines in the spectrum of the sun that have not yet been identified with any element. It is believed that these unidentified lines do not represent new elements but rather the familiar elements in highly ionized states.

It has been found by studying these lines from the sun that the chemical composition is very similar to that of the earth with the exception of the relative abundance of hydrogen and the rare gasses. This difference is believed to be due to the difference in mass of the sun and earth. The sun, with its larger mass and greater gravity, would be able to hold on to elements which exist only in the gaseous form. In fact, the whole universe is quite uniform in its composition.
The remainder are stone. When meteorites are analyzed chemically they react just like ordinary earth stone or iron. Also, when analyzed spectroscopically they give off the same lines as earth stone or iron. This is evidence that our interpretation of the constitution of the stars by the spectroscope is correct.

One interesting question proposed by the astronomer is: "How old are these meteorites and when did the iron first cool to form a solid piece of metal?" The chemist can answer this question for him. Careful analysis reveals small quantities of helium locked inside the iron crystals. Helium is a gas and would have escaped from the liquid iron. Thus, when the liquid iron first became solid, there undoubtedly was no helium present. Where did it come from? Further analysis reveals a small amount of uranium. Uranium decomposes slowly and forms helium. This, then, is the clue to the age of the meteorite. From a careful determination of the relative quantities of uranium and helium, it can be calculated that the iron meteorites solidified 2,500,000,000 years ago.

**Rotation of the Sun.** The spectroscope can be used to glean additional information; for instance, to determine how rapidly the sun is rotating about its own axis. This is done by an application of the Doppler effect with light. A good experiment to illustrate the Doppler effect is to have a friend get in one automobile and you in another; then to drive past each other in opposite directions at 40 miles per hour. Have your friend keep his hand on the horn button. As your friend approaches, his horn will sound high in pitch like "eee"; as the car goes away from you after you have passed it, the horn will sound low in pitch like "oor." Then, even with your eyes shut (but don't do it!) you can tell whether the car is approaching or leaving just by the sound. Now let us suppose that there is a horn on each side of the sun. The horn on the side which is approaching you would go "eee"; the one on the side that was leaving you would go "oor." The faster the rotation of the sun, the faster would one horn be approaching and the other horn be leaving, and therefore the greater the difference in pitch.

There is no horn and there are no sound waves but there is hydrogen on both sides of the sun and the hydrogen is giving out light waves. By analyzing these waves with a spectroscope, we can tell the difference in wave length of the light waves of the same spectral lines and hence deduce the speed of rotation.

At the Mount Wilson Solar Observatory there is a giant combination telescope and spectroscope which over-all is half as long as a football field. The image of the sun formed by this telescope is 16 inches in diameter. The slit of the spectroscope, which is the window into which light enters for analysis, is only about 1/50 of an inch wide. This small window may be placed on one side of the 16-inch image of the sun or on the other side. When this is done, a difference in wave length is found between the hydrogen lines from the east and west sides of the sun and calculations show that the sun takes four weeks to rotate once. It also shows that the equator rotates at a different speed from the poles. This is evidence of the fluid nature of the surface of the sun.

**Temperature of Stars.** Another question asked of the astronomer is: "What is the temperature of stars?" By far the most reliable way of telling the temperature is to ask a spectroscopist to determine the ionization of the atoms. Atoms are like people in that they take off some of their clothes when they get hot. Motion pictures of people walking up and down a city street would show the people all bundled up in overcoats, hats, and mufflers, if the day was cold. If the men were all in shirt sleeves the...
day was warm. Atoms are clothed in electrons. On Gamma Velorum, where it is very hot, somewhere around 50,000° K. on the surface, the atoms have all shed two or three electrons. On such a star there is no opportunity for a chemist who is interested in linking atoms together in diverse combinations, because the first electrons to be lost are the valence electrons. Every atom leads an individual existence. It is too hot for any two atoms to join together to form a compound. The spectroscope lines in the spectrum from a star show its temperature just as truly as a motion picture showing shirt sleeves on passing pedestrians indicates a warm day. On a cooler star such as the sun, some atoms, like calcium, feel it is still too warm and have taken off one electron, but most others, such as iron, are fully clothed. In fact, on the sun at 6000° K., some atoms have joined together, and we observe such a compound as cyanogen, which is carbon linked to nitrogen.

On the really cool stars, such as Betelgeuse, which is a mere 2600° K., nearly all the atoms are fully clothed with electrons and compounds are quite abundant. Titanium oxide is a common compound on stars if oxygen is plentiful. These observed temperatures are surface temperatures. They are the outside temperatures of a body that is doing its best to cool off by radiation. The inside of the star, where the heat is generated by an atomic-bomb reaction, is much hotter. It reaches 29,000,000° K. inside the sun. Here it is so hot that the atoms have taken off their electron clothes.

The electrons that atoms wear when they are cool are like hoop skirts that keep them away from their neighbors but with the electrons removed, as in the center of a hot star, the atoms can pack closely together. Consequently, the matter in the center of many stars is very heavy. If a man were made of some of this heaviest matter, and weighed just as much, he would be about one inch high. He would be so hot that he would immediately set fire to his surroundings and give off so many X-rays that he would kill all life in the immediate vicinity. Obviously, this is an impractical material of construction here on earth.

The Planets. Complicated chemical compounds—and hence life—cannot exist on a star, but must have something like an earth which, because it is too small to have atomic-bomb reactions taking place of their own accord, is cool.

The moon is a forbidding mass of gray rock with no atmosphere. The rocks, which reflect only 7 per cent of the sunlight, are gray because of the ferrous iron in them. Mercury, the smallest and innermost planet, is like a moon in that it, too, is a mass of dry rock with no atmosphere.

Jupiter is a beautiful planet. It has belts of red, brown, and green-colored atmosphere. Here again, the spectroscope comes to our aid to find out what is what, this time by absorption spectrosocpoy, and we find that the atmosphere is a mixture of methane and ammonia. It is suspected that the red and brown colors come from traces of sodium and potassium dissolved in the clouds of ammonia.

Saturn is a little further away from the sun than Jupiter, a little cooler, and most of the ammonia has been frozen out of the atmosphere, particularly from the north and south pole that take on the green color of pure methane. Here on earth we pipe marsh gas or other natural gas to our gas stoves, pay whatever is indicated by the gas meter, and burn it in air which is free. On Saturn we would have to pipe air to our air stoves, pay what is indicated on the air meter, and burn it in gas which is free. This is just one of the many differences between life here and there—but we do not believe there can be any life there!

Mars is a dying world. It looks rusty. In fact, it is rusty. This is because the iron in the soil on its surface rocks has been oxidized to the red ferric oxide. The little vegetation which is on Mars is unable to keep a supply of oxygen in the air. This may be because there is very little water on Mars, only enough to form white polar ice caps during the winter season.

Venus is an embryonic world. It reflects 60 per cent of the sunlight and appears white. This white color is attributed to dense clouds of moisture in its carbon dioxide atmosphere. When the sun fades out a little bit so that Venus cools down a little bit, there is a good chance that plants can start to grow. Once this happens, oxygen will be put in the atmosphere in increasing amounts and finally animal life as we know it may be possible.

Our general survey of cosmic chemistry thus reveals that the same chemical elements and the same chemical laws which govern their behavior apply throughout the entire universe. There may be excessively high and low temperatures and pressures, but the chemist, with his training on earth, would be able to understand what is going on anywhere he might be placed in the universe. The chemical reactions on earth are the most complicated of all, because temperatures are neither high enough to break up complex compounds nor so low that the atoms are too inactive to combine. Therefore, if a chemist wishes to practice his profession to its most complete development, it is advisable for him to remain on the earth.
From an economic standpoint, in many countries of the world the food industry far surpasses all others. This is true here in the United States. Farm workers number 6½ million in full-time employment, with a peak number of 10 million during harvest. The manufacturing and processing segments of the food industry employ 1½ million more. Retail food stores add yet another million. It is estimated that a full 30 per cent of the working population of the United States is in the food industry, directly or indirectly, if we include those in transportation, can manufacture, and the like. Out of a current annual disposable income of $231 billion, $57 billion, or approximately 25 per cent, will be spent for food this year, comprising over 30 per cent of the budget of the average American family. These figures serve to emphasize the major role that the food industry plays in our society. On the strictly personal side, food is the matter of first importance to the individual. It has been stated that, "Half the struggle of life is a struggle for food." For those fortunate enough to live in the United States, expenditures for food, as we have seen, demand scarcely a third of one's income, but in most of the world, at the economic level at which the majority of families live, about as much of one's individual effort, or earnings, must be spent for food, as upon all other items of living combined, if health and efficiency are to be maintained. It is little wonder, then, that chemists, in their development of scientific knowledge, have been called upon to give much attention to chemical aspects of foods.

In the past generation we have seen the spread of chemistry more and more into medical and biological research. Little by little this has filtered down into the teaching approaches to these branches of science. Similarly in the future we will witness a change of teaching content in this young and expanding field of food chemistry. The stimulation of research in our own and other major food companies will, in the years to come, call for a larger fraction of the available chemists and impose a growing responsibility on teachers of chemistry to prepare students specifically for this field.

The rate of increase of professionally trained persons in the industry is well illustrated by the rapid rise in the number of food technologists. In 1937 one might have mustered a total of a few hundred in the entire industry. Today there are well over five thousand scientists and engineers who could be designated as food technologists. There has been a similar growth in the number of institutions offering formal training in this profession. From a single one in 1940 such curricula are now offered in at least a dozen major colleges and universities.

MAJOR ASPECTS

In the hard school of experience mankind patiently learned successful methods for the growing of food crops. He discovered how to process foodstuffs for utilization in his kitchen, and worked out certain methods of storage, which enabled him to hold foods after harvest or processing for later consumption. Thus, through the centuries, there developed well-established arts in soil tillage, seed selection, harvesting methods, and the preparation of foodstuffs for human consumption. The origin of the arts of butter churning and cheese making are lost in the mists of antiquity. The pyramids of Egypt reveal that knowledge of baking had reached a high stage of perfection in the days of the Pharaohs. Methods for fermentation of grain and other sources of alcohol for beverage use are as old as the history of mankind. Science, on the other hand, is newly come to the food industry.

In considering the place of chemistry in this field we may view it from the standpoint of the chemical aspects of the materials themselves, which might be termed in vitro. Or we may approach the subject from a study of the manner in which foods support life—an in vivo approach. One may begin with the

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1 Address delivered to the NEACT at the 14th Summer Conference, University of Vermont, Burlington, Vermont, August 22, 1952.
2 Source: Department of Commerce. First half projected to annual rate.
production of foodstuffs and find how chemistry has improved agricultural methods. One could then turn to a consideration of the chemical changes involved in various methods of food processing, e. g., salting, smoking, preserving, pickling, freezing, and dehydrating. Finally, one might study the ramifications of chemistry in the storing of foods to prevent oxidation, rancidification, discoloration, and other chemical reactions which render food unappetizing, unpalatable, and even toxic.

The application of chemistry to foods, as items in the diet, has, in the past fifty years, been successively concerned largely with: (1) a study of the energy relationships for food; (2) investigation of the role of the various mineral elements in nutrition; (3) a breakdown of the proteins into their constituent amino acids; (4) isolation, identification, and synthesis of vitamins; and, most recently, (5) investigation of the mechanisms by which recognized dietary elements react in the body to achieve their observed functions.

If one examines the horticultural branch of the food industry, one quickly realizes why agricultural chemicals constitute one of the fastest growing segments of chemical industry. From 100 million pounds of annual production twenty years ago, the yearly output of such chemicals (not including fertilizers) has grown to 1.2 billion pounds, valued at $250 million. The importance of this development to farmers is illustrated by the report of the Mississippi Agricultural Experiment Station for 1950, that no less than three-quarters of the state’s cotton output that year resulted directly from the application of insecticides for boll-weevil control. It is estimated that even today agricultural pests in the United States cause an annual crop loss of $4 billion from fungi and plant disease, $4 billion from insects, and $5 billion from weeds. Their complete elimination could increase crop yields by 40 per cent.

When one reflects that our population in the United States has for some years been increasing by 2 million annually, one can easily calculate that by 1975 we shall require a third larger food supply than in 1950. Farm population has been declining for years, and arable land cannot be greatly increased beyond that under cultivation today, and then only at heavy expense. Through more intensive application of improved agricultural chemicals we can hope to obtain higher yields of better foods with less manpower. Chemistry has a large part to play in arriving at this goal.

PESTICIDES

While it is true that the bulk of pesticides used still consist of the tried and true inorganics such as sulfur, lime, arsenates and arsenites, organic chemical research is turning out a growing stream of new compounds for agriculture. World War II highlighted the value of DDT in controlling malaria and typhus. This compound is highly toxic to insects, both as a contact and stomach poison, and has found widespread use in controlling codling moths and corn borers, as well as flies and mosquitoes. DDT is the common abbrevia-

- DDT is the common abbrevia-
- tion for 1, 1, 1-trichloro-2, 2-bis (p-chlorophenyl) ethane. If we replace the two chlorines on the benzene rings with methoxy groups, we obtain methoxy-chlor, which is less than 10 per cent as toxic to higher animals as DDT. It is therefore useful near harvest time for fruits and vegetables, as well as preferable for a flyspray in dairy barns. If fluorine replaces these chlorine atoms, we obtain DFDT, while introducing a hydrogen for chlorine in the ethane radical of DDT yields TDE.
- Many of the chlorinated hydrocarbons, such as benzene hexachloride, are effective insecticides. BHC is really hexachlorocyclohexane, five isomers of which have been isolated. The gamma form is the effective one. Crude BHC contains about 12 per cent of this, and has a strong musty odor which limits its usefulness on food crops, although it is proving very helpful against the boll weevil. "Lindane," which is mostly gammexane, can be used on crops where the cruder BHC form is unacceptable.
- Chlordane, which is an octochlor derivative of substituted methanoundene, and toxaphene, which is a mixture of chlorinated terpenes, mostly camphene, have proved effective against flies, grasshoppers, cotton insects, and livestock pests.
- Another group of new organic insecticides are phosphorus compounds, of which Parathion is probably the best known. These are highly toxic at extremely low concentrations. They act to inhibit cholinesterase, an enzyme found in the nerve tissue of animals. These phosphorus-containing compounds destroy the delicate functioning of the nervous system, and thus kill the insect.
- Defoliating agents and herbicides have been a fruitful field for chemical research. Doubtless many of you have tried 2, 4-D (which is 2, 4-dichlorophenoxyacetic acid) to kill that perennial pest of our lawns, plantain. This compound destroys a wide range of broad-leaved plants. A closely related compound, (2, 4, 5-T) tri-chlorophenoxyacetic acid, is now being used effectively against various types of brush and woody plants, particularly mesquite. Calcium cyanamide and Endothal are finding increasing application in the defoliation of cotton.
Most of these conditioners are derivatives of hydrolyzed polyacrylonitrile. This type of compound was developed by American Cyanamid some fifteen years ago, as a chemical to be used in the per buna type of rubber. Polyacrylonitriles have also been used for oil well muds for some years. Monsanto's sales staff saw possibilities in promoting these polymers as soil conditioners, and this company launched a large advertising campaign last fall on their Krilium for this use. Despite the high cost of the acrylonitriles, the excellent results obtained in improvement of the tilth of heavy soils appeared to offer a real opportunity for developing a wide market for such soil conditioners. The sodium salt is water soluble, and hence, can be sprayed onto the top layer of soil. The insoluble form has to be mixed with the upper layer of soil after digging. The expense involved at present is so high as to definitely limit the market. Prices decrease from a single pound cost of five dollars to four dollars in ten-pound lots. Many companies are promoting this use of acrylonitriles under brand names such as Soilife, Aerotil, Poly-Ack and Agrilon. There is promise that the acetylene branch of the industry will eventually be able to produce polyacrylonitrile at a cost of $30 per pound, which might enable these soil conditioners to be sold in quantity at a price as low as $1 per pound. It remains to be determined how far the application of these relatively costly chemicals will progress in the agricultural field.

Allied in interest to these soil conditioners are the chemical fertilizers, which are constantly expanding in variety and tonnage. In 1950 synthetic ammonia production had grown to approximately 1.5 million tons, world-wide. Phosphatic fertilizer production is increasingly important in expanding our food crops. With continued support of basic chemical research, and better use of our scientific knowledge, we can reasonably expect to feed our 200 million citizens in 1975 as well, if not better, than we did 150 million in 1950.

FOOD PROCESSING

When one turns to the processing of foods, one finds that science is slowly displacing the older art, and that chemistry cooperates with physics and biology in steadily improving the technology of the industry. Chemical analysis has become a reliable tool for control of raw materials and plant processes, despite the limitations imposed by the complicated natural systems occurring in foods. New methods utilizing the improvements in instrumentation and techniques such as flame photometry and infrared spectroscopy are being rapidly developed by the analytical chemist and applied to foods. Chemical research is bringing many new detergents to help the sanitarian in his efforts to keep food plants clean. The chemist has shown the meat packer how to cure hams and bacons quickly and uniformly by "pumping" them with a brine of exact composition and acidity. By-products of the meat industry, through chemical research, now yield valuable hormone extracts, fatty-acid compounds, enzyme preparations, pharmaceuticals, and vitamins. Cortisone and ACTH, which promise to be valuable in controlling rheumatoid arthritis, are recent end products of such studies. Similarly, in the fish industry, chemical research has isolated valuable vitamins from shark, haddock, and haddock livers, and, more recently, the "animal factor" in "stick water" which lead to the isolation of vitamin B₁₂.

While physics and biology make major contributions to successful processing of foods by sterilization, chemistry provides much useful information on changes which occur during processing. The plant man is thereby supplied with data which enable him to change operating conditions intelligently, so as to achieve his goal of preservation with a minimum of change in the product.

In preserving foods by freezing, chemical research has been applied to provide methods for the selection of suitable varieties, evaluation of proper maturity, and improvement of packaging. The recent tremendous upsurge in frozen concentrated fruit juices, while made possible largely by engineering developments, owes much of its popularity to the work of the chemists in maintaining uniformity of product quality.

These examples are but a few of the innumerable applications of chemistry to food processing which have insured a wide variety of choice in quality foods ready for our tables at a few minutes notice. But in the slowly moving channels of distribution, which carry the product from the food plant to the consumer's cupboard, there is an inevitable time lag, during which chemical change is continually threatening the color, flavor, and wholesomeness of the food.

Methods for retarding oxidative changes have long engaged a considerable part of the attention of the food chemist. Natural fats, whether animal or vegetable, succumb quickly to oxidation. Hydrogenation of vegetable oils results in stable fats which serve well the margarine and baking, and (quite recently) the ice-cream industry. The development by the chemist of edible antioxidants, such as nordihyroguaiacic acid, propylgallate esters, and butylated hydroxyanisole, and their use in minute amounts now gives us lard and other animal fats of excellent keeping quality, even under quite adverse condition.

Butter fat is notoriously short lived, so far as good flavor is concerned. In butter, it slowly splits through lipolysis to develop rancidity or fishiness. The chemist has learned that the shorter the period between the cow and the churn, the longer the storage life of the butter, other factors being constant. When reduced to dry form, whole milk will become unpalatable under ordinary atmospheric conditions in sixty to ninety days because of oxidative rancidity. Chemical research has led to complete elimination of this off-flavor through packing in a sealed container, under an atmosphere of nitrogen or carbon dioxide. It was established that if the residual oxygen is reduced to about 1 ml. per 100 grams of milk powder no oxidative change detectable in flavor will occur, though a certain lack of freshness in taste will be evident with time.
BROWNING

Another type of undesirable change which develops in certain kinds of food with prolonged storage is known as nonenzymatic browning. It has been established that this arises from a chemical reaction between reducing sugars and amino acids and is termed the sugar-protein reaction. Although first remarked upon by Maillard in 1912, the most intense study of the phenomenon has occurred in the past ten years, stimulated by widespread deterioration of many foods shipped to our Armed Services during World War II.

The incidence of browning causes unpalatability in evaporated and sweetened condensed milks, dried eggs, dehydrated vegetables, dried soup mixes, and dried fruits, as well as many other food products. The problem of the cause of nonenzymatic browning was vigorously attacked from many angles during the late war. Departments of pure chemistry have now become interested in the chemical reactions involved in this phenomenon. They are investigating the nature of the degradation products which result in the brown coloration in foods. These researchers are finding some extremely interesting facts of wider application than in food chemistry alone. One interesting observation is that the browning reaction can be avoided by reducing moisture content in foods to very low levels or by considerably increasing it.

Browning in dried eggs during storage was found to be greatly retarded by reducing the moisture content below one percent. Prefermentation of the dextrose present in the egg albumen slowed down browning appreciably. Addition of lactose or sucrose before spray-drying greatly extended storage life of dried whole egg and gave greater than normal solubility after storage.

In dairy products browning is a complex function of time and temperature. At certain stages it appears to be autocatalytic. It is characterized by the development of acidity, a fall in pH and in oxidation-reduction potential, and pronounced loss of optical activity. The extent of the reaction in dried milk and dried whey is similar to those effective for dried eggs. Browning greatly retarded by reducing the moisture content below one percent. Prefermentation of the dextrose present in the egg albumen slowed down browning appreciably.

An imitation maple syrup by a controlled browning reaction in ordinary sucrose syrup. This development makes possible the enjoyment of the maple type of sirup flavor by many thousands who could never be supplied from the small stocks available of natural maple sirup.

FOOD ADDITIVES

One very timely topic at the moment is the matter of chemical additives in food. The reports of the Delaney Committee, which have just been made public, have spotlighted the role of chemicals in the food industry. Their use is by no means novel, for sodium bicarbonate, calcium chloride, disodium phosphate, various citrates, and tartrates have been standard in food processing for years. Vanillin, edible dyes, gums, and benzoate have long had official sanction. The difficulty today arises out of the sales promotion of new chemicals, mostly organic, by manufacturers who may lack complete data regarding the chronic toxicity which the compound may develop with continued ingestion of foods to which they may be added. Just recently, standards for bread have been set by the Food and Drug Administration, which ruled out the use of such synthetic emulsifiers as poly-oxyethylene monostearate, while permitting those of natural origin such as mono- and di-glycerides. A ruling of this sort appears a bit difficult to justify on chemical grounds, and the Court of Appeals has granted a stay in the effective date, pending a judicial review of the evidence.

NUTRITION

Equally important in a consideration of the chemistry in foods is the development of our understanding of their nutritional aspects. In the early years of this century, as nutritional chemistry developed, we found much about the energy relationships and functional character of fats, proteins, and carbohydrates. Improvement in methods for detecting trace elements and new techniques in biochemical studies with live subjects then led to an appreciation of the necessity for iron, copper, molybdenum, calcium, cobalt, and other minerals in the diet of men and animals.

By the beginning of World War II, there had come a general recognition that the human diet to be adequate should contain: (1) milk, meat, eggs, fish or other high quality animal proteins, (2) green leafy vegetables, (3) tomatoes, oranges, lemons, berries, and other good sources of ascorbic acid, (4) sufficient fats and carbohydrates to provide needed calories for energy. Subse-
quent research in the chemistry of nutrition has strengthened the earlier view that these foods contain all the nutrients essential to maintaining good health. Most recently the emphasis in nutritional research has turned to the problem of the mechanisms by which the recognized dietary elements react in the body to achieve their observed functions. Here the utilization of isotopes, both stable and radioactive, has provided a useful tool for biochemical syntheses to help unravel the fate of nutrients in the intermediary metabolism. It is now well recognized that there is an interdependence of problems involving the different components of the diet which necessitates a reorientation of viewpoint.

One of the most active aspects of present-day research in this field is that concerned with the multiple forms in which vitamins occur in food linked to many different and interchangeable groups. Man appears able to utilize the vitamins efficiently, despite these varieties of conjugated forms.

Certain evidence now available tends to show that rapid early growth may actually prove undesirable at times, since it may result in overweight and increased instances of degenerative diseases during maturity. Under particular specialized conditions of abnormal metabolism, there are some indications that nutritional optimal diets may not be desirable. The subject of the relationship of the level of cholesterol in the blood to such degenerative conditions as hardening of the arteries and cardio-vascular abnormalities has been the objective of many extensive research programs, both with humans and experimental animals. While the deposition of cholesterol on artery walls frequently is found in older people, this does not appear to be an essential characteristic of the aging process. It is difficult to make interpretations of the relative importance of the level of cholesterol intake and faulty utilization in the metabolism. Since it has been demonstrated that surplus fats and sugars within the body may be major sources of labile acetate groups, which form a major unit in the cholesterol synthesis, it is suggested that a reduction in total caloric intake, rather than a particular decrease in high cholesterol-containing food, such as eggs, may be the real answer to retarding the deposition of cholesterol in the arteries. With an increase in the average expectancy of life, such problems in geriatrics as these become increasingly important in the general public health picture.

Another striking example of the interrelationships between nutrients is the interchangeability which has been discovered between ascorbic acid and ACTH in correcting the defective metabolism of aromatic amino acids in premature infants. There are many interchanges apparently of this sort, such as that between methionine and choline, and between folic acid and B₁₂. In the rate of growth and prevention of anemic conditions, in experimental animals, there seems to be a sparing action of methionine, folic acid, and vitamin B₁₂. In some of the most recent work in this field there are indications that the addition of the citrovorum factor or folic acid is of considerable value as a protective agent against macrocytic anemia. This factor may also be of importance in the clinical management of leukemias, serving as an adjunct to the folie acid antagonists which are used in the clinical treatment of neoplastic diseases. This latter finding is another example of the interrelationship of nutrients with which research in food utilization is so greatly concerned today. It is not too much to hope that the extension of our chemical knowledge in this direction may provide methods whereby the modern degenerative conditions and derangements of metabolism such as cardio-vascular diseases, diabetes, kidney disease, neoplastic disease, and rheumatoid diseases may at last be brought under control.

There has arisen considerable controversy concerning the addition of a chemical for nutritional purposes through the advocacy of fluoridation of public water supplies, as a means of controlling dental caries. The preponderance of evidence seems to indicate that, under good technical control, the addition of fluorides maintained in the water supply in the proportion of one part per million may greatly benefit a large fraction of our population. Considerable controversy still exists in certain communities relative to fluoridation, but present evidence minimizes the danger of chronic toxicities resulting from such a practice.

**FOOD SYNTHESIS**

One final aspect of the chemistry of foods merits further brief consideration. Chemical research is leading to the synthesis of food substances under controlled conditions in laboratory or plant. Yeasts and algae are being grown for foods. Citric and tartaric acids are being produced by deep vat fermentation methods until they now begin to pose a serious threat to supplies from natural sources. Thiamine and ascorbic acid from organic synthesis probably represent the first steps in obtaining most of the vitamins from other sources than natural elaboration in foodstuffs. Fats are being obtained by synthesis from petroleum and it only remains to discover how their nutritional properties can be improved to make these an important factor in our overall fat supply. Petroleum has also become a major source of synthetic alcohol, though long-established legal requirements that potable spirits must come from grain still prevents its use as a beverage or food.

It would appear that synthetic chemistry will in the not too far distant future loom large as a producer of food substances. I have indicated some of the directions in which significant progress has been made and in which intensive research effort is being exerted towards the understanding of the manner in which foods function in the body and in the development of improved methods of cropping and processing of foods. Through the application of chemistry and its sister sciences the food industry will continue to provide for the American housewife in the years to come a bill-of-fare which is more varied, more nutritionally adequate, and far less laborious in its preparation.
To the Editor:

There is available at gas stations in New Orleans a cleaning fluid, the composition of which I do not know. Some time ago I procured two or three gallons (it is quite inexpensive) which my wife proceeded to use in cleaning draperies. To protect her hands she wore rubber gloves which she bought at the "5 and 10." After two or three immersions it was obvious that the rubber gloves were getting bigger. Indeed, what happened took on such a ludicrous complexion that we found ourselves in unabatable laughter. The gloves got bigger and bigger—the fingers got as large as rolling pins and the wrist of the glove was eventually large enough for me to step into! How long this enlarging process could have continued I do not know for my merriment at this episode forbade further experimental inquiry! I leave it as an exercise for the chemists to show the mechanism analytically and to predict the upper limit.

JULIUS SUMNER MILLER
Los Angeles, California

To the Editor:

Ricardo Carvalho Ferreira writes (J. CHEM. EDUC., 29, 372 (1952)) that G. E. Villar, in 1938, was the first to propose the actinide hypothesis, and that Glockler and Popov (J. CHEM. EDUC., 28, 212 (1951)) were not the first to propose that the neutron may be included in the periodic table as the element of atomic number zero, although C. D. Coryell (J. CHEM. EDUC., 29, 62 (1952)) thought they were. However, Ferreira does not know who the originator of the latter idea is.

Villar was not the first to propose the actinide hypothesis (although it should be added that his work is very much worth-while and ought to be referred to more often). J. R. Rydberg, the celebrated spectroscopist, did so, 39 years ago (Lunds Univ. Års., 9 (18), 5 (1913)), though he did not, of course, use the term "actinide." V. M. Goldschmidt, the noted crystallographer and geochemist, who first proposed the name "lanthanide" (Goldschmidt, T. Barth, and G. Lunde, Norske Videnskaps-Akad. I. Mat.-Naturv. Klasse, No. 7, 10 (1925)), also first proposed the name "actinide" (Travaux du Congres Jubilaire Mendeleev, 2, 387 (1937)). For those who are interested in other details, the most complete and most reliable treatment of the history of the actinide hypothesis is that of Glenn T. Seaborg ("Place in Periodic System and Electronic Structure of the Heaviest Elements," Nucleonics, 5 (5), 16 (1949)).

C. G. Bedreag (Compt. rend., 200, 1197 (1935)) was probably the first to include the neutron, as the "element" of atomic number zero, in the periodic system. He also included alpha particles, positive and negative protons, electrons, positrons, and neutrinos in his table. A decade earlier, F. H. Loring considered including the electron and, if I recall correctly, though I am now unable to locate it in the literature, he later included the neutron and considered it to be the first noble gas.

Personally, however, I can see no advantage whatsoever in including anything but actual elements in a periodic table, for is not the purpose of a periodic table to point out the relationships among the chemical elements? (E.g., see Hakala, R. W., J. Phys. Chem., 56, 178 (1952).) I do not wish to appear (overly) ficious, but how many outer electrons does a neutron have?!

Having discussed Ferreira's problem brings to mind another question of prior authorship: who first wrote

\[ Z = 2(1^2 + 2^2 + 2^2 + 3^2 + 3^2 + \ldots) \]

to give the atomic numbers of the noble gases? Although this series is ascribed to Rydberg, the reference which is always cited (Phil. Mag., 28, 144 (1914)) does not mention this series at all; what it does mention, however, is extremely interesting. According to the authors of books and articles in which this reference is cited, Rydberg was supposed to have noticed regularity in the atomic numbers of the noble gases, thus giving rise to the series now bearing his name. Yet in the reference cited, Rydberg argues strongly against Moseley's atomic numbers! Here is the story behind the argument.

As a result of his extensive studies of the numerical relationships among the atomic weights of the elements, Rydberg came to the conclusion that the chemical and physical properties of atoms are not periodic functions of their atomic weights but, instead, of what he called the "ordinal numbers" of the elements ("Elektron, der erste Grundstoff," Håkan Ohlssons Boktryckeri, Lund, Sweden, 1906, pp. 8 and 9; available at the John Crerar Library, Chicago) and that, therefore, the elements should be arranged according to their "ordinal numbers" and not their atomic weights. (See also his article in Rev. gen. sci., 25, 734 (1914.).) Having determined the ordinal numbers of all the known elements, he was then able to (correctly) point out all the remaining gaps in the periodic system.

He arranged all the elements, known and unknown, in quadratic groups of \( 4p \) elements each, where \( p \) had the values 1, 2, 3, and 4, giving groups of 4, 16, 36, and 64 elements, each consisting of two subgroups of \( 2p^2 \) elements; i.e., there were 2 periods of 2 elements each, 2 periods of 8 elements each, 2 periods of 18 elements each, and 2 periods of 32 elements each in his system (Lunds Univ. Års., 9 (18), 5 (1913)). (Rydberg was a spectroscopist, with a spectroscopist's love of order and symmetry.)

Since the inert gases were thought to be the key to the
As a result, his "ordinal numbers" did not agree with Moseley's atomic numbers—Rydberg's were all, except in the case of hydrogen, two units too large. In the article which is much cited as the supposed source of the so-called Rydberg series, Rydberg concludes: "In the complete coincidence of the order of Mr. Moseley's numbers and of my ordinals of the elements, I see a very strong support of my system, according to which there should be respectively 4, 16, 36, and 64 elements in the first four groups. But then we shall also get my ordinals instead of the numbers used by Mr. Moseley." Who, then, originated the "Rydberg" series?

We have thus seen that Rydberg deserves a good deal more credit than he is given, though he apparently does not deserve some that he is given. (Textbook authors, please note!).

In view of the original reason for this communication, it should be added that Rydberg's system was not accepted because of the seeming evidence against a second rare-earth series in the seventh period (the eighth in Rydberg's table) (Soddy, F., Ann. Rpts., 13, 254 (1916)). It is of interest to note that Charles Janet, in 1928, published a periodic table incorporating Rydberg's quadratic groupings with the van den Broek-Moseley atomic numbers ("La Classification Hélicoïdale des Éléments Chimiques," Fascicle No. 4, Imprimerie Départementale de l'Oise, Beauvais, France, Nov., 1928; Chem. News, 138, 372, 388 (1929)). Janet's efforts have also gone unappreciated until quite recently.

Reino W. Hakala
Syracuse University
Syracuse, New York

To the Editor:

Doctor Henry F. Holtzclaw, Jr.'s, article (February 1952) on "Laboratory synthesis in general freshman chemistry" merits comment. The following values of synthesis in the laboratory, implicit in his paper, warrant more explicit emphasis:

(1) Successful use of principles of chemistry rather than merely instruction about them.

(2) Relief from the boredom of repetitious test tube quality tests in "goose-step" with the rest of the class. In synthesis there is something created in weighable amounts.

(3) Synthesis in process often induces self-initiated procedures that challenge the performer's resourcefulness.

(4) Motivated library search with the expectation that the results of the search are to be shared by the next generation of students working upon inorganic preparations.

(5) Such experiments permit both the student and the teacher to evaluate their success. Both the quality and quantity of the yield testify to the technique and other skills of the experimenter.

The writer used a somewhat different plan in the use of inorganic preparations from that described by Dr. Holtzclaw. He restricted the assignment to members of his class who had attained an upper-quartile rank in the general chemistry class. Such a student was invited to substitute "preps" for certain of the routine "test tube experiments." If that student accepted such an assignment he retired to the library and found and prepared two different patterns for the preparation he had chosen. He made an oral report of these two plans to his laboratory assistant and indicated one he had decided to try. In this report he was expected to defend his choice under the criticism of his assistant.

The completed report on the experiment included:

1. Presentation of a carefully weighed and packaged total of the preparation.

2. A written report including: (a) Quantities and character of the raw materials used; (b) listing and brief exposition of specific reaction controls involved in the preparation; (c) reactions, i. e., equations, with computations of the theoretical yield and the percentage of it actually obtained; (d) self-criticism of techniques used and suggestions for improvement; and (e) at least one new reference upon a standard 3X5-in. library card for addition to the Freshman Inorganic Preparations Bibliography kept in the department library.

The writer found that his students seemed to experience quite as much of a lift in preparing such familiar substances as alums, bleaching powder, or sodium bicarbonate as in attempting to prepare the newer, less well-known substances such as "aluminates," "oxalato ferrates," or complex "cobalti" or "cobaltito" compounds.

B. Clifford Hendricks
Longview, Washington
Film Reviews

**THE MOLECULAR THEORY OF MATTER**

**Description:** 16 mm., sound, 10 min.

**Producer:** Encyclopedia Britannica

**Reviewers:** (A) William K. Viertel, N. Y. State Agricultural and Technical Institute
(B) Jelks Banksdale, Alabama Polytechnic Institute
(C) R. T. Schenck, New York University

**Possible Utility:** (A) "...cannot fail to interest beginning students. It is, however, very elementary, and I could only recommend it for high school, college freshman chemistry courses for those taking chemistry for the first time." (B) "...should serve as a valuable aid in teaching general chemistry but it does not replace conventional teaching methods."

**Film Content:** (taken from (A), (B), and (C)) - This film covers the material given on the kinetic-molecular theory in most general chemistry textbooks and closely follows the presentation in Schlesinger's "General Chemistry." It shows, with ordinary movie shots and animated drawings, how matter is believed to be constituted, and how molecules behave in gaseous, liquid, and solid states. For example, it shows the diffusion of bromine vapor in air and in a vacuum, how evaporation and condensation occur, how a gas exerts pressure, etc. The small size and great numbers of molecules are emphasized.

**General Criticism and Rating:** (A) "In my opinion it is a very satisfactory film; the information given is up to date and pertinent." (B) "The film is generally accurate and is to be recommended. The portions on the mining and handling of sulfur are particularly good. Interest is enhanced by the excellence of the color photography. The narration is clear, to the point, and accurate." Rated "excellent" by McBride High School, St. Louis, Mo.

**Suggestions for Improvement:** (A) "The only thing I felt that was needed was some recognition of other sulfur sources as in copper and zinc smelting or recovery of hydrogen sulfide, or burning pyrite. This is becoming more important daily." (B) "Little, if any, improvement could be effected in the film as a general survey. Of course, it does not cover the chemistry of sulfur compounds, but it makes no claim of doing so. I would recommend it as it stands."

**SULFUR**

**Description:** 16 mm., sound-color, 16 min.

**Producer:** U. S. Bureau of Mines in cooperation with Texas Gulf Sulphur Co.

**Reviewers:** (A) W. G. Kessel, Indiana State Teachers College
(B) Theodore Moeller, University of Illinois

**Possible Utility:** (A) "I think it could be used at any level from general science students in junior high school through college and adults that want to know about this element." (B) "This presentation is best suited to general chemistry courses either at the high-school or freshman college level. It has no especial merit for advanced courses, but it would be useful in general survey courses.

**Film Content:** (A) "This excellent film begins with a consideration of the general importance of the element sulfur. Discusses to some extent the nature of elemental sulfur deposits, gives diagrams of the geological formations and also animations that show the Frasch process in detail. Considerable emphasis is given to amounts produced and the exports of the element. A rather comprehensive survey given in terms of uses found in the various industries. Also a summary of sulfur in sulfuric acid production and its importance to industry."

**Suggestions for Improvement:** (A) "...cannot fail to interest beginning students. It is, however, very elementary, and I could only recommend it for high school, college freshman chemistry courses for those taking chemistry for the first time." (B) "...should serve as a valuable aid in teaching general chemistry but it does not replace conventional teaching methods."

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**YELLOW MAGIC**

**Description:** 16 mm., sound-color, 33 min.

**Producer:** Freeport Sulfur Co.

**Reviewers:** (A) S. Young Tyree, Jr., University of North Carolina
(B) Frederic B. Dutton, Michigan State College

**Possible Utility:** (A) "...I would consider the film suitable for use in almost any type of chemical course that has to do with compounds involving sulfur. Through this film, an appreciation of how and where we obtain sulfur may be passed on to the student."

**Film Content:** (B) "Opens in narrative form as retiring employee relates early history of sulfur mining. History and background about 11 minutes. Excellent description of Frasch Process, rock formations... Auxiliary installations about 14 minutes. Uses and applications about 8 minutes." (A) "The film opens showing a testimonial dinner to one Tom Clark who is evidently retiring from long, active service with the Freeport Sulfur Company. At the insistence of the toastmaster, Tom Frash makes a speech and as he talks, the camera follows his story of the development of modern sulfur mining technology. A short while is devoted to describing the early discovery of sulfur in Louisiana and Texas, as well as the early troubles of getting at this sulfur. This very easily works into a scene where Herman Frash talks glibly enough to get the capital necessary to make his first drilling operation. The need of the country for sulfur is explained briefly and dependence of the country on...
CHEMICAL ENGINEERING TECHNIQUES

B. E. Lauer and R. F. Heckman, Professor and Assistant Professor of Chemical Engineering at the University of Colorado. Reinhold Publishing Corp., New York, 1952. v + 496 pp. 100 fgs. 15.5 × 23.5 cm. $6.

A CHEMICAL engineering text without a chemical or mathematical equation? Impossible! No, not at all. Lauer and Heckman have produced such a book, free from chemical equations and calculations. Nevertheless it deals with the chemical industry from a new viewpoint—that of Unit Tasks.

The unit concept did much for chemical engineering education, unit operations became the core of the curriculum. This was followed by a study of the unit chemical processes. Important texts exist in both fields. Lauer and Heckman introduce a new approach, the "unit tasks." These are the units in the series of steps from the beginning to the end of the processing. The six main divisions of the job are (I) Assembly of Materials, (II) Preparation of Materials for Reaction, (III) Production and Distribution of Energy, (IV) Conditions Effecting the Chemical Reaction, (V) Separation and Purification of Materials, and (VI) Further Treatment of Products for Sale, Shipment, Storage, or Other Use.


After the unit tasks and subtasks have been determined for the given job, the final step is to select the particular technique which will accomplish best the required task. If the task is the separation of a liquid from a liquid (Chapter 14) it is apparent that a number of techniques are available and its selection is based on a number of factors. The pertinent factors are outlined at the beginning of each chapter. With liquids, it is of immediate importance whether the liquids are insoluble or soluble in one another. If insoluble in one another, the liquids can be separated by gravity, centrifuging or gas flotation; slime removal and treatment of emulsions are discussed. If the liquids are in solution, a larger number of techniques is available: evaporation, distillation, solvent extraction, salting out, freezing, adsorption, ion exchange, chromatography, and chemical reaction. Each technique is discussed with as much detail as its importance warrants; distillation is discussed as batch, continuous, vacuum, molecular, pressure, azeotropic and extractive. The application and advantage of each technique is pointed out; equipment is discussed briefly and frequently illustrated.

During the preparation of the book the authors collected about 1250 illustrations of equipment for techniques. Of these, only 100 appear in the book. The illustrations have been classified by chapters and made into film strips which can be used by the instructor. Slides as well as film strips can be obtained. This is an enormous aid to the instructor as well as to the students. As a text, where will this book fit into the chemical engineering curriculum? Will it provide the answers? The authors' answer is: yes. They say: "This book will supply the instructor with a ready-made series of film strips which can be used to give a new and different viewpoint to the subject of chemical engineering. The text is a complete unit, organized, written to be used in sequence, with a study manual provided."

The unit task concept is developed and used in this book. Lauer and Heckman say: "The difficulties involved in prospecting for sulfur are vividly shown when the camera follows a prospecting crew through the marshland. . . ."

"Finally, the importance of sulfur to the world is covered by listing roughly in order of importance the uses to which sulfur is put . . . ."

General Criticism and Rating: (A) "...one laboratory that shows a man titrating a solution, and the speaker explains that this operation is called 'titrating.' This small incident, I feel, is the cue that should tell us the level at which the film is pitched. Some hint of the level of the film may be obtained by noting that sulfuric acid as a word or formula appears nowhere in the film. For example, the statement is made that sulfur is of great importance to agriculture as a fertilizer, dustings, and sprays with no suggestion of the chemical compounds involved." (B) "Good use of animated drawings."

* CHEMICAL ENGINEERING TECHNIQUES

B. E. Lauer and R. F. Heckman, Professor and Assistant Professor of Chemical Engineering at the University of Colorado. Reinhold Publishing Corp., New York, 1952. v + 496 pp. 100 fgs. 15.5 × 23.5 cm. $6.

A CHEMICAL engineering text without a chemical or mathematical equation? Impossible! No, not at all. Lauer and Heckman have produced such a book, free from chemical equations and calculations. Nevertheless it deals with the chemical industry from a new viewpoint—that of Unit Tasks.

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Polarography, Volume I


To those who have had occasion to use the polarographic method, the book "Polarography" by Kolthoff and Lingane is as familiar as a bottle of mercury. To these investigators the first volume of the new edition will need no introduction other than to say that it contains a thorough discussion of the principles and techniques of the field from the time of its discovery by Heyrovsky in 1920 through the developments of 1950.

The need for a revision of the 12-year-old first edition is emphasized by the authors in the preface to the new edition. They say, "In the dozen years since the first edition of this book appeared, the polarographic literature has tripled in size and the current rate of growth exceeds 200 journal articles per year." Judging by Volume I of the second edition that need has been well filled.

The new edition is in two volumes. Volume I discusses: Theoretical Principles, and Instrumentation and Technique. Many of the 19 chapter headings will be familiar to the users of the first edition. There are, however, four new chapters covering: Adsorption, Catalytic Waves, Common Operations in Polarographic Analysis, and Discussion of the Analysis of Specific Elements and Compounds, both inorganic and organic, together with sections on biological applications and amperometric titrations. The division of material between the two volumes is a logical one, the development being from a treatment of polarography per se in Volume I to the detailed discussion of individual analyses in Volume II.

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Discussion of the analysis of specific elements and compounds, both inorganic and organic, together with sections on biological applications and amperometric titrations have been reserved for Volume II. The division of material between the two volumes is a logical one, the development being from a treatment of polarography per se in Volume I to the detailed discussion of individual analyses in Volume II.

Both the neophyte and the experienced polarographer will find the discussion of the Modified Equation for the Doping Electrode Diffusion Current and the much augmented chapter on Factors That Govern The Diffusion Current useful in theoretical studies as well as in the practical application of the method. Chapter XVIII, Common Operations In Polarographic Analysis, can be recommended as a useful guide to those who are about to run their first polarogram.
have been noted. Thus the standard deviation calculations based on the data in Table 5.1 are in error, and the self-absorption curve for C14 drawn in Figure 6.10 is incorrect. Inconsistencies in notation and terminology were noted in places, as d and f for density (pages 70 and 74), and the interchange of "standard deviation" (page 51), "mean deviation," (page 53) and "statistical accuracy," (page 69). Such errors bespeak a certain haphazardness in the preparation of the original manuscript.

Despite these and other inconsistencies which, it is hoped, will be corrected in future editions, the book serves the useful purpose of compiling in a single, small volume many of the practical aspects of radioisotope tracer assay. Although emphasis is placed on beta-ray measurements and on absolute evaluations of radioactivity, the investigator contemplating a radioisotopic tracing program for the first time will find this book helpful in planning his measurements.

PRINCETON, NEW JERSEY

THE ENZYMES


This treatise is the result of an impressive effort on the part of the editors, J. B. Sumner and K. Myrbäck, who, with 76 collaborators, many of them eminent in their respective fields, have attempted to survey the whole of enzymology. The treatise is composed of 78 chapters, with author and subject indexes at the end of each volume, and is organized along traditional lines, i.e., a series of introductory chapters followed by a chapterwise treatment of all of the enzyme systems that are generally recognized as entities.

The first chapter is devoted to a rather informal account of the development of enzymology, its domain and terminology, and a discussion, which is largely historical in character, of the concept of the intermediate complex and its consequences. In the latter instance the discussion is neither rigorous nor general. That enzymes are primarily proteins hardly justifies the inclusion in this treatise of a chapter which essays to cover both the physical chemistry and chemical kinetics of enzymes, particularly when it is done at the expense of a rigorous and general treatment of the most characteristic property of enzymes, viz., their catalytic activity. It is the reviewer’s opinion that, since the physical chemistry of proteins has been adequately covered in several excellent and modern monographs, it would have been wise to dispense with the discussion of the physical chemistry of proteins in Chapter two and to devote all of the space allotted to this chapter to the subject of general enzyme kinetics, for a really satisfactory treatment of this topic has not been given in any review written in the last 20 years.

The topic of enzyme specificity is treated in the classical manner in Chapter three, and while the account is an interesting and readable one it fails to recognize one of the most common errors of enzyme chemistry, i.e., the drawing of conclusions in respect to the effect of structure on the combination process from isolated experiments in which the only thing measured is the rate of appearance of a reaction product or the rate of disappearance of the substrate. Chapters four, five, six, and eight are concerned with the biological aspects of enzyme reactions rather than with the properties of enzymes per se. While these areas are certainly fertile and important ones they are in a sense applied enzyme chemistry, at least in their present stage of development, and consequently are of greater interest to the biologist than to the chemist. The inhibition of enzyme-catalyzed reactions is treated in Chapter seven and the account is primarily descriptive in character. The treatment given to the kinetics of enzyme inhibition is not extensive and is at the level found in most of the earlier monographs on enzymology.

The remaining of the treatise, i.e., Chapters nine through 78, is devoted, for the most part, to a description of the biochemical and properties of particular enzyme systems. Since many of these chapters are of limited interest to the general reader attention will be called to only those chapters in which the treatment is such as to interest the reader who wishes to know more about the general features of enzyme-catalyzed reactions than is given in the so-called introductory or general chapters.

Chapter 16 is devoted to a discussion of the properties of β-glucosidase, and aside from any special interest in this enzyme system the chapter is noteworthy because it provides an interesting example of the kind of information that may be obtained through the use of quantitative procedures. Chapter 25 contains an informative analysis of the dependency of the Michaelis constant upon pH in the arginine-arginase system and Chapter 31, a very reasonable treatment of the synthesis of saccharides through phosphorolysis, a reaction of considerable general interest. The other three chapters of Volume I that contribute to a general understanding of enzymatic processes are, Chapter 29, which contains a sound account of the problem, in this case the characteristics of enolase; Chapter 40, an informative treatment of the furmarase and aconitate systems, and Chapter 43, which provides an excellent example of one of the better analyses of an enzyme system, in this instance, carbonic anhydrase.

Chapter 44, by L. Michaelis, is not only of value for its discussion of the theory of oxidation and reduction, but also because it contains some of the last thoughts of a man whose contribution to enzyme chemistry were outstanding. Chapters 45 through 48 are devoted to various aspects of the transphosphorylation process, and all of these chapters, and particularly the latter, are worthy of the attention of the reader who is not interested in any particular enzyme system but is interested in the general aspects of enzyme chemistry. The same is also true of the material covered in chapters 52 through 56, for in these chapters the authors have been able to draw upon the tremendous amount of work that has been done with the codehydrogenases, sucinic dehydrogenas, the flavin containing enzymes, the cytochromes, and the so-called hydroperoxidases. Chapter 56 is of particular interest, aside from its consideration of the mechanism of action of the hydroperoxidases, for it contains an excellent account of the evidence and arguments that provide support for the postulation of an intermediate enzyme-substrate complex. Chapter 61, which is devoted to a discussion of the role of enzymes in luminescence, is of interest because of its consideration of the effect of extrinsic factors such as temperature, pressure, and pH upon such systems. An excellent account of the integration of a multitude of enzyme systems is found in the essay on anaerobic glycolysis, respiration and the Pasteur effect, given in Chapter 63, and in the account of urea synthesis, provided by Chapter 67. The treatment of enzymatic mechanisms in carbon dioxide fixation, given in Chapter 72, is an excellent exposition of a fascinating phase of enzyme chemistry which will give the general reader a good idea of the power and scope of the methods which are currently being used in enzymology.

In the preceding paragraphs the reviewer has attempted to point out those sections of the treatise which would be of interest to the reader whose goal is to gain an understanding of the present status of enzyme chemistry. It is obvious that investigators who are actively engaged in some phase of enzymology will find the treatise of considerable value, not only for bibliographic purposes, but also for an appreciation of the "state of the art" in the various branches of enzymology. The experienced investigator will be annoyed at the lack of precision in many statements, the widespread use of inadequate treatments, the grand speculations based upon enormous extrapolations, and, more seriously, the incomplete reporting by investigators of the exact character of their experimental systems. However, he will realize that this is not entirely the fault of the authors of this book. The fact is,
that enzymology is still in a primitive stage and its history abounds in generalities most of which are probably incorrect. The cautious reader, who is well versed in the principles of chemistry, will derive much benefit from this treatise for he will reject that which is not reconcilable with these principles and learn from that which is.

CARL NIEMANN

• BIOCHEMISTRY AND HUMAN METABOLISM
Burnham S. Walker, Professor of Biochemistry, William Boyd, Professor of Immunoochemistry, and Isaac Asimov, Assistant Professor of Biochemistry, all of Boston University School of Medicine. Foreword by John T. Edsall, Professor of Biological Chemistry, Harvard. The Williams & Wilkins Co., Baltimore, 1952. viii + 812 pp. 21 figs. 48 tables. 15.5 x 23.5 cm. $9.

This is a treatise designed for the use of medical students. It includes a unique selection of material with emphasis on subjects usually studied after a preceding course in biochemistry. Extensive treatment is given to cancer (an entire chapter), to chemical aspects of reproduction and heredity, to pathology and to the chemistry of infection. Even the description of vitamins is included along with deficiency diseases as an aspect of pathology.

With so much space given to the chemistry of disease, the fundamentals of biochemistry are treated briefly. Carbohydrates are presented in 16 pages included in the chapter on Tissue Chemistry. Similarly, lipids are allotted 10 pages and the steroinds with 8 pages in the same chapter. The first chapter is on proteins and amino acids and is followed by one on theories of protein structure. The latter has of necessity to be speculative, although what definite information is available is admirably summarized.

An entire section of nine chapters (278 pages) is given over to metabolism including the chemistry of food and digestion and numerous aspects of abnormal metabolism. The chapter on enzymes is unique and timely. The one on chemistry of hormones is highly to be recommended, and has a nomenclature of the atomic theory which had existed in one form or another for one hundred and fifty years. This was in part because many of his ideas were too far ahead of his time to be accepted, and by the idea of "imponderable fluids" (heat, light, electricity, and so on), which dominated the minds of many of his contemporaries.

Besides his theoretical work, Lomonosov undertook the practical task of operating a glass factory, chiefly to aid his efforts to establish a mosaic industry in Russia. The factory was not a financial success, and no one carried on his ambitious program. The latter has of necessity to be speculative, although what definite information is available is admirably summarized.

The cautious reader, who is versed in the principles of chemistry, will derive much benefit from this treatise for he will reject that which is not reconcilable with these principles and learn from that which is.

CARL NIEMANN

• ACIDS AND BASES: THEIR QUANTITATIVE BEHAVIOUR

One of Methuen's Monographs on Chemical Subjects, this small book is described as a brief and unified account of some of the applications of the subject of acids and bases to a wide variety of chemical problems.

Chapter I on the nature of acids and bases gives the history of the terms, the experimental bases of the Arrhenius concepts and the Brönsted-Lowry formulation.

Chapter II discusses in more detail the equilibria in water, the nature of buffers and titration curves.

Chapter III covers the field of non-aqueous solvents, which has received so much attention lately from practicing analysts.

Chapter IV gives a highly simplified treatment of inter-ionic attraction theory as applied to these topics and makes some mention of the Hammett and other such ideas.

Chapter V is on acid strength and molecular structure and Chapter VI on acid-base catalysis.

In the last chapter (VII) the Lewis definitions are introduced and critically discussed.

The cautious reader, who is well versed in the principles of chemistry, will derive much benefit from this treatise for he will reject that which is not reconcilable with these principles and learn from that which is.

CARL NIEMANN

• RUSSIA'S LOMONOSOV
Boris N. Menshutkin. Translated from the Russian by Jeannette Eyre Thal and Edward J. Webster, under the direction of W. Chapin Huntington. Princeton University Press, 1952. viii + 208 pp. 11 figs. 5 plates. 14.5 x 22 cm. $4.

Menshutkin is, in a sense, the discoverer of Lomonosov as a scientist. Beginning in 1904 he made it his life work to edit and publish the writings of Lomonosov which had been buried in the archives of the St. Petersburg Academy of Sciences. Finally, in 1937, he summed up his work in this definitive biography, here translated by the Russian Translation Project of the American Council of Learned Societies.

Lomonosov was one of the world's universal geniuses. His name as a poet, historian, and philologist survived in Russia, but the cult of glorification of everything done by the Russians had become dominant in the Soviet Union. As a result, his works can be read without the constant necessity for discounting many statements which are found in the more recent historical material from the U. S. S. R.

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Lomonosov saw the atoms as concrete objects, and founded his whole system of physics and chemistry in philosophical terms. Lomonosov had no such misconception. If his ideas had been considered a failure.

Lomonosov was one of the first to appreciate fully the significance of the atomic theory which had existed in one form or another since 1862 from the days of the Greeks. Most of his predecessors and contemporaries who had espoused this theory had thought of it in speculative terms. Lomonosov saw the atoms as concrete objects, and founded his whole system of physics and chemistry in philosophical terms.

He was able to express the kinetic theory in terms of modern form. He was not led into the errors induced by the idea of "imponderable fluids" (heat, light, electricity, and so on), which dominated the minds of many of his contemporaries. Even Lavoisier still considered calorie a material substance, but Lomonosov had no such misconception. If his ideas had been much wider known and accepted the phlogiston theory would probably never have occupied the influential position it did.

Lomonosov undertook the practical task of operating a glass factory, chiefly to aid his efforts to establish a mosaic industry in Russia. The factory was not a financial success, and no one carried on his ambitious program of designing mosaic pictures; so this enterprise, too, might have been a failure.

In fact, considered from the viewpoint of his apparent influence on subsequent history, Lomonosov's life cannot be accounted a success. Yet he was well known to his contemporaries, and it is probable that his ideas would have been much wider known and accepted the phlogiston theory would probably never have occupied the influential position it did.
highly probable that an investigation of his influence in western Europe would reveal that his ideas were more effective than they seem at first glance.

This book may be read solely as the biography of one of the world's great scientists, for the picture it gives of life in eighteenth century Russian intellectual circles, or for the light which it casts on the conduct of science in Russia even today. In any case, the experience will be rewarding.

HENRY M. LEICESTER

College of Physicians and Surgeons
San Francisco, California

• AN INTRODUCTION TO THE CHEMISTRY OF THE SILICONES


The approach to his subject as well as the general excellence of the first edition have been admirably maintained by Professor Rochow in the present book. It comprises a critical survey of the field which is at the same time comprehensive and general enough to completely satisfy the non-specialist and near-specialist. New chapters have been added and are entitled: The Carbon-Silicon Bond, Synthesis of Organosilicon Compounds, and The Physical Chemistry of Silicones. Further, the tables of compounds and references are now more readily available in a separate chapter.

While this reviewer is not in agreement with several of the conclusions and hypotheses presented in the chapter on the Carbon-Silicon bond, the author's remarks at the end of this chapter very properly leave the reader with the impression that in describing the ionic composition of river waters seems improper. An up-to-date bibliography suitable for further elaboration of the topics is appended to each chapter.

EDWARD D. GOLDBERG

Scripps Institution of Oceanography
La Jolla, California

• EINLEITUNG IN DAS STUDIUM DER CHEMIE

Ira Remsen. Translated into German by H. Reihlen. 15th edition. Theodor Steinkopf, Dresden, 1950. xvi + 345 pp. 60 figs. 5 tables. 15.5 x 23.5 cm. DM 10.

The ghost of dear old Dr. Remsen will smile benignly on this, the 15th German edition of his "Introduction to General Chemistry," for he will find it not different in spirit from his first (1884) edition. Dr. Reihlen, who unfortunately suffered a heart attack shortly before its publication, will be there with Remsen, in a niche well earned by this work of labor and love: for few indeed are the textbooks which so withstand the ravages of time.

It is sound, classical general chemistry, brought essentially up to date. As such, it may be useful to the graduate student for pre-exam reading in scientific German; for the type is clear and captioned, and the vocabulary simple. But teachers of chemistry in the United States will find scarcely any new approaches, little to fire the student's imagination, and few drawings. Today's front-page science is not profess to be and is not a comprehensive treatise on the subject. Such a work is still unwritten.

L. H. SOMMER

Pennsylvania State College
State College, Pennsylvania

• PRINCIPLES OF GEOCHEMISTRY


A textbook in geochemistry has long been awaited by workers in earth sciences. The present book attempts to frame earth evolution against a background of chemical theories along with information from the other natural sciences. The author surveys the geochemical domain, following the principles of V. M. Goldschmidt, with chapters on the history and definition of geochemistry; elementary cosmological theory; the structure and composition of the earth; a review of thermodynamics and crystal chemistry; igneous rocks; sedimentation processes; the hydrosphere; the atmosphere; the biosphere; metamorphism; and the geochemical cycle.

Although most of the topics are covered adequately for an initial exploration of this field, the reviewer feels that a more generalized and a more basic presentation of the nuclear and atomic properties of matter are necessary. Isotopic fractionation in nature has already provided a wealth of information on paleochemical investigations, especially in the cases of oxygen and sulfur. The role of naturally occurring radioactive elements in geo-chronology is dealt with very lightly. To realize the full implications of such phenomena the characteristics of nuclear species must be elucidated.

Further, the concept of the ionic potential is certainly less useful than a generalization of chemical properties based upon electronic structures of the elements in interpreting the disposition of matter in both time and space. It is extremely difficult to explain the geochemical paths of manganous and calcium ions, both with similar ionic potentials, without such a study.

The book is relative free of errors, although the use of salinities in describing the ionic composition of river waters seems improper. An up-to-date bibliography suitable for further elaboration of the topics is appended to each chapter.

HUBERT N. ALVEA

Princeton University
Princeton, New Jersey

• THE MERCK INDEX OF CHEMICALS AND DRUGS


The sixth edition will increase the value to chemists of this well-known book. It is only ten per cent larger than the previous edition, but it differs in several important respects. The main section, on chemicals and drugs, has been expanded to more than 1000 pages—nearly double the size in the fifth edition. The section on clinico-chemical tests and reagents has been eliminated and substituted in this edition by a shorter section on Organic "Name" Reactions. This section (70 pages) can be exceedingly valuable to a chemist for it describes briefly, with literature references, more than 300 organic reactions which are known by their authors' names. Who has not been embarrassed by his inability to identify and recall obscure organic "name" reaction?

A new section on radioisotopes and their use in medical therapy is included, as well as a short table of standard buffers for pH calibration. The useful tables of the earlier editions, too numerous to list separately, have been retained and brought up to date.

Finally, an up-to-date periodic table and table of atomic weights on the inside covers put the finishing touches on an excellent special-use chemical handbook.
is the primary contribution of statistical methods to chemical experimentation. Chemists have developed a facility for extracting the information from their experimental data (by awkward methods sometimes) but have not, in general, gained an appreciation of the need for experimental designs giving efficient estimates of effects and valid estimates of experimental errors.

This manual has been prepared as an adequate description of how the present knowledge on design of experiments can be applied in chemical investigation. It contains a collection of methods most commonly employed by the author in connection with his work in one of the largest industrial research organizations. The book is built on case histories. A knowledge of the mathematics of probability is not a requisite, but the author conveys a fundamental understanding of the philosophical logic and practical limitations of statistical technique.
The long awaited, 25-year CUMULATIVE INDEX to the Journal of Chemical Education is now ready. This is not a compilation of the annual indexes. It's a completely new index made from a study of each issue published since January, 1924. In fact, this Cumulative Index is a veritable bibliography of the entire field of chemical education.

You will find it a source book full of ideas that can be used to enhance your teaching and to help you in your laboratory work. Teachers will find the bibliography of lecture demonstrations alone worth more than the price of the index.

An indication of the wealth of material available may be had by scanning this list of some of the principal items with the approximate number of entries under each.

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Examination

A new examination for Chemist, Engineer, Mathematician, Metallurgist, Physicist, and Electronic Scientist, has been announced by the Board of U. S. Civil Service Examiners for the Potomac River Naval Command, to fill positions paying from $3410 to $10,800 a year in Naval field establishments in Washington, D. C., and vicinity and in the Engineer Center at Fort Belvoir, Virginia. Positions of electronic scientist in other Federal agencies in Maryland, North Carolina, Virginia, and West Virginia, will also be filled from this examination.

No written test is required. To qualify, applicants must have had appropriate education or experience or a combination of both. In addition, for the higher paying jobs, they must also show professional experience in the field of work for which they apply. Applications will be accepted from college students who expect to complete the required study within 9 months. Age limits for positions paying $3410 are 18 to 35 years; for all other positions, 18 to 62. These age limits are waived for veterans.

New Literature

A new 8-page booklet titled “Facts and Figures on Three Powerful X-Ray Tools for Non-Destructive Analysis” is available gratis from C. J. Woods, Research and Control Instruments Division, North American Philips Co., Inc., 750 South Fulton Avenue, Mount Vernon, New York. Diagrams are used to show the principles of operation for the three instruments, data are given on recommended fields of application, and results to be obtained are explained.

In addition, the booklet clearly illustrates how the simplest film diffraction unit consisting of the basic X-ray generator plus a camera can be converted to spectrometer and spectrograph use through the addition of these components.

The September issue of CA Notebook has just been published by the Chicago Apparatus Co., 1735 North Ashland Ave., Chicago 22, Illinois. Thirty-two pages illustrate and describe laboratory apparatus including balances, hot plates, colorimeters, distillation units, and laboratory furniture. Copies may be secured by applying to the Chicago Apparatus Co.

A new catalogue describing over 200 different thermometers ranging from −330° to +760°F. and introducing two newly developed thermometers, has just been offered to our readers. Copies of Catalog A-52 may be obtained from Brooklyn Thermometer Co., 217-09 Merrick Boulevard, Springfield Gardens, Long Island, New York.

The current issue of The Beckman Bulletin, published by Beckman Instruments, Inc., South Pasadena 36, California, includes some notes on the uses of the flame photometer as well as a story on the theory and design of the high frequency conductometer.

Arthur S. LaPine & Co.'s September issue of Lanco Apparatus News contains eight pages with announcements about mechanical convection ovens, constant temperature circulating system, heating tape, balances, stopcock adapters, and other laboratory equipment. Copies may be secured by writing to the company at 6001 S. Knox Ave., Chicago 29, Illinois.

Labitems for September features a brief but interesting article headed, “New absolute and differential manometers simplify measurement of pressure and vacuum.” In addition, the latest laboratory items are illustrated and described. Copies can be secured from the Emil Greiner Co., 20-26 N. Moore St., New York 13, New York.

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**Braided Tygon Tubing**

Tygon flexible plastic tubing with a triple wire, stainless steel outer braid has just been made available by the U. S. Stoneware Co. of Akron, Ohio. This new form of Tygon tubing was developed to meet the demand for a chemically resistant, translucent, nontoxic, flexible tubing and hose for high pressure applications.

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**New Apparatus Catalogs**

Scientific Glass Apparatus Co., Inc., Bloomfield, New Jersey, has just announced the publication of two new catalogs. One, known as the “General,” has 1000 pages illustrating and describing a complete line of scientific instruments, apparatus, and general laboratory glassware and supplies. The second, entitled “Inter-Joint” Glassware, contains 420 pages covering their entire line of manufactured glassware, both standard and special.

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A particularly good feature is the inclusion of 26 experiments, and the graphs and tables of data obtained from them constitute the illustrative material of the text. These experiments could be undertaken with profit by anyone desiring an experimental indoctrination in polarography.

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