CHEMICAL THEORY, A PRACTICAL METHOD FOR TEACHING IT.*

BY FREEMAN P. STROUP.

One of the many problems that the teacher of chemistry has to solve is that of presenting the subject of chemical theory to his pupils in such a clear manner that all of them may get a fair grasp of it. The student who has an analytical mind, and whose preliminary training has been such as would develop it, has comparatively little trouble in understanding the explanations given in the ordinary text-books on chemistry, particularly when these are analyzed for him by an instructor; but to the student not blessed with an analytical mind, or whose early training has been faulty—the student who can not solve correctly the simplest mathematical problems—the correct writing of a chemical formula offers serious difficulties, while the correct balancing of chemical equations seems to him a veritable Chinese wall standing between him and the goal he is striving to reach.

All teachers who are at all interested in their work rejoice to see their bright pupils do good work, but the conscientious instructor gets more real enjoyment out of noting the gleams of dawning intelligence that occasionally light up the countenance of one of the dullards of his class as he begins to comprehend something which is being explained, possibly something which the majority of his classmates had grasped long before. In his efforts to reach these unfortunates the writer of this paper has tried various schemes, some of his own invention, some devised by others, and some his own adaptation of the ideas of others, and out of his experiences, extending over nearly a score of years, there has been evolved a system which he has used for several years and has found very helpful. Not only has its use enabled him to give his poorest students a fair understanding of chemical theory, but, he believes, even his brightest students have been given a stronger hold on the subject than they could have gotten otherwise with the same amount of study. To some of you this "card system" (so called for want of a better name) may seem too much on the order of the "kindergarten" to be given a place in a college professor's methods, but so long as it produces results that are worth while, he feels justified in using it, and in passing it along to his fellows in the fraternity.

EQUIPMENT.

The equipment is simple and need not be expensive, as it may be made from cheap and easily obtainable materials. If a wooden blackboard is available, one into which small nails may be driven, it will serve very well. In its absence one can be made from Compoboard or some similar light material, and enclosed in a frame made of floor lumber or similarly grooved board. It should be made so that both sides are available for use, one for Organic formulas and the other for Inorganic formulas and equations, and, of course, should be provided with hooks or supports so disposed that either side may be used at the pleasure of the operator. Inasmuch as the system is generally used to supplement blackboard instruction the board should be painted a dead black. There should be at least 30 by 60 inches of clear space inside of the frame. Horizontally across the faces of the board should be stretched wires, the chief function of which is that of supporting the

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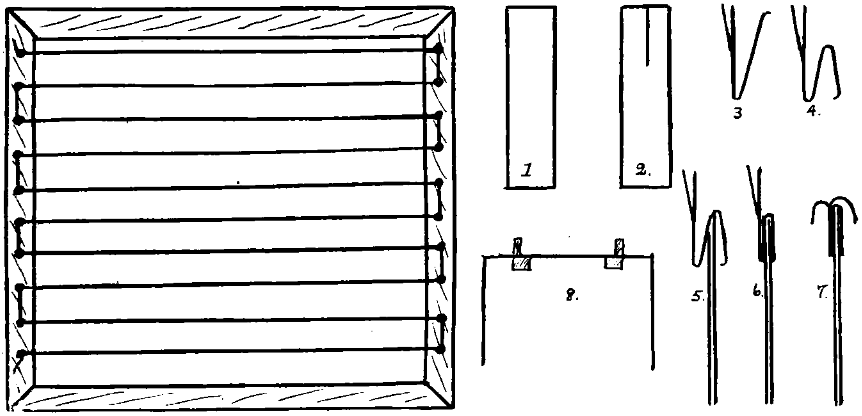
cards used in demonstrations. Number 22 tinned steel or iron wire (about the size of ordinary broom wire) is quite suitable, as it can be easily stretched and, unlike copper wire or twine, remains taut. On the Inorganic side of the board the wires should be just three inches (the width of the cards) apart, and, because the space between two adjacent wires is intended to indicate a valence of one, a heavy white line should be drawn on the board under each wire. On the Organic side the wires are for support only, hence no lines should appear under them, and it is better to have them somewhat more than just three inches apart. At least eight wires are needed on each side, but more may be used to advantage on the Inorganic side.



Part I. **Part II.**

Exhibit A.

Part I.—Board (30 by 30 inches) suitable for Formulas; should be 30 by 60 inches for equations.

Part II —Details for two-way card-hooks: 1, Blank, $1^1/_4$ by $^3/_8$ inches; 2, blank with slit; 3 and 4, edge, showing bending stages; 5, 6 and 7, attaching to cards; 8, card with hooks attached but only one-half of hooks turned down.

There will be needed a lot of dark-colored cards, each to contain the symbol of an element or the formula of a group. The writer made his set from cards intended originally for photograph mounts. A considerable saving may be effected by using both sides of each card, in which case, however, care should be taken to put on opposite sides such symbols or groups as are not apt to appear together in a chemical formula. If both sides are "positive" or both "negative" there will be no trouble. Six inches is a good length for the Inorganic cards and eight inches for the Organic. If only one side of cards is to be used, suitable supporting hooks may be obtained from a good stationer. If both sides are to be used, two sets of hooks may be used, or two-way hooks may be made easily from thin tin-plate (such as is used in making containers for certain well-known types of confections). A little study of the drawings (Exhibit A) should enable anyone possessing a pair of old shears, a small pair of pliers, a hammer, a little time and patience, to turn them out readily and in quantity.

The lettering on the cards may be done with crayon, but, preferably, with "white ink" put on with a camel's hair brush. If the "ink" is not obtainable from a stationer, one may be made from mucilage of acacia and zinc oxide, using water for thinning. Zinc oxide seems to be the best pigment, as it is quite opaque, spreads well and remains white, even in an atmosphere containing hydrogen sulphide. A trace of phenol or oil of cloves will keep the "ink" from spoiling.

The Organic cards should be uniformly 3 inches wide, while the Inorganic cards should be 3, 6, or 9 inches wide, according as the symbol or group to be placed thereon has a valence of one, two or three. Cards for atoms or groups of higher valencies are not likely to be needed, as, once the students understand the use of the one-, two- and three-valency cards and the formulas developed with them, they will be able to work out mathematically formulas involving higher valencies. For demonstrating formulas only, a good working set of cards contains three each of the commonly used organic groups and of the commonly used univalent and bivalent inorganic atoms and groups, and two each of the ordinary trivalent atoms and groups. For demonstrating equations readily, about four times as many cards of each kind will be needed. Ordinarily, however, it is not necessary to show more than a few type equations (see Exhibit C), in which case cards for only a few elements and groups are required in quantity.

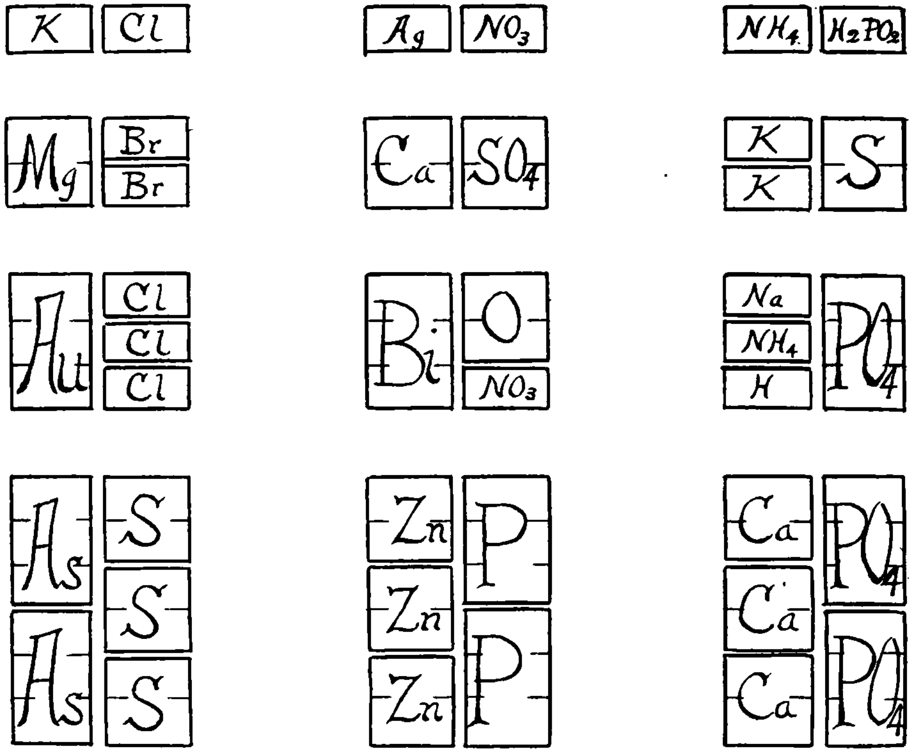


EXHIBIT B.

For demonstrating organic "graphic" formulas it is convenient to have a card for CH_4, another for NH_3, each three spaces wide, and a third one for C_6H_6, seven spaces wide. The lettering on these should be, preferably, in a color distinct from that on the smaller cards. "White ink" tinted with a little lead chromate will do very well.

DEMONSTRATIONS.

Chemical Formulas.—A few typical formulas will be sufficient to demonstrate the use of this card system. In beginning the study of chemical theory with a new class of students the average teacher takes up binary compounds first, and later the more difficult ternary compounds, the majority of which fall under the heads, Acids, Bases and Salts. By means of this system the student can be brought easily to see that in the former an atom or atoms of one element are linked to an atom or atoms of another element, the number of each depending upon their several valencies, while in the latter there are groups of atoms, acting as units, with definite valencies, and that the writing of formulas of ternary compounds should be no more difficult than the writing of formulas of binary compounds. He is taught that a formula is not correctly written unless the total valencies of the positive part (the left side) equals the total valencies of the negative part (the right side). In a card system formula the perpendicular width of the formula should be uniform throughout its length.

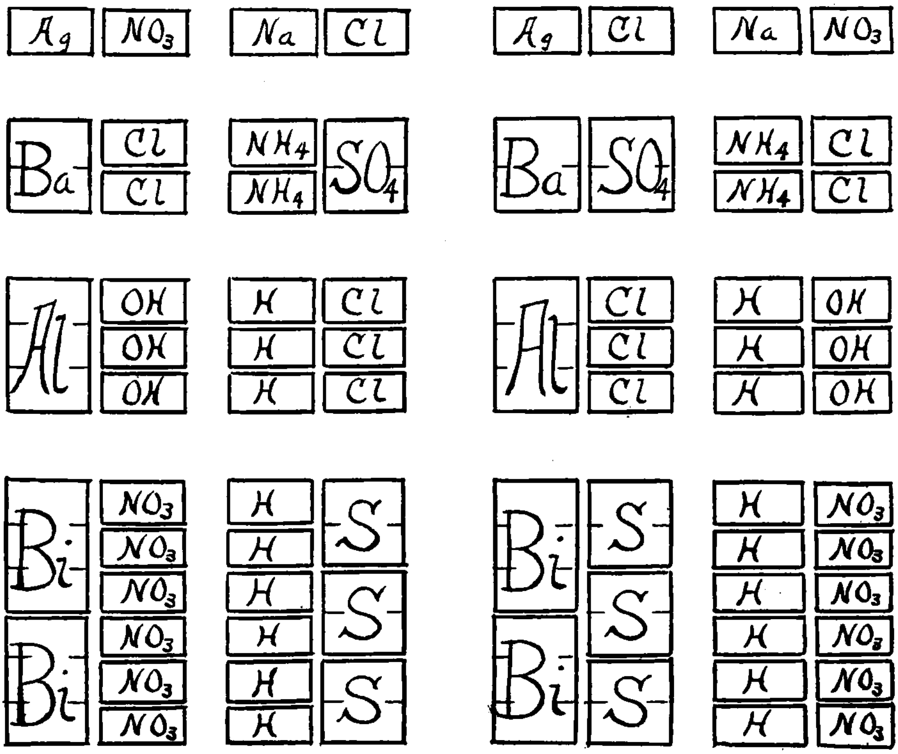


Exhibit C.

Referring to Exhibit B it will be noted that some of the formulas show combinations of two kinds of atoms, some combinations of an atom with a group, some combinations of groups with groups. Students are not apt to go far wrong with formulas of the type of KCl, $AgNO_3$, $NH_4H_2PO_2$ and $CaSO_4$, as only two cards are needed in each case. Now let the teacher put together one Mg and one Br, or one K and one S, and the dullest pupil will see at once that something is out of balance, and will be apt to see that for one Mg two Br, and for one S two K will be required to give a balanced formula. It will then be quite easy for him to understand $AuCl_3$, $BiONO_3$, and $NaNH_4HPO_4$. The last three formulas in the set give the instructor a nice opportunity to develop a formula in stages. Taking As_2S_3 for illustration, one As and one S do not balance, one As and two S overbalance as to S, two As and two S overbalance as to As, while two As and three S just balance. By the time a half dozen such formulas, using different combinations each time, are worked out before him, it is a dense student, indeed, who does not begin to see things in their true perspective, and begin to wonder why he did not grasp them before.

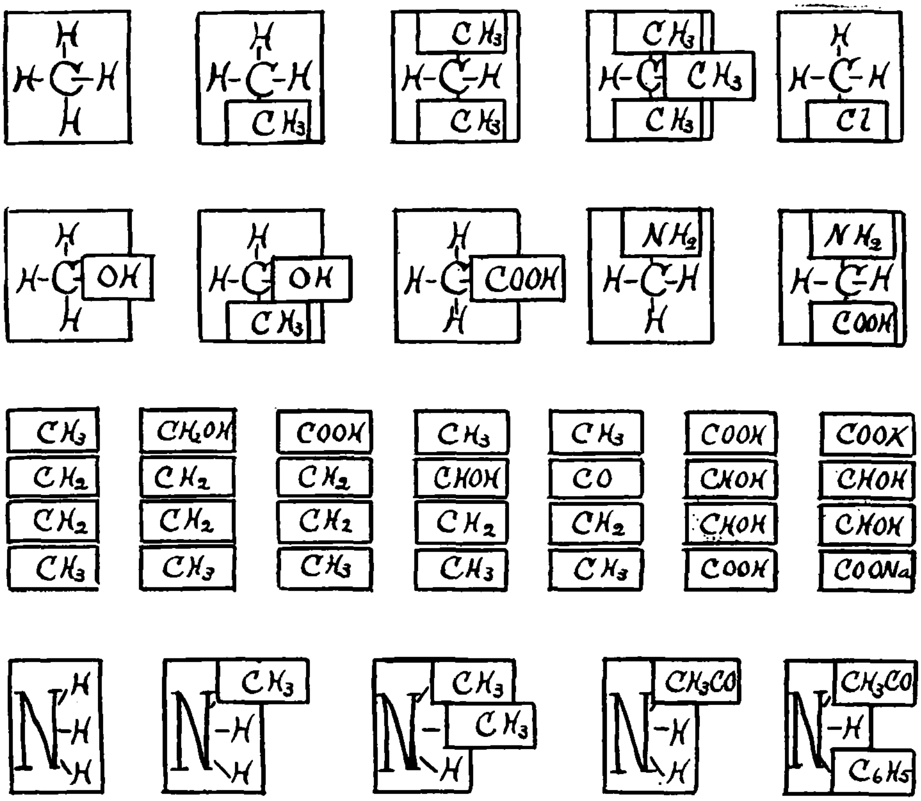


EXHIBIT D.

Of course, after a formula has been built up with the cards, it should be translated into the form in which it would appear in chemical literature, and the proper chemical name should also be taught at this time. It seems best not to attempt any but inorganic formulas at first, but, later, after organic compounds have been taken up for systematic study, formulas of Acetates, Tartrates, Citrates, Benzoates, Salicylates, etc., both of inorganic and organic bases may be shown.

Organic Formulas.—The two main classes of organic compounds are the saturated open-chain and the closed-chain (or cyclic) hydrocarbons and their derivatives, mostly substitution compounds. The former have as their nucleus Methane (CH_4), the latter Benzene (C_6H_6). Certain nitrogenous compounds can best be considered as derivatives of Ammonia or Amine (NH_3). Exhibit D illustrates just a few of the possibilities of the card system as a means of building up complex formulas from simple ones, and for showing the structural relationships that exist between seemingly unrelated substances.

The card system is particularly well adapted to the explaining of isomerism among organic compounds, its effectiveness being best shown, perhaps, with the aromatic compounds, those based on C_6H_6 (Exhibit E). It is easier to shift a card from one position to another than to make the necessary changes in a written formula, and, besides, the writer has noticed that many students "catch on" quicker when they see a card shifted from one place to another than when they see one lot of chalk rubbed off the board, another put on in the restoring of a letter or group, and still another change made at some other place in the formula. In teaching class reactions it is instructive to take up the syntheses of several more or less complex but well-known substances, beginning with the underlying hydrocarbon. One of the best for illustrative purposes is that of Phenacetin, and this may be worked out beautifully with the card system, and generally makes a lasting impression on the minds of most students. Exhibit F suggests how it works out, if the cards are used in the order indicated by the numbers.

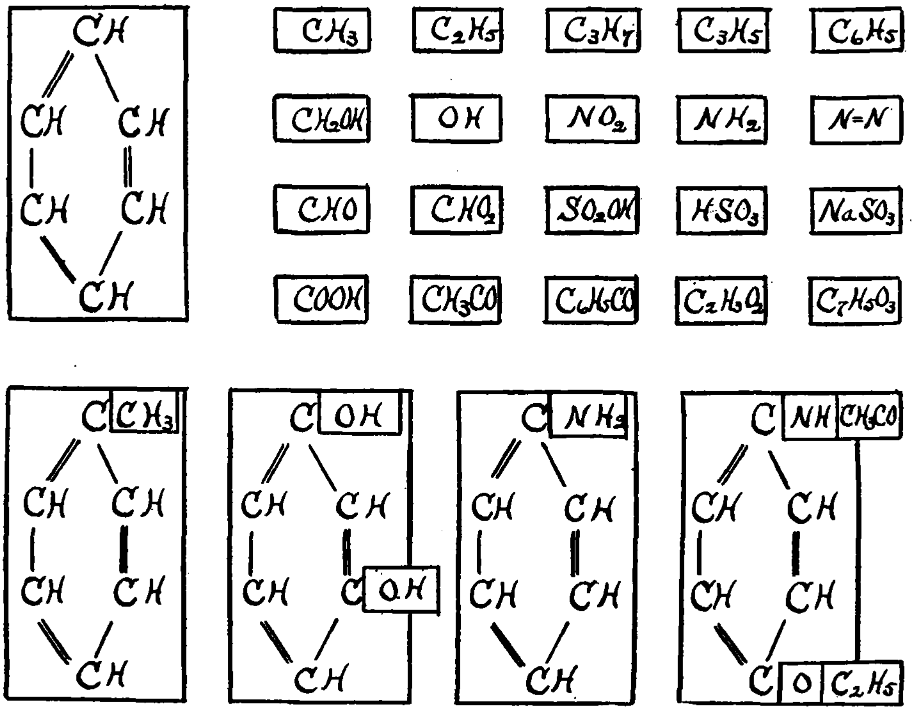


EXHIBIT E.

Chemical Equations.—Exhibit C gives only a few typical equations of the many that may be developed by the card system. It works perfectly for equations involving simple interchange of atoms or groups, without change of valence, but it is not well adapted to the showing of oxidation and reduction equations, where there is change of valence; but, inasmuch as most of the equations which the beginner meets in his studies are of the interchange type, it is worth while to use it. Of course, card system equations should be promptly translated into the ordinary text-book form, for that, after all, is the end sought, the system being only a means readily to attain that end. After the student has once learned to balance equations of this type he can be more or less easily trained in the balancing of oxidation and reduction equations. It should be observed that, by considering each card as standing for an ion, the ionization theory may be effectively demonstrated. Cards making up formulas of highly ionized compounds may be left some distance apart, while those composing the formulas of un-ionized compounds may be butted closely together.

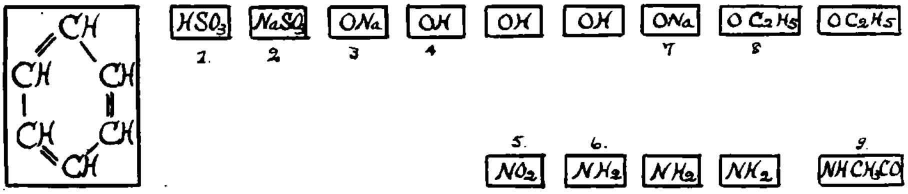


EXHIBIT F.

Some of the writer's pupils have made for home use sets of miniature cards from thick paper or thin cardboard, considerably to their advantage. The mere making of the cards, even though never used, is instructive, as the maker becomes thus impressed with the symbols of elements, the formulas of important groups, and, what is of vast importance to him, the valencies of these.

Enough has been said to give you a fair conception of the possibilities in this system. Actual use of it will bring to light possibilities not suggested in this paper. With the hope that others may have even a greater degree of success with it than the writer has had, he gladly passes it on to his fellow-workers in the teaching fraternity. Should any of them think it worth trying he would be pleased to hear what success they have had with it, and he would be glad to receive suggestions as to how it may be improved.

ENTRANCE REQUIREMENTS TO PHARMACY.*

BY WILLIS G. GREGORY.

Recognizing both the serious shortage in drug clerks and the desirability of attracting to pharmacy the most desirable recruits, the New York State Board of Pharmacy has tried to meet both conditions.

Of course, the temptation is ever present in any emergency to surrender some of the safeguards that have been laboriously constructed through years of endeavor. But unless absolutely necessary, no backward step should be taken.

The problem then was how can present needs be satisfied without the sacrifice of much future good. The Colleges of Pharmacy in our state all reported that high school graduates sometimes declined to study pharmacy because of the

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