HOME-MADE STRUCTURAL MODELS

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For some years the author has been interested in models to show the relative arrangements of ions in ionic crystals and of atom kernels and valence electrons in molecules of co-valent substances. The models shown are a few of the ones made here by the author and one or two specially skillful NYA students. The ideas on the structure of the NaCl, CsCl, CaF_2, and SiO_2 models are taken largely from C. W. Stillwell's excellent series of articles published in the Journal of Chemical Education.[1] The wooden balls used in most of these models were turned out on the college lathe by one of the students. It is possible now however to buy balls of various colors from the chemical apparatus houses. Holes were bored at desired angles and dowel sticks were used to connect the parts.

The sodium chloride structure consists of a 6:6 coordination where each Na^+ ion is surrounded by six Cl^- ions and each Cl^- ion by six Na^+ (except at the corners and edges, of course). Many other salts such as LiBr, NaBr, KBr, RbBr, CaO, CaS, CdO, MgS, LiF, LiCl, LiBr, LiI, NaF, NaI, KF, KCl, KI, etc. show this structure. Larger ions like cesium have a coordination of 8 so that eight Cs^+ ions surround each Cl^- ion and vice versa. Other examples are CsBr, NH_4Cl, CsI, etc. An example of a divalent-monovalent salt is found in the case of CaF_2 where each Ca^{++} ion is surrounded by eight F^- ions but each F^- ion is surrounded by only four Ca^{++} ions. The final result then is twice as many fluorides as calciums. This model is not entirely complete but it should be noted that alternate cubes made by 8 F^- ions do not contain Ca^{++} ions while the others do.

The SiO_2 model is interesting because while it is not ionic it shows a continuous structure and that this material is actually a high polymer where each silicon kernel is surrounded by four oxygen kernels but each oxygen by only two silicons. The bonds here are covalent formed from one electron from silicon and one from oxygen in each case.

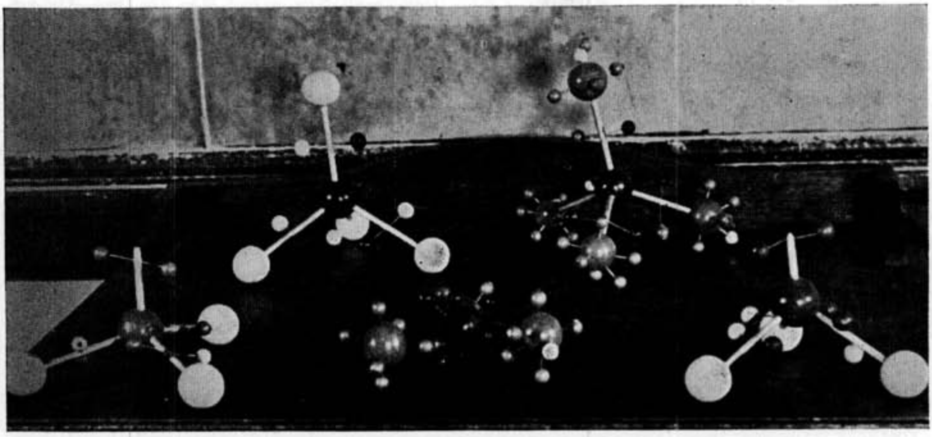
The other models are on a different plan and attempt to show the relative electronic arrangement of some common substances. No attempt at definitely placing electrons has been made since they are of course always in a complicated type of motion. The electrons are shown in different colors only to help visualize their origin and not because electrons from one element are different from those of others.

The methane molecule CH_4 is shown by a (black) carbon kernel at the center tetrahedrally surrounded by four (yellow) hydrogen kernels. Between each hydrogen and the central carbon are a small yellow and a small black ball representing the covalent bond. Ammonia (NH_3) is shown by a (blue) nitrogen kernel with 5 (blue) electrons three of which are shared with one (yellow) electron contributed by each of three hydrogens. This leaves a pair of (blue) electrons unshared which could add a hydrogen ion (H^+) "landing" without any electron. To show this a yellow ball was fitted with a metal tube from an old cork borer just the size to fit on the dowel which bears the two blue electrons. This new group is the ammonium ion (NH_4^+) and has a positive charge because of the shortage of one electron.

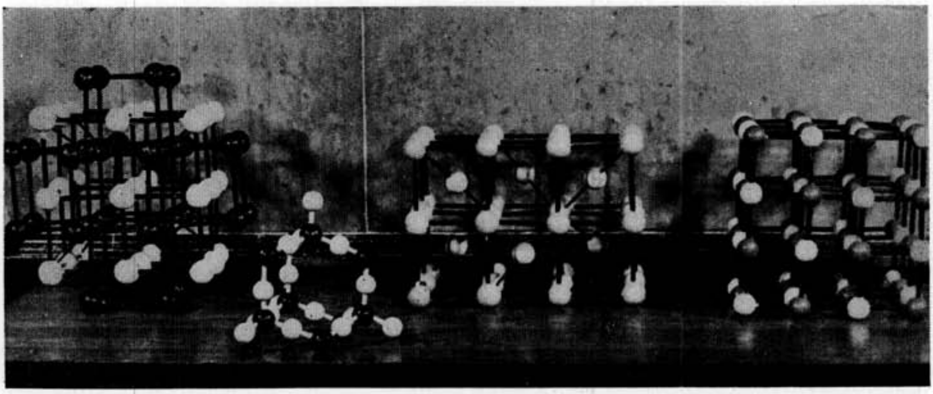
Similarly a water molecule consisting of a (red) oxygen kernel with its 6 red electrons is joined to two (yellow) hydrogens each bringing one electron. There are however two pairs of (red) unshared electrons. A hydrogen ion might take up this position to yield the hydronium ion (H_3O^+). It is conceivable but unlikely that a second H^+ would share the second pair of electrons to produce H_4O^{++}.

The other two models deal with the sulfate and nitrate ions. The sulfate (SO_4^{--}) is made from a (green) sulfur

[1] C. W. Stillwell, J. Chem. Ed. *10* 590-599, 667-674 (1933), *11* 159-168 (1934). See also his text "Crystal Chemistry" McGraw-Hill, 1938.



Hydronium ion H_3O^+ | Methane CH_4 | Nitrate ion NO_3^- | Sulphate ion SO_4^{--} | Ammonia NH_3



Cs^+Cl^- 8:8 | SiO_2 2:4 | $Ca^{++}F_2$ 4:8 | Na^+Cl^- 6:6

kernel at the center with six (green) electrons surrounded tetrahedrally by four (red) oxygen kernels carrying six (red) electrons each. Two of these oxygens are joined to sulfur by a dative covalence where the sulfur furnishes the pair of electrons in each core (these are shown in green). The other two oxygens are joined by one red and one green electron showing a simple covalence while the valence shell of each of the latter two oxygens is completed by one (yellow) electron from an outside source, thus giving the sulfate a negative charge of two. The nitrate ion (NO_3^-) is shown by a (blue) nitrogen kernel with its five (blue) electrons and three (red) oxygens each with six red electrons. One oxygen shares a pair of red and one of blue electrons making a double bond. One oxygen shares a pair of blue electrons contributed by the nitrogen alone (a dative covalence) and one oxygen shares a pair consisting of one red and one blue electron making a normal covalence. Its valence shell is completed by a (yellow) electron from an outside source this making the ion bear a negative charge of one.

By varying the colors used the sulfate model could be used for SiO_4^{----}, PO_4^{---}, ClO_4^-, and OsO_4, etc., while the nitrate model would also illustrate CO_3^{--}, etc. By leaving off some of the dative covalent oxygens the reduced SO_3^{--}, PO_3^{--}, ClO_3^-, ClO_2^-, ClO^- ions etc. might be shown.