TEACHING HYDROGEN BONDING : A NEW APPROACH

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While dealing with school science teaching, sometimes we are placed in a very embarrassing position because we do not have any model or demonstration to make the lesson interesting. Under these circumstances we should try to correlate teaching with environment. In this article an attempt has been made to motivate teachers of chemistry to teach hydrogen bonding at the +2 level through environment.

Hydrogen Bonding – How Much it Concerns us

Man, the elemental component of society, is a product of environment and heredity. Environment means our surroundings, the climate, the kind of house we live in, the type of food we eat, the type of clothes we wear, and other articles of daily use which concern us. Heredity decides the kind of person we are likely to become, but the combined influence of heredity and environment acting together decides what we actually do become. The everlasting aspect of both these factors from the chemist's point of view is that these make use of hydrogen bonding.

What is an Hydrogen Bond?

When a hydrogen atom is attached to a highly electronegative atom, A, the electrons A-H bond are found more towards the electronegative atom. The strong positive charge of the hydrogen nucleus is then attracted by the lone pair of electrons of the electronegative atom of the same or a different molecule, resulting in the formation of a hydrogen bond:

A — — H — — — B

A and B may be same or different electronegative atoms. The broken line indicates the hydrogen bond.

O — — — H — — — O. Example of the same electronegative atoms.

N — — — H — — — O. Example of different electronegative atoms.

Hydrogen Bonding in Ice

The commonest thing in our environment is water, and both the liquid and solid forms of water possess hydrogen bonding. The crystal structure of ice contains an oxygen atom surrounded by four other oxygen atoms through hydrogen atoms in a tetrahedral arrangement as shown in Figure 1.

Water in the liquid form (Fig.1) contains hydrogen bonding with a similar arrangement. This evidently means that only a fraction of the total hydrogen bonding breaks when ice melts and is converted into the liquid form.

How much Hydrogen Bonding is Broken when Ice Melts

We have already discussed that in ice each molecule has a complete set of hydrogen bonds which bind it to four other molecules. Water vapour, on the other hand, behaves as if the molecular units are separated water molecules of 18 amu. This obviously shows that the process of conversion of ice into vapours is a process in which all the hydrogen bonds are broken.

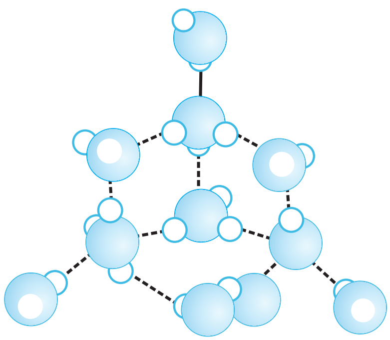

Fig.1: Hydrogen bonding in Water–Shaded sphere: Oxygen atom; Hollow sphere: Hydrogen atom

$CH_{4(s)}\quad CH_{4(g)}\quad \Delta_S H = 2kcal/mole$

The enthalpy of sublimation is 12 Kcal/mole.

$H_2O_{(s)}\quad H_2O\quad \Delta_S H = 12kcal/mole$

Methane in contrast to water can form no hydrogen bonds in the solid phase. For solid methane, the sublimation process requires 2 Kcal/mole of methane.

The enthalpy of sublimation for methane denotes an energy quantum to separate molecules against Vander Waal's attraction, and this is a requirement for any system, including water. As Vander Waal's forces depend upon the size and shape of the molecules, and water and methane both being tetrahedral species have the same molecular size . It, therefore, seems plausible to expect that the extent of Vander Waal's attraction in both cases is the same. On this basis the breaking of the hydrogen bonds in ice requires 12–2= 10 Kcal/mole of energy. When ice melts, about 1.4 Kcal of thermal energy is absorbed per mole of water (remembering that a mole of ice contains 18 g ice and phase change of 1 g ice requires 80 calorie of thermal energy). This is 14 per cent of the total energy required for the breaking of all the hydrogen bonds. We therefore conclude that the melting of ice breaks about 14 per cent of the hydrogen bonds and leaves the remaining bonds intact.

Hydrogen Bonding Affects Solubility

When an uncharged organic compound dissolves to any appreciable extent in water, the solubility may be attributed to hydrogen bonding. Thus, dimethyl ether is completely miscible with water, whereas dimethyl sulphide is only slightly soluble in water. Oxygen as compared to sulphur has a far greater tendency to form hydrogen bonds.

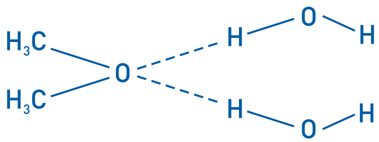

Fig.2: Hydrogen bonding between ether and water

Carbohydrates such as glucose and sugar which are important articles of our daily use dissolve in water due to the formation of hydrogen bonding. Urea, another organic compound and an important fertiliser, is soluble in water due to hydrogen bonding. Each urea molecule provides seven sites for the formation of hydrogen bonds with water molecules.

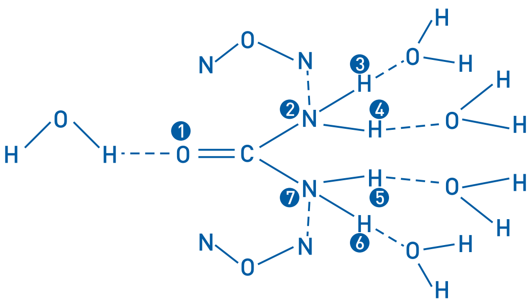

Fig. 3: Hydrogen bonding in urea and water

Hydrogen Bonding in some Compounds of Daily Medicinal Usage

When something goes wrong with our ears, eyes and throat, we use hydrogen peroxide, boric acid and glycerine, respectively, to cure the disease. All these medicinal compounds contain hydrogen bonding. Whether the hydrogen bonding plays any part or not in curing these diseases we do not know definitely but hydrogen bonding helps in aggregation of these compounds. The aggregation of boric acid molecule to give solid is shown in Figure 4.

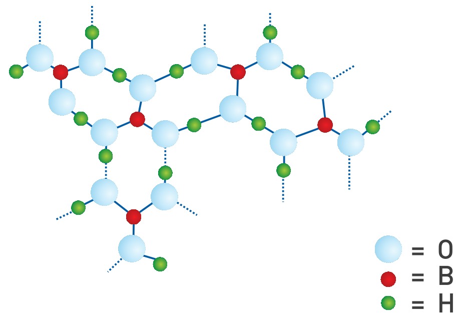

Fig.4. Hydrogen bonding in boric acid — broken lines indicate hydrogen bonding

Synthetic Fibres and Hydrogen Bonding

Synthetic fibres surround us. They are made by man. Synthetic fibres are polymers and result from a repeating arrangement of small molecules. Some of the synthetic fibres also contain hydrogen bonding. The commonest example is that of nylon which is a polyamide. The long polyamide chains are held together by the formation of hydrogen bond between the CO and —NH groups as shown in Figure 5.

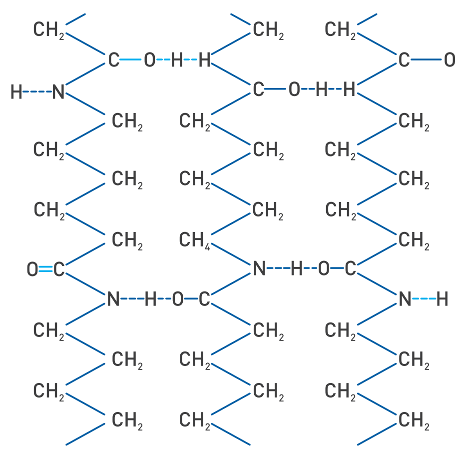

Fig. 5: Hydrogen bonding in polyamide—broken lines indicate hydrogen bonding.

Cleansing Action of Soap and Hydrogen Bonding

Everyone knows that water makes things wet. But do you know that it is possible to make water 'wetter'.? By that we mean that substances may be added to water which enable water to soak into materials better. To understand this, we must realise that the surface of water acts like an elastic film due to hydrogen bonding. To some extent the film tries to keep water away from the things it touches, that is, water soaks into many materials only to a very small extent. If the surface film of water is broken or weakened, the water is better able to soak into the things it touches. In other words, water is wetter. When soap is added to water, the anion of the fatty acid of soap breaks the hydrogen bonding of water molecules in its immediate vicinity, and makes the surface film of water weak. This enables water to soak into fabrics faster and farther than it could otherwise do. The dirt particles attached to the fabric in turn are surrounded by water which rinses them away. This accounts for the effectiveness of soap as a cleansing agent.

Hydrogen Bonding and Humanity

Man himself is fabricated of H-bonded materials. Nucleic acids are of great interest because they are the units of heredity, the genes, and because they contain hydrogen bond of the type N — — — H — — — O.

Water, which itself contains hydrogen bonding, influences the chemical behaviour of metabolism through fresh hydrogen bonds. Water molecules can attach themselves to other molecules in the system by forming hydrogen bonds in either of two ways. Firstly the water molecule may supply the positive centre hydrogen atom as in the case of the negative centre supplied by fats in the body.

Alternatively, the water molecule may supply the negative centre of oxygen atom to interact with the positively charged hydrogen atoms, as in the case of the positive centre supplied by proteins in the body.

In the end it may be emphasised that these are only a few examples of the things that directly concern us. The teacher can make use of several other examples to arouse the interest of the child in the learning of this topic which is of immense use to him.