Intermolecular Forces

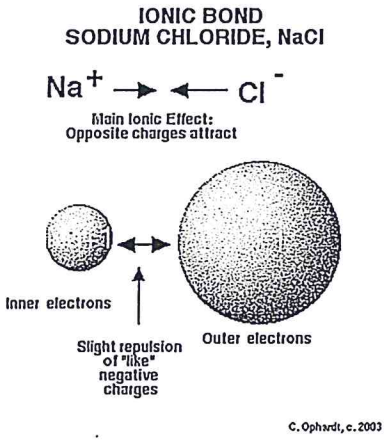
The physical properties of melting point, boiling point, vapor pressure, evaporation, viscosity, surface tension, and solubility are related to the strength of attractive forces between molecules. These attractive forces are called Intermolecular Forces. The amount of "stick togetherness" is important in the interpretation of the various properties listed above.

Introduction

There are four types of intermolecular forces. Most of the intermolecular forces are identical to bonding between atoms in a single molecule. Intermolecular forces just extend the thinking to forces between molecules and follows the patterns already set by the bonding within molecules.

Ionic Forces

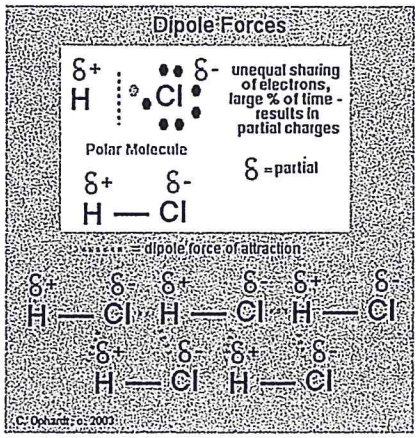
The forces holding ions together in ionic solids are electrostatic forces. Opposite charges attract each other. These are the strongest intermolecular forces. Ionic forces hold many ions in a crystal lattice structure. Review - Ionic Bonds



Dipole Forces

Polar covalent molecules are sometimes described as "dipoles", meaning that the molecule has two "poles". One end (pole) of the molecule has a partial positive charge while the other end has a partial negative charge. The molecules will orientate themselves so that the opposite charges attract principle operates effectively.

In the example on the left, hydrochloric acid is a polar molecule with the partial positive charge on the hydrogen and the partial negative charge on the chlorine. A network of partial + and - charges attract molecules to each other. Review - Polar Bonds



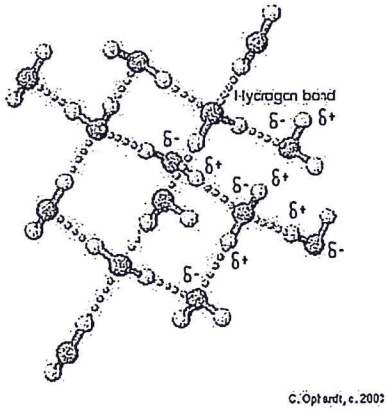
Hydrogen Bonding

The hydrogen bond is really a special case of dipole forces. A hydrogen bond is the attractive force between the hydrogen attached to an electronegative atom of one molecule and an electronegative atom of a different molecule. Usually the electronegative atom is oxygen, nitrogen, or fluorine. Link to more extensive discussion: Hydrogen Bonding

In other words - The hydrogen on one molecule attached to O or N that is attracted to an O or N of a different molecule.

In the graphic below, the hydrogen is partially positive and attracted to the partially negative charge on the oxygen or nitrogen. Because oxygen has two lone pairs, two different hydrogen bonds can be made to each oxygen. This is a very specific bond as indicated. Some combinations that are not hydrogen bonds include: hydrogen to another hydrogen or hydrogen to a carbon.

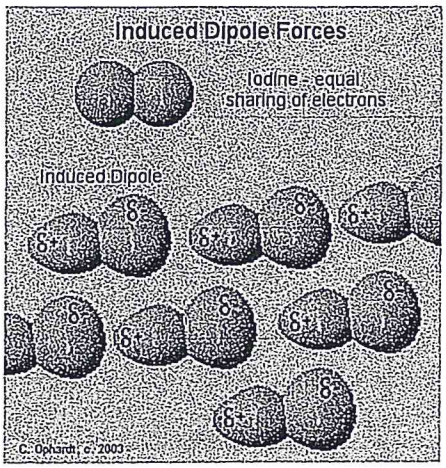
Hydrogen Bonding in Water



Induced Dipole Forces

Forces between essentially non-polar molecules are the weakest of all intermolecular forces. "Temporary dipoles" are formed by the shifting of electron clouds within molecules. These temporary dipoles attract or repel the electron clouds of nearby non-polar molecules.

The temporary dipoles may exist for only a fraction of a second but a force of attraction also exist for that fraction of time. The strength of induced dipole forces depends on how easily electron clouds can be distorted. Large atoms or molecules with many electrons far removed from the nucleus are more easily distorted. Review - Non-Polar Bonds



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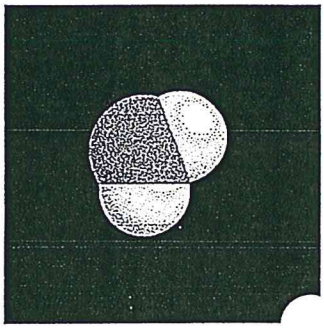
Intermolecular Forces

Skills to develop

- Classify intermolecular forces as ionic, covalent, London dispersion, dipole-dipole, or hydrogen bonding.
- Explain properties of material in terms of type of intermolecular forces.
- Predict the properties of a substance based on the dominate intermolecular force.

Intermolecular Forces



Forces binding atoms in a molecule are due to **chemical bonding**. The energy required to break a bond is called the **bond-energy**. For example the average bond-energy for O-H bonds in water is 463 kJ/mol. On average, 463 kJ is required to break 6.023×10^{23} O-H bonds, or 926 kJ to convert 1.0 mole of water into 1.0 mol of O and 2.0 mol of H atoms. A space filling model of water molecule is shown here.

The forces holding molecules together are generally called **intermolecular forces**. The energy required to break molecules apart is much smaller than a typical bond-energy, but intermolecular forces play important roles in determining the properties of a substances. Intermolecular forces are particularly important in terms how molecules interact and form biological organisms or even life. This link gives an excellent introduction to the interactions between molecules.

Classifying Intermolecular Forces

In general, intermolecular forces can be divided into several categories. The four prominent types are:

1. **Strong ionic attraction**
   Recall lattice energy and its relations to properties of solid. The more ionic, the higher the lattice energy. Examine the following list and see if you can explain the observed values by way of ionic attraction:
   LiF, 1036; LiI, 737; KF, 821; MgF_2, 2957 kJ/mol.
2. **Intermediate dipole-dipole forces**
   Substances whose molecules have dipole moment have higher melting point or boiling point than those of similar molecular mass, but their molecules have no dipole moment.
3. **Weak London dispersion forces or van der Waal's force** These forces alway operate in any substance. The force arisen from induced dipole and the interaction is weaker than the dipole-dipole interaction. In general, the heavier the molecule, the stronger the van der Waal's force of interaction. For example, the boiling points of inert gases increase as their atomic masses increases due to strong Landon dispersion interactions.

4. **Hydrogen bond**
   Certain substances such as H_2O, HF, NH_3 form hydrogen bonds, and the formation of which affects properties (mp, bp, solubility) of substance. Other compounds containing OH and NH_2 groups also form hydrogen bonds. Molecules of many organic compounds such as alcohols, acids, amines, and aminoacids contain these groups, and thus hydrogen bonding plays a important role in biological science.
5. **Covalent bonding**
   Covalent is really intramolecular force rather than intermolecular force. It is mentioned here, because some solids are formed due to covalent bonding. For example, in diamond, silicon, quartz etc., the all atoms in the entire crystal are linked together by covalent bonding. These solids are hard, brittle, and have high melting points. Covalent bonding holds atoms tighter than ionic attraction.
6. **Metallic bonding**
   Forces between atom in metallic solids belong to another category. Valence electrons in metals are rampant. They are not restricted to certain atoms or bonds. Rather they run freely in the entire solid, providing good conductivity for heat and electric energy. These behaviour of electrons give special properties such as ductility and mechanical strength to metals.

The division into types is for convenience in their discussion. Of course all types can be present simultaneously for many substances. Usually, intermolecular forces are discussed together with The States of Matter, which is linked to a well illustrated web-site.

Intermolecular forces also play important roles in solutions, a discussion of which is given in Hydration, solvation in water. A summary of the interactions is illustrated in the following diagram: