How a Solution Forms

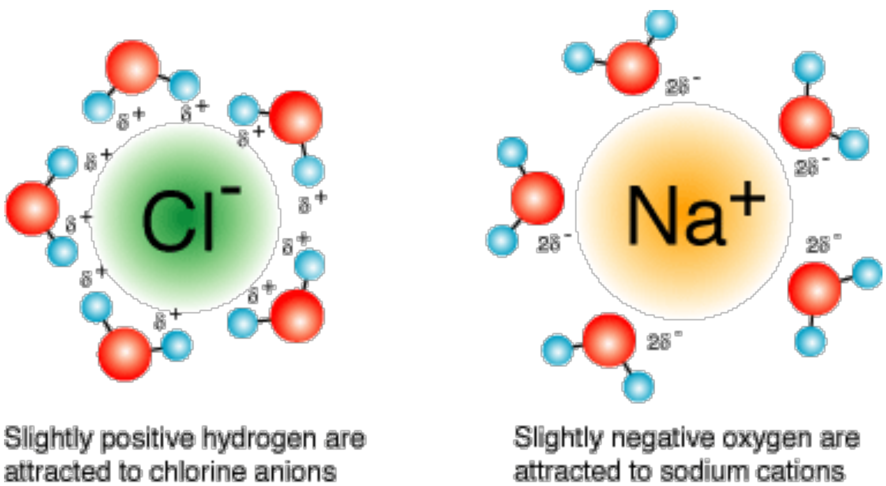
Some substances dissolve in a solvent, and others do not. To understand why such differences occur, we need to know how a solution forms.

Ionic Solvation

Consider the formation of a solution of sodium chloride in water. Sodium chloride is an ionic compound made up of Na^{+} and Cl^{-} ions.

When sodium chloride is placed in water, the polar water molecules exert attractive forces on the sodium and chloride ions that are stronger than the attractive forces the ions exert on each other. Because the ions are more attracted to the water molecules than they are to each other, the water molecules are able to separate the ions from one another. This is known as **dissociation**.

Once separated from their crystal, the Na^{+} and Cl^{-} ions are surrounded by water molecules as shown below. This is known as **dissolution**.



Once surrounded by water molecules, the individual ions are considered to be dissolved in water. In chemical reactions, substances that are dissolved in water are said to be in the **aqueous** state.

$$NaCl(s) \xrightarrow{H_2O(l)} Na^{+}(aq) + Cl^{-}(aq)$$

The formation of a solution is known as **solvation**. If the solvent is water, then we can also call it **hydration**.

Molecular Solvation

Similar principles operate in dissolving a molecular (covalent) compound, such as sugar, in water. The only major difference is that, in a molecular solution, entire molecules are pulled away from the solid structure and move into solution.

$$C_{12}H_{22}O_{11}(s) \xrightarrow{H_2O(l)} C_{12}H_{22}O_{11}(aq)$$

Dissociation Equations

When ionic compounds dissolve in water, they no longer exist in compound form. Instead, they separate into their component ions. This separation of positive and negative ions is called **dissociation**.

The dissociation of an ionic compound can be illustrated as a chemical equation like the one below:

$$NaCl(s) \rightarrow Na^{+}(aq) + Cl^{-}(aq)$$

This is known as a **dissociation equation**. The solute is written on the reactant side. On the product side we write the ions that the solute is made of. The equation must be balanced.

Note: Molecular compounds do not undergo dissociation when dissolving.

Polarity and Solubility

Polar solutes will dissolve in polar solvents. The attraction between the charged ends of the water molecules and the charged ends of the solute particles holds the polar solute in solution. Sugar in water is an example.

Ionic compounds will also dissolve in polar solvents. When sodium chloride dissolves in water, the positively charged sodium ions are attracted to the partially negative oxygen atoms in the water molecules. Similarly, the negatively charged chloride ions are attracted to the partially positive hydrogen atoms in the water. This attraction holds the ions in solution.

Non-polar solutes will not dissolve in polar solvents. The forces of attraction between individual water molecules are stronger than the forces of attraction between water and the solute particles. As a result, dissociation cannot occur. Oil in water is an example.

Non-polar solutes will dissolve in (some) non-polar solvents. The forces of attraction between the solvent particles are weak, as are the forces of attraction between the solute particles. Because all the forces are weak, they are easily overcome in order for dissociation to occur. Oil in kerosene is an example.

Heat of Solution

The separation of solute particles from one another (dissociation) and of solvent particles from one another requires energy. It is, therefore, an endothermic process (energy is absorbed).

The formation of attractions between solute particles and solvent particles (dissolution) is an exothermic process (energy is released).

Whether energy, in the form of heat, is absorbed or released in the overall process of solution formation depends on the balance between these two processes. If the amount of energy absorbed is greater than the amount of energy released, then the formation of the solution is endothermic. Dissolving ammonium nitrate in water is an endothermic process used in cold packs.

$$NH_4NO_3(s) + heat \rightarrow NH_4^+(aq) + NO_3^-(aq)$$

The heat in this reaction is absorbed from outside the cold pack, thereby cooling the injured area.

When the amount of energy absorbed is less than the amount of energy released, then the formation of the solution is exothermic. Dissolving calcium chloride in water is an exothermic process used in hot packs.

$$CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2Cl^-(aq) + heat$$

The heat in this reaction is given off to the surroundings, thereby warming the injured area.

The overall energy change during the formation of a solution is called the **heat of solution**.

Worksheet

1. What type of compound will dissociate in water? What type will not?

2. What part of the water molecule would be attracted to a solute ion such as Cl^-? Na^+?

3. Write the dissociation equation for the dissolving of each of the following in water.

   a) $PbSO_4(s)$

   b) $C_6H_{12}O_6(s)$

   c) $KBr(s)$

   d) $NaF(s)$

   e) $CH_3OH(l)$

   f) calcium chloride(s)

   g) $Na_2CO_3(s)$

4. Describe what occurs during the process of an ionic solid dissolving into water. Include what happens to the solute and to the solvent.