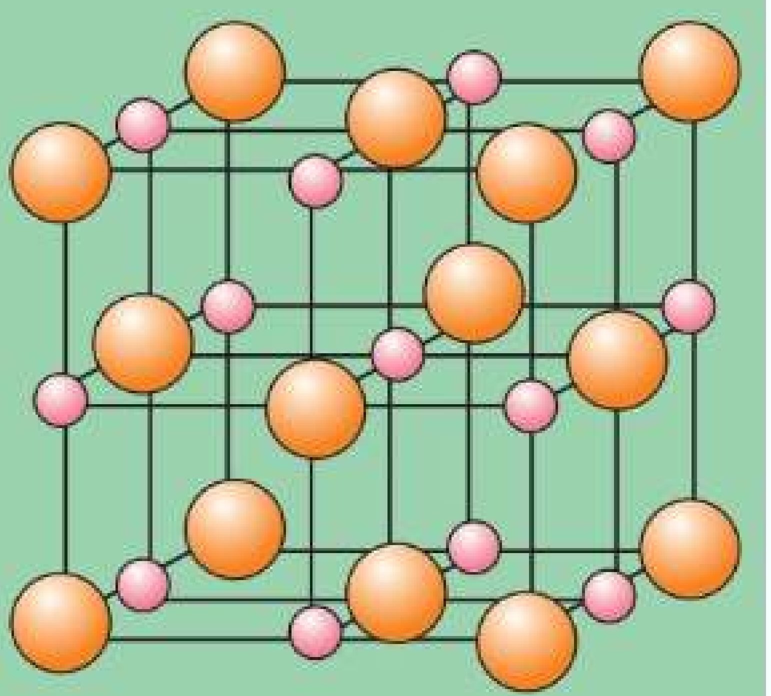
Chapter 18

Salts



Student Learning Outcomes

After studying this chapter, students will be able to:

- Explain that salts are ionic compounds formed due to electrostatic attraction between oppositely charged ions (in which the positive ions come from bases and negative ions come from acids)
- Explain why at STP salts are solids with high melting points.
- Describe that under normal conditions, ionic compounds are usually solids with lattice structures.
- Explain why the molten and aqueous solutions of salts are good conductors of electricity by making reference to the idea of mobile ions
- Describe the general solubility rules for salts. (these are:

(a) sodium, nitrate, potassium and ammonium salts are soluble

(b) chlorides are soluble except lead and silver

(c) carbonates are insoluble except sodium, potassium and ammonium

(d) hydroxides are insoluble except sodium, potassium, ammonium and calcium (partially) .

- Describe the preparation, separation and purification of soluble salts by reactions of acids with alkali (titration), excess metal, excess insoluble base, excess insoluble carbonate.

18.1 Arrangement of Ions in Salts

When acids neutralize bases or alkalis, salts and water are formed. For example, sodium hydroxide, an alkali, neutralizes hydrochloric acid to form sodium chloride and water. This reaction is called neutralization reaction.

$$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

A salt is a chemical combination of positive and negative ions. These oppositely charged ions are then bonded together by the electrostatic force of attraction. The strength of this attraction depends on the magnitude of the charges and the distance between the ions.

These oppositely charged ions then arrange themselves in a regular and repeating pattern to give a three dimensional network structure called a crystal lattice. The properties shown by the ionic compounds are due to the presence of this ordered structure. Under ordinary conditions of temperature and pressure ionic compounds exist as crystalline solids.

In NaCl, each sodium ion is surrounded by six chloride ions and each chloride ion, in turn, is surrounded by six sodium ions. Figure 18.1 shows how these ions are arranged in the crystal lattice having the shape of a face-centered cube. The bigger chloride ions are present at the corners and at the centre of each face of the cube while the smaller sodium ions occupy the edges of the cube.

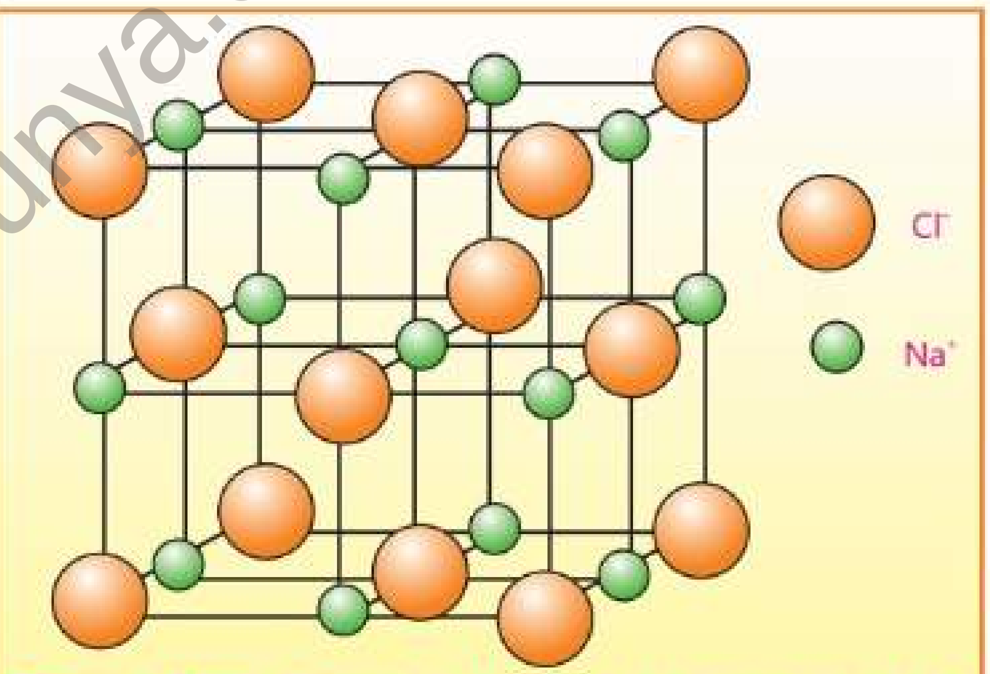


Figure 18.1: Crystal lattice of sodium chloride

Interesting Information

Common salt was a valuable commodity in the past. It was even used as currency.

18.2 Melting Points of Ionic Compounds

Since very strong electrostatic forces of attraction are present between the ions within a crystal lattice, a significant amount of energy is needed to break these forces. This is the reason why the melting points of ionic compounds are generally very high. During the process of melting these attractive forces break down and let the ions move freely. The melting points of ionic compounds depend upon the charges present on the ions and their sizes. Higher charges and smaller ion sizes lead to stronger attractions and hence the higher melting points.

18.3 Conduction of Electricity by Ionic Compounds

Ionic compounds do not conduct electricity in solid state, however, they start conducting electricity in molten state or when they are dissolved in water. In the solid state ions are held together by strong forces of attractions, they are not free to move and, therefore, cannot conduct electricity. When ionic compounds are heated to their melting points, their ions become free to move around and hence start conducting electricity. Similarly, when ionic compounds are dissolved in water, the forces of attraction between ions break down and the ions are again free to move independently.

Ionic compounds serve as strong electrolytes because they dissociate completely into ions when dissolved in water.

18.1 Quick Check!

1. How the ions present in NaCl arrange themselves to form a crystal lattice?
2. Do you expect melting point of KCl to be higher or lower than NaCl?

18.4 Soluble and Insoluble Salts

Several factors effect the solubility of a salt including the nature of salt and the temperature. Soluble salts include all sodium, potassium, and ammonium salts. Similarly all metallic nitrates are soluble in water and the same is true for most chlorides and sulfates. In contrast all carbonates with the exception of carbonates of sodium, potassium and ammonium are insoluble in water. Similarly, chlorides of silver and lead and sulfates of barium and lead are also insoluble in water.

Hydroxides of sodium, potassium and ammonium are soluble while calcium hydroxide is only partially soluble in water. All other hydroxides are insoluble in water.

The following table shows the pattern for the solubility of salts in water.

Table 18.1 Solubility of salts in water

Salts	Soluble	Insoluble
Salts of sodium, potassium and ammonium and all nitrates	All	None
Chlorides, bromides and iodides	Most soluble	Silver, Lead (II)
Sulphates	Most soluble	Barium, Lead (II), Calcium
Carbonates	Sodium, Potassium, Ammonium	Most insoluble
Hydroxides	Sodium, Potassium, Ammonium, Calcium (partially soluble)	Most insoluble

18.5 Preparation of Soluble Salts

Salts which are soluble in water can be prepared by adopting the following two methods.

(a) Reaction of water soluble acid with water soluble base

This method is also called a titration method. It involves the reaction of a water soluble acid and a water soluble base. The acid and base are selected depending on the nature of salt which is to be prepared.

For the preparation of soluble potassium nitrate, appropriate volumes of potassium hydroxide and nitric acid are made to react together in a conical flask.

$$KOH_{(aq)} + HNO_{3\,(aq)} \longrightarrow KNO_{3\,(aq)} + H_2O_{(l)}$$

Figure 18.2: Evaporating dish

The solution present in the conical flask now contains the soluble salt and water. Transfer the solution to an evaporating dish. If the salt being prepared is stable towards heat, then evaporate the solution to dryness to get the salt. Alternatively, heat the solution gently until a thin film of crystals is formed on the surface of the solution. Cool this solution slowly which is now saturated with salt. Filter this mixture to get the pure crystals of the salt. Dry the crystals between the folds of the filter papers.

Interesting Information

Copper sulphate is used as a fungicide. Other salts are used in water softening and glass manufacture.

Activity 18.1 Prepare pure crystals of sodium sulphate.

Method Add 50 cm^3 of 1 mol/dm^3 solution of sodium hydroxide in a neat conical flask with the help of a pippet. Add a few drops of phenolphthalein indicator to get a pink colour solution. Run 1 mol/dm^3 solution of sulphuric acid from the burette into the conical flask until the colour of solution changes from light pink to colourless. Note down the volume of sulfuric acid used to neutralize sodium hydroxide.

$$2NaOH_{(aq)} + H_2SO_{4\,(aq)} \longrightarrow Na_2SO_{4\,(aq)} + 2H_2O$$

Repeat the experiment taking the same volumes of sodium hydroxide and sulphuric acid but without using the indicator. Transfer this neutralized solution to an evaporating dish and heat it gently until one-third of the solution is left. Dip a glass rod into this hot solution and take it out. If the immersed end of the glass rod turns cloudy, the solution is concentrated enough for crystals to form. Cool down the solution for the crystallization to occur completely. Filter and wash the crystals with a little cold distilted water to remove any soluble impurities and the acid attached. Dry the crystals within the fold of filter papers or in an oven.

(b) Reaction of an acid with an insoluble base

This is also a neutralization reaction between the soluble acid and an insoluble base. The insoluble base may be an appropriate metal oxide, a metal carbonate or a metal hydroxide. The acid and the insoluble base are selected depending upon the salt to be prepared. A salt is also formed when an acid reacts with a metal.

This method involves the mixing of the selected acid with the selected base or a metal with constant stirring to ensure that the acid has fully reacted with the base or the metal. The insoluble base or the metal should always be added in excess to make sure that all the acid present has reacted. Filter the mixture to remove the excess amount of the base or the metal. Evaporate the filtrate to get a saturated solution. Allow the solution to cool down when pure crystals of the salt will start appearing. Filter and dry the crystals carefully.

$$Cu(OH)_{2\,(s)} + 2HCl_{(aq)} \longrightarrow CuCl_{2\,(aq)} + 2H_2O_{(l)}$$

$$Mg_{(s)} + H_2SO_{4\,(aq)} \longrightarrow MgSO_{4\,(aq)} + H_{2\,(g)}$$

$$CaCO_{3\,(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2\,(aq)} + Co_{2\,(g)} + H_2O_{(l)}$$

Activity 18.2 Prepare pure crystals of zinc sulphate.

Method Take about 25 cm^3 dilute sulphuric acid in a beaker and warm it gently. Go on adding small granules of zinc metal slowly with constant stirring till the metal starts settling down at the bottom of the beaker. Filter the solution to remove undissolved zinc metal and collect the filtrate. Evaporate the filtrate in an evaporating dish by gentle heating to concentrate the solution without overheating or boiling. Cool down the solution slowly and allow the crystals to appear. Once all the crystals have formed, carefully filter the mixture to get the crystals. Allow the crystals to dry on filter paper.

$$Zn_{(s)} + H_2SO_{4\,(aq)} \longrightarrow ZnSO_{4\,(aq)} + H_{2\,(g)}$$

18.2 Quick Check!

1. Which salts of barium and calcium are soluble in water?
2. How barium sulphate is prepared in the laboratory?

EXERCISE

A Multiple Choice Questions

Choose and tick the correct answer from the given choices.

1. Which base is not soluble in water?

(a)	KOH	(b)	$Mg(OH)_2$
(c)	NaOH	(d)	Na_2CO_3

2. The shape of the crystal of NaCl is:

(a)	Cubic	(b)	Hexagonal
(c)	Rombic	(d)	Trigonal

3. Which salts are always soluble in water?

(a) Chlorides (b) Sulphates

(c) Nitrates (d) Carbonates

4. Which salt will be formed when marble pieces react with dilute nitric acid?

(a) Sodium nitrate (b) Calcium nitrate

(c) Potassium nitrate (d) Magnesium nitrate

5. Water insoluble salt is:

(a) Calcium sulphate (b) Sodium sulphate

(c) Potassium sulphate (d) Magnesium sulphate

B Short Answer Questions

18.1. Which factors are responsible for the strength of electrostatic forces between ions?

18.2. Is lead (II) chloride soluble in water? Give comments.

18.3. Which lead salts are insoluble in water?

18.4. Name two insoluble carbonates.

18.5. What is a crystal lattice?

C Constructed Response Questions

18.1. Why are melting points of ionic salts generally very high?

18.2. Why ionic salts exist in solid state?

18.3. How will you prepare calcium sulphate in the laboratory?

18.4. Compare the melting points of NaCl and $MgCl_2$.

18.5. How would you prepare pure crystals of copper sulfate in the laboratory?

D Descriptive Questions

18.1. Explain the formation of sodium chloride crystal?

18.2. Explain the methods of preparation of two soluble salts.

18.3. How are the following salts prepared?

$$K_2SO_4,\ CuCl_2,\ CaCl_2$$

18.4. Describe which salts are soluble in water and which are insoluble.