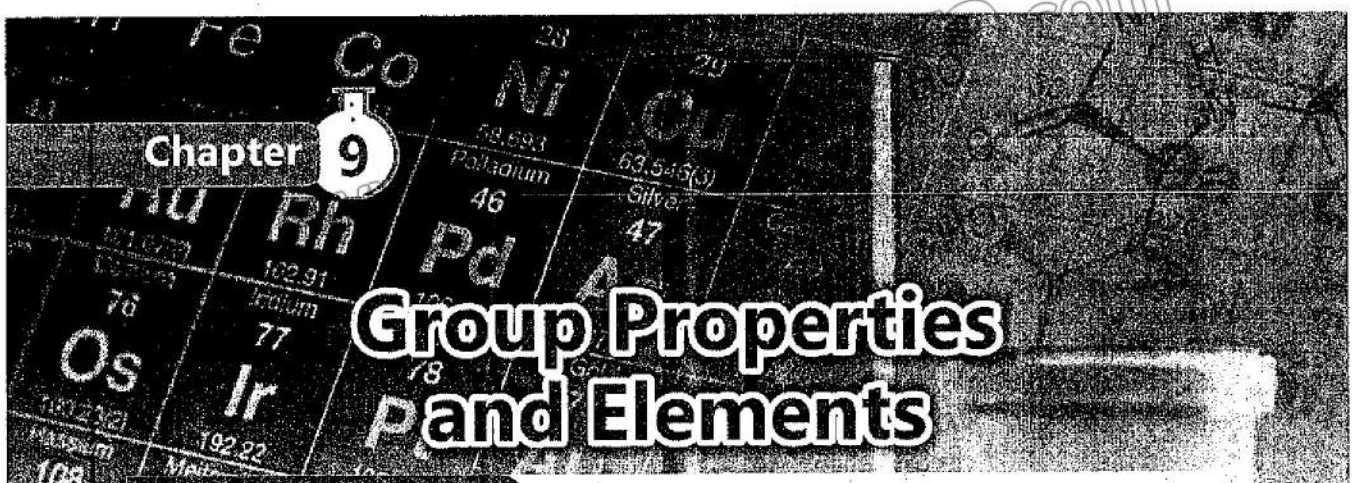

Student Learning Outcomes

After studying this chapter, students will be able to:

- Define group 1 Alkali metals as relatively soft metals with general trends down the group limited to decreasing melting point, increasing density and increasing reactivity.
- Predict properties of other elements in group 1, given information about the elements.
- Predict properties of elements in group 1 in order of reactivity given relevant information.
- Define group 17 halogens as diatomic non-metals with general trends limited to increasing density, and decreasing reactivity.
- Identify the appearance of halogens at rtp as fluorine as pale-yellow gas, chlorine as yellow -green gas, bromine as red -brown liquid, iodine as grey- black solid
- Explain the displacement reactions of halogens with other halide ions and also as reducing agents
- Predict the properties of elements in group 17, given information about the elements
- Analyse the relative thermal stabilities of the hydrogen halides and explain these in terms of bond strengths Transition elements
- Describe the transition elements as metals that: have high densities, high melting points, variable oxidation numbers, form coloured compounds and act as catalysts for industrial purposes. (Some examples include catalysts being used are the Haber process, catalytic converters, Contact process and manufacturing of margarine)
- Define the Group 18 noble gases as unreactive, monatomic gases
- Explain this in terms of electronic configuration properties of metals
- Compare the general physical properties of metals and non-metals (Specifically in terms of:
  a. thermal conductivity
  b. electrical conductivity
  c. malleability and ductility
  d. melting points and boiling points)

9.1 Properties of Group 1 Elements

Elements present in a group of the periodic table show similar chemical properties owning to the presence of same number of electrons in their outermost shells. However, a small variation in the chemical properties of elements is expected because the atomic size increases down the group.

All the elements present in group 1 have ns^1 configuration in their outer shells. They are also called alkali metals. This single electron can be removed easily which makes these metals very reactive except the first element hydrogen which is a gas and a non-metal. When we move from top to bottom in this group, the atomic size increases. Owing to this, it becomes easier for elements to lose electron down the group which is reflected in the increased reactivities of the lower members of the group.

Lithium reacts with water steadily giving hydrogen and lithium hydroxide. Sodium reacts vigorously while potassium reacts violently with water giving their respective water soluble hydroxides.

$$Li_{(s)} + H_2O_{(l)} \longrightarrow Li\,OH_{(aq)} + H_{2\,(g)}$$

$$Na_{(s)} + H_2O_{(l)} \longrightarrow NaOH_{(aq)} + H_{2\,(g)}$$

$$K_{(s)} + H_2O_{(l)} \longrightarrow KOH_{(aq)} + H_{2\,(g)}$$

Similarly, reaction of these metals with chlorine becomes more vigorous as we go down the group.

$$2Li_{(s)} + Cl_{2(g)} \xrightarrow{\text{Heat}} 2LiCl_{(s)}$$

$$2Na_{(s)} + Cl_{2(g)} \xrightarrow[\text{vigorous reaction}]{\text{Heat}} 2NaCl_{(s)}$$

$$2K_{(s)} + Cl_{2(g)} \xrightarrow[\text{violent reaction}]{\text{Heat}} 2KCl_{(s)}$$

Exercise

Keeping in view the trends of reactivity in first group elements how would they react with oxygen?

Interesting Information!

Li, Na and K are lighter than water but rubidium sinks in water. Cesium explodes on contact with water, possibly shattering the container.

Increase in the atomic size down the group also weakens the interatomic attraction of the atomic metals. This fact makes them softer down the group and their melting points decrease.

As we go down the first group, both the size and volume of the atoms increase as the number of electrons and protons increases. But the increase in

mass of the elements is greater than the increase in volume; so the density which is defined as the mass per unit volume increases gradually down the group. (Table 9.1)

Table (9.1) Physical Properties of First Group Metals

Metal	Li	Na	K	Rb	Cs
Melting point °C	180	98	64	39	28
Density g/cm^3	0.53	0.97	0.86	1.53	1.87

9.2 Properties of Group 17 Elements

All the elements in the group 17 have seven electrons in their outermost shells (n^2,s^5). They are electronegative non-metals because they have strong tendency to accept one electron to become an anion. They exist as diatomic molecules and behave as very reactive non-metals. Atomic radii, melting and boiling points of halogens increase when you go down the group. This is because the atoms get larger as they have more electrons. Because of their larger size they experience stronger intermolecular forces between molecules. Because of this, they require more heat energy to overcome their intermolecular forces and so their melting and boiling points are increased. They react with alkali and alkaline earth metals to give salts. These elements are thus named as Halogens which means salt-forming elements. Unlike metals, the reactivity of halogens decreases from top to bottom in the group. This is due to the fact that atomic size increases down the group and tendency to accept electron from other atoms decreases making them less reactive.

The attractive forces present between the halogen molecules increase down the group so as we go down the group the halogens become more dense.

Fluorine gas is very pale yellow, chlorine gas yellowish green while bromine is fuming red-brown liquid. Iodine exists as shiny grey crystals which easily turns into dark purple vapours when they are warmed up.

Metal halides are formed when halogens react directly with alkali and alkaline earth metals. Metal halides behave usually as ionic compounds.

Oxidation is a process in which an electron is lost. The substance which loses an electron is called a reducing agent.

$$Na_{(s)} \longrightarrow Na^+ + e$$

On the contrary, reduction is a process in which an electron is gained and the substance which accepts the electron is called an oxidizing agent.

$$Cl_2 + 2e \longrightarrow 2Cl^-$$

Oxidation-reduction are simultaneous reactions. In other words an, electron is lost only when there is a substance to accept it.

Halogens are reducing agents and their reducing power decreases down the group.

$$Cl_2 > Br_2 > I_2$$

This fact gives a unique property to halogens when a halogen having more reducing power displaces an ion of another halogen from its compound.

$$Cl_{2(aq)} + 2NaBr_{(aq)} \longrightarrow 2NaCl_{(aq)} + Br_{2(g)}$$

$$Cl_{2(aq)} + 2NaI_{(aq)} \longrightarrow 2NaCl_{(aq)} + I_{2(v)}$$

$$Br_{2(aq)} + 2NaI_{(aq)} \longrightarrow 2NaBr_{(aq)} + I_{2(v)}$$

Halogens react with hydrogen to give hydrogen halides. Hydrogen halides behave as strong acids in water.

$$H_2 + X_2 \longrightarrow 2HX$$

All halides exist in gaseous state at ordinary temperature except hydrogen fluoride which is a liquid. Bond length between hydrogen and halogen increases down the group because as the halogen atom gets bigger the bonding pairs of electron get further away from the halogen nucleus. The bond between hydrogen and halogen therefore gets weaker. The weaker the bond, the less heat energy it will need to break it. Hence the thermal stability of hydrogen halides decreases down the group.

$$HF > HCl > HBr > HI$$

Exercise

How do halogens react with water?

Interesting Information!

Water in swimming pool is sterilized with chlorine.

9.3 Group Properties of Transition elements

Elements present at the centre of the modern periodic table from group 3 to group 12 are called d block elements or transition elements. All transition elements are metals having the similar properties. Transition elements are often hard with higher densities. Their melting and boiling points are also high. These metals show variable oxidation states and the compounds they form are often coloured. They are malleable and ductile.

Transition metals and their compounds function as catalysts in many important chemical reactions. Metals often absorb other substances on their surface and activate them in this process. Iron, a transition metal, is used as a catalyst in one of the most important industrial reactions which gives ammonia. It is called Haber process. This ammonia is used to prepare urea fertilizer.

$$2N_{2(g)} + 3H_{2(g)} \xrightarrow{Fe} 2NH_{3(g)}$$

Platinum was originally used as a catalyst in the contact process for the manufacture of sulphuric acid. This expensive catalyst is, however, rendered inactive due to the presence of arsenic as impurity in sulphur dioxide. Vanadium pentoxide (V_2O_5) is now preferred as a catalyst.

$$SO_{2(g)} + O_{2(g)} \xrightarrow{V_2O_5} SO_{3(g)}$$

$$SO_{3(g)} + H_2O_{(l)} \longrightarrow H_2SO_{4(aq)}$$

A catalytic converter is a device used in the exhaust of an automobile which converts more harmful gases produced in the engine to such gases which do not pollute the atmosphere. Platinum, palladium and rhodium are the catalysts used in catalyic converters.

A transition metal nickel is used as a catalyst for the hydrogenation of oils to give solid margarine. Margarine is less likely to spoil than butter.

Things to Know

Transition metals have high tensile strength. What does it mean?

9.4 Properties of Noble Gases

Elements present in group 18 of the modern periodic table are called Noble elements. All noble elelments are monoatomic gases having very low boiling points, Helium (He), Neon (Ne), Krypton (Kr), Xenone (Xe) and Radon (Ra). All these gases have eight electrons (s^2p^6) in their outermost shells except He which has s^2 electronic configuration. Since their outer shells are complete, they show very little chemical reactivity.

9.5 Physical Properties of Metals and Non-metals

Metals and non-metals can be distinguished based on their physical and chemical properties.

Metals are defined as the elements which can generally form cations easily. They also tend to form metallic bond. Metals can be hammered into thin sheets. This property is called malleability. Metals can also be drawn into wires and this property is named as ductility. Metallic bond in metals allows metals to be the best conductor of heat and electricity. Metals are lustrous which means that they have a shiny appearance. Due to high tensile strength metals can hold heavy weights. When metals are hit by an object, they make a ringing sound. Metals can not be cut easily because they are hard substances.

Due to the presence of strong metallic bond metals generally have high melting and boiling points. Their densities are also very high. Alkali metals being soft metals are treated as exceptions. Example of metals include copper, silver, iron, lead aluminium, gold, platinum, zinc, etc.

Non-metals generally gain electrons easily. Non-metals show a greater variety of colours and physical states compared to metals. Non-metals cannot be beaten into thin sheets because being brittle they break into pieces when hammered. Sulphur and phosphorous exist in powdered forms and cannot be made into sheets. Non-metals cannot be melted and drawn into wires. Non-metals do not have free electrons due to which the bonds between their atoms are weak and they break down when stretched.

As there are no free electrons so non-metals cannot conduct heat and electricity. Graphite is the only exception. It conducts electricity because of its special crystalline arrangements. The electrons which are present between the layers of graphite crystal are loosely held and hence they can become mobile. The conduction of electricity of graphite is due to the mobility of these electrons.

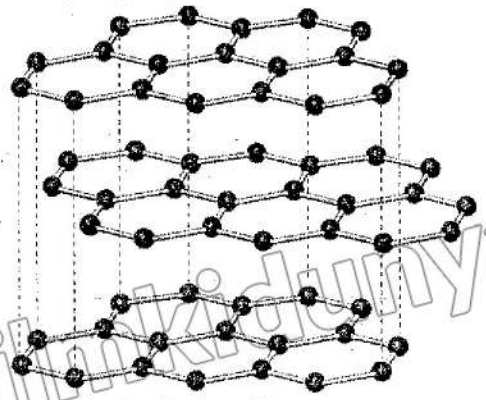

Fig (9.1): Graphite structure

Non-metals cannot be polished because they either exist in powder or gaseous form. Most of the powders are dull in texture. Due to non-ductile and non-malleable properties, non-metals are not strong at all. Their bonds being weak break easily. All non-metals have low melting and boiling points. The melting point of sulphur is 115°C. Graphite and diamond have high melting points and these are exceptions. Non-metals have low densities as compared to metals. This means that in non-metals atoms are not strongly bound with each other. Examples of non-metals are oxygen, nitrogen, chlorine, sulphur, carbon, bromine, etc.

Interesting Information!

About 75% of all the elements in the periodic table are metals. There are total 20 non-metals which exist in a solid or liquid or gaseous state at room temperature.

Comparison of the Physical Properties of Metals and Non-metals

Metals	Non-metals
1. Metals usually have high melting and boiling points.	1. Non-metals may be solids, liquids or gases at room temperature. They show wide range of melting and boiling points.
2. Metals are good conductors of heat and electricity.	2. Non-metals are bad conductors of heat and electricity (except graphite).
3. Metals can be made into different shapes by applying pressure. Metals can therefore be easily drawn into wires and sheets.	3. Non-metals are brittle.
4. Metals are usually lustrous solids (except mercury).	4. Non-metals are dull and cannot be polished (except iodine).
5. Metals are generally tough and strong.	5. Non-metals are neither tough nor strong.

Interesting Information!

According to one report nine elements are facing serious threat of extinction. Some of those elements are arsenic, gallium, gold, helium and zinc.

Key Points

1. Atomic size increases from top to bottom for elements of group-1. It becomes easier for elements to lose their single electron.
2. Chemical reactivity of the elements in group-1 increases down the group.
3. Due to increase in their atomic sizes, the interatomic attraction decrease down the first group elements. This makes them softer and their melting points decrease down the group.
4. Due to increase in the size and volume of atoms, the densities of alkali metals increases down the group.
5. Group 17 elements or halogens exist as diatomic molecules. They are very reactive non-metals and react with alkali and alkaline earth metals.
6. Halogens are reducing agents and their reducing power decreases down the group.
7. In hydrogen halides the bond between hydrogen and halogen gets weaker as we go down the group. Hence, the thermal stability of hydrogen halides decreases down the group.
8. d – block elements or transition elements are all metals. They are often hard and have higher densities. These elements and their compounds are used as catalysts in important industrial reactions.
9. Noble gases are all unreactive gases because their outermost shells are complete.
10. Metals and non-metals have very different physical properties.

Exercise

1. Tick (✓) the correct answer.

(i) Which halogen will have the least reactivity with alkaline earth metals?

(a) Chlorine (b) Iodine
(c) Bromine (d) Fluorine

(ii) Which compound do you expect to be coloured?

(a) KCl (b) $BaCl_2$
(c) $AlCl_3$ (d) $NiCl_2$

(iii) In which element there exists the strongest forces of attraction between atoms?

(a) Mg (b) Ca
(c) Sr (d) Ba

(iv) Elements of which group are all coloured?

(a) Second group (b) Sixth group
(c) Fourth group (d) Fifth group

(v) Which halogen acid is unstable at room temperature?

(a) HBr (b) HI

(c) HCl (d) HF

(vi) Which oxide is the most basic oxide?

(a) Na_2O (b) Li_2O (c) MgO (d) CO

(vii) Which group elements are the most reactive elements?

(a) Transition metal Group (b) First group

(c) Second group (d) Third group

(viii) The following solutions of a halogen and a sodium halide are mixed together. Which solution will turn dark because of a reaction?

(a) Br_2 and NaCl (b) Br_2 and NaF

(c) Cl_2 and NaF (d) Cl_2 and NaI

(ix) X is a monoatomic gas, which statement about this is correct?

(a) X burns in air (b) X is coloured

(c) X is unreactive (d) X will displace iodine from it

(x) Which property is correct for group 1 elements?

(a) Low catalytic activity (b) High density

(c) Low electrical conductivity (d) High melting point

2. Questions for Short Answers

i. Why does it become easier to cut an alkali metal when we move from top to bottom in a group I?

ii. Predict the reactivity of potassium towards halogens.

iii. In the following reaction, chlorine acts as a reducing agent. What is the oxidizing agent?

$$Cl_{2(aq)} + 2NaBr_{(aq)} \longrightarrow 2NaCl_{(aq)} + Br_{2(g)}$$

iv. Why does iodine exist in the solid state at room temperature?

v. How does Ni catalyse the reaction involving hydrogenation of oil?

3. Constructed Response Questions

i. Which noble gas should have the lowest boiling point and why?

ii. Compare the reactions of alkali metals with chlorine.

iii. Why are almost all the metals solids while non-metals generally exist as gases and solids?

iv. Name any three elements in the periodic table which exist as liquids.

v. Why are transition elements different from normal elements?

vi. Compare the reactivity of chlorine and bromine as reducing agent.

vii. Which element is the most reactive and which is the least reactive among halogens? Give two reasons to explain your answer.

4. Descriptive Questions

i. Explain the role of catalytic converter in an automobile.

ii. Why do the chemical reactivities of alkali metals increase down the group whereas they decrease down the group in case of halogens?

iii. Why are metals generally tough and strong whereas non-metals are neither tough nor strong?

iv. Both alkali metals and halogens are very reactive elements with roles opposite to each other. Explain.

v. Why hydrogen bromide is thermally unstable as compared to hydrogen chloride?

vi. Compare the properties of metals and non-metals.

vii. V_2O_5 catalyst is preferred over platinum in the oxidation of sulphur dioxide. Give reasons.

5. Investigative Questions

i. Explain the role of sodium as heat transfer agent in the atomic nuclear power plant. Which property of sodium is utilized in this role?

ii. Why and how does lithium behave differently from the rest of the alkali metals?

iii. Why aluminum metal is used in the manufacture of cooking utensils whereas magnesium is not considered useful for this purpose?