displace the less reactive metal from its solution.

(*v*) Metals at the top of the series are very reactive and, therefore, they do not occur free in nature. The metals at the bottom of the series are least reactive and, therefore, they normally occur free in nature. For example, gold, the last element of the series is found almost as free element.

CHEMICAL PROPERTIES OF NON-METALS

Non-metals have usually 4 to 8 electrons in their outermost shells. They have the tendency to accept electrons to complete their octets. By accepting the electrons, they form negatively charged ions and, therefore, they are **electronegative elements**. For example, nitrogen, oxygen and fluorine can accept 3, 2 and 1 electrons respectively to complete their octets as :

$$N + 3e^- \longrightarrow N^{3-} \quad \textit{gains 3 electrons}$$
$$O + 2e^- \longrightarrow O^{2-} \quad \textit{gains 2 electrons}$$
$$F + e^- \longrightarrow F^- \quad \textit{gains 1 electron}$$

Let us compare some of the reactions of non-metals with those of metals. These are discussed below :

1. Reaction of non-metals with oxygen

Non-metals react with oxygen to form ***acidic* or *neutral oxides***. The acidic oxides dissolve in water to give acids. These acidic oxides turn blue litmus red.

Acidic oxides

The oxides of **carbon, sulphur, phosphorus, etc. are acidic** and, therefore, they turn blue litmus solution red. For example,

(*i*) Carbon reacts with oxygen of air to form carbon dioxide.

$$\underset{\text{Carbon}}{C(s)} + O_2(g) \longrightarrow \underset{\text{Carbon dioxide}}{CO_2}$$

Carbon dioxide dissolves in water to form an acid called carbonic acid.

$$CO_2(g) + H_2O(l) \longrightarrow \underset{\substack{\text{Carbonic acid}\\ \text{(an acid)}}}{H_2CO_3(aq)}$$

The solution of carbon dioxide gas in water turns blue litmus red, showing that it is acidic oxide.

(*ii*) Sulphur burns in air to give sulphur dioxide.

$$S(s) + O_2(g) \longrightarrow \underset{\text{Sulphur dioxide}}{SO_2(g)}$$

(b) Sulphur dioxide dissolves in water to form sulphurous acid which turns blue litmus red.

$$SO_2(g) + H_2O(l) \longrightarrow \underset{\text{Sulphurous acid}}{H_2SO_3(aq)}$$

Sulphur also forms an oxide, sulphur trioxide which dissolves in water to give sulphuric acid.

$$2S(s) + 3O_2(g) \longrightarrow 2SO_3(g)$$

$$SO_3(g) + H_2O(l) \longrightarrow \underset{\text{Sulphuric acid}}{H_2SO_4(aq)}$$

(iii) When phosphorus is burnt in air, it reacts with oxygen of air to form phosphorus pentoxide (P_2O_5). This is also *acidic oxide* and dissolves in water to give an acid, phosphoric acid which turns blue litmus red.

$$\underset{\text{Phosphorus}}{P_4(s)} + 5O_2(g) \longrightarrow \underset{\text{Phosphorous pentoxide}}{2P_2O_5(s)}$$

$$2P_2O_5(s) + 6H_2O(l) \longrightarrow \underset{\text{Phosphoric acid}}{4H_3PO_4(aq)}$$

The acidic oxides of non-metals, neutralise bases to form salt and water. For example,

$$SO_2 + 2NaOH \longrightarrow \underset{\text{Sodium sulphite}}{Na_2SO_3} + H_2O$$

Neutral oxides

Some oxides of non-metals are neutral. For example, carbon monoxide (CO), nitric oxide (NO), nitrous oxide (N_2O), water (H_2O), etc.

For example,

$$2C(s) + O_2(g) \longrightarrow \underset{\text{Carbon monoxide (Neutral oxide)}}{2CO(g)}$$

$$2H_2(g) + O_2(g) \longrightarrow \underset{\text{Water (Neutral oxide)}}{2H_2O(l)}$$

These oxides are neutual because these neither turn blue litmus solution red nor red litmus solution blue.

2. Reaction of non-metals with water

Non-metals do not react with water or steam to give hydrogen gas. This is because non-metals cannot give electrons to reduce the hydrogen ions of water into hydrogen gas.

3. Reaction with acids

Non-metals do not react with dilute acids and, therefore, hydrogen gas is not liberated when non-metals are treated with dilute acids. Therefore, non-metals do not displace hydrogen from dilute acids. For example, carbon, sulphur or phosphorus do not react with dilute acids such as dil. HCl or dil. H_2SO_4 to produce hydrogen gas. We have seen that hydrogen can only be displaced from dilute acids if electrons are supplied to H^+ ions of the acid.

$$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

$$2H^+(aq) + 2e^- \longrightarrow H_2(g)$$

But the non-metals are electron acceptors and, therefore, they cannot give electrons to H^+ ions of an acid. Hence hydrogen gas is not liberated.

4. Reaction with hydrogen

Non-metals react with hydrogen under different conditions to form

corresponding hydrides. For example, H_2O, H_2S, NH_3, HCl, CH_4 etc., are common hydrides of oxygen, sulphur, nitrogen, chlorine and carbon respectively.

$$2H_2(g) + O_2(g) \xrightarrow{\text{Electric spark}} 2H_2O(l)$$

$$H_2(g) + S(s) \longrightarrow H_2S(g)$$

$$N_2(g) + 3H_2(g) \xrightarrow[400\text{-}600\ atm]{775} 2NH_3(g)$$

$$H_2(g) + Cl_2(g) \xrightarrow[\text{sunlight}]{\text{Diffused}} 2HCl(g)$$

5. Reaction with chlorine

Non-metals react with chlorine to form covalent chlorides such as HCl, PCl_3, CCl_4 etc. For example,

Non-metals react with chlorine under different conditions to form corresponding chlorides. For example,

$$H_2(g) + Cl_2(g) \xrightarrow[\text{sunlight}]{\text{Diffused}} \underset{\text{Hydrogen chloride}}{2HCl(g)}$$

$$P_4(s) + 6Cl_2(g) \longrightarrow \underset{\text{Phosphorus trichloride}}{4PCl_3(l)}$$

6. Reaction with salt solutions

A more reactive non-metal displaces a less reactive non-metal from its salt solution. For example, when chlorine is passed through a solution of sodium bromide, then bromine is liberated.

$$\underset{\text{Sodium bromide}}{2NaBr(aq)} + Cl_2(g) \longrightarrow 2NaCl(aq) + Br_2(g)$$

However, bromine cannot displace chlorine from its salt solution.

$$2NaCl(aq) + Br_2 \longrightarrow \text{No reaction.}$$

Therefore, ***chlorine is more reactive non-metal than bromine.***

Distinction between Metals and Non-metals

Although there is no sharp line of distinction between metals and non-metals yet there are some distinctive differences. The main points of differences between metals and non-metals are summarised below :

Table 2. Comparison among the properties of Metals and Non-metals.

Property	Metals	Non-metals
Electronic structure	Metals have 1 to 3 electrons in the outermost shell of their atoms.	Non-metals have 4 to 8 electrons in the outermost shell of their atoms (except hydrogen and helium which have 1 to 2 electrons respectively in their outermost shells).
Physical properties		
1. *State of existence*	Metals are mostly solids at room temperature except mercury which is a liquid metal.	Non-metals exist in all the three states of matter *i.e.*, solids, liquids and gases.
2. *Lustre*	Metals are lustrous (shiny) and can be polished.	They are usually non-lustrous except diamond which is a very hard substance.
3. *Hardness*	Metals are generally hard.	Non-metals are comparatively soft.
4. *Density*	Metals have usually high densities except alkali and alkaline earth metals which are light.	Non-metals usually have low densities.

5. *Conductivity*	Metals are good conductors of heat and electricity.	Non-metals are poor conductors of heat and electricity. Graphite is an exception because it is a good conductor of electricity.
6. *Malleability and ductility*	Metals are usually malleable and ductile.	They are usually brittle.
Chemical properties		
7. *Nature of oxides*	Metals form **basic** oxides, though some metal oxides are amphoteric also.	Non-metals form **acidic** or neutral oxides.
8. *Displacement of hydrogen from acids*	Metals displace hydrogen from acids and form salts.	Non-metals do not displace hydrogen from acids.
9. *Reaction with chlorine*	Metals react with Cl_2 to form electrovalent chlorides.	Non-metals react with Cl_2 to form covalent chlorides.
10. *Reaction with hydrogen*	With hydrogen, only a few metals combine to form electrovalent hydrides.	With hydrogen, non-metals form many stable hydrides which are covalent.
11. *Electropositive or electronegative character*	Metals are **electropositive** in character.	Non-metals are **electronegative.**
12. *Oxidising and reducing agent*	Metals act as **reducing** agents.	Non-metals act as **oxidising** agents.

Solved Examples

❑ **Example 1. Which of the following elements are metals ?**

(*a*) $^{24}_{12}X$ (*b*) $^{19}_{9}Y$ (*c*) $^{31}_{15}Z$

Solution : From the atomic numbers, the electronic configurations may be written. The electronic configurations can help us to predict whether the given element is a metal or not.

(*a*) $^{24}_{12}X$. The atomic number is 12. The electronic configuration of the element is 2, 8, 2. Since it has two electrons in the outermost shell, it is a **metal.**

(*b*) $^{19}_{9}Y$. The atomic number is 9 and its electronic configuration is 2, 7. Since it has more than 3 electrons in its valence shell, it is **not a metal.**

(*c*) $^{31}_{15}Z$. The atomic number is 15 and its electronic configuration is 2, 8, 5. It is **not a metal.**

❑ **Example 2. The electronic configurations of some elements are given below :**

Element	Electronic configuration		
	K	L	M
A	2	8	7
B	2	8	1
C	2	8	8
D	2	2	
E	1		

Which of these are metals ?

Solution : We know that metals have 1 to 3 electrons in their outermost shells. The inspection of electronic configurations of these elements shows that **B and D are metals.**

A is not a metal though it contains 1 electron. It is an exception (H).

❑ **Example 3. Complete and balance the following equations :**

(*i*) $Na + O_2 \longrightarrow$

(*ii*) $Na_2O + H_2O \longrightarrow$

(*iii*) $Cu + HCl \longrightarrow$

(*iv*) $Cu^{2+}(aq) + Zn(s) \longrightarrow$

Solution :

(*i*) $4Na + O_2 \longrightarrow 2Na_2O$ Sodium oxide

(*ii*) $Na_2O + H_2O \longrightarrow 2NaOH$ Sodium hydroxide

(*iii*) $Cu + HCl \longrightarrow$ No reaction

(*iv*) $Cu^{2+}(aq) + Zn(s) \longrightarrow Cu(s) + Zn^{2+}(aq)$

❑ **Example 4. Which of the following displacement reactions cannot occur ?**

(*a*) $CuSO_4(aq) + Fe \longrightarrow FeSO_4(aq) + Cu$

(*b*) $FeSO_4(aq) + Zn \longrightarrow ZnSO_4(aq) + Fe$

(*c*) $ZnSO_4(aq) + Pb \longrightarrow PbSO_4(aq) + Zn$

(*d*) $2AgNO_3(aq) + Cu \longrightarrow Cu(NO_3)_2 + 2Ag$

(*e*) $MgSO_4(aq) + Cu \longrightarrow CuSO_4 + Mg$

Solution : A more reactive metal (placed higher in the activity series) can displace the less reactive metal from its solution. Out of the above five reactions,

(*c*) cannot occur because zinc is more reactive than lead.

(*e*) cannot occur because magnesium is more reactive than copper.

❑ **Example 5. A, B and C are three elements which undergo chemical changes according to following equations :**

(*i*) $A_2O_3 + 2B \longrightarrow B_2O_3 + 2A$

(*ii*) $3CSO_4 + 2B \longrightarrow B_2(SO_4)_3 + 3C$

(*iii*) $3CO + 2A \longrightarrow A_2O_3 + 3C$

(a) Which of these is most reactive ?
(b) Which of these is least reactive ?
(c) Arrange these elements in order of increasing reactivity.

Solution : We know that a more reactive metal can displace a less reactive metal from its solution or oxide. On this basis, we can say

(i) metal B displaces metal A from its oxide A_2O_3, therefore, B is more reactive than A.

(ii) metal B displaces metal C from its salt CSO_4, therefore, B is more reactive than C.

(iii) metal A displaces metal C from its oxide, therefore, A is more reactive than C.

Thus, it may be concluded

(a) B is most reactive metal.

(b) C is least reactive metal.

(c) Order of reactivity is B > A > C.

Example 6. On the basis of the given reactions, indicate which is most reactive and least reactive metal out of zinc, copper or iron ?

$CuSO_4(aq) + Fe(s) \longrightarrow FeSO_4(aq) + Cu(s)$

$FeSO_4(aq) + Zn(s) \longrightarrow ZnSO_4(aq) + Fe(s)$

Solution : In the reaction,

$$CuSO_4(aq) + Fe(s) \longrightarrow FeSO_4(aq) + Cu(s)$$

iron displaces copper from copper sulphate solution, therefore, iron is more reactive than copper. In the reaction,

$$FeSO_4(aq) + Zn(s) \longrightarrow ZnSO_4(aq) + Fe(s)$$

zinc displaces iron from iron sulphate solution, therefore, zinc is more reactive than iron. Thus, zinc is the most reactive and copper is the least reactive.

Example 7. Give an example of a metal which

(a) is a liquid at room temperature
(b) can be easily cut with a knife
(c) is the best conductor of heat
(d) is the poorest conductor of heat.
(e) used in electrical appliances
(f) combines with oxygen at room temperature

Solution :

(a) Mercury (b) Sodium (c) Silver
(d) Lead (e) Copper (f) Sodium

Example 8. Write an equation for the reaction of

(a) iron with steam
(b) calcium with water
(c) potassium with water.

Solution :

(a) Iron with steam

$$\underset{\text{Steam}}{Fe + 4H_2O} \longrightarrow \underset{\text{Iron (II, III) oxide}}{Fe_3O_4} + H_2$$

(b) Calcium with water

$$Ca + H_2O \longrightarrow \underset{\text{Calcium oxide}}{CaO} + H_2$$

(c) $2K + 2H_2O \longrightarrow \underset{\text{Potassium hydroxide}}{2KOH} + H_2$

Example 9. Name two metals which will displace hydrogen from dilute acids and two metals which will not displace.

Solution : Metals which can displace H_2 from dilute acids : Zinc and magnesium.

Metals which cannot displace H_2 from dilute acids: copper and silver.

Example 10. Name a metal which offers higher resistance to the passage of electricity than copper.

Solution : Lead.

Example 11. Name a metal which can melt even in your hand. To which group of the periodic table does it belong ?

Solution : Generally metals have high melting and boiling points. However, gallium has very low melting point. It can melt even in the hand. It belongs to group III-A of the periodic table.

Example 12. Name any two neutral oxides.

Solution : (i) Carbon monoxide (CO)
(ii) Water (H_2O).

Example 13. Name one non-metal and one metal which are in liquid state at room temperature.

Solution : Liquid non-metal : Bromine
Liquid metal : Mercury.

Example14. What type of oxides are formed when non-metals combine with oxygen ?

Solution : Non-metals combine with oxygen to form acidic oxides (such as CO_2, SO_2) and neutral oxides (CO, N_2O). They never form basic oxides.

Example15.

(a) What are strategic metals ? Give one example also.

(b) State the reason for the following behaviour of zinc metal :

On placing a piece of zinc metal in a solution of mercuric chloride it acquires a shining silvery surface but when it is placed in a solution of magnesium sulphate no change is observed.

Solution : (a) The metals which are essential for the country's economy or its defence are called strategic metals. These metals and their alloys are used in atomic energy, space science projects, jet engines, high grade steels, etc.

For example, titanium.

(b) When a piece of zinc metal is placed in a mercuric chloride solution, it displaces mercury from its solution. This is because zinc is more reactive than mercury.

$Zn(s) + HgCl_2(aq) \longrightarrow ZnCl_2(aq) + Hg(l)$

The displaced mercury gives shining silvery surface.

However, when zinc is placed in a solution of magnesium sulphate, no reaction takes place. This is because magnesium is more reactive than zinc.