CHAPTER

4

Chemical Bonding and Redox Reactions

Chemical Bonding

Ions

An ion is an electrically charged species. A positively charged ion is called **cation,** while a negatively charged ion is called **anion.**

- A cation contains less electrons than a normal atom while an anion contains more electron than a normal atom.
  e.g. cation Na^+, H^+, Mg^{2+} and anion Cl^-, F^-, I^-.
- The metal atom lose electrons to form cations and non-metal atom accept electrons to form anions.
- There is no change in atomic number or number of protons when an atom forms ion.

Isoelectronic species

Species having the same number of electrons but different nuclear charge are known as isoelectronic species. They also have same bond order.

Types of Chemical Bond

Electrovalent bond or Ionic bond

The bond is formed by the transfer of electrons from one atom to another.

- These bonds are formed between metals and non-metals.
- *Properties of electrovalent compounds are*
  (a) These are usually crystalline solids.
  (b) These have high melting point.
  (c) These conduct electricity when dissolved in water and also soluble in water.
  (d) These are insoluble in organic solvents like alcohol etc.
  (e) If the electronegativity difference of two atoms is 1.7, the bond between them is fifty per cent ionic.

Some Electrovalent Compounds

Name	Formula	Ions present
Aluminium oxide (Alumina)	Al_2O_3	Al^{3+}, O^{2-}
Ammonium chloride	NH_4Cl	NH_4^+ and Cl^-
Calcium chloride	$CaCl_2$	Ca^{2+} and Cl^-
Calcium nitrate	$Ca(NO_3)_2$	Ca^{2+} and NO_3^-
Copper sulphate	$CuSO_4$	Cu^{2+} and SO_4^{2-}
Magnesium chloride	$MgCl_2$	Mg^{2+} and Cl^-
Magnesium oxide	MgO	Mg^{2+} and O^{2-}
Potassium chloride	KCl	K^+ and Cl^-
Sodium chloride	NaCl	Na^+ and Cl^-
Sodium hydroxide	NaOH	Na^+ and OH^-

Covalent bond

This bond is formed by the sharing of electrons between two atoms.

- When a non-metal combines with another non-metal, a covalent bond is formed.
- The bond formed between the atoms of the same elements is also a covalent bond.
- **Covalents bonds are of three types**
- Single covalent bond (by sharing of one pair of electrons)
- Double covalent bond (by sharing of two pairs of electrons)
- Triple covalent bond (by sharing of three pairs of electrons)
- *Properties of covalent compounds are*
- These are usually liquids or gases, having usually low melting point and boiling point.
- These do not conduct electricity and are insoluble in water but dissolve in organic solvents.
- These show stereoisomerism because covalent bond is directional in nature.

Some Covalent Compounds

Name	Formula	Elements present
Alcohol (Ethanol)	C_2H_5OH	C, H and O
Ammonia	NH_3	N and H
Acetylene (Ethyne)	C_2H_2	C and H
Carbon dioxide	CO_2	C and O
Carbon disulphide	CS_2	C and S
Carbon tetrachloride	CCl_4	C and Cl
Cane sugar	$C_{12}H_{22}O_{11}$	C, H and O
Ethane	C_2H_6	C and H
Ethylene	C_2H_4	C and H
Glucose	$C_6H_{12}O_6$	C, H and O
Methane	CH_4	C and H

Coordinate bond

This type of bond is formed by one sided sharing of one pair of electrons between two atoms.

- The atom having completed octet which provides the electron pair for sharing is known as donor.
- The other atom which accept the electron pair is called the acceptor atom.

Hydrogen bond

This bond is electrostatic force of attraction between hydrogen atom covalently bonded to a highly electronegative atom and any other electronegative atom which is present in the same or different molecules.

- It is mainly of two types :
- Intermolecular H-bonding (*e.g.*, H_2O, HF, NH_3 molecule)
- Intramolecular H-bonding (*e.g.*, *o*-nitrophenol)
- Molecules having O—H, N—H or H—F bond show abnormal properties due to H-bond formation.

Oxidation and Reduction

Oxidation

- The process which involves gain of oxygen or loss of hydrogen or loss of one or more electrons (de-electronation) from an atom, ion or molecule is called oxidation *e.g.*, $Mg \longrightarrow Mg^{2+} + 2e^-$
- The positive valency of an element increases by its oxidation.

Reduction

- The process which involves the gain of hydrogen or one or more electrons (electronation) or loss of oxygen by an atom, ion or molecule is called reduction. *e.g.*, $S + 2e^- \rightarrow S^{2-}$
- Reduction involves decrease in the positive valency of an element.

Oxidising Agent (Oxidant)

- It is a substance which accepts electron in the chemical reaction *i.e.*, electron acceptors are oxidising agent.
- All the positively charged species behave like oxidising agents.
- Oxidising agents are Lewis acids.

Reducing Agent (Reductant)

- The substance which donates electron in a chemical reaction is called reducing agent, *i.e.*, electron donors are reducing agents.
- All the negatively charged species behave like reducing agents. Reducing agents are Lewis base.

Oxidising agents	Reducing agents	Both oxidising and reducing agents
$KMnO_4$, $Cr_2O_7^{2-}$, H_2SO_4, HNO_3, O_2, CO_2 etc.	Na, Al, Fe, Zn, LiH, NaH, $(COOH)_2$ etc.	H_2O_2, SO_2, HNO_2, $NaNO_2$, O_3, Na_2SO_3 etc.

Redox Reactions

The reactions which involve oxidation and reduction as its two half-reactions, are called redox reactions.

- When the same element is oxidised or reduced, the reaction is called disproportionation reaction.

Oxidation States

It is the real or imaginary charge which an atom appears to have in its combined state.

- Oxidation state of an element may be positive, negative, zero or fractional.

Rules for determining oxidation state

- The oxidation state of an element in its free or uncombined state is zero. Oxidation state of O in O_2 and O_3 is zero.
- Oxidation state of hydrogen in most of its compounds is plus one (+1).
- Oxidation state of oxygen in most of its compounds is minus two (−2).
- Oxidation state of elements of IA, IIA and IIIA sub-group elements in their compounds are +1, +2 and +3 respectively.
- Oxidation state of any ion is equal to its charge.
- The algebraic sum of oxidation states of all the elements in the neutral molecule is zero.
- The algebraic sum of the oxidation states of all elements present in polyatomic ion is equal to the charge on the ion.
- Oxygen shows positive oxidation state in OF_2.
- Oxidation state of fluorine (F) is always − 1.

Exercise

1. Which of the following is a covalent compound?
   (a) NaCl (b) $CaCl_2$
   (c) $MgCl_2$ (d) C_2H_2

2. Formation of cation occurs by
   (a) gain of electron (b) loss of electron
   (c) gain of protons (d) loss of proton

3. Formation of anions occurs by
   (a) loss of neutrons (b) gain of protons
   (c) gain of electrons (d) None of these

4. A bond formed by the transfer of electrons between atoms of the elements is called
   (a) ionic bond (b) covalent bond
   (c) coordinate bond (d) hydrogen bond

5. Ionic compounds dissolve in
   (a) any solvent (b) polar solvent
   (c) non-polar solvent (d) organic solvent

6. Strongest bond is
   (a) C═C (b) C═C
   (c) C≡C (d) All are equally strong

7. Hydrogen bonding is maximum in
   (a) ethanol (b) diethyl ether
   (c) ethyl chloride (d) triethyl amine

8. NaCl has
   (a) covalent bond (b) ionic bond
   (c) coordinate bond (d) None of these

9. Molten NaCl is a good conductor of electricity due to the presence of
   (a) free electrons (b) free ions
   (c) free molecules (d) None of these

10. The compound which contains ionic bond is
    (a) CH_4 (b) N_4
    (c) $CaCl_2$ (d) CCl_4

11. With reference to ionic compounds, consider the following statements.
    1. Ionic compounds are insoluble in alcohol.
    2. Ionic compounds in the solid state are good conductor of electricity.

    Which of these statements is/are correct?
    (a) Only 1 (b) Only 2
    (c) Both 1 and 2 (d) Neither 1 nor 2

12. Which one has hydrogen bonding?
    (a) HCl (b) HBr
    (c) HF (d) HI

13. Of the following elements, which one has the same oxidation state in all of its compounds?
    (a) Hydrogen (b) Fluorine
    (c) Carbon (d) Oxygen

14. When iron is rusted, it is
    (a) oxidised (b) reduced
    (c) evaporated (d) decomposed

15. Starch iodide paper is used to test for the presence of
    (a) iodine (b) iodide iron
    (c) oxidising agent (d) reducing agent

16. Oxidation is defined as
    (a) loss of electrons (b) gain of electrons
    (c) gain of protons (d) loss of protons

17. A redox reaction is
    (a) proton transfer reaction (b) ion combination reaction
    (c) a reaction in solution (d) electron transfer reaction

18. The conversion of sugar $C_{12}H_{22}O_{11} \rightarrow CO_2$ is
    (a) oxidation (b) reduction
    (c) Both (a) and (b) (d) None of these

19. Which one of the following reducing agents can also act as an oxidising agent? **(CDS 2010 II)**
    (a) H_2 (b) H_2S
    (c) SO_2 (d) HI

20. Oxidation number of N in N_3H is
    (a) −3 (b) +3
    (c) $+\frac{1}{3}$ (d) $-\frac{1}{3}$

21. Reduction involves
    (a) gain of electrons
    (b) addition of oxygen
    (c) increase in oxidation number
    (d) loss of electrons

22. Which of the following statements is/are true?
    1. The process of oxidation leads to a gain of electrons.
    2. The process of oxidation leads to a loss of electrons.
    3. The process of reduction leads to a gain of electrons.
    4. The process of reduction leads to loss of electrons.
    (a) Only 1 (b) Only 4
    (c) 2 and 3 (d) 1 and 4

23. 'Loss of electrons' is known as
    (a) reduction (b) oxidation
    (c) redox reaction (d) expansion

24. Reducing agent can
    (a) accept protons (b) donate protons
    (c) accept electrons (d) donate electrons

25. Match Column I (Process of chemical weathering of rocks) with Column II (Description) and select the correct answer using the codes given below the Columns.

Column I	Column II
A. Carbonation	1. Decomposition of materials containing lime, potassium etc.
B. Hydration	2. Minerals in rocks rust.
C. Hydrolysis	3. Cause of additional stress in rock.
D. Oxidation	4. Decomposition of feldspars present in many igneous rock.

Codes

	A	B	C	D
(a)	1	3	4	2
(b)	4	2	1	3
(c)	1	2	3	4
(d)	4	3	1	2

26. The common oxidation state of alkali metals in the combined state is
(a) +1 (b) +2
(c) −1 (d) −2

27. Consider the following statements.
1. Phosphorous exhibits oxidation states of 3 and 5.
2. Iron exhibits oxidation state of +2 and +3.
Which of the statement given above is/are correct?
(a) Only 1
(b) Only 2
(c) Both 1 and 2
(d) Neither 1 nor 2

Answers

1. (d)	**2.** (b)	**3.** (c)	**4.** (a)	**5.** (b)	**6.** (c)	**7.** (a)	**8.** (b)	**9.** (b)	**10.** (c)
11. (a)	**12.** (c)	**13.** (b)	**14.** (a)	**15.** (c)	**16.** (a)	**17.** (d)	**18.** (a)	**19.** (c)	**20.** (d)
21. (a)	**22.** (c)	**23.** (b)	**24.** (d)	**25.** (a)	**26.** (a)	**27.** (c)			

Hints and Solutions

19. SO_2 can act as a reducing agent as well as an oxidising agent.
It reduces ferric sulphate to ferrous sulphate.

$$Fe_2(SO_4)_3 + SO_2 + 2H_2O \longrightarrow 2FeSO_4 + 2H_2SO_4$$

It also oxidises H_2S to S.

$$2H_2S + SO_2 \longrightarrow 2H_2O + S$$

20. Let the oxidation states of N in N_3H is x.

$$N_3H$$
$$3x + (+1) = 0$$
$$3x = -1$$
$$x = -\frac{1}{3}$$