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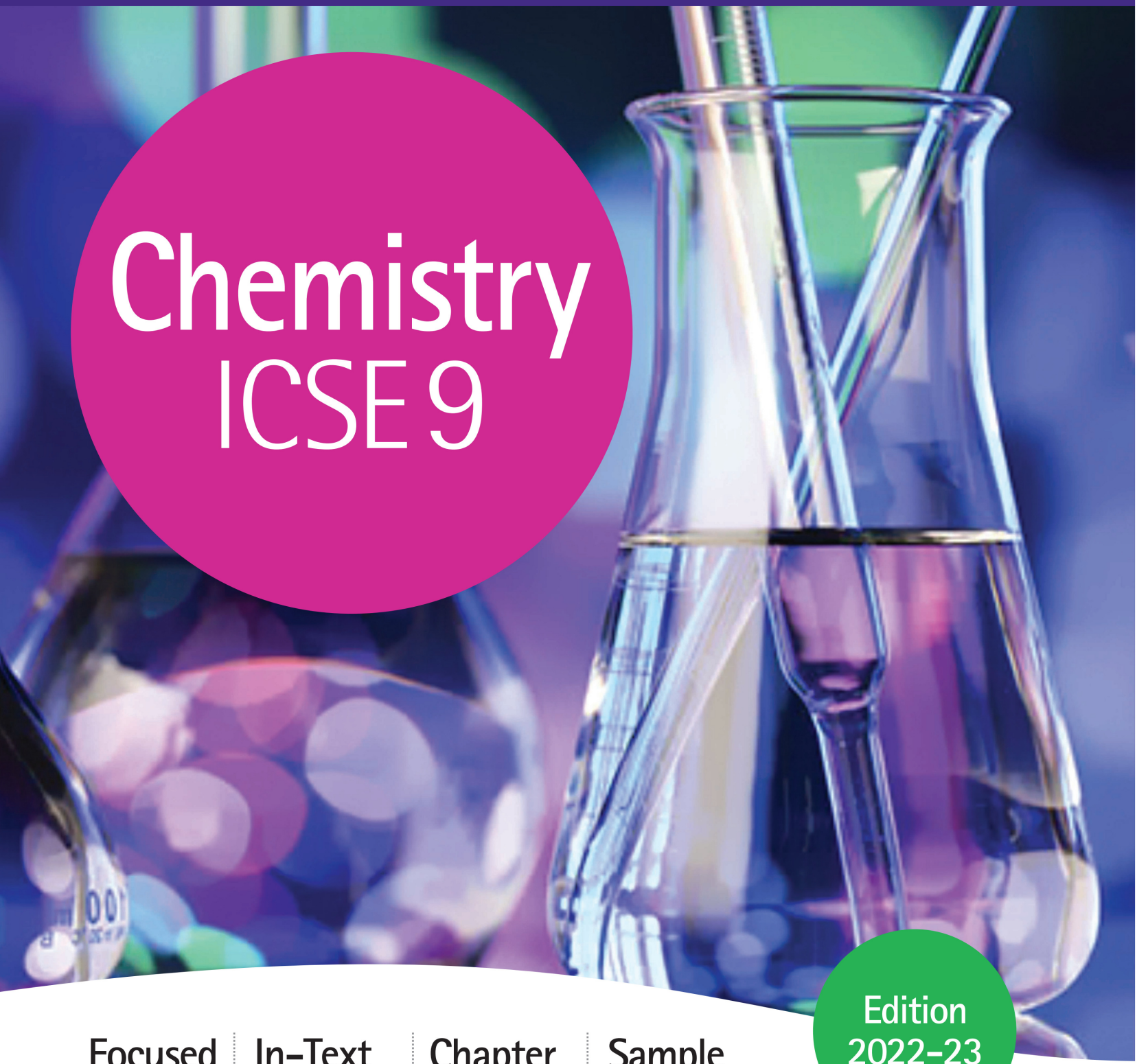

Chemistry ICSE 9

Focused Theory | In-Text Exercises | Chapter Exercises | Sample Papers

Edition 2022-23

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Chemistry

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Chemistry
ICSE 9

A WORD
With The Readers

All in One ICSE Chemistry Class 9 has been written keeping in mind the needs of students studying in 9th ICSE. This book has been made in such a way that students will be fully guided to prepare for the exam in the most effective manner, securing higher grades.

The purpose of this book is to aid any ICSE student to achieve the best possible grade in the exam. This book will give you support during the course as well as advice you on revision and preparation for the exam itself. The material is presented in a clear & concise form and there are ample questions for practice.

KEY FEATURES

- **Focused Theory** contains the necessary study material well supported by Definitions, Facts, Figures, etc.
- **Solved Examples** Solved Examples have been given with each concept. The Special point about these examples is, they have been given in such a way that they cover all the aspects of a concept.
- **Check Point** These are intext exercises given between the text material. These exercises have 4-5 questions based on the related concept.
- **Summary** at the end of each chapter, summary is given. It contains crux of the chapter in pointer form that provides the quick revision of the whole chapter.
- **Exam Practice** The exercise contains questions in that format in which these are asked in the examinations. Questions have been categorised as Fill in the Blanks, MCQs, Match the Following, Very Short Answer, Short Answer and Long Answer Type Questions. All the questions given here are fully solved.
- **Chapter Exercise** It is the Assessment exercise for the complete chapter. With this exercise, students can assess their understanding of the chapter and can prepare for it accordingly.
- **Challengers** It includes some special questions based on the pattern of olympiad and other competitions to give the students a taste of the questions asked in competitions. These are not meant for school examinations.
- To make this book complete in all aspects, **Experiments** and **5 Sample Questions Papers** based on the exam pattern & syllabus have also been given.
- At the end of book there is **Latest ICSE Specimen Paper**.

At the end it can be said that **All in One** Chemistry for ICSE 9th has all the material required for examination and will surely guide students to the Way to Success.

We are highly thankful to ARIHANT PRAKASHAN, MEERUT for giving us such an excellent opportunity to write this book. The role of Arihant DTP Unit and Proof Reading team is praise worthy in making of this book.

Huge efforts have been made from our side to keep this book error free, but inspite of that if any error or whatsoever is skipped in the book then that is purely incidental, apology for the same, please write to us about that so that it can be corrected in the further edition of the book. Suggestions for further improvement of the book will also be welcomed & incorporated in further editions.

In the end, we would like to wish BEST OF LUCK to our readers!

Authors

PREVIEW

Chemistry
ICSE 9

CHAPTER THEORY

Contains the necessary study material well supported by Definitions, Facts, Figure, etc.

CHECK POINT

There are intext exercises given between the text material. These exercises have 4-5 questions based on the related concept.

CHAPTER 1

The Language of Chemistry

The abbreviation is an important fact, which is used in every field of study to save space, time and labour. In chemistry, the names of elements and compounds are abbreviated by using symbols and formulae. Earlier, chemists tried to represent the substances by different pictograph representation such as circle [O] for oxygen atom. Later, **John Berzelius** suggested that the initial letter of an element should represent the particular element. This method led to the foundation of IUPAC system of chemical symbols and formulae. In this chapter, we will discuss about symbols of elements, formulae of radicals, compounds and balancing of simple chemical equations.

Chapter Objectives
- Chemical Symbols
- Valency
- Chemical Formulae
- Radicals
- Chemical Equation
- Relative Atomic Mass (Atomic Weight)
- Relative Molecular Mass (Molecular Weight)
- Percentage Composition

Chemical Symbols

A symbol represents the abbreviation for the full names of the element. In another words, symbol represents the simplified form of an element.

Significance of the Symbol

A symbol has qualitative as well as quantitative significance as explained below

(i) Qualitatively, symbol represents name of the element.
(ii) Quantitatively, symbol represents one atom of the element.

e.g., The symbol C represents

Qualitatively (a) Carbon
Quantitatively (b) One atom of carbon
(c) 12 parts by weight of carbon

CHECK POINT 01

1 Why is it necessary to use symbol for the elements?
2 What is wrong in the following symbols? Give the correct symbol in each case.
(i) Sodium (So) (ii) Hydrogen (Hg) (iii) Copper (Co)
(iv) Sulphur (S) (v) Calcium (CA)
3 Name any two elements whose symbols do not start with the same letter as that of the name of the element.
4 Why the symbols of few elements, like sodium, do not start with the initial letter of the name?
5 Write the latin name of the following elements.
(i) Mercury (ii) Gold

CHECK POINT 02

1 Give the symbol and valency of the following ions.
(i) Hydroxide ion (ii) Carbonate ion.
2 What is the role of valency in the combination of atoms?
3 An element has $Z = 11$, what is the valency of the element? Also, name the element.
4 Write the formula of following compounds.
(i) Magnesium sulphate (ii) Sodium bromide
(iii) Calcium chloride (iv) Potassium nitrate
(v) Sodium phosphate
5 Give the names of following compounds.
(i) $HClO_3$ (ii) $HClO_2$

EXAM PRACTICE

Fill in the Blanks

1. Dalton used symbol ..... for oxygen and ..... for hydrogen.
Sol. [O], [H]
2. Symbol represents ..... atom(s) of an element.
Sol. one
3. Valency of carbon in CH_4 is (i) ....., in C_2H_6 (ii) ....., in C_2H_4 (iii) ..... and in C_2H_2 is (iv) ..... whereas valency of iron in $FeCl_2$ is (v) ..... and $FeCl_3$ is (vi) ..... .
Sol. (i) 4, (ii) 4, (iii) 4, (iv) 4, (v) 2, (vi) 3
4. Nitrite is (i) ..... and (ii) ..... radical, nitride is (iii) ..... and (iv) ..... radical and nitrate is (v) ..... and (vi) ..... radical.
Sol. (i) NO_2^-, (ii) monovalent, (iii) N^{3-}, (iv) trivalent, (v) NO_3^-, (vi) monovalent
5. The formula of caustic potash is ..... .
Sol. KOH
6. The formula of washing soda is ..... .
Sol. Na_2CO_3

Multiple Choice Questions

16. The abbreviation used in the chemistry
(a) to represent name of elements
(b) to represent reactions
(c) Both (a) and (b)
(d) None of the above
Sol. (c)
17. Modern atomic symbols are based on the method proposed by
(a) Berzelius (b) Bohr (c) Dalton (d) Newton
Sol. (a)
18. The symbol for carbonate ion is
(a) CO (b) CO_3^- (c) CO_3^{2-} (d) CO_2
Sol. (c)
19. Valency of copper in Cu_2Cl_2 and $CuCl_2$ are respectively
(a) 2, 1 (b) 1, 2 (c) 1, 1 (d) 2, 2
Sol. (b)
20. The valency of iron in Fe_2O_3 is
(a) +1 (b) +2
(c) +3 (d) Both (b) and (c)
Sol. (c)

CHAPTER EXERCISE

Fill in the Blanks

1. Valency of an element is number of electrons (i) ....., (ii) ..... or contributed for (iii) ..... by an atom of the element in order to get the stable ..... configuration.
2. Chemical formula of glucose is represented as ..... .
3. The prefix 'tri' is used to indicate ..... atoms of an element.
4. Cl^-, F^-, CO_3^{2-} and SO_4^{2-} are ..... radicals.

Multiple Choice Questions

7. The symbol of neon is
(a) NE (b) ne
(c) Ne (d) nE
8. The chemical formula of sodium chlorate is $NaClO_3$ then the chemical formula of sodium hypochlorite is
(a) NaClO
(b) $NaClO_2$
(c) $NaClO_4$
(d) Na_2ClO_2

Match the Following

12. Match the following columns.

	Column I (Name)		Column II (Radicals)
(i)	Dichromate	(a)	CrO_4^{2-}
(ii)	Nitrite	(b)	ZnO_2^{2-}
(iii)	Mercuric	(c)	SO_3^{2-}
(iv)	Zincate	(d)	MnO_4^-
(v)	Permanganate	(e)	N^{3-}
(vi)	Sulphite	(f)	Pb^{4+}
(vii)	Stannic	(g)	Pb^{2+}
(viii)	Nitride	(h)	MnO_4^-
(ix)	Plumbous	(i)	ClO_3^-
(x)	Hypochlorite	(j)	$Cr_2O_7^{2-}$

1 Mark Questions

13. The symbol 'S' for sulphur but 'Na' for sodium and 'Si' for silicon. Explain it.
14. Write the name of two elements, which show

EXAM PRACTICE

It contains questions in that format in which these are asked in the examinations, i.e., Fill in the Blanks, MCQs, Match the Following, Very Short Answer, Short Answer & Long Answer Type Questions. All the questions are fully explained.
The explanations given here teach the students, how to write the explanations in the examinations to get full marks.
Students can use these questions for practice and assess their understanding & recall of the chapter.

CHAPTER EXERCISE

At the end of the chapter, these unsolved questions are given for assessment of students. By practicing these questions, students can assess their preparation level of the chapter.

for ICSE 9th Examination, it is a complete book which can give you all; Study, Practice & Assessment. It is hoped that this book will reinforce and extend your ideas about the subject and finally will place you in the ranks of toppers.

CHALLENGERS

It includes some special questions based on the pattern of olympiad and other competitions to give the students a taste of the questions asked in competitions. These are not meant for school examinations.

CHALLENGERS*

1 The formula of oxide of an element Z is Z_2O_3. What is the valency of element Z?
(a) 2 (b) 0 (c) 3 (d) 4

2 The element B shows valencies of 4 and 6. The formulae of its two oxides respectively are
(a) BO_3, BO_2 (b) B_2O_6, BO_4 (c) BO_2, BO_3 (d) BO_4, B_2O_6

3 The formula of the sulphate of an element X is $X_2(SO_4)_3$. The formula of nitride of the element X is
(a) X_2N (b) XN_2 (c) XN (d) X_2N_3

4 "Hydrogen sulphide gas burns in air to give water and sulphur dioxide". The balanced equation for this reaction is
(a) $H_2S(g) + 3O_2(g) \longrightarrow H_2O(l) + SO_2(g)$ (b) $2H_2S(g) + 3O_2(g) \longrightarrow 2H_2O(l) + 2SO_2(g)$
(c) $2H_2S(g) + 1.5O_2(g) \longrightarrow 2H_2O(l) + 2SO_2(g)$ (d) $H_2S(g) + 3O_2(g) \longrightarrow H_2O(g) + SO_2(g)$

5 Some compounds alongwith their chemical formulae are given below.

Compounds	Chemical formulae
Magnesium nitrate	$Mg(NO_3)_2$
Aluminium nitride	AlN
Zinc phosphate	$Zn_3(PO_4)_2$
Calcium oxide	CaO

On the basis of formulae given above, the valencies or charges on ions are given below. Select the incorrect option.
(a) Nitride ion, – 3 (b) Phosphate ion, – 3
(c) Calcium ion, + 1 (d) Nitrate ion, – 1

Explanations to Challengers

Chapter 1. The Language of Chemistry

1. (c) Valency of one atom of oxygen = 2
Z has valency equal to 3.
$\because$ Z^{3+} O^{-2}
Z_2 O_3

2. (c) If element B shows valency = 4
then formula of its oxide will be

Symbol B O
Charge +4 −2
B_2O_4 or BO_2

Similarly,

Symbol B O
Charge +6 −2
B_2O_6 or BO_3

3. (c) From the formula of the sulphate [$X_2(SO_4)_3$] it is clear that the valency of metal X is +3.

Symbol X N
Charge +3 −3

On crossing the valencies, we get
$X_3N_3 \equiv XN$

4. (b) Hydrogen sulphide + air → water + sulphur dioxide
$2H_2S(g) + 3O_2(g) \longrightarrow 2H_2O(l) + 2SO_2(g)$
(Balanced equation)

5. (a) Magnesium nitrate

Symbol Mg NO_3
Charge +2 −1
$\Rightarrow Mg(NO_3)_2$

Aluminium nitride

Symbol Al N
Charge +3 −3
$\Rightarrow Al_3N_3$ or AlN

Zinc phosphate

Symbol Zn PO_4
Charge +2 −3
$\Rightarrow Zn_3(PO_4)_2$

Chapter 2. Chemical Changes and Reactions

1. (b) Liquid A(oil) contains carbon and hydrogen as a main component and is inflammable in nature. While liquid B (water) contains hydrogen and oxygen and is used to extinguish fire. Hence, they differ in their chemical composition.

2. (c) For an exothermic reaction, heat releases during reaction so temperature increases whereas endothermic reactions proceeds with absorption of heat which decreases the temperature of reaction.

SAMPLE QUESTION PAPER 1

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS IX

CHEMISTRY (FULLY SOLVED)

GENERAL INSTRUCTIONS
1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

Section-A [40 *Marks*]

1. (a) Fill in the blanks.
(i) Neutrons and protons are found in ..... of the atom.
(ii) Electrons present in outermost shell of an atom is called ..... electrons.
(iii) The number of protons present in an atom is called ..... number of an atom.
(iv) There are ..... electrons in outer shell of neon.
(v) An atom having eight electrons and eight protons can be represented by the symbol as ..... . [5]

(b) Choose the most appropriate answer.
(i) What is the percentage composition of hydrogen in water ? (Relative atomic mass of H = 1, O = 16)
(a) 22.7 % (b) 18.4 %
(c) 11.1 % (d) 16.2 %

(c) Correct the underlined words in each of the following cases.
(i) Washing soda is used to remove temporary hardness of water.
(ii) Hard water is used for washing purposes.
(iii) Water has low dielectric constant.
(iv) The chemical formula of ozone is O_2.
(v) An atom contains electron and proton in the nucleus. [5]

(d) Write the complete balanced equation of the following.
(i) $Pb(NO_3)_2 \xrightarrow{\Delta}$
(ii) $MgO \xrightarrow{\text{Combustion}}$
(iii) $NaCl + AgNO_3 \longrightarrow$
(iv) $NH_4CNO \xrightarrow{\Delta}$

Latest ICSE Specimen Paper

Chemistry (Fully Solved)

General *Instructions*
1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section I** and any 4 questions from **Section II**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

Section-I [40 *Marks*]

1. (A) Fill in the blanks with the correct choice given in brackets. (5)
(i) In an ionic compound, the bond is formed due to ..... of electrons. [sharing/transfer]
(ii) Zinc is ..... reactive than aluminium. [less/more]
(iii) The chemical reaction in which heat is absorbed is known as ..... reaction. [endothermic/exothermic]
(iv) The molecular formula of ammonium sulphate is ..... [NH_4SO_4/$(NH_4)_2SO_4$]
(v) If an element has two electrons in its outermost shell, then it is likely to be ..... . [metallic/non-metallic]

(C) Name the gas evolved in each of the following cases: (5)
(i) Copper carbonate is heated strongly.
(ii) Action of dilute hydrochloric acid on
(c) Sodium nitrate
(d) Washing soda crystals
(iv) The gas which has a rotten egg smell is
(a) hydrogen
(b) ammonia
(c) sulphur dioxide
(d) hydrogen chloride
(v) The temperature of 0° celcius on the Kelvin scale is equal to
(a) – 273 K (b) 273 K
(c) 0 K (c) 100 K

SAMPLE QUESTION PAPER and SPECIMEN PAPER

To make the students practice in the real sense, we have provided 5 Sample Question Papers, exactly based on the latest pattern and Latest Specimen Paper.

Chemistry
ICSE 9

CONTENTS

COURSE STRUCTURE

*There will be one paper of **two hours** duration of 80 marks and Internal Assessment of practical work carrying 20 marks.*

*The paper will be divided into two sections, **Section I** (40 marks) and **Section II** (40 marks).*

***Section I** (compulsory) will contain short answer questions on the entire syllabus.*

***Section II** will contain six questions. Candidates will be required to answer any four of these six questions.*

***Note:** All chemical reactions should be studied with reference to the reactants, products, conditions, observations and the (balanced) equations.*

1. The Language of Chemistry

(i) Symbol of an element; valency; formulae of radicals and formulae of compounds. Balancing of simple chemical equations.

- *Symbol – definition; symbols of the elements used often.*
- *Valency - definition; hydrogen combination and number of valence electrons of the metals and non-metals; mono, di, tri and tetra valent elements.*
- *Radicals – definition; formulae and valencies*
- *Compounds – name and formulae.*
- *Chemical equation – definition and examples of chemical equations with one reactant and two or three products, two reactants and one product, two reactants and two products and two reactants and three or four products; balancing of equations. (by hit and trial method).*

(ii) Relative Atomic Masses (atomic weights) and Relative Molecular Masses (molecular weights): either - standard H atom or 1/12th of carbon 12 atom.

- *Definitions*
- *Calculation of Relative Molecular Mass and percentage composition of a compound.*

2. Chemical Changes and Reactions

(i) Types of chemical changes.

- *Direct combination*
- *Decomposition*
- *Displacement*
- *Double decomposition*

(The above to be taught with suitable chemical equations as examples).

(ii) Energy changes in a chemical change.

Exothermic and endothermic reactions with examples – evolution/absorption of heat, light and electricity.

3. Water

(i) Water as a universal solvent.

- *Solutions as 'mixtures' of solids in water; saturated solutions.*
- *Qualitative effect of temperature on solubility (e.g. solutions of calcium sulphate, potassium nitrate and sodium chloride in water).*

(ii) Hydrated and anhydrous substances.

(a) Hydrated substances:

Water of Crystallisation – meaning and examples

(b) Anhydrous substances:

Meaning and examples only

(c) Properties:

- *Efflorescence*
- *Deliquescence*
- *Hygroscopy*
- *Removal of hardness*

(i) By boiling

(ii) By addition of washing soda

(Definition and examples of each of the above).

(iii) Drying and Dehydrating Agents

Meaning and examples only.

(iv) Soft water and Hard water

- *Meaning, (in terms of action of soap)*
- *Advantages and disadvantages of soft water and hard water.*
- *Types and causes of hardness.*

4. Atomic Structure and Chemical Bonding

(i) Structure of an Atom, Mass Number and Atomic number, Isotopes and Octet Rule.

- *Definition of an atom*
- *Constituents of an atom - nucleus (protons, neutrons) with associated electrons; mass number, atomic number.*
- *Electron distribution in the orbits - $2n^2$ rule, Octet rule. Reason for chemical activity of an atom.*
- *Definition and examples of isotopes (hydrogen, carbon, chlorine).*

(ii) Electrovalent and Covalent Bonding, Structures of Various Compounds – Orbit Structure

(a) Electrovalent Bond

- *Definition*
- *Atomic orbit structure for the formation of Electrovalent compounds (e.g. NaCl, $MgCl_2$, CaO);*

(b) Covalent Bond

- *Definition*
- *Atomic orbit structure for the formation of Covalent molecules on the basis of duplet and octet of electrons (examples: hydrogen, chlorine, oxygen, nitrogen, hydrogen chloride, water, ammonia, carbon tetrachloride, methane.)*

5. The Periodic Table

Dobereiner's Triads, Newland's law of Octaves, Mendeleev's contributions; Modern Periodic Law, the Modern Periodic Table. (Groups and periods)

- *General idea of Dobereiner's triads, Newland's law of Octaves, Mendeleev's periodic law.*
- *Discovery of Atomic Number and its use as a basis for Modern Periodic law.*
- *Modern Periodic Table (Groups 1 to 18 and periods 1 to 7).*
- *Special reference to Alkali metals (Group 1), Alkaline Earth metals (Group 2) Halogens (Group 17) and Zero Group (Group 18).*

6. Study of the First Element - Hydrogen

Position of the non-metal (Hydrogen) in the periodic table and general group characteristics with reference to valency electrons, burning, ion formation applied to the above mentioned element.

(i) Hydrogen from: water, dilute acids and alkalis.

(a) Hydrogen from water:

- *The action of cold water on sodium potassium and calcium.*
- *The action of hot water on magnesium.*
- *The action of steam on aluminium, zinc, and iron; (reversibility of reaction between iron and steam).*
- *The action of steam on non-metal (carbon).*

Students can be shown the action of sodium and calcium on water in the laboratory. They must be asked to make observations and write equations for the above reactions.

Application of activity series for the above mentioned reactions.

(b) Displacement of hydrogen from dilute acids:

- *The action of dilute sulphuric acid or hydrochloric acid on metals: Mg, Al, Zn and Fe*

(To understand reasons for not using other metals and dilute nitric acid)

(c) Displacement of hydrogen from alkalis:

- *The action of Alkalis ((NaOH, KOH) on Al, Zn and Pb –unique nature of these elements.*

(ii) The preparation and collection of hydrogen by a standard laboratory method other than electrolysis.

In the laboratory preparation, the reason for using zinc, the impurities in the gas, their removal and the precautions in the collection of the gas must be mentioned.

(iii) Industrial manufacture of hydrogen by Bosch process:

- *Main reactions and conditions.*
- *Separation of CO_2 and CO from hydrogen.*

(iv) Oxidation and reduction reactions

Differences in terms of addition and removal of oxygen / hydrogen.

7. Study of Gas Laws

(i) The behaviour of gases under changes of temperature and pressure; explanation in terms of molecular motion (particles, atoms, molecules); Boyle's Law and Charles' Law; absolute zero; gas equation; simple relevant calculations.

- *The behaviour of gases under changes of temperature and pressure; explanation in terms of molecular motion(particles, atoms, molecules).*
- *Boyle's Law: statement, mathematical form, simple calculations.*
- *Charles' Law: statement, mathematical form, simple calculations.*
- *Absolute zero Kelvin scale of temperature.*
- *Gas equation* $p_1 V_1 / T_1 = p_2 V_2 / T_2$*; simple relevant calculations based on gas equation.*

(ii) Relationship between Kelvin scale and Celsius Scale of temperature; Standard temperature and pressure.

- *Conversion of temperature from Celsius Scale to Kelvin scale and vice versa. Standard temperature and pressure. (Simple calculations).*

8. Atmospheric Pollution

(a) Acid rain – composition, cause and its impact.

Sulphur in fossil fuels giving oxides of sulphur when burnt. High temperatures in furnaces and internal combustion engines produce oxides of nitrogen. (Equations to be included). Acid rain affects soil chemistry and water bodies.

(b) Global warming: Greenhouse gases – their sources and ways of reducing their presence in the atmosphere.

(Water vapour, carbon dioxide, methane and oxides of nitrogen)

(c) Ozone depletion

- *Formation of ozone – relevant equations*
- *Function in the atmosphere.*
- *Destruction of the ozone layer – chemicals responsible for this to be named but reactions not required.*

INTERNAL ASSESSMENT OF PRACTICAL WORK

Candidates will be asked to observe the effect of reagents and/or of heat on substances supplied to them. The exercises will be simple and may include the recognition and identification of certain gases listed below.

Gases Hydrogen, Oxygen, Carbon dioxide, Chlorine, Hydrogen chloride, Sulphur dioxide, Hydrogen sulphide, Ammonia, Water vapour, Nitrogen dioxide.

Candidates are expected to have completed the following minimum practical work.

Simple Experiments on:

1. Action of heat on the following compounds:
   (a) copper carbonate, zinc carbonate
   (b) washing soda, copper sulphate crystals
   (c) zinc nitrate, copper nitrate, lead nitrate
   (d) ammonium chloride, iodine, ammonium dichromate

   Make observations, identify the products and make deductions where possible.

2. Action of dilute sulphuric acid on the following substances. (warm if necessary)
   (a) a metal
   (b) a carbonate
   (c) a sulphide
   (d) a sulphite

   Make observations, identify the gas evolved and make deductions

3. Apply the flame test to identify the metal in the unknown substance.
   (a) a sodium salt
   (b) a potassium salt
   (c) a calcium compound

4. Simple experiments based on hard water and soft water – identification of hardness – simple softening – by heating the temporary hard water, using washing soda and advantage of using detergents over soap in hard water.

5. Find out the sources of pollution of water bodies in the locality. Suggest preventive steps to control it.

CHAPTER

1

The Language of Chemistry

The abbreviation is an important fact, which is used in every field of study to save space, time and labour. In chemistry, the names of elements and compounds are abbreviated by using symbols and formulae. Earlier, chemists tried to represent the substances by different pictograph representation such as circle [O] for oxygen atom. Later, **John Berzelius** suggested that the initial letter of an element should represent the particular element. This method led to the foundation of IUPAC system of chemical symbols and formulae. In this chapter, we will discuss about symbols of elements, formulae of radicals, compounds and balancing of simple chemical equations.

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A symbol has qualitative as well as quantitative significance as explained below

(i) Qualitatively, symbol represents name of the element.

(ii) Quantitatively, symbol represents one atom of the element.

e.g., The symbol C represents

Qualitatively (a) Carbon

Quantitatively (b) One atom of carbon

(c) 12 parts by weight of carbon

Different ways to write the symbols of elements

The symbols of elements can be written in the following ways

- In few cases, first letter of the name of the element is taken as its symbol and written in capital.
  e.g., Carbon—C, Oxygen—O, Nitrogen—N
- In few cases, the symbol of element have been derived from their Latin names.
  e.g., Sodium—Na (discovered from Natrium)
  Potassium—K (discovered from Kalium)
- In few cases, the symbol of element has two letters, first letter is written in capital and second letter is written in small.
  e.g., Calcium—Ca, Cobalt—Co, Nickel—Ni
- In the present days, the symbol of element having atomic number more than 100, have three letters, first letter is written in capital then two letters are written in small.
  e.g., Unnilbium : Unb

Symbols for Some Elements

Element	Symbol	Element	Symbol	Element	Symbol
Aluminium	Al	Copper	Cu	Nitrogen	N
Argon	Ar	Fluorine	F	Oxygen	O
Barium	Ba	Gold	Au	Potassium	K
Boron	B	Hydrogen	H	Silicon	Si
Bromine	Br	Iodine	I	Silver	Ag
Calcium	Ca	Iron	Fe	Sodium	Na
Carbon	C	Lead	Pb	Sulphur	S
Chlorine	Cl	Magnesium	Mg	Uranium	U
Cobalt	Co	Mercury	Hg	Zinc	Zn
Chromium	Cr	Neon	Ne		

Symbols of Some Elements based upon their Latin Names

Element	Latin Name	Symbol
Sodium	Natrium	Na
Potassium	Kalium	K
Iron	Ferrum	Fe
Copper	Cuprum	Cu
Lead	Plumbum	Pb
Mercury	Hydragyrum	Hg
Gold	Aurum	Au
Tin	Stannum	Sn

Symbols of Some Elements Involving Three Letters

Element	Symbol
Unnilbium	Unb
Unniltrium	Unt
Unnilquadium	Unq

CHECK POINT 01

1 Why is it necessary to use symbol for the elements?

2 What is wrong in the following symbols? Give the correct symbol in each case.
(i) Sodium (So) (ii) Hydrogen (Hg) (iii) Copper (Co)
(iv) Sulphur (S) (v) Calcium (CA)

3 Name any two elements whose symbols do not start with the same letter as that of the name of the element.

4 Why the symbols of few elements, like sodium, do not start with the initial letter of the name?

5 Write the latin name of the following elements.
(i) Mercury (ii) Gold

Valency

The combining power (or capacity) of an element is called its **valency**. Valency can be used to find out how the atoms of an element will combine with the atom(s) of another element to form a chemical compound. It is also referred to the number of electrons that atom can gain, lose or share during a chemical reaction.

Elements that have one, two or three electrons present in their outermost shell are known as metals. The electrons that are present in the outermost shell are known as valence electrons. Metals form univalent, divalent, trivalent and tetravalent cation by losing their valence electrons. Elements that have five, six or seven electrons present in their outermost shell are known as **non-metals**. They form univalent, divalent, trivalent and tetravalent anion by gaining electrons. Thus, the valency of an ion is equal to the charge on the ion.

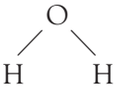
Valency in terms of hydrogen is defined as the number of hydrogen atoms that are attached with the elements.

e.g.,

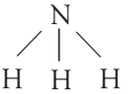
(i) One atom of hydrogen is attached with one atom of chlorine to form a molecule of hydrogen chloride. So, the valency of chlorine is one.

H—Cl

(ii) Two atoms of hydrogens are attached with one atom of oxygen to form a molecule of water. So, the valency of oxygen is two.



(iii) Three atoms of hydrogens are attached with one atom of nitrogen. So, the valency of nitrogen is three.



Names, Symbols and Valency of Some Ions

Valency	Ion of Metallic Element	Symbol	Ion of Non-Metallic Element	Symbol	Polyatomic Ions	Symbol
1	Sodium	Na^+	Hydrogen	H^+	Ammonium	NH_4^+
	Potassium	K^+	Hydride	H^-	Hydroxide	OH^-
	Silver	Ag^+	Chloride	Cl^-	Nitrate	NO_3^-
	Copper (I)*	Cu^+	Bromide	Br^-	Hydrogen Carbonate (bicarbonate)	HCO_3^-
			Iodide	I^-		
2	Magnesium	Mg^{2+}	Oxide	O^{2-}	Carbonate	CO_3^{2-}
	Calcium	Ca^{2+}	Sulphide	S^{2-}	Sulphite	SO_3^{2-}
	Zinc	Zn^{2+}			Sulphate	SO_4^{2-}
	Iron (II)*	Fe^{2+}				
	Copper (II)*	Cu^{2+}				
3	Aluminium	Al^{3+}	Nitride	N^{3-}	Phosphate	PO_4^{3-}
	Iron (III)*	Fe^{3+}	Phosphide	P^{3-}		
4.	Lead (IV)	Pb^{4+}	Carbide	C^{4-}		

Note *These elements show more than one valency i.e., variable valency. Here, the roman numeral written in brackets shows their valency.

Chemical Formulae

The shortest way to represent a compound with the help of symbols and valency of elements is known as **chemical formula.** Chemical formula of a compound shows its constituent elements and the number of atoms of each combining element. In ionic compounds, the charge on each ion is used to determine the chemical formula of a compound. A chemical formula is also known as **molecular formula** as it denote the molecule of an element or of a compound, *e.g.,* 2NaCl represents two molecules of sodium chloride and each molecule contains one atom of sodium and one atom of chlorine.

Writing Chemical Formulae

To write the chemical formula for simple compounds

(i) Write the symbols of constituent elements and their valencies.
(ii) Write the symbol of cation first followed by the symbol of anion.
(iii) Then criss-cross their charges or valencies to get the formula.
(iv) The positive and negative charges must balance each other and the overall structure must be neutral.

Note The simplest compounds made up of two different elements are also called binary compounds.

e.g., **Hydrogen sulphide**

Symbols $H \quad S$
Charges $1 \quad -2$
Formula H_2S

Note When the subscript is 1, then it is not written.

Carbon tetrachloride

Symbols $C \quad Cl$
Charges $4 \quad -1$
Formula CCl_4

Magnesium chloride

Symbols $Mg \quad Cl$
Charges $+2 \quad -1$
Formula $MgCl_2$

Calcium oxide

Symbols $Ca \quad O$
Charges $+2 \quad -2$
Formula Ca_2O_2 or CaO

Note When the valency of both elements are numerically equal, the subscripts are not written.

Aluminium oxide

Symbols $Al \quad O$
Charges $+3 \quad -2$
Formula Al_2O_3

Sodium nitrate

Symbols $Na \quad NO_3$
Charges $+1 \quad -1$
Formula $NaNO_3$

Potassium carbonate

Symbols $K \quad CO_3$
Charges $+1 \quad -2$
Formula K_2CO_3

Aluminium hydroxide

Symbols $Al \quad OH$
Charges $+3 \quad -1$
Formula $Al(OH)_3$

Ammonium sulphate

Symbols $NH_4 \quad SO_4$
Charges $+1 \quad -2$
Formula $(NH_4)_2SO_4$

Note We use brackets when we have two or more of the same ions in the formulae.

Tin (IV) oxide

Symbols $Sn \quad O$
Charges $+4 \quad -2$
Formula Sn_2O_4 or SnO_2

Note All subscripts must be reduced to lowest term (except for molecule or covalent compound)

Importance of Chemical Formula

The chemical formula of a compound has quantitative significance /importance. It represents

- the respective numbers of different atoms present in one molecule of the compound.
- the ratios of the respective masses of the elements present in the compound.
- both the molecule and the molecular mass of the compound.

e.g., The formula CO_2 represents that

(i) the chemical formula of carbon dioxide is CO_2.

(ii) each molecule contains one carbon atom joined by chemical bonds with two oxygen atoms.

(iii) the molecular mass of CO_2 is 44g as the atomic mass of carbon is 12 g and that of oxygen is 16 g.

Naming Chemical Compounds

Following rules are followed while naming the chemical compound from chemical formula

In binary compounds with one metal atom and a non-metal atom, the metal is named first and non-metal is named at the end with suffix 'ide'. *e.g.,*

$Na_2O \longrightarrow$ Sodium oxide

$Ca_3N_2 \longrightarrow$ Calcium nitride

The compounds containing two non-metals are named by using prefix mono, di, tri, etc.

$PCl_3 \longrightarrow$ Phosphorus trichloride

$PCl_5 \longrightarrow$ Phosphorus pentachloride

The name of the compounds containing oxygen depend on the number of oxygen atoms present in the compound. The prefix 'hypo' is used, if the number of oxygen atoms is less than 2. The suffix 'ite' is used, if the number of oxygen atom is 2. The suffix 'ate' and prefix 'per' is used when the number of oxygen atoms is more than 3.

$NaClO_4$ – Sodium perchlorate

NaClO – Sodium hypochlorite

$NaClO_3$ – Sodium chlorate

The acids containing two elements where one atom is hydrogen that combines with one non-metal are named by adding prefix *hydro* and suffix-*ic* to the name of second element.

Bases are named as hydroxides after the name of the metal or radical.

HCl– Hydrochloric acid (acid)

NH_4OH – Ammonium hydroxide (base)

Radicals

Radical is an atom or group of atoms having a charge of positive or negative and shown as a single unit in chemical reaction.

Radicals have their own valencies and chemical formulae.

e.g., Ammonium radical : NH_4^+

Sodium radical : Na^+, Chloride radical : Cl^-

Types of Radicals

There are four types of radicals

(i) **Acid Radicals** Radicals having negative charge on it are called acid radicals. *e.g.,* F^-, CO_3^{2-}, SO_4^{2-}, etc.

They are also referred as electropositive radicals or cations.

(ii) **Basic Radicals** Radicals having positive charge on it are called basic radicals. *e.g.,* Na^+, NH_4^+, Zn^{2+}, etc.

They are also referred as electronegative radicals or anions.

(iii) **Simple Radicals** Radicals made up of only one kind of atoms are called simple radicals. e.g., F^-, Na^+, K^+, etc.

(iv) **Compound Radicals** Radicals made up of two or more type of atoms are called compound radicals. *e.g.,* CO_3^{2-}, OH^-, NH_4^+, etc.

List of Some Common Basic Radicals (electrovalent positive ions)

Radicals having +1 charges (Monovalent)			**Radicals having +2 charges** (Divalent)			**Radicals having +3 charges** (Trivalent)			**Radicals having +4 charges** (Tetravalent)		
Hydrogen	–	H^+	Magnesium	–	Mg^{2+}	Ferric	–	Fe^{3+}	Stannic [Tin (IV)]	–	Sn^{4+}
Lithium	–	Li^+	Calcium	–	Ca^{2+}	Chromium	–	Cr^{3+}	Platinic [Platinum (IV)]	–	Pt^{4+}
Sodium	–	Na^+	Cobalt	–	Co^{2+}	Aluminium	–	Al^{3+}	Plumbic [Lead (IV)]	–	Pb^{4+}
Ammonium	–	NH_4^+	Nickel	–	Ni^{2+}	Bismuth	–	Bi^{3+}			
Silver	–	Ag^+	Zinc	–	Zn^{2+}						
Cuprous	–	Cu^+	Ferrous	–	Fe^{2+}						
Mercurous	–	Hg^+	Cupric	–	Cu^{2+}						
			Mercuric [Mercury (II)]	–	Hg^{2+}						
			Platinous [Platinum (II)]	–	Pt^{2+}						

List of Some Common Acid Radicals (electrovalent negative ions)

Radicals having –1 charges (Monovalent)			**Radicals having –2 charges** (Divalent)			**Radicals having –3 charges** (Trivalent)			**Radicals having –4 charges** (Tetravalent)		
Hydride	–	H^-	Carbonate	–	CO_3^{2-}	Nitride	–	N^{3-}	Carbide	–	C^{4-}
Chloride	–	Cl^-	Sulphite	–	SO_3^{2-}	Phosphide	–	P^{3-}	Pyrophosphate	–	$P_2O_7^{4-}$
Bromide	–	Br^-	Sulphate	–	SO_4^{2-}	Phosphite	–	PO_3^{3-}	Ferrocyanide	–	$[Fe(CN)_6]^{4-}$
Cyanide	–	CN^-	Oxide	–	O^{2-}	Phosphate	–	PO_4^{3-}			
Nitrite	–	NO_2^-	Chromate	–	$Cr_2O_4^{2-}$	Ferricyanide	–	$[Fe(CN)_6]^{3-}$			
Nitrate	–	NO_3^-	Dichromate	–	$Cr_2O_7^{2-}$						
Acetate	–	CH_3COO^-	Oxalate	–	$C_2O_4^{2-}$						
Chlorate	–	ClO_3^-	Peroxide	–	O_2^{2-}						
Bicarbonate	–	HCO_3^-									
Bisulphate	–	HSO_4^-									

Example 1. Write the chemical formula of the compound aluminium phosphate.

Sol. Symbols Al PO_4
Charges +3 –3
Formula $AlPO_4$

CHECK POINT 02

1 Give the symbol and valency of the following ions.
(i) Hydroxide ion (ii) Carbonate ion.
2 What is the role of valency in the combination of atoms?
3 An element has $Z = 11$, what is the valency of the element? Also, name the element.
4 Write the formula of following compounds.
(i) Magnesium sulphate (ii) Sodium bromide
(iii) Calcium chloride (iv) Potassium nitrate
(v) Sodium phosphate
5 Give the names of following compounds.
(i) $HClO_3$ (ii) $HClO_2$

Chemical Equation

A chemical equation is the symbolic representation of a chemical reaction. Symbols and formulae of the reactants (substances written on the left hand side of the arrow) and products (substances written on the right hand side of the arrow) are used for the same. *e.g., The reaction of burning of methane gas can be written in words as*

$$\underset{\text{(Reactants)}}{\text{Methane} + \text{Oxygen}} \xrightarrow{\Delta} \underset{\text{(Products)}}{\text{Carbon dioxide} + \text{Water}}$$

This equation is called **word equation**. The word equation can be change into a chemical equation by writing symbol and formulae of the substance in place of their name.

$$\underset{\text{Methane}}{CH_4(g)} + \underset{\text{Oxygen}}{2O_2(g)} \xrightarrow{\Delta} \underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Water}}{2H_2O(g)}$$

Chemical reactions may involve

(i) One reactant and two or more products.

$$CaCO_3 \longrightarrow CaO + CO_2$$

(ii) Two reactants and one product.

$$NH_3 + HCl \longrightarrow NH_4Cl$$

(iii) Two reactants and two products.

$$Na_2SO_4 + BaCl_2 \longrightarrow BaSO_4 + 2NaCl$$

(iv) Two reactants and three or more products

$$Cu + 2H_2SO_4 \longrightarrow CuSO_4 + 2H_2O + SO_2$$

Writing a Chemical Equation

Various steps involved in writing a chemical equation are as follows

(i) A chemical equation shows change of reactants to products through an arrow (→) placed between them.

(ii) On the left hand side (LHS) of the arrow, reactants are written with a plus sign (+) between them. Similarly, on the right hand side (RHS), products are written with a plus sign (+) between them.

(iii) The arrow head points toward the products and shows the direction of the reaction *e.g.,* The reaction between magnesium (Mg) and oxygen (O_2) resulting into the formation of magnesium oxide can be written as

$$\underset{\text{(Reactants)}}{2Mg + O_2} \longrightarrow \underset{\text{(Product)}}{2MgO}$$

Balanced Chemical Equation

A balanced chemical equation is that in which the total number of atoms of each element are equal on both sides of the equation. According to the law of conservation of mass, 'mass can neither be created nor destroyed during a

chemical reaction.' It means that in a chemical reaction total mass of reactants should be equal to total mass of products.

Following method is used for balancing an equation

Hit and Trial Method

This method consists of counting the number of atoms of each element on both sides and try to equalise them.

Several steps involved in balancing a chemical equation are as follows

Step **I** Writing unbalanced equation and enclosing the formulae in brackets.

$$\underset{\text{Sodium}}{(Na)} + \underset{\text{Water}}{(H_2O)} \longrightarrow \underset{\text{Sodium hydroxide}}{(NaOH)} + \underset{\text{Hydrogen}}{(H_2)}$$

Step **II** Making list of elements as shown in unbalanced equation.

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
Na	1	1
H	2	3
O	1	1

Step **III** Balancing first element From the table [in step (b)], it is clear that it is only the hydrogen atoms, which are unbalanced. So, firstly we try to balance it.

Atoms of H	In reactants	In products
Initially	2 (in H_2O)	3 (1 in NaOH and 2 in H_2)
To balance	2×2	2×1 in NaOH, 2 in $H_2 = 4$ H- atoms

Thus, now the equation becomes

$$(Na) + 2\,(H_2O) \longrightarrow 2\,(NaOH) + (H_2)$$

Step **IV** **Balancing second element** We examine the obtained equation and select another element which is still unbalanced. In the above equation, Na is still unbalanced. *To balance the number of Na-atoms*

Atoms of Na	In reactants	In products
Initially	1 (in Na)	2 (in NaOH)
To balance	2×1	2

Thus, after balancing Na and removing the brackets, we get the equation

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$

Step **V** Balancing other elements If we further examine the reaction, no element is found to be unbalanced. This method of balancing chemical equation is called **hit-and-trial method.**

Step **VI** **Checking the correctness of equation** To check the correctness of the equation, we further tabulate the atoms of each element separately.

Element	Number of atoms in reactants	Number of atoms in products
Na	2	2
H	4	4
O	2	2

The above table clearly reveals that the obtained equation is a balanced chemical equation.

Example 2. Balance the following equation.

$$C_2H_6 + O_2 \longrightarrow CO_2 + H_2O$$

Sol. First of all enclose all the formulae in brackets.

$$(C_2H_6) + (O_2) \longrightarrow (CO_2) + (H_2O)$$

Hydrogen possesses maximum number of atom. So, first of all to balance hydrogen multiply H_2O molecules by 3.

$$(C_2H_6) + (O_2) \longrightarrow (CO_2) + 3(H_2O)$$

Now, to balance carbon atom multiply CO_2 molecules by 2.

$$(C_2H_6) + (O_2) \longrightarrow 2(CO_2) + 3(H_2O)$$

There are 7 O-atoms on RHS. To make 7 O-atoms at LHS, we have to write 7/2 before O_2 but we can use only whole number to balance the equation, so we write 7/2 before O_2 and multiply the whole equation by 2.

$$\left[C_2H_6 + \frac{7}{2}O_2 \longrightarrow 2CO_2 + 3H_2O\right] \times 2$$

Thus, on removing the brackets from equation, the equation becomes $2C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$

Making a Chemical Equation More Informative

The following facts remain unexplained in a chemical equation shown in step (d)

(i) Physical states of substances
(ii) Reaction conditions
(iii) Evolution/absorption of energy

Some of these limitations of a chemical equation can be overcome by adding the following symbols or information as discussed below

(i) The physical state of the reactants and products can be represented by using the symbols, (*s*) for solid, (*l*) for liquid, (*g*) for gas and (*aq*) for aqueous solution, alongwith their respective formulae. The word aqueous (*aq*) is used, if the reactant or product is present as a solution in water.

$$2Na(s) + 2H_2O(l) \longrightarrow 2NaOH\,(aq) + H_2(g)$$

Precipitate can also be represented by using an arrow pointing downwards (↓) instead of using symbol (*s*).

In the same way, the gaseous state of an evolved gas can be represented by using an arrow pointing upward direction (↑) instead of using symbol (*g*). *e.g.*, Magnesium reacting with dilute sulphuric acid is represented by the chemical equation.

$$\underset{\text{Magnesium}}{Mg(s)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq)} \longrightarrow \underset{\text{Magnesium sulphate}}{MgSO_4(aq)} + \underset{\text{Hydrogen}}{H_2\uparrow}$$

(ii) The specific conditions of the reaction like temperature, pressure, catalyst, etc., are written above or below the arrow in the chemical equation.

$$\underset{\text{Carbon monoxide}}{CO(g)} + \underset{\text{Hydrogen}}{2H_2(g)} \xrightarrow{340\ \text{atm}} \underset{\text{Methanol}}{CH_3OH(l)}$$

(iii) Evolution of heat or absorption of heat can be indicated by writing [+ Heat] on the right hand side or left hand side of the equation, respectively.

Burning of carbon in the presence of air.

e.g., $\underset{\text{Carbon}}{C(s)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2(g)} + \text{Heat}$

Note Although it is not always necessary to mention the physical states and reaction conditions in a balanced chemical equation. So, you can left this step until it is asked in the question.

Information Conveyed by a Balanced Chemical Equation

(i) A chemical equation gives us information about the substance (reactants and products) participating in a chemical reaction.

(ii) It give information us about the symbol and formulae of all the substances involve in a particular reaction.

(iii) It tells us about the physical state of the reactants and products.

(iv) It gives us information whether heat is evolved or absorbed during a chemical reaction.

(v) It ensures us that number of atoms present in reactants (LHS) is equal to the number of atoms present in products (RHS).

(vi) It tells us about the weights of reactant consumed and of product formed, the number of atoms or molecules of reactants and products that are involved in a reaction, the number of gram of atoms or gram moles of the substance that are participating in the reaction, etc.

(vii) It also proves the law of conservation of mass.

Limitations of Chemical Equation

(i) A chemical equation does not tell us about the feasibility of a chemical reaction. It means we cannot predict whether a particular reaction will take place or not.

(ii) It does not tell us whether a particular reaction will proceed at a slow, moderate or fast speed.

Relative Atomic Mass (Atomic Weight)

It is defined as the number of times a given atom is heavier than $\frac{1}{12}$th of mass of 1 atom of carbon – 12 (C –12) or it is the average mass of the atom as compared to $\frac{1}{12}$th the mass of one carbon – 12 atom. Thus,

$$\text{Relative atomic mass} = \frac{\text{Mass of 1 atom of the element}}{\frac{1}{12}\text{ th the mass of one C-12 atom}}$$

Atomic Mass Unit

It is defined as the mass unit equal to exactly 1/12th of the mass of one atom of C–12 isotope. Earlier, it was abbreviated as amu but according to latest recommendation of IUPAC, it is now written as 'u'–unified mass.

$$1 \text{ amu or /u} = 1.6605 \times 10^{-24}\ g$$

Note Mass of an atom of hydrogen = 1.6736×10^{-24} g

Thus, in terms of amu,

$$\text{Mass of hydrogen atom} = \frac{1.6736 \times 10^{-24}\text{ g}}{1.66056 \times 10^{-24}\text{ g}}$$

$$= 1.0078 \text{ amu}$$

$$= 1.0080 \text{ amu}$$

Relative Molecular Mass (Molecular Weight)

It is defined as the ratio of the average mass of one molecule of an element or compound to one – twelfth of the mass of an atom of carbon – 12 isotope.

Relative molecular mass of a compound is the sum of relative atomic masses of the atomic species as given in the chemical formula.

Example 3. Calculate relative molecular mass of (i) ammonia (NH_3) and (ii) sugar ($C_{12}H_{22}O_{11}$).

Sol.

(i) Relative mass of NH_3,

mass of 1 atom of nitrogen is $1 \times 14 = 14$ amu

Mass of 3 atoms of hydrogen is $3 \times 1 = 3$ amu

So, mass of NH_3 is $1 \times 14 + 3 \times 1 = 14 + 3 = 17$ amu

(ii) Relative mass of sugar ($C_{12}H_{22}O_{11}$)

= Mass of 12 atoms of carbon + Mass of 22 atoms of hydrogen + Mass of 11 atoms of oxygen

$= 12 \times 12 + 22 \times 1 + 11 \times 16$

$= 144 + 22 + 176 = 342$ amu

Percentage Composition

The percentage composition of an element in a compound is the percentage of the mass contributed by the element to the total mass of the compound.

It is obtained by dividing mass of that element in the compound by the total mass of the compound and multiplying by 100 *i.e.*,

Percentage composition of element

$$= \frac{\text{Mass contributed by the element}}{\text{Total molecular mass of compound}} \times 100$$

Example 4. Calculate percentage of oxygen in water. Given that the relative atomic masses of H = 1, O = 16.

Sol. Relative molecular mass of $H_2O = 1 \times 2 + 16 = 18$

Percentage composition of oxygen

$$= \frac{\text{Mass contributed by oxygen}}{\text{Total molecular mass of water}} \times 100 = \frac{16}{18} \times 100$$

$= 88.89\ \%$

$\therefore$ Percentage composition of oxygen in water is 88.89%

CHECK POINT 03

1 Write the skeletal and balanced equation for the following reaction:

Potassium bromide (*aq*) + Barium iodide (*aq*) $\longrightarrow$ Potassium iodide (*aq*) + Barium chloride (s)

2 Which of the following reactions is balanced, *A* or *B*?

A : $2\,NaCl + 2H_2O \xrightarrow{\text{Electricity}} 2NaOH + 2Cl_2 + H_2\uparrow$

B : $Ca(OH)_2 + Cl_2 \longrightarrow CaOCl_2 + H_2O$

3 What is the value of 1 amu in grams?

4 Complete the following.

Relative atomic mass is defined as the number of times a given atom is heavier than …… of the mass of 1 atom of carbon –12.

5 What will be the mass of hydrogen atom in amu?

6 Calculate the percentage composition of K in $KClO_3$.

Ans. $K = 31.83\%$

SUMMARY

- Symbols of elements are derived from one or two letters of names of the elements in English, Greek, Latin, German, etc. First letter is written in capital and second one in small e.g., Iron. Fe(from ferrum).
- Valency is the combining capacity of an element and it is charge in case of ions.
- Chemical formula is the shortest way to represent a compound with the help of symbols and valency of elements.
- Radical is an atom or a group of atoms, which behave as a single unit, having their own combining capacity and has positive or negative charge.
- Chemical equation is the symbolic representation of a chemical reaction that describes a chemical change in terms of symbols and formulae.
- A balanced chemical equation is that, in which the total number of atoms of each element are equal on both sides of the equation.
- The method involved for balancing chemical equation is hit and trial method.
- Hit and trial method This method consist of counting the number of atoms of each element on both sides and try to equalise them.
- Relative atomic mass of the atom of an element is defined as the average mass of the atom, as compared to 1/12th the mass of one carbon –12 atom.
- Relative molecular mass is the ratio of the average mass of one molecule of an element or compound to one-twelth of the mass of an atom of carbon –12 isotope.
- Percentage composition of an element in a compound is the percentage of the mass contributed by the element to the total mass of the compound.

EXAM PRACTICE

Fill in the Blanks

1. Dalton used symbol …… for oxygen and …… for hydrogen.

Sol. [O], [H]

2. Symbol represents …… atom(s) of an element.

Sol. one

3. Valency of carbon in CH_4 is (i) ……, in C_2H_6 (ii) ……, in C_2H_4 (iii) …… and in C_2H_2 is (iv) …… whereas valency of iron in $FeCl_2$ is (v) …… and $FeCl_3$ is (vi) …… .

Sol. (i) 4, (ii) 4, (iii) 4, (iv) 4, (v) 2, (vi) 3

4. Nitrite is (i) …… and (ii) …… radical, nitride is (iii) …… and (iv) …… radical and nitrate is (v) …… and (vi) …… radical.

Sol. (i) NO_2^-, (ii) monovalent, (iii) N^{3-}, (iv) trivalent, (v) NO_3^-, (vi) monovalent

5. The formula of caustic potash is …… .

Sol. KOH

6. The formula of washing soda is …… .

Sol. Na_2CO_3

7. Limestone is …… .

Sol. $CaCO_3$

8. Formula of iron (III) carbonate is …… .

Sol. $Fe_2(CO_3)_3$

9. Sodium chloride has two radicals. Sodium is …… radical whereas chloride is …… radical.

Sol. basic, acid

10. Essential condition for a chemical equation is that it must be …… and should be …… .

Sol. balanced, molecular

11. $2H_2O + 2Cl_2 \longrightarrow \ldots\ldots + O_2$

Sol. 4HCl

12. $2NaHCO_3 \longrightarrow \ldots\ldots + H_2O + CO_2$

Sol. Na_2CO_3

13. Balancing of chemical equations is based upon (i) ……, as in a reaction total mass of the (ii) …… must be equal to the total mass of the (iii) …… as number of atoms of each element should be (iv) …… on both sides.

Sol. (i) law of conservaion of mass, (ii) products, (iii) reactants, (iv) equal.

14. A chemical equation has …… as well as …… significance.

Sol. qualitaive, quantitative

15. …… does not tell about the energy changes during chemical reactions.

Sol. Chemical equation

Multiple Choice Questions

16. The abbreviation used in the chemistry

(a) to represent name of elements
(b) to represent reactions
(c) Both (a) and (b)
(d) None of the above

Sol. (c)

17. Modern atomic symbols are based on the method proposed by

(a) Berzelius (b) Bohr (c) Dalton (d) Newton

Sol. (a)

18. The symbol for carbonate ion is

(a) CO (b) CO_3^- (c) CO_3^{2-} (d) CO_2

Sol. (c)

19. Valency of copper in Cu_2Cl_2 and $CuCl_2$ are respectively

(a) 2, 1 (b) 1, 2 (c) 1, 1 (d) 2, 2

Sol. (b)

20. The valency of iron in Fe_2O_3 is

(a) +1 (b) +2
(c) +3 (d) Both (b) and (c)

Sol. (c)

21. The formula of compound represents

(a) a radical (b) a molecule
(c) a particle (d) an atom

Sol. (b)

22. The correct chemical formula of aluminium oxide is

(a) AlO (b) AlO_3 (c) Al_2O_3 (d) Al_3O_2

Sol. (c)

23. The chemical reaction,

$$(NH_4)_2Cr_2O_7 \xrightarrow{\Delta} N_2 + 4H_2O + Cr_2O_3$$

is an example of

(a) two reactants and two products
(b) one reactant and two or three products
(c) two reactants and one product
(d) two reactants and three or four products

Sol. (b)

Match the Following

24. Match the following columns.

	Column I (Name of radicals)		Column II (Formula of radicals)
(i)	Phosphite	(a)	$[Fe(CN)_6]^{3-}$
(ii)	Ferrocyanide	(b)	$C_2O_4^{2-}$
(iii)	Oxalate	(c)	$P_2O_7^{4-}$
(iv)	Pyrophosphate	(d)	PO_3^{3-}
(v)	Phosphate	(e)	PO_4^{3-}

Sol. (i) → (d), (ii) → (a), (iii) → (b), (iv) → (c), (v) → (e)

25. Match the following columns.

	Column I (Name of the compound)		Column II (Formula)
(i)	Sodium carbonate	(a)	Na_2SO_4
(ii)	Sodium chlorate	(b)	Na_2CO_3
(iii)	Sodium sulphate	(c)	$NaClO_2$
(iv)	Sodium nitrate	(d)	$NaNO_2$
(v)	Sodium nitrite	(e)	Na_2SiO_3
(vi)	Sodium bisulphate	(f)	$NaHCO_3$
(vii)	Sodium silicate	(g)	$NaHSO_4$
(viii)	Sodium bicarbonate	(h)	$NaNO_3$

Sol. (i) → (b), (ii) → (c), (iii) → (a), (iv) → (h), (v) → (d), (vi) → (g), (vii) → (e), (viii) → (f)

26. Match the following columns.

	Column I (Name of equation)		Column II (Examples)
(i)	Skeleton equation	(a)	$Na + H_2O \longrightarrow NaOH + H$
(ii)	Balanced equation	(b)	$2Na + 2H_2O \longrightarrow 2NaOH + H_2$
(iii)	Atomic equation	(c)	$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$
(iv)	Molecular equation	(d)	$CaCO_3 + HCl \longrightarrow CaCl_2 + H_2O + CO_2$

Sol. (i) → (d), (ii) → (c), (iii) → (a), (iv) → (b)

1 Mark Questions

27. The chemical symbol of sodium is Na. Write its Latin name.

Sol. The Latin name of sodium is Natrium.

28. If the symbol for cobalt (Co) were written as CO, what would be incorrect with it?

Sol. CO represents carbon monoxide whereas, Co represents cobalt.

29. What is the chemical symbol for nitrogen gas?

Sol. Nitrogen gas exists in the form of diatomic molecule, so its symbol is N_2.

30. What is the chemical symbol for hydrogen gas?

Sol. H_2

31. What is the combining capacity of an element called?

Sol. Valency is the combining capacity of an element.

32. An element 'Y' shows variable valencies of 3 and 5. Write the formulae of its oxides.

Sol. Y_2O_3, Y_2O_5 are its oxides.

33. An element Z has a valency of 3. What is the formula of oxide of Z?

Sol. $\overset{+3}{Z}\ \overset{-2}{O} = Z_2O_3$

34. What is the chemical formula of ammonium phosphate?

Sol. $\overset{+1}{NH_4}\ \overset{-3}{PO_4} = (NH_4)_3PO_4$

35. What is the molecular formula of aluminium hydroxide?

Sol. $Al(OH)_3$

36. What are the correct formulae of sodium sulphide and sodium sulphite : NaS, Na_2SO_4 or Na_2S, Na_2SO_3?

Sol. Na_2S (sodium sulphide), Na_2SO_3 (sodium sulphite).

37. If an element X has its valency equal to 3, what will be its formula with carbonate ion?

Sol. $\overset{+3}{X}\ \overset{-2}{CO_3} = X_2(CO_3)_3$

38. What do you mean by chemical equation?

Sol. Chemical equation is the symbolic representation of an actual chemical reaction.

e.g., $AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$

39. Write an example of one reactant and two products.

Sol. *An example of one reactant and two products is*

$$MgCO_3 \xrightarrow{\Delta} MgO + CO_2$$

b 2 Marks Questions

40. 'An aqueous solution of ferrous sulphate reacts with an aqueous solution of sodium hydroxide to form a precipitate of ferrous hydroxide and an aqueous solution of sodium sulphate'. Write down the above statement in the form of a chemical equation.

Sol. *The chemical equation is*

$$FeSO_4(aq) + NaOH(aq) \longrightarrow \underset{\text{(ppt.)}}{Fe(OH)_2} + Na_2SO_4(aq)$$ *[2]*

41. Why should an equation be balanced? Mention it by giving a simple chemical equation.

Sol. A balanced chemical equation proves the law of conservation of mass *i.e.,* the total mass of the substances on either side of the equation is same.

e.g., $\underset{100\text{ g}}{CaCO_3} + \underset{2\times(36.5)=73\text{ g}}{2HCl} \longrightarrow \underset{111\text{ g}}{CaCl_2} + \underset{18\text{ g}}{H_2O} + \underset{44\text{ g}}{CO_2}$

Total mass of reactants = Total mass of products *[2]*

42. Give difference between relative atomic mass and relative molecular mass.

Sol. **Relative Atomic Mass** It is defined as the number of times a given atom is heavier than $\frac{1}{12}$th of mass of 1 atom of carbon – 12 or it is the average mass of the atom as compared to $\frac{1}{12}$th mass of one carbon – 12 atom. *[1]*

Relative Molecular Mass It is defined as the ratio of average mass of one molecule of an element or compound to $\frac{1}{12}$th of the mass of an atom of carbon – 12 isotope. *[1]*

c 3 Marks Questions

43. Which of the following symbols of element are incorrect? Write their correct symbols.

(i) Carbon—C

(ii) Aluminium—Al

(iii) Helium—He

Sol. (i) Correct; Carbon = C *i.e.,* capital letter must be used. *[1]*

(ii) Incorrect; Aluminium = Al *i.e.,* 2nd letter should be small while first letter is capital. *[1]*

(iii) Correct; Helium = He *i.e.,* 1st letter is capital, then 2nd letter should be small. *[1]*

44. Write the formulae and valency of the following radicals or ions.

(i) Oxalate (ii) Bicarbonate

(iii) Dichromate

Sol. (i) Oxalate $C_2O_4^{2-}$ (Valency = – 2) *[1]*

(ii) Bicarbonate HCO_3^- (Valency = – 1) *[1]*

(iii) Dichromate $Cr_2O_7^{2-}$ (Valency = – 2) *[1]*

45. What is the valency of underlined element in the given compounds?

(i) $\underline{Ca}_3N_2$ (ii) $\underline{Zn}SO_4$

(iii) $\underline{C}Cl_4$

Sol. (i) Ca_3N_2, Valency of calcium = + 2 *[1]*

(ii) $ZnSO_4$; Valency of zinc = + 2 *[1]*

(iii) CCl_4 ; Valency of carbon = + 4 *[1]*

46. (i) Write chemical formulae of the following compounds.

(a) Aluminium nitride

(b) Ammonium phosphate

(ii) Name an element which shows a variable valency. Write the formulae of its two chlorides.

Sol. (i) (a) AlN

(b) $(NH_4)_3PO_4$ *[2]*

(ii) Iron (Fe), it forms $FeCl_2$ and $FeCl_3$ with chlorine. *[1]*

47. Write the formulae of

(i) sodium chloride

(ii) aluminium oxide

(iii) ammonium sulphate

Sol. (i) $\overset{+1}{Na}\times\overset{-1}{Cl} = NaCl$ *[1]*

(ii) $\overset{+3}{Al}\times\overset{-2}{O} = Al_2O_3$ *[1]*

(iii) $\overset{+1}{NH_4}\times\overset{-2}{SO_4} = (NH_4)_2SO_4$ *[1]*

48. Write the chemical formulae, using criss-cross method.

(i) Magnesium bicarbonate

(ii) Barium nitrate

(iii) Potassium nitrate

Sol. (i) Mg^{+2} HCO_3^{-1}

Formula is $Mg(HCO_3)_2$ *[1]*

(ii) Ba^{+2} NO_3^{-1}

Formula is $Ba(NO_3)_2$ *[1]*

(iii) K^{+1} NO_3^{-1}

Formula is KNO_3 *[1]*

49. Write down the names of compounds represented by the following formulae.

(i) $Al_2(SO_4)_3$ (ii) $CaCl_2$

(iii) K_2SO_4 (iv) KNO_3

(v) $CaCO_3$

Sol. (i) Aluminium sulphate

(ii) Calcium chloride

(iii) Potassium sulphate

(iv) Potassium nitrate

(v) Calcium carbonate *[3]*

50. Choose simple and compound radicals out of the following

Cl^-, SO_4^{2-}, S^{2-}, Na^+, NH_4^+, Ni^{2+}

Sol. Cl^- : Simple radical

SO_4^{2-} : Compound radical

S^{2-} : Simple radical

Na^+ : Simple radical

NH_4^+ : Compound radical

Ni^{2+} : Simple radical *[3]*

51. Correct the following statements.

(i) The molecular formula of water (H_2O) represents 9 parts by mass of water.

(ii) A molecule of an element is always monoatomic.

(iii) A balanced equation obeys the law of conservation of mass and hence, does an unbalanced equation.

Sol. (i) The molecular formula of water (H_2O) represents 18 parts by mass of water. *[1]*

(ii) A molecule of an element is not always monoatomic. *[1]*

(iii) A balanced equation obeys the law of conservation of mass while unbalanced equation does not. *[1]*

52. Write the essential or necessary requirements of a chemical equation.

Sol. (i) Chemical equation should represent a true chemical change. *[1]*

(ii) Balanced chemical equation should be balanced *i.e.,* number of atoms of each element should be equal on both sides of the equation. *[1]*

(iii) Molecular chemical equation should be molecular *i.e.,* all the substances present in the chemical equation should be represented in their molecular forms. *[1]*

4 Marks Questions

53. Complete the following table.

Acid Radicals → **Basic Radicals ↓**	**Phosphate**	**Hydroxide**	**Carbonate**	**Sulphate**	**Nitrate**	**Chloride**
Magnesium	$Mg_3(PO_4)_2$	$Mg(OH)_2$	$MgCO_3$	$MgSO_4$	$Mg(NO_3)_2$	$MgCl_2$
Potassium						
Iron (II)						
Calcium						
Ammonium						
Silver						
Zinc						
Sodium						

Sol.

Acid Radicals → / Basic Radicals ↓	Phosphate	Hydroxide	Carbonate	Sulphate	Nitrate	Chloride
Magnesium	$Mg_3(PO_4)_2$	$Mg(OH)_2$	$MgCO_3$	$MgSO_4$	$Mg(NO_3)_2$	$MgCl_2$
Potassium	K_3PO_4	KOH	K_2CO_3	K_2SO_4	KNO_3	KCl
Iron (II)	$Fe_3(PO_4)_2$	$Fe(OH)_2$	$FeCO_3$	$FeSO_4$	$Fe(NO_3)_2$	$FeCl_2$
Calcium	$Ca_3(PO_4)_2$	$Ca(OH)_2$	$CaCO_3$	$CaSO_4$	$Ca(NO_3)_2$	$CaCl_2$
Ammonium	$(NH_4)_3PO_4$	NH_4OH	$(NH_4)_2CO_3$	$(NH_4)_2SO_4$	NH_4NO_3	NH_4Cl
Silver	Ag_3PO_4	AgOH	Ag_2CO_3	Ag_2SO_4	$AgNO_3$	AgCl
Zinc	$Zn_3(PO_4)_2$	$Zn(OH)_2$	$ZnCO_3$	$ZnSO_4$	$Zn(NO_3)_2$	$ZnCl_2$
Sodium	Na_3PO_4	NaOH	Na_2CO_3	Na_2SO_4	$NaNO_3$	NaCl

[4]

54. Sodium chloride reacts with silver nitrate to produce silver chloride and sodium nitrate.
(i) Write the chemical equation.
(ii) Check whether it is balanced, if not then balance it.
(iii) Calculate the weights of reactants and products.
(iv) Write the law which this chemical equation satisfies.

Sol. (i) $NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$ ***[1]***
(ii) It is a balanced chemical equation. ***[1]***
(iii) Total weight of reactants = 58.5 + 170 = 228.5
Total weight of products = 143.5 + 85 = 228.5 ***[1]***
(iv) It is based upon the law of conservation of mass *i.e.,* in a chemical reaction total mass of the reactants must be equal to the total mass of the products. ***[1]***

e 5 Marks Questions

55. Write the important limitations or drawbacks of a chemical equation.

Sol. The chemical equation does not indicate about the
(i) physical states of the reactants and products.
(ii) reversibility of the reaction.
(iii) conditions necessary for the reaction to occur.
(iv) concentrations of the reactants and products.
(v) heat changes during chemical reactions.
(vi) whether any precipitate is formed or not.
(vii) whether any gas is evolved or not.
(viii) time taken by the reaction for completion.
(ix) rate at which the reaction takes place.
(x) extent upto which the reaction takes place.
(xi) mechanism of the reaction. ***[5]***

56. How are the limitations or drawbacks of a chemical equation removed?

Sol. Some of the drawbacks of chemical equation can be removed as follows
(i) The physical states of the reactants and products can be indicated by using the symbol, *i.e., s* for solids, *l* for liquids, *g* for gases and *aq* for aqueous solutions.
e.g., $Zn(g) + 2HCl(g) \longrightarrow ZnCl_2(g) + H_2(g)$ ***[1/2]***
(ii) The conditions necessary for the reaction to occur are represented by the arrow between the reactants and products.
e.g., $Fe(s) + S(s) \xrightarrow{Heat} FeS(s)$ ***[1/2]***
(iii) The concentration of the solution of reactants can be shown by writing dil. for dilute and conc. for concentrated solution. *e.g.,*
$Cu(s) + 2H_2SO_4(conc.) \xrightarrow{\Delta} CuSO_4(aq) + SO_2(g) + 2H_2O(l)$ ***[1]***
(iv) The heat changes during a reaction are indicated by writing $+Q$ kJ or $-Q$ kJ along with the products for exothermic and endothermic reactions respectively *e.g.,*
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l) + 572\ kJ$ ***[1/2]***
$C(s) + H_2O(g) \longrightarrow CO(g) + H_2(g) - 131\ kJ$ ***[1/2]***

(v) The evolution of a gas can be indicated by writing arrow pointing upwards (↑). *e.g.,*

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)\uparrow$$

(vi) The formation of a precipitate is indicated by writing an arrow pointing downwards (↓) or by word ppt. below the formula of the product. *e.g.,*

$$AgNO_3(aq) + NaCl(aq) \longrightarrow \underset{\text{(ppt.)}}{AgCl(s)\downarrow} + NaNO_3(aq)$$ **[1/2]**

(vii) In case of reversible reaction, double headed arrows (⇌) are put between the reactants and products.

e.g., $N_2(g) + O_2(g) \overset{3000\,^\circ C}{\rightleftharpoons} 2NO(g)$ **[1/2]**

(viii) The rate of reaction can be shown by writing slow or fast along with the products. *e.g.,*

$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$ (Fast) **[1/2]**

$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$ (Slow) **[1/2]**

57. Write the balanced chemical equation of the following reactions.

(i) Sodium chloride + Manganese dioxide + Sulphuric acid → Sodium hydrogen sulphate + Manganese sulphate + Water + Chlorine

(ii) Sulphur + Nitric acid ⟶ Sulphuric acid + Nitrogen dioxide + Water

(iii) Potassium dichromate + Hydrochloric acid ⟶ Potassium chloride + Chromium chloride + Water + Chlorine

(iv) Aluminium sulphate + Sodium hydroxide ⟶ Sodium sulphate + Sodium meta-aluminate + Water

(v) Potassium permanganate + Hydrochloric acid ⟶ Potassium chloride + Manganese chloride + Chlorine + Water

(vi) Iron pyrites + Oxygen ⟶ Ferric oxide + Sulphur dioxide

(vii) Aluminium carbide + Water ⟶ Aluminium hydroxide + Methane

(viii) Zinc sulphide + Oxygen ⟶ Zinc oxide + Sulphur dioxide

(ix) Nitric acid + Calcium hydroxide ⟶ Calcium nitrate + Water

(x) Silver chloride ⟶ Silver + Chlorine

Sol. (i) $2NaCl + MnO_2 + 3H_2SO_4 \longrightarrow 2NaHSO_4 + MnSO_4 + 2H_2O + Cl_2$ **[1/2]**

(ii) $S + 6HNO_3 \longrightarrow H_2SO_4 + 6NO_2 + 2H_2O$ **[1/2]**

(iii) $K_2Cr_2O_7 + 14HCl \longrightarrow 2KCl + 2CrCl_3 + 7H_2O + 3Cl_2$ **[1/2]**

(iv) $Al_2(SO_4)_3 + 8NaOH \longrightarrow 3Na_2SO_4 + 2NaAlO_2 + 4H_2O$ **[1/2]**

(v) $2KMnO_4 + 16HCl \longrightarrow 2KCl + 2MnCl_2 + 5Cl_2 + 8H_2O$ **[1/2]**

(vi) $4FeS_2 + 11O_2 \longrightarrow 2Fe_2O_3 + 8SO_2$ **[1/2]**

(vii) $Al_4C_3 + 12H_2O \longrightarrow 4Al(OH)_3 + 3CH_4$ **[1/2]**

(viii) $2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$ **[1/2]**

(ix) $2HNO_3 + Ca(OH)_2 \longrightarrow Ca(NO_3)_2 + 2H_2O$ **[1/2]**

(x) $2AgCl \xrightarrow{\text{Sunlight}} 2Ag + Cl_2$ **[1/2]**

58. Balance the following equations.

(i) $P + HNO_3 \longrightarrow NO_2 + H_2O + H_3PO_4$

(ii) $HNO_3 + H_2S \longrightarrow NO_2 + H_2O + S$

(iii) $H_2O + Cl_2 \longrightarrow HCl + O_2$

(iv) $Pb_3O_4 + HCl \longrightarrow PbCl_2 + H_2O + Cl_2$

(v) $NO_2 + H_2O \longrightarrow HNO_2 + HNO_3$

(vi) $KOH + Cl_2 \longrightarrow KCl + KClO + H_2O$

(vii) $MnO_2 + HCl \longrightarrow MnCl_2 + H_2O + Cl_2$

(viii) $Pb_3O_4 \longrightarrow PbO + O_2$

(ix) $Cu + O_2 \xrightarrow{\Delta} CuO$

(x) $BaCl_2 + Al_2(SO_4)_3 \longrightarrow AlCl_3 + BaSO_4$

Sol. (i) $P + 5HNO_3 \longrightarrow 5NO_2 + H_2O + H_3PO_4$ **[1/2]**

(ii) $4HNO_3 + 2H_2S \longrightarrow 4NO_2 + 4H_2O + S$ **[1/2]**

(iii) $2H_2O + 2Cl_2 \longrightarrow 4HCl + O_2$ **[1/2]**

(iv) $Pb_3O_4 + 8HCl \longrightarrow 3PbCl_2 + 4H_2O + Cl_2$ **[1/2]**

(v) $2NO_2 + H_2O \longrightarrow HNO_2 + HNO_3$ **[1/2]**

(vi) $2KOH + Cl_2 \longrightarrow KCl + KClO + H_2O$ **[1/2]**

(vii) $MnO_2 + 4HCl \longrightarrow MnCl_2 + 2H_2O + Cl_2$ **[1/2]**

(viii) $2Pb_3O_4 \longrightarrow 6PbO + O_2$ **[1/2]**

(ix) $2Cu + O_2 \xrightarrow{\Delta} 2CuO$ **[1/2]**

(x) $3BaCl_2 + Al_2(SO_4)_3 \longrightarrow 2AlCl_3 + 3BaSO_4$ **[1/2]**

Numerical Based Questions

59. Calculate the relative molecular mass of the following compound.

(i) Lead sulphate (ii) Calcium phosphate

(Given, atomic masses of various elements, Ca = 40 u, S = 324, O = 16 u, Pb = 207 u and P = 314)

Sol. (i) Relative molecular mass of lead sulphate ($PbSO_4$)

= atomic mass of Pb + atomic mass of S + 4 × atomic mass of O

$= 207 + 32 + 4 \times 16$

$= 207 + 32 + 64$

$= 303$ u ***[1]***

(ii) Relative molecular mass of calcium phosphate $[Ca_3(PO_4)_2]$

$= 3 \times$ atomic mass of Ca $+ 2 \times$ (atomic mass of P) $+ 8 \times$ (atomic mass of O)

$= 3 \times 40 + 2 \times 31 + 8 \times 16$

$= 120 + 62 + 128 = 310$ u ***[1]***

60. Calculate the percentage composition of nitrogen in urea NH_2CONH_2.

Sol. Relative molecular mass of urea (NH_2CONH_2)

$= 2 \times$ atomic mass of N $+ 1 \times$ atomic mass of C $+ 4 \times$ atomic mass of H $+ 1 \times$ atomic mass of O.

$= 2 \times 14 + 1 \times 12 + 4 \times 1 + 1 \times 16$

$= 28 + 12 + 4 + 16 = 60\ u$

Percentage composition of nitrogen

$$= \frac{\text{Mass contributed by } N}{\text{Total molecular mass of } NH_2CONH_2} \times 100$$

$$= \frac{28}{60} \times 100 = 46.67\ \%$$

[3]

CHAPTER EXERCISE

Fill in the Blanks

1. Valency of an element is number of electrons (i) ....., (ii) ..... or contributed for (iii) ..... by an atom of the element in order to get the stable ..... configuration.

2. Chemical formula of glucose is represented as ..... .

3. The prefix 'tri' is used to indicate ..... atoms of an element.

4. Cl^-, F^-, CO_3^{2-} and SO_4^{2-} are ..... radicals.

5. The chemical equation which simply represents the ..... and ..... of the various substances taking part in the chemical reaction is said to be ..... equation.

6. In this equation,

$$C_2H_4(g) + XO_2(g) \longrightarrow 2CO_2(g) + YH_2O(g)$$

X and Y are respectively ..... and ..... .

Multiple Choice Questions

7. The symbol of neon is

(a) NE (b) ne

(c) Ne (d) nE

8. The chemical formula of sodium chlorate is $NaClO_3$ then the chemical formula of sodium hypochlorite is

(a) NaClO

(b) $NaClO_2$

(c) $NaClO_4$

(d) Na_2ClO_2

9. Oxygen, nitrogen and platinum are respectively

(a) trivalent, trivalent, tetravalent

(b) divalent, trivalent, trivalent

(c) divalent, tetravalent, trivalent

(d) divalent, trivalent, tetravalent

10. Cl^-, F^-, K^+ and Na^+ are the examples of

(a) basic radical

(b) acid radical

(c) simple radical

(d) compound radical

11. Which of the following is balanced chemical equation?

(a) $2H_2SO_4 + C \longrightarrow CO_2 + SO_2 + H_2O$

(b) $Na_2CO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O + CO_2$

(c) $MgCl_2 + Na_2CO_3 \longrightarrow MgCO_3 + NaCl$

(d) $Al + NaOH + H_2O \longrightarrow NaAlO_2 + H_2$

Match the Following

12. Match the following columns.

	Column I (Name)		Column II (Radicals)
(i)	Dichromate	(a)	CrO_4^{2-}
(ii)	Nitrite	(b)	ZnO_2^{2-}
(iii)	Mercuric	(c)	SO_4^{2-}
(iv)	Zincate	(d)	MnO_4^{2-}
(v)	Permanganate	(e)	N^{3-}
(vi)	Sulphite	(f)	Pb^{4+}
(vii)	Stannic	(g)	Pb^{2+}
(viii)	Nitride	(h)	MnO_4^-
(ix)	Plumbous	(i)	ClO_3^-
(x)	Hypochlorite	(j)	$Cr_2O_7^{2-}$
		(k)	ClO^-
		(l)	Hg^+
		(m)	NO_2^-
		(n)	SO_3^{2-}
		(o)	Sn^{2+}
		(p)	Sn^{4+}
		(q)	Hg^{2+}

1 Mark Questions

13. The symbol 'S' for sulphur but 'Na' for sodium and 'Si' for silicon. Explain it.

14. Write the name of two elements, which show variable valency.

15. Give one example each of bivalent cations and bivalent anions.

16. Mention the cation and anion present in the CH_3COONa.

17. How are the elements with variable valency named?

18. Define atomic mass unit.

2 Marks Questions

19. MNO_3 is the formula of nitrate of metal M. Give the formula of oxide of metal M.

20. Write the following equations and balance them.

(i) Silver oxide + Hydrogen peroxide ⟶ Silver + Water + Oxygen

(ii) Calcium carbonate + Hydrochloric acid ⟶ Calcium chloride + Water + Carbon dioxide

3 Marks Questions

21. Write the valency of

(i) carbon in CH_4

(ii) phosphorus in PH_3

(iii) sulphur in SF_6

(iv) fluorine in CaF_2

(v) nitrogen in N_2O_3

(vi) nitrogen in N_2O_5

22. An element 'X' has a valency 1.

(i) Write the chemical formula of its phosphide.

(ii) Write the chemical formula of its chloride.

(iii) Is element 'X' a metal or a non-metal?

4 Marks Questions

23. 'Methane burns in oxygen to form carbon dioxide and water'. Write the chemical equation for the given chemical reaction and balance it.

24. Write the significance of *s*, *l*, *g* and *aq* in a chemical equation.

5 Marks Questions

25. Discuss about the following method using a chemical equation.
Hit and trial method.

26. Write the formulae and then balance the following chemical equations.

(i) Lime water + Carbon dioxide ⟶ Calcium carbonate + Water

(ii) Magnesium + Silver nitrate ⟶ Magnesium nitrate + Silver

(iii) Butane + Oxygen ⟶ Carbon dioxide + Water

(iv) Sodium hydroxide + Sulphuric acid ⟶ Sodium sulphate + Water

(v) Potassium bicarbonate + Sulphuric acid ⟶ Potassium sulphate + Carbon dioxide + Water

(vi) Chlorine + Sodium hydroxide ⟶ Sodium chloride + Sodium chlorate + Water

(vii) Red lead oxide ⟶ Lead monoxide + Oxygen

(viii) Ferric chloride + Ammonium hydroxide ⟶ Ferric hydroxide + Ammonium chloride

Numerical Based Questions

27. Calculate the relative molecular mass of the following

(i) H_2SO_4

(ii) $(NH_4)_2SO_4$

28. Calculate the percentage composition of various elements in Na_2CO_3.

[Given that, the relative atomic masses of O = 16, Na = 23, C = 12].

Ans. Na = 43.4%, C = 11.3%, O = 45.3%

CHALLENGERS*

1 The formula of oxide of an element Z is Z_2O_3. What is the valency of element Z?

(a) 2 (b) 0 (c) 3 (d) 4

2 The element B shows valencies of 4 and 6. The formulae of its two oxides respectively are

(a) BO_3, BO_2 (b) B_2O_6, BO_4 (c) BO_2, BO_3 (d) BO_4, B_2O_6

3 The formula of the sulphate of an element X is $X_2(SO_4)_3$. The formula of nitride of the element X is

(a) X_2N (b) XN_2 (c) XN (d) X_2N_3

4 "Hydrogen sulphide gas burns in air to give water and sulphur dioxide". The balanced equation for this reaction is

(a) $H_2S(g) + 3O_2(g) \longrightarrow H_2O(l) + SO_2(g)$ (b) $2H_2S(g) + 3O_2(g) \longrightarrow 2H_2O(l) + 2SO_2(g)$

(c) $2H_2S(g) + 1.5O_2(g) \longrightarrow 2H_2O(l) + 2SO_2(g)$ (d) $H_2S(g) + 3O_2(g) \longrightarrow H_2O(g) + SO_2(g)$

5 Some compounds alongwith their chemical formulae are given below.

Compounds	Chemical formulae
Magnesium nitrate	$Mg(NO_3)_2$
Aluminium nitride	AlN
Zinc phosphate	$Zn_3(PO_4)_2$
Calcium oxide	CaO

On the basis of formulae given above, the valencies or charges on ions are given below. Select the incorrect option.

(a) Nitride ion, – 3 (b) Phosphate ion, – 3

(c) Calcium ion, + 1 (d) Nitrate ion, – 1

6 Consider the following reaction,

X calcium carbonate + Y phosphoric acid $\longrightarrow$ calcium phosphate + X water + X carbon dioxide.

What is the value of X and Y?

	X	Y		X	Y		X	Y		X	Y
(a)	3	1	(b)	3	4	(c)	1	3	(d)	3	2

7 Consider the following statements.

I. A chemical equation tells us about the substances involved in a reaction.

II. It gives information about the symbols and formula of substances involved in a reaction.

III. It tells us about the atoms or molecules of the reactants and products involved in a reaction.

The correct statement(s) is/are

(a) Only I (b) I and II (c) II and III (d) All of these

8 Consider the following equations.

$$Pb(NO_3)_2(aq) + 2KI(aq) \longrightarrow PbI_2(w) + 2KNO_3(x)$$

$$Zn(y) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(z)$$

What are w, x, y and z in the above equations?

	w	x	y	z		w	x	y	z
(a)	(*aq*)	(*aq*)	(*aq*)	(*g*)	(b)	(*aq*)	(*s*)	(*s*)	(*g*)
(c)	(*s*)	(*aq*)	(*aq*)	(*g*)	(d)	(*s*)	(*aq*)	(*s*)	(*g*)

Answers

1. (c) **2.** (c) **3.** (c) **4.** (b) **5.** (c) **6.** (d) **7.** (d) **8.** (d)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 111.

CHAPTER

2

Chemical Changes and Reactions

Various kinds of changes occur around us all the time. Some of the changes are natural while some are man-made. These changes can be differentiated as physical and chemical changes. In physical change, only a change in state is involved while chemical change brings a change in chemical properties of matter. In this chapter, we will discuss about the various types of chemical changes and the chemical reactions which represent chemical changes.

Chapter Objectives

- Chemical Changes
- Energy Changes in a Chemical Change

Chemical Changes

In chemical changes, one substance react with another substance to undergo a change in chemical composition *i.e.,* a change in which always a new substance is formed with new property. A chemical change is also called a chemical reaction. *e.g.,* Burning of coal, formation of curd from milk, etc.

Following conditions are necessary for a chemical change

1. Mixing (Closing)

For a chemical reaction to occur, the reactants has to be in close proximity. In some cases, reaction easily occurs even in solid state while some reaction requires an aqueous state.

$$Pb(NO_3)_2(s) + 2KI(s) \longrightarrow 2KNO_3(s) + PbI_2(s)$$

$$NaCl(aq) + AgNO_3(aq) \longrightarrow \underset{\text{White ppt.}}{AgCl\downarrow} + NaNO_3(aq)$$

2. Heat

Heating increases the kinetic energy of the molecules of the substance and thus, the substances are able to react with each other easily.

e.g., Iron (Fe) filings and sulphur (S) powder do not react through mixing but they react when this mixture is heated and produce iron sulphide (FeS) as shown below.

$$Fe + S \xrightarrow{\Delta} FeS$$

3. Light

Light is a form of energy that can facilitate a chemical reaction. Such chemical reactions are called **photochemical reactions**.

e.g., Hydrogen gas (H_2) and chlorine gas (Cl_2) do not react with each other readily but when the mixture of these two gases is exposed to diffused sunlight, they combine to form hydrogen chloride gas.

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

4. Electricity

Few chemical changes or reactions can be brought by applying electrical energy to the substance. These are electrochemical reactions. *e.g.,* Electrolysis of water.

5. Pressure

Pressure plays an important role in carrying out certain reactions, which otherwise do not occur by bringing the particles closer *e.g.,* Nitrogen and hydrogen gases usually do not react but when subjected to a high pressure (200 atm). They combine to form ammonia gas (NH_3).

$$N_2 + 3H_2 \overset{200\ atm}{\rightleftharpoons} 2NH_3$$

6. Catalyst

A catalyst is a substance, which does not participate in a reaction but helps the other reacting substances to react faster *e.g.,* In the formation of ammonia from nitrogen and hydrogen, iron filings act as a catalyst for the reaction by enhancing the rate of a reaction.

$$N_2 + 3H_2 \underset{\text{Fast reaction}}{\overset{Fe/200\ atm}{\rightleftharpoons}} 2NH_3$$

Role of Promoters

Promoter increase the efficiency of a catalyst, hence, making the reaction faster. *e.g.,* Molybdenum acts as a promoter for iron catalyst during the formation of ammonia gas.

$$N_2 + 3H_2 \underset{\text{Faster reaction}}{\overset{Fe\text{-}Mo,\ 200\ atm}{\rightleftharpoons}} 2NH_3$$

Types of Chemical Change Chemical Reaction

On the basis of chemical changes taking place, these reactions can be divided into following types

1. Combination Reaction

A reaction, in which two or more reactants combine to form a single product, is called **combination reaction**.

Based on the types of reactants involved, *the combination reaction can take place in following manner*

(i) **Two or more compounds combine to give single product** Calcium oxide (quick lime) dissolved in water, to form calcium hydroxide (slaked lime). The reaction is highly exothermic *i.e.,* a lot of heat is produced during the reaction.

$$\underset{\text{Quick lime}}{CaO(s)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Slaked lime}}{Ca(OH)_2(aq)} + \text{Heat}$$

(ii) **Two elements combine to form a compound**

(a) Burning of Coal

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

(b) Reaction between hydrogen gas and oxygen gas to form water.

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

(c) Nitrogen gas reacts with hydrogen gas to form ammonia gas.

$$\underset{\text{Nitrogen}}{N_2(g)} + \underset{\text{Hydrogen}}{3H_2\ (g)} \rightleftharpoons \underset{\text{Ammonia}}{2NH_3(g)}$$

(iii) **An element and a compound combine to give a new compound** Ferrous chloride (*i.e.,* a compound) reacts with chlorine (*i.e.,* an element) to form a new compound, ferric chloride.

$$\underset{\text{Ferrous chloride}}{2FeCl_2} + \underset{\text{Chlorine}}{Cl_2} \longrightarrow \underset{\text{Ferric chloride}}{2FeCl_3}$$

Similarly, when carbon monoxide reacts with oxygen then carbon dioxide is produced.

$$\underset{\text{Carbon monoxide}}{2CO(g)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{2CO_2(g)}$$

2. Decomposition Reaction

A reaction in which a single reactant breaks down to form two or more products is known as decomposition reaction.

e.g., $$\underset{\text{Potassium nitrate}}{2KNO_3(s)} \xrightarrow{\Delta} \underset{\text{Potassium nitrite}}{2KNO_2(s)} + O_2(g)$$

On the basis of the form of energy required for the reaction, these reactions are of three types

(i) **Thermal Decomposition** These reactions used the energy in the form of heat for the decomposition of the reactant. *e.g.,*

(a) $$\underset{\text{Calcium carbonate}}{CaCO_3(s)} \xrightarrow{\text{Heat}} \underset{\text{Calcium oxide}}{CaO(s)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

(b) $2Pb(NO_3)_2(s) \xrightarrow{Heat} 2PbO(s) + 4NO_2(g) + O_2(g)$
Lead nitrate (White salt) → Lead oxide (Yellow) + Nitrogen dioxide (Brown fume) + Oxygen

(c) $2KClO_3(s) \xrightarrow{Heat} 2KCl(s) + 3O_2(g)$
Potassium chlorate → Potassium chloride + Oxygen

(ii) **Electrolysis** These reactions involve the use of electrical energy for the decomposition of the reactant molecules.

e.g.,

(a) $2H_2O(l) \xrightarrow{Electric\ current} 2H_2(g) + O_2(g)$
Water → Hydrogen + Oxygen

(b) $2NaCl(l) \xrightarrow{Electric\ current} 2Na(s) + Cl_2(g)$
Molten sodium chloride → Sodium + Chlorine

(iii) **Photolysis or Photochemical Decomposition**

These reactions involve the use of light energy for the purpose of decomposition. *e.g.,*

(a) $2AgCl(s) \xrightarrow{Sunlight} 2Ag(s) + Cl_2(g)$
Silver chloride → Silver + Chlorine

(b) $2AgBr(s) \xrightarrow{Sunlight} 2Ag(s) + Br_2(l)$
Silver bromide → Silver + Bromine

Note The reaction of decomposition of silver halides is used in photography.

3. Displacement Reaction

A reaction in which a more reactive element displaces a less reactive element from its salt solution is called displacement reaction. *e.g.,*

(i) $Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$
Zinc metal (Grey) + Copper sulphate solution (Blue) → Zinc sulphate solution (Colourless) + Copper metal (brown)

(ii) $Fe(s) + CuSO_4(aq) \longrightarrow FeSO_4(aq) + Cu(s)$
Iron metal + Copper sulphate (Blue) → Ferrous sulphate Or Iron (II) sulphate (Green) + Copper metal

Activity Series

The series in which the metals are arranged in the decreasing order of their reactivity. In this series, the element (metal) can displace the other one from its salt, on the basis of reactivity of the two elements.

K	Potassium	Most reactive element
Na	Sodium	
Ca	Calcium	
Mg	Magnesium	
Al	Aluminium	
Zn	Zinc	Reactivity decreases on going down the series
Fe	Iron	
Pb	Lead	
H	Hydrogen	
Cu	Copper	
Hg	Mercury	
Ag	Silver	
Au	Gold	Least reactive element

- The elements lying above in the activity series displace the elements lying below in the activity series from its salt solution.
- Metals present above hydrogen in this activity series, displace it from mineral acids (HCl, HNO_3, H_2SO_4, etc.) and H_2O.

e.g., $Zn + 2HCl \longrightarrow ZnCl_2 + H_2\uparrow$

4. Double Displacement Reaction

The reaction in which two different ions or the group of atoms in the reactant molecules are displaced by each other, is called a double displacement reaction. It is also known as double decomposition reaction.

e.g., $CuO + 2HCl \longrightarrow CuCl_2 + H_2O$

These are of two types

(i) **Precipitation Reaction** Such double displacement reaction in which an insoluble salt is formed as one of the product while the other one remains in the aqueous state, is called precipitation reaction and that insoluble salt is called a precipitate (ppt).

e.g.,

(a) $Na_2SO_4(aq) + BaCl_2(aq) \longrightarrow BaSO_4\downarrow + 2NaCl(aq)$
Sodium sulphate + Barium chloride → Barium sulphate (White ppt.) + Sodium chloride

(b) $AgNO_3(aq) + NaBr(aq) \longrightarrow AgBr\downarrow + NaNO_3(aq)$
Silver nitrate + Sodium bromide → Silver bromide (Yellow ppt.) + Sodium nitrate

(ii) **Neutralisation Reaction** It is a double displacement reaction in which acid and base reacts with each other to form neutral products (salt and water).

e.g.,

(a) $\underset{\text{Sodium hydroxide (Base)}}{NaOH} + \underset{\text{Hydrogen chloride}}{HCl} \longrightarrow \underbrace{\underset{\text{Sodium chloride (Salt)}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(l)}}_{\text{Neutral, neither acidic nor basic solution}}$

(b) $\underset{\text{Potassium hydroxide (Base)}}{2KOH} + \underset{\text{Sulphuric acid}}{H_2SO_4} \rightarrow \underset{\text{Potassium sulphate (Salt)}}{K_2SO_4} + \underset{\text{Water}}{2H_2O}$

Note The products of neutralisation reaction is usually dissolved in aqueous state and do not form precipitate.

CHECK POINT 01

1. Mention any two conditions required for a chemical change.
2. Name the products formed when calcium carbonate is heated.
3. Why are decomposition reactions called the opposite of combination reactions?
4. Name two salts that are used in photography.
5. Name the reaction, in which two compounds exchange their ions to form two new compounds.
6. Name insoluble substance formed in a reaction between barium chloride and sodium sulphate.

Energy Changes in a Chemical Change

It is one of the characteristics of the chemical changes that they proceed with change in energy of the reacting substances. The difference in total energies, before and after a reaction, is evolved or absorbed in the form of heat, light, sound, electricity, mechanical energy, etc.

On the basis of energy changes, the chemical reactions are divided into following four categories

(i) Exothermic Reaction

The reaction which is accompanied by the evolution of heat, is called **exothermic reaction**. It causes a rise in temperature.

e.g., Methane burns in presence of oxygen to form carbon dioxide and releases a huge amount of energy.

(a) $\underset{\text{Methane}}{CH_4(g)} + \underset{\text{Oxygen}}{2O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Water}}{2H_2O(g)} + \text{Heat}$

(b) $\underset{\text{Magnesium}}{2Mg(s)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Magnesium oxide}}{2MgO(s)} + \text{Heat}$

Respiration is an exothermic process in which complex food material is break down to release energy in presence of oxygen.

$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(aq) + 6H_2O(l) + \text{Energy}$

(ii) Endothermic Reaction

The reaction, which occur by the absorption of heat/energy is called endothermic reaction. It causes a fall in temperature. It is also called **hypothermic reaction**.

e.g., (a) $\underset{\text{Mercuric oxide}}{2HgO(s)} + \text{Heat} \longrightarrow \underset{\text{Mercury}}{2Hg(l)} + \underset{\text{Oxygen}}{O_2(g)}$

(b) $\underset{\text{Ammonium chloride}}{NH_4Cl(s)} + \text{Heat} \longrightarrow \underset{\text{Ammonia}}{NH_3(g)} + \underset{\text{Hydrochloric acid}}{HCl(s)}$

(iii) Photochemical Reaction

A chemical reaction, which occurs with the assistance of light is called **photochemical reaction.**

Some examples of photochemical reactions are as follow

(a) Combination of Hydrogen

Hydrogen (H_2) and chlorine (Cl_2) gas combines to produce hydrogen chloride gas (HCl) in the presence of diffused sunlight.

$$H_2 + Cl_2 \xrightarrow{\text{Diffused sunlight}} 2HCl$$

(b) Photosynthesis

It is a series of complex photochemical reaction to produce carbohydrate (glucose) from carbon dioxide (CO_2) and water in the presence of sunlight and chlorophyll.

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

Note Chlorophyll is a green pigment, found in the leaves of plants. It traps light energy and initiates the process of photosynthesis.

(iv) Electrochemical Reaction

A chemical reaction which proceed by the absorption of electricity is called electrochemical reaction. If electrochemical reaction results in dissociation of a molecule, it is called electrolysis.

e.g., Water acidulated with little acid dissociates into hydrogen (H_2) and oxygen (O_2) gas.

$$2H_2O \xrightarrow{\text{Electricity}} 2H_2 + O_2$$

Electrochemical reaction find applications in electrochemical cells to produce electricity as well as in electrolytic cell for electroplating, production of compound, etc.

CHECK POINT 02

1 Give one reaction which is accompanied by evolution of heat.
2 ''Respiration is an exothermic process''. Justify your statement.
3 Endothermic reaction is also known as ..... .
4 What is meant by the term photochemical reaction?
5 Define the term electrochemical reaction. Give one example.

SUMMARY

- When one or more substances (elements or compounds) undergoes a chemical change with the absorption or evolution of energy to give new substances, this change is called a chemical reaction.
- Breaking of the old bonds and formation of the new bonds is responsible for the occurrence of a chemical reaction.
- Conditions which facilitate the chemical change are (i) substances need to be in close proximity (ii) heat (iii) light (iv) pressure (v) catalyst (vi) electricity.
- A reaction in which two or more reactants combine to form a single product is called combination reaction.
  e.g., Calcium oxide dissolved in water to form calcium hydroxide.
- A reaction in which a single reactant breaks down to form two or more products is known as decomposition reaction.
  e.g., Thermal decomposition of calcium carbonate.
- Displacement reaction is the reaction in which a more reactive element displace a less reactive element from their salt solutions.
- Double displacement reaction is of two types
  (i) Precipitation reaction
  (ii) neutralisation reaction.
- Precipitation Reaction Reaction in which an insoluble salt is formed as one of the product while the other remain in the aqueous state.
  e.g., $Na_2SO_4(aq) + BaCl_2(aq) \longrightarrow BaSO_4 \downarrow + 2NaCl(aq)$.
- Neutralisation Reaction Reaction in which acid and base react with each other to form neutral products.
  e.g., $NaOH + HCl \longrightarrow NaCl(aq) + H_2O(l)$
- Reactions accompanied by the evolution of heat are called exothermic (e.g., respiration), whereas the reactions occurring by the absorption of heat are called endothermic reaction (e.g., photosynthesis).
- A chemical reaction, which occurs with the absorption of light energy is called photochemical reaction.
  e.g., $2AgNO_3 \xrightarrow{\text{Sunlight}} 2Ag + 2NO_2 + O_2$
- An electrochemical reaction proceeds in the presence of electricity e.g., Electrolysis of molten NaCl, electrolysis of acidulated water.

EXAM PRACTICE

Fill in the Blanks

1. (i) ..... is always either taken in or given out. If it is given out then heat or (ii) ..... may be produced during the chemical change. A chemical reaction involves the change of substances called (iii) .....to new substances called (iv) .....This chemical change occurs as the atoms in the reaction undergo (v) ..... .

Sol. (i) Energy (ii) light
(iii) reactants (iv) products
(v) rearrangement

2. Chemical changes bring a change in the ..... properties of matter.

Sol. chemical

3. When calcium oxide reacts with water to form calcium hydroxide, the reaction is called ..... reaction.

Sol. combination

4. Decomposition of substance using heat is called ..... decomposition.

Sol. thermal

5. If one of the product in double displacement reaction is insoluble in aqueous medium, the reaction is called ..... reaction.

Sol. precipitation

6. When acid or base reacts to form neutral salt solution, the reaction is called ..... .

Sol. neutralisation

7. In exothermic reaction, ... of heat occurs.

Sol. evolution

Multiple Choice Questions

8. Fill in the blank.
During a chemical reaction overall mass of the product formed is …… that of reactants.
(a) equal to
(b) greater than
(c) less than
(d) sometimes less than sometimes greater than

Sol. (a)

9. Chemical change sometimes evolve energy in the form of
(a) heat
(b) light
(c) sound
(d) All of these

Sol. (d)

10. In which of the following process new substance(s) are formed?
(a) Melting of ice
(b) Sublimation of naphthalene
(c) Photosynthesis
(d) All of these

Sol. (c)

11. The catalyst used as a promotor for the formation of ammonia gas is
(a) Fe (b) Mo
(c) Pd (d) Ni

Sol. (b)

12. When crystals of lead nitrate are heated strongly in a dry test tube
(a) crystals immediately melt
(b) a brown residue is left
(c) white fumes appear in the tube
(d) a yellow residue is left

Sol. (d)

13. Dilute hydrochloric acid is added to granulated zinc taken in a test tube. The following observations are recorded. Point out the correct observation.
(a) The surface of metal becomes shining
(b) The reaction mixture turns milky
(c) Odour of a pungent smelling gas is recorded
(d) A colourless and odourless gas is evolved

Sol. (d)

14. On immersing an iron nail in $CuSO_4$ solution for few minutes, you will observe that
(a) no reaction takes place
(b) the colour of solution fades away
(c) the surface of iron nails acquire a black coating
(d) the colour of solution changes to green

Sol. (b)

15. Name the precipitate formed when barium chloride solution is mixed with sodium sulphate solution.

(a) NaCl (b) BaO (c) $BaSO_4$ (d) Na_2O

Sol. (c)

16. The products formed by neutralisation reaction are

(a) salt and water
(b) salt and oxygen
(c) salt and hydrogen
(d) hydrogen and oxygen

Sol. (a)

17. Electrolysis of acidulated water is a decomposition reaction.
The molar ratio of hydrogen and oxygen gas liberated during electrolysis of water is

(a) 2 : 1 (b) 1 : 1
(c) 1 : 2 (d) 4 : 1

Sol. (a)

Match the Following

18. Match the Column I with Column II.

	Column I (Processes)		**Column II** (Products)
(i)	Combination	(a)	$Na + Cl_2$
(ii)	Thermal decomposition	(b)	$NaCl + H_2O$
(iii)	Electrolysis	(c)	$Ca(OH)_2$
(iv)	Precipitation	(d)	$CaO + CO_2$
(v)	Neutralisation	(e)	$BaSO_4 + NaCl$

Sol. (i) → (c), (ii) → (d), (iii) → (a), (iv) → (e), (v) → (b)

a 1 Mark Questions

19. Why do we store silver chloride in dark coloured bottles?

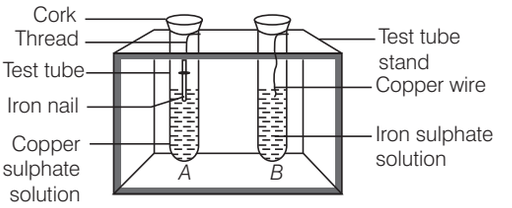
Sol. Dark coloured bottles interrupt the path of light such that light cannot reach to silver chloride contained in the bottles and its decomposition is prevented. It is known that silver chloride decomposes to silver and chlorine in the presence of light.

20. Arrange the following metals in the decreasing order of reactivity Na, K, Cu and Ag.

Sol. *The decreasing order of reactivity of the given metals is*
K > Na > Cu > Ag

21. Observe the two test tubes *A* and *B* in the diagram given below and answer the following questions.

(i) In which test tube, reaction will take place?
(ii) Name the type of reaction.



Sol. (i) In test tube, *A*
(ii) Displacement reaction.

22. Why is photosynthesis considered an endothermic reaction?

Sol. Photosynthesis is considered as an endothermic reaction because energy in the form of sunlight is absorbed by the green plants.

b 2 Marks Questions

23. Identify the type of reaction in the following examples.

(i) $Na_2SO_4(aq) + BaCl_2(aq) \longrightarrow BaSO_4(s) + 2NaCl(aq)$

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

(iii) $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$

Sol. (i) Double displacement reaction.
(ii) Displacement reaction.
(iii) Combination reaction. *[2]*

24. State the type of chemical reactions of the following.

(i) $2Pb(NO_3)_2 \xrightarrow{\Delta} 2PbO + 4NO_2 + O_2$

(ii) $2AgBr(s) \xrightarrow{\text{Sunlight}} 2Ag(s) + Br_2(l)$

(iii) $C + O_2 \xrightarrow{\Delta} CO_2$

Sol. (i) Thermal decomposition reaction
(ii) Photolysis
(iii) Combination reaction *[2]*

25. A white salt on heating decomposes to give brown fumes and a residue is left behind.

(i) Name the salt.
(ii) Write the equation for the decomposition reaction.

Sol. (i) Lead nitrate *[1/2]*

(ii) $\underset{\text{Lead nitrate (White salt)}}{2Pb(NO_3)_2(s)} \xrightarrow{\text{Heat}} \underset{\text{Lead oxide (Residue)}}{2PbO(s)} + \underset{\text{Nitrogen dioxide Brown fumes}}{4NO_2(g)} + \underset{\text{Oxygen}}{O_2(g)}$ *[1½]*

26. Why does the colour of copper sulphate solution change when an iron nail is dipped in it?

Sol. The colour of copper sulphate solution changes when an iron nail is dipped in it because iron being more reactive than copper, displaces copper metal from aqueous copper sulphate solution. Thus, blue colour of copper sulphate disappears and green colour of ferrous sulphate is formed. *[1]*

$$\underset{\text{Grey}}{Fe(s)} + \underset{\text{Blue}}{CuSO_4(aq)} \longrightarrow \underset{\text{Green}}{FeSO_4(aq)} + \underset{\text{Brown}}{Cu(s)}$$ *[1]*

27. What happens when dilute hydrochloric acid is added to iron filings?

Sol. Iron being a reactive metal, produces H_2 gas along with its salt, iron (II) chloride on reaction with dilute hydrochloric acid. This is a displacement reaction.

$$\underset{\text{Iron}}{Fe(s)} + \underset{\text{Hydrochloric acid}}{2HCl(aq)} \longrightarrow \underset{\text{Iron (II) chloride}}{FeCl_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$ *[2]*

Note Those metals which are present above hydrogen in the reactivity series, show similar reaction with dilute HCl and H_2SO_4 and produce H_2 gas along with the corresponding salt.

28. What is a precipitate? Give example.

Sol. A precipitate is a solid substance formed on mixing two solutions *e.g.,* In the reaction between lead nitrate and potassium iodide solution, a yellow precipitate of lead iodide appears. *[1]*

$$\underset{\text{Lead nitrate}}{Pb(NO_3)_2(aq)} + \underset{\text{Potassium iodide}}{2KI(aq)} \longrightarrow \underset{\text{Lead iodide (Yellow ppt)}}{PbI_2(s)} + \underset{\text{Potassiun nitrate}}{2KNO_3(aq)}$$ *[1]*

29. (i) Give an example for a combination reaction which is exothermic.

(ii) Name any two metals which do not react with water.

Sol. (i) $\underset{\text{Calcium oxide}}{CaO} + \underset{\text{Water}}{H_2O} \longrightarrow \underset{\text{Slaked lime}}{Ca(OH)_2} + \text{Heat}$ *[1]*

(ii) Silver, gold *[1]*

C 3 Marks Questions

30. When solutions of silver nitrate and potassium chloride are mixed, a white precipitate forms. The ionic equation for the reaction is

$$Ag^+(aq) + Cl^- \longrightarrow AgCl(s)$$

(i) (a) What is the name of the white precipitate?

(b) Is it a soluble or insoluble compound?

(ii) Is the precipitation of silver chloride a redox reaction?

Sol. (i) (a) White precipitate of silver chloride (AgCl) is formed.

(b) Silver chloride (AgCl) is an insoluble compound. *[1]*

(ii) It is not a redox reaction.

$$\underset{\text{Sodium chloride}}{NaCl} + \underset{\text{Silver nitrate}}{AgNO_3(aq)} \longrightarrow \underset{\text{Silver chloride}}{AgCl(s)} + \underset{\text{Sodium nitrate}}{NaNO_3(aq)}$$ *[1]*

In this reaction, cations Ag^+ and Na^+ have exchanged their anions NO_3^- and Cl^- and a precipitate of AgCl has been formed. *[1]*

31. Write the balanced chemical equation for the reactions that take place during respiration. Identify the type of combination reaction that takes place during this process and justify the name. Give one more example of this type of reaction.

Sol. $C_6H_{12}O_6(aq) + 6O_2(aq) \longrightarrow 6CO_2(aq) + 6H_2O + \text{Energy}$ *[1]*

It is an exothermic reaction because a large amount of heat is released *e.g.,* Burning of natural gas.

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g) + \text{Heat}$$ *[2]*

32. In the electrolysis of water,

(i) name the gas collected at the cathode and at the anode.

(ii) why is the volume of gas collected at one electrode is double of the other?

(iii) why are a few drops of dil. H_2SO_4 added to the water?

Sol. (i) Gas collected at cathode – Hydrogen

Gas collected at anode – Oxygen *[1]*

(ii) On electrolysis, water decomposes according to the following reaction

$$2H_2O \xrightarrow[\text{Electric current}]{\text{On passing}} 2H_2(g) + O_2(g)$$

This water decomposes to given hydrogen and oxygen in the ratio 2:1 by volume. So, double volume of the gas collected is hydrogen. *[1]*

(iii) A few drops of dil. H_2SO_4 are added to water to make it a better conductor of electricity. *[1]*

d 4 Marks Questions

33. Write the balanced chemical equation for the following and identify the type of reaction in each case.

(i) Lead nitrate (*aq*) + Potassium iodide (*aq*) ⟶ Lead iodide + Potassium nitrate (*aq*)

(ii) Zinc carbonate (*s*) $\xrightarrow{\Delta}$ Zinc oxide (*s*) + Carbon dioxide (*g*)

(iii) Hydrogen (*g*) + Chlorine (*g*) ⟶ Hydrogen chloride (*g*)

(iv) Magnesium(*s*) + Hydrochloric acid (*aq*) ⟶ Magnesium chloride (*aq*) + Hydrogen (*g*)

Sol. (i) $Pb(NO_3)_2 + 2KI \longrightarrow PbI_2 + 2KNO_3$

Type Double displacement reaction. *[1]*

(ii) $ZnCO_3(s) \xrightarrow{\Delta} ZnO(s) + CO_2(g)$

Type Thermal decomposition reaction. *[1]*

(iii) $H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$

Type Combination reaction. *[1]*

(iv) $Mg(s) + 2HCl(aq) \longrightarrow MgCl_2 + H_2(g)$

Type Displacement reaction. *[1]*

34. Complete and balance the following equations.

(i) $N_2 + O_2 \longrightarrow$ (ii) $Ca(NO_3)_2 \xrightarrow{\Delta}$

(iii) $PbO_2 \xrightarrow{\Delta}$ (iv) $NO + O_2 \longrightarrow$

(v) $Pb(NO_3)_2 + 2NaCl \longrightarrow$

Sol. (i) $N_2 + O_2 \longrightarrow 2NO$

(ii) $2Ca(NO_3)_2 \xrightarrow{\Delta} 2CaO + 4NO_2 + O_2$

(iii) $2PbO_2 \xrightarrow{\Delta} 2PbO + O_2$

(iv) $2NO + O_2 \longrightarrow 2NO_2$

(v) $Pb(NO_3)_2 + 2NaCl \longrightarrow PbCl_2 + 2NaNO_3$ *[4]*

35. (i) Classify the following reactions into different types.

(a) $AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$

(b) $CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq)$

(c) $2KClO_3(s) \xrightarrow{\Delta} 2KCl(s) + 3O_2(g)$

(ii) Which of the above reaction(s) is/are precipitation reaction(s)? Why is a reaction called precipitation reaction?

Sol. (i) (a) Double displacement reaction and precipitation reaction

(b) Combination reaction

(c) Thermal decomposition *[2]*

(ii) Reaction (a) is also a precipitation reaction, as white precipitate (insoluble product) of silver chloride (AgCl) is formed in the reaction.

Due to the formation of precipitate (a white coloured solid mass), reaction is called precipitation reaction. *[2]*

e 5 Marks Questions

36. Identify the type of chemical reaction taking place in each of the following.

(i) Barium chloride solution is mixed with copper sulphate solution and a white precipitate is observed.

(ii) On heating copper powder in air in a China dish, the surface of copper powder turns black.

(iii) On heating green coloured ferrous sulphate crystals, reddish brown solid is left and small of a gas having odour of burning sulphur is experienced.

(iv) Iron nails when left dipped in blue copper sulphate solution become brownish in colour and the blue colour of copper sulphate fades away.

(v) Quicklime reacts vigorously with water releasing a large amount of heat.

Sol. (i) Double displacement reaction, precipitation reaction. *[1]*

(ii) Combination reaction, oxidation reaction. *[1]*

(iii) Thermal decomposition. *[1]*

(iv) Displacement reaction. *[1]*

(v) Combination and exothermic reaction. *[1]*

37. You are provided with two containers made up of copper and aluminium. You are also provided with solutions of dilute HCl, dilute HNO_3, $ZnCl_2$ and H_2O. In which of the above containers these solutions can be kept?

Sol. The container made up of copper or aluminium is suitable for storing some solutions. This can be decided by studying their reactions with Cu and Al, based on activity series. *[1]*

(i) **Reactions of copper with**

(a) **Dilute HCl**

$$Cu + \text{dil. } HCl \longrightarrow \text{No reaction.}$$

So, it can be stored in Cu container.

(b) **Dilute HNO_3**

Being a strong oxidising agent, dilute HNO_3 reacts with copper, so it cannot be stored in copper container.

(c) **$ZnCl_2$**

Copper is less reactive than zinc so it does not react with $ZnCl_2$ solution. Therefore, it can be stored in copper container.

(d) **H_2O**

Copper does not react with water. So, its container can store H_2O in it. *[2]*

(ii) **Reactions of aluminium with**

(a) **Dilute HCl**

Al reacts with dilute HCl, so it cannot be kept in aluminium container.

$$2Al + 6\ HCl \longrightarrow 2AlCl_3 + 3H_2$$

(b) **Dilute HNO_3**

When dil. HNO_3 is kept in Al container, it forms a protective layer of aluminium oxide on it, therefore it can be kept in Al container.

(c) **$ZnCl_2$**

Al is more reactive than zinc, so, it connnot keep $ZnCl_2$ solution in it.

$$2Al + 3ZnCl_2 \longrightarrow 2AlCl_3 + 3Zn$$

(d) **H_2O**

Aluminium does not react with water (hot or cold). Therefore, water can be kept in aluminium container.

Aluminium is attacked by steam to form aluminium oxide and hydrogen.

$$2Al(s) + 3H_2O(g) \longrightarrow Al_2O_3(g) + 3H_2(g)$$

[2]

CHAPTER EXERCISE

Fill in the Blanks

1. The position of copper is ..... to that of hydrogen in the activity series.

2. ..... is a pigment, found in plants which helps in photosynthesis by entraping the light energy.

3. …… gas is released during respiration.

4. During endothermic reaction, energy is ..... .

Multiple Choice Questions

5. Close contact of reacting substances during a chemical reaction is required for the exchange of
(a) energy (b) electrons (c) protons (d) All of these

6. $AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$

The above reaction is
(a) double displacement reaction (b) precipitation reaction
(c) combination reaction (d) Both (a) and (b)

7. The process by which we can get sodium and chlorine in elemental form from common salt is
(a) photolysis (b) thermal decomposition
(c) electrolysis (d) displacement reaction

8. Aluminium metal reacts with sulphuric acid to form
(a) aluminium sulphate and hydrogen
(b) aluminium sulphate and oxygen
(c) aluminium sulphate and water
(d) aluminium sulphate and sulphur dioxide

9. When dilute hydrochloric acid is added to zinc pieces taken in a test tube
(a) small bubbles of hydrogen gas appear on the surface of zinc pieces
(b) the colour of the solution becomes yellow
(c) a pungent smelling gas gets liberated
(d) no change takes place

10. In an endothermic reaction
(a) heat is released
(b) the energy content of products is greater than that heat content of reactants
(c) the energy content of products is lesser than that heat content of reactants
(d) heat is neither absorbed nor released

11. Magnesium burns in the environment of
(a) O_2 (b) N_2
(c) Both (a) and (b) (d) Neither (a) nor (b)

1 Mark Questions

12. Name the required conditions for a faster reaction to produce ammonia gas.

13. Which chemical process is used for obtaining a metal from its oxide?

14. What kind of chemical reaction takes place when electric current is passed through fused sodium chloride?

15. Write the chemical equation for a reaction which can be brought out in laboratory with the help of diffused sunlight.

16. Predict the precipitate formed when sodium sulphate (Na_2SO_4) reacts with barium chloride.

17. Write any two industrial applications of electrochemical reaction.

2 Marks Question

18. (i) What is displacement reaction?

(ii) $Zn + CuSO_4(aq) \longrightarrow X + Y$
What is X and Y in the above reactions?

3 Marks Question

19. A, B and C are three elements which undergo chemical reaction according to the following equations.

$$A_2O_3 + 2B \longrightarrow B_2O_3 + 2A$$
$$3CSO_4 + 2B \longrightarrow B_2(SO_4)_3 + 3C$$
$$3CO + 2A \longrightarrow A_2O_3 + 3C$$

Answer the following questions with reason.
(i) Which element is the most reactive?
(ii) Which element is the least reactive?
(iii) What is the type of reactions listed above?

4 Marks Question

20. Give an example of each of the following chemical changes.
(a) A reaction, where colour change is observed.
(b) A reaction involving
(i) formation of insoluble salt.
(ii) formation of neutral products.
(c) An exothermic and endothermic reaction involving carbon as one of the reactants.

5 Marks Question

21. (i) What is meant by activity series of metals? Arrange the metals zinc, magnesium, aluminium, copper and iron in a decreasing order of reactivity?
(ii) What will you observe when you put
(a) some zinc pieces into blue copper sulphate solution.
(b) some copper pieces into green ferrous sulphate solution?
(iii) Write the balanced chemical equations also.

CHALLENGERS*

1 Liquid *A* :  — Oil Liquid *B* :  — Water

Ravi tested both the above liquids and found that these two differ in their odour as well as in inflammability. The former one is highly inflammable while the latter is used to extinguish fire. He predicts such a difference is due to difference in their

(a) density (b) chemical composition
(c) melting point (d) boiling point

2 Three beakers labelled as *A*, *B* and *C* each contains 25 mL of water. A small amount of NaOH, anhyd. $CuSO_4$ and NaCl were added to the beakers *A*, *B* and *C*, respectively. It was observed that there was an increase in the temperature of the solutions of the beakers *A* and *B* whereas, in case of beaker *C*, the temperature of the solution falls. Which one of the following statements is/are correct?

I. In beakers *A* and *B*, exothermic process has occurred.
II. In beakers *A* and *B*, endothermic process has occurred.
III. In beaker *C*, exothermic process has occurred.
IV. In beaker *C*, endothermic process has occurred.

(a) Only I (b) Only II (c) I and IV (d) II and III

3 Which of the following colour change occur when the gases after thermal decomposition of ferrous sulphate came in contact with an acidified solution of potassium dichromate?

(a) Green to orange (b) Red to colourless
(c) Orange to green (d) Blue to green

4 Consider the following equation for the process of photosynthesis, used by green plants to prepare their own food.

$$x\,CO_2(y) + z\,H_2O(l) \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6(p) + 6O_2(aq) + 6H_2O(l)$$

Choose the correct words for *x*, *y*, *z* and *p*.

	x	y	z	p		x	y	z	p
(a)	6	(*g*)	12	(*s*)	(b)	6	(*g*)	10	(*s*)
(c)	6	(*g*)	12	(*aq*)	(d)	6	(*aq*)	12	(*s*)

5 A precipitation reaction is one in which two soluble reactants form an insoluble product. The insoluble product is a solid which usually sinks to the bottom of the liquid.

The table shows the solubility of the compounds that form when some chemicals react. The compounds that are soluble are marked with a tick (✓). The compounds that are insoluble are marked with a cross (✗).

	Carbonate	Chloride	Hydroxide	Nitrate	Sulphate
Barium	✗	✓	✓	✓	✗
Lead	✗	✗	✗	✓	✗
Mercury	✗	✗	✗	✓	✓
Potassium	✓	✓	✓	✓	✓
Sodium	✓	✓	✓	✓	✓

Which of the following word equations represents a precipitation reaction?

(a) Sodium nitrate + Barium chloride → Sodium chloride + Barium nitrate
(b) Mercury sulphate + Potassium nitrate → Mercury nitrate + Potassium sulphate
(c) Potassium sulphate + Barium hydroxide → Potassium hydroxide + Barium sulphate
(d) Potassium chloride + Sodium hydroxide → Potassium hydroxide + Sodium chloride

6 Which of the following is correct order of reactivity of element?

(a) K > Ca > Al > Pb > Ag > Hg
(b) Zn > Fe > Pb > H > Au > Ag
(c) Na > Mg > Zn > Pb > H > Ag
(d) Na > Mg > Pb > Zn > H > Au

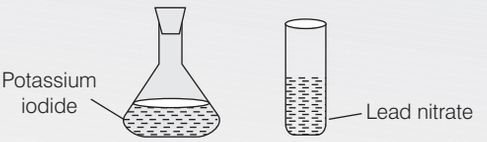
7 What happens when ferrous sulphate crystals are heated?

(a) A gas having the smell of burning sulphur is evolved
(b) No gas is evolved
(c) Brown coloured gas is evolved
(d) Colourless and odourless gas is evolved

8 The carbonate of metal *X* is a white solid. It decomposes when heated to form carbon dioxide and a yellow solid oxide. What is metal *X*?

(a) Lead (b) Potassium (c) Sodium (d) Copper

9 Sonu wanted to react potassium iodide solution with aqueous solution of lead nitrate to obtain a yellow precipitate of lead iodide. To carry out the reaction, he made the following experimental set up.



But accidently the lead nitrate solution fall down and more lead nitrate is not available in the laboratory. Could you suggest which of the following salt he can use for performing this activity?

(a) Lead sulphate (insoluble) (b) Lead acetate
(c) Ammonium nitrate (d) Potassium sulphate

10 When mercury (II) thiocyanate is heated

I. a decomposition reaction takes place.
II. an endothermic reaction takes place.
III. carbon disulphide gas is evolved.

The true statements are

(a) I and II (b) II and III (c) I and III (d) I, II and III

Answers

1. (b) **2.** (c) **3.** (c) **4.** (c) **5.** (c) **6.** (c) **7.** (a) **8.** (a) **9.** (b) **10.** (c)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 111-112.

CHAPTER

3

Water

After the air, water is one of the most common substance on the earth's surface. About 2/3 of earth's surface is covered with water. It is found in the free as well as in combined state.

Chapter Objectives

- Occurrence
- Water as Universal Solvent
- Physical Properties of Water
- Solutions
- Solubility
- Hydrated and Anhydrous Substances
- Removal of Hardness

Occurrence

Water is the most common, abundant and easily obtainable compound as compared to all other known compounds. It is a crucial compound for the survival of life. It can exist in solid (as ice, snow, etc.), liquid (as lakes, river, sea, etc.) or gas (as water vapour).

It constitutes a major part of all the living organism *e.g.,* It forms about 65% of human body and almost 95% of some plants. However, its distribution over the earth's surface is not uniform. However, the fraction of water available for human use is oblique only 0.003% of the total global water availability.

Water as Universal Solvent

Ancient philosophers thinked that water is an element. In 1781, A.L. Lavoisier showed that water is a compound of hydrogen and oxygen atoms combined together in the ratio of 2 : 1.

Because of its tendency to dissolve almost all the substances, water is regarded as **universal solvent**. Ionic compounds (polar compounds) dissolve in it because of its high dielectric constant (78.39), whereas some covalent compounds are soluble in it because of the formation of hydrogen bonds in between the water and covalent molecule.

Physical Properties of Water

The important physical properties of water are as follows

(i) Pure water is a transparent, colourless, tasteless and odourless substance. It takes the odour of the substance, which is dissolved in it. Thick layer of water appears as greenish blue.

(ii) Its freezing point, boiling point, heat of vaporisation and heat of fusion is higher than the hydrides of other elements of group 16. This is because of the presence of intermolecular hydrogen bonding in between water molecules.

(iii) Water has a high specific heat, thermal conductivity surface tension, dipole moment and dielectric constant than many other liquids and thus plays a vital role in the biosphere.

(iv) Water has its maximum density of 1 gcm^{-3} or $10^3 kgm^{-3}$ at 4°C and minimum volume.

Solutions

A homogeneous mixture of two or more substances is called solution. A solution is sometimes also called as a **true solution**. Lemonade, soda water, salt solution, sugar solution, etc., all are the examples of solutions.

In a solution, there is homogeneity at the particle level *i.e.,* the particles of dissolved substances are evenly distributed in the solution and are indistinguishable from one another.

There are two main components of a solution

(i) **Solvent** (Dissolving Phase) The component (usually present in larger amount) of the solution that dissolves the other component in it is called the **solvent**.

(ii) **Solute** (Dissolved Phase) The component (usually present in lesser quantity) of the solution that is dissolved in the solvent is called the **solute**.

Some common examples of solution

(i) In sugar solution, sugar is the solute and water is the solvent.

(ii) A solution of iodine in alcohol known as **tincture of iodine**, has iodine (solid) as the solute and alcohol (liquid) as the solvent.

(iii) Aerated drinks like soda water, etc., are gas in liquid solutions in which CO_2 (gas) as solute and water (liquid) as solvent is present.

Properties of a Solution

Some important properties of a solution are as follow

(i) A solution is a homogeneous mixture.

(ii) The particles of a solution are smaller than 1 nm (10^{-9} m) in diameter. Therefore, they cannot be seen by naked eyes.

(iii) Due to very small particles, they do not scatter a beam of light passing through the solution. So, the path of light is not visible in a solution.

(iv) A solution is stable *i.e.,* the solute particles do not settle down when left undisturbed. The solute particles cannot be separated from the mixture by the process of filtration.

Concentration of a Solution

The concentration of a solution is the amount of solute present in a given amount (mass or volume) of solution, or the amount of solute dissolved in a given mass or volume of the solvent.

Concentration of solution

$$= \frac{\text{Amount of solute}}{\text{Amount of solution}} = \frac{\text{Amount of solute}}{\text{Amount of solvent}}$$

In a solution, the relative proportion of the solute and solvent can be varied.

(i) **Depending upon the amount of solute present in comparison to solvent,** *it can be classified as*

(a) **Dilute solution** The solution in which amount of solute is very less as compared to the amount of solvent is called dilute solution.

(b) **Concentrated solution** The solution in which amount of solute is relatively more as compared to the amount of solvent is called concentrated solution.

(ii) **Depending upon the amount of solute present in a given amount of solvent,** *it can be classified as*

(a) **Saturated solution** A solution in which no more amount of solute can be dissolved at a given temperature, is called **saturated solution**.

(b) **Unsaturated solution** If the amount of solute contained in a solution is less than the saturation level, it is called an **unsaturated solution**.

Solutions Based upon Physical States

Types of solutions	Solute	Solvent	Examples
Gaseous solutions	Gas	Gas	Mixture of nitrogen and oxygen gases and air.
	Liquid	Gas	Chloroform mixed with nitrogen gas and humidity.
	Solid	Gas	Camphor in nitrogen gas and dust or smoke.
Liquid Solutions	Gas	Liquid	Oxygen in water and carbon dioxide in water.
	Liquid	Liquid	Alcoholic beverages are basically solutions of ethanol in water.
	Solid	Liquid	Sucrose (table sugar) or salt in water
Solid solutions	Gas	Solid	Hydrogen dissolves in metals, especially in palladium.
	Liquid	Solid	Mercury with sodium forming an amalgam.
	Solid	Solid	Alloys like bronze and many others.

Solubility

Solubility of a substance is its maximum amount that can be dissolved in a specified amount (100g) of solvent at a specified temperature. It depends on nature of solute, nature of solvent, temperature and pressure.

Solubility of a Gas in a Liquid

The solubility of different gases in the same solvent varies *e.g.,* Gases like hydrogen, oxygen, nitrogen and helium, etc. dissolves in water to a small extent whereas the gases like NH_3, HCl, SO_2, etc., are highly soluble in water.

Effect of Temperature and Pressure

The solubility of most gases in liquids decreases with increase of temperature. An increase in pressure on the surface of water increases the solubility of a gas in water. This is in accordance to Henry's law.

According to this law, the mass of gas dissolved by a fixed volume of liquid is directly proportional to the pressure on the surface of the liquid at any given temperature.

Solubility of a Solid in a Liquid

Solids are soluble in a liquid if their intermolecular interactions are similar. The solubility of a solid in a liquid at any temperature is defined as the maximum amount of the solid (solute) in gram which can be dissolved in 100 g of the liquid (solvent) to form the saturated solution at that particular temperature.

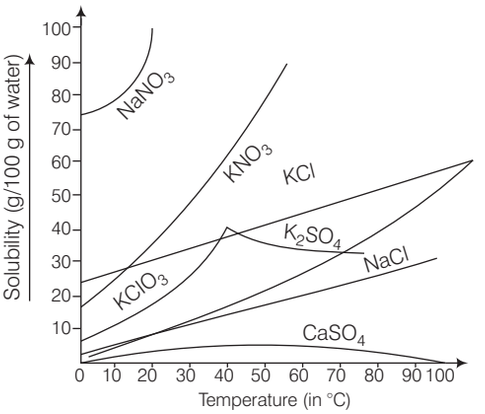
Effect of Temperature and Pressure

The solubility of a solid in a liquid is significantly affected by temperature change.

For most of the solids, solubility in water increases with rise in temperature. Pressure does not have any significant effect on solubility of solids in liquids.

Solubility Curves

The graph drawn for the change of solubility of a substance against temperature, (*i.e.,* with the rise of fall) is called solubility curve. In solubility curve, the solubility is plotted along *Y*-axis and temperature is plotted along *X*-axis which is shown below.



Variation in solubility of some solids with changing temperature

From the solubility curve, *it is concluded that the solubilities of some substances like*

(i) Solubility of sodium chloride increases very little with the increase in temperature.

(ii) Solubility of potassium nitrate and potassium sulphate increases considerably with the increase in temperature.

(iii) Solubility of $CaSO_4$ and $Na_2SO_4 \cdot 10H_2O$ increase with the rise in temperature and then decreases after attaining maximum value.

Applications of Solubility Curves

Solubility curves are used

(i) To calculate the amount of substance which will crystallise out when a hot saturated solution is cooled to a lower temperature.

(ii) To calculate the solubility of a given substance at the specific temperature.

(iii) To compare the solubilities of different substances at the specific temperature.

CHECK POINT 01

1 Why true solutions are homogeneous in nature?

2 What happens when a crystal of solute is introduced into a saturated solution of the solute?

3 Explain, how can you increase the solubility of a gas in liquid?

4 What is the effect of temperature on solubility of a solid in liquid?

5 Mention any two applications of solubility curves.

Hydrated and Anhydrous Substances

On the basis of presence or absence of water molecules, substances are divided into following two categories. *There are as follows*

(i) Hydrated Substances

The crystals of some salts contain water of crystallisation. This water of crystallisation gives the shape of crystals. Sometimes, it gives the colour of crystal such as copper sulphate which is blue is colour. Such salts are said to be hydrated salts.

Note: A crystal is a homogeneous solid bounded by the plane surface directed at definite angle and having definite geometrical shape. e.g., NaCl, $CuSO_4$, etc. crystallisation is the process of separating out the crystals from the not saturated solution on cooling it slowly.

Water of Crystallisation

The fixed amount of water that is associated with hydrated crystals which is an integral part of the crystal, is said to be water of crystallisation. It is also known as water of hydration.

When crystals are heated above 100°C, the water of crystallisation loose their chemical combination. The vapours are produced and condense to form liquid.

Salts Containing Water of Crystallisation

S.No.	Chemical name	Common name	Chemical formula
1.	Sodium carbonate decahydrate	Washing soda	$Na_2CO_3 \cdot 10H_2O$
2.	Sodium sulphate decahydrate	Glauber's salt	$Na_2SO_4 \cdot 10H_2O$
3.	Magnesium sulphate heptahydrate	Epsom salt	$MgSO_4 \cdot 7H_2O$
4.	Copper (II) sulphate pentahydrate	Blue vitriol	$CuSO_4 \cdot 5H_2O$
5.	Zinc sulphate heptahydrate	White vitriol	$CuSO_4 \cdot 7H_2O$
6.	Hydrated potassium aluminium sulphate	Potash alum	$K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$
7.	Calcium sulphate semihydrate	Plaster of Paris	$CaSO_4 \cdot \frac{1}{2} H_2O$

(ii) Anhydrous Substances

When a substance contains no water, then it is said to be anhydrous substance. *They lack water of crystallisation some of the examples of anhydrous substances are*

- Common salt (NaCl)
- Gaseous HCl
- Nitre (KNO_3)
- Ammonium chloride (NH_4Cl)
- Sugar ($C_{12}H_{22}O_{11}$)

Anhydrous substance can be obtained from hydrated substances by removing their water of crystallisation. It can be done through.

- direct heating
- By using dehydratng agent (like conc. H_2SO_4)
- Heating under vacuum
- Heating is hot and dry air.

Properties

Important properties of hydrated and anhydrous substances are as follows

(i) Efflorescence

The phenomenon in which a compound loses its water of crystallisation on exposure to dry air is called efflorescence and substances are said to be efflorescent substances. Due to this phenomenon hydrated salts when left exposed to atmosphere lose their water of crystallysation and crumble down to form powder. *The condition of efflorescence is*

Vapour pressure of hydrated crystals > Atmospheric vapour pressure

Some of the examples of efflorescent substances are

(a) Washing soda ($Na_2CO_3 \cdot 10H_2O$)

$$\underset{\text{Hydrated sodium carbonate}}{Na_2CO_3 \cdot 10H_2O} \xrightarrow{\text{Dry air}} \underset{\text{Monohydrate}}{Na_2CO_3 \cdot H_2O} + 9H_2O$$

(b) Epsom salt ($MgSO_4 \cdot 7H_2O$)

$$\underset{\text{Magnesium sulphate heptahydrate}}{MgSO_4 \cdot 7H_2O} \xrightarrow{\text{Dry air}} \underset{\text{Monohydrate}}{MgSO_4 \cdot H_2O} + 6H_2O$$

(c) Glauber's salt ($Na_2SO_4 \cdot 10H_2O$)

$$\underset{\text{Hydrated sodium sulphate}}{Na_2SO_4 \cdot 10H_2O} \xrightarrow{\text{Dry air}} \underset{\text{Anhydrous}}{Na_2SO_4} + 10H_2O$$

Note The higher the temperature of the air, the higher the efflorescence. The reason is that the air absorbs more water with increase in temperature and decrease is moisture. It is minimized in the humid conditions.

(ii) Deliquescence

Some of the water soluble substances, when left exposed to atmosphere at ordinary temperature absorb moisture, lose their crystalline form and get converted into their saturated solution. Such a substance is called a **deliquescent substance** and the phenomenon is said to be deliquescency.

The condition of deliquescence is

Vapour pressure inside the crystals << Atmospheric vapour pressure.

Some of the examples of deliquescent substances are

- Caustic soda (NaOH)
- Caustic potash (KOH)
- Calcium chloride ($CaCl_2$)
- Magnesium chloride ($MgCl_2$)

Note During the rainy season, table salt (NaCl) turns moist and forms a solution on exposure to air. But, pure NaCl is not deliquescent. The commercial table salt contains impurities such as $MgCl_2$ and $CaCl_2$ which are deliquescent substances.

(iii) Hygroscopy

The phenomenon where certain substances absorb moisture (water vapour) from the atmosphere when they are exposed to air is called hygroscopy such substances are called **hygroscopic substances**. They have tendency to take up moisture from the air.

Some of the examples of hygroscopic substances are

- Quicklime (CaO)
- Phosphorus pentaoxide (P_2O_5)
- Concentrated sulphuric acid (H_2SO_4)

CHECK POINT 02

1. Give the examples of hydrated substance.
2. What is the chemical formula of potash alum?
3. What is the colour of anhydrous copper sulphate?
4. Mention the condition for efflorescence.
5. Is table salt deliquescent in nature?

Drying and Dehydrating Agents

The substance that can readily absorb moisture from other substance without chemically reacting with them is called **drying agent.** It is used to absorb water vapour from the air.

Some examples of drying agents are

- Anhydrous zinc chloride ($ZnCl_2$)
- Anhydrous calcium chloride ($CaCl_2$)
- Phosphorus pentaoxide (P_2O_5)
- Dry sodium sulphate (Na_2SO_4)

Almost all hygroscopic substances are drying agents. Drying agent are also known as desiccants or desiccating agents. The substance that can remove even the chemically combined water molecules from compound is called **dehydrating agent.**

Some examples of dehydrating agents are

- **Concentrated sulphuric acid** It can remove water of molecules from blue vitriol.

$$\underset{\text{(Blue vitriol)}}{CuSO_4 \cdot 5H_2O} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\text{(White)}}{CuSO_4} + 5H_2O$$

- Concentrated phosphoric acid (H_3PO_4)
- Hot aluminium oxide (Al_2O_3)

Soft and Hard Water

Water free from soluble salts of calcium and magnesium is called soft water. It gives lather with soap (sodium or potassium salt of higher fatty acids). It is suitable for use. The most common examples of soft water are distilled water and rain water. Hard water contains soluble salt of calcium or magnesium. It does no give lather with soap. This is because of the precipitation of the insoluble soap (calcium or magnesium stearate).

$$\underset{\substack{\text{Calcium chloride present in hard water}}}{CaCl_2} + 2\underset{\text{sodium stearate (soap soluble)}}{C_{17}H_{35}COO^-Na^+} \longrightarrow \underset{\text{calcium stearate (insoluble soap)}}{(C_{17}H_{35}COO)_2Ca}\downarrow + 2NaCl$$

Cause of Hardness

Water of springs, wells and rivers contains dissolved minerals. It is due to the presence of bicarbonates, sulphates and chlorides of calcium and magnesium which cause hardness of water. When water flows over beds of limestone ($CaCO_3$) and dolomite ($MgCO_3$), carbon dioxide (CO_2) slowly converts some of these into soluble calcium and magnesium bicarbonates. It gets mixed with the water and make it hard.

Types of Hardness

The hardness of water is of two types

(i) Temporary Hardness

It occurs due to dissolved bicarbonate of calcium and magnesium [$Ca(HCO_3)_2$ and $Mg(HCO_3)_2$], so it is also called **carbonate hardness.** This type of hardness is temporary because it can be easily removed by just boiling and filtering the water.

$$Ca^{2+}CO_3^{2-}(s) + H_2O(l) + CO_2(g) \longrightarrow \underset{\text{Temporary hardness}}{Ca^{2+}(HCO_3)_2}$$

(ii) Permanent Hardness

It occurs due to dissolved chlorides and sulphates of calcium and magnesium. This type of hardness cannot be removed by simple methods like boiling or filtration, so it called **permanent hardness**.

Removal of Hardness

The process of removal of hardness from water is called softening of water.

Methods used for removal of hardness are as follows

(i) **Boiling** Temporary hardness of water can be removed by boiling. Due to boiling $Mg(HCO_3)_2$ is converted insoluble $Mg(OH)_2$, whereas $Ca(HCO_3)_2$ is converted into insoluble $CaCO_3$ and gets pecipitated. These precipitates can be removed by filtration or decantation.

$$Mg(HCO_3)_2(aq) \xrightarrow{\Delta} Mg(OH)_2\downarrow + 2CO_2\uparrow$$

$$Ca(HCO_3)_2(aq) \xrightarrow{\Delta} CaCO_3\downarrow + H_2O + CO_2\uparrow$$

(ii) **Treatment with washing soda** Permanent hardness of water can be removed by adding washing soda. Washing soda reacts with soluble salts in hard water to form insoluble carbonates that can be filtered off.

$$MCl_2 + Na_2CO_3 \longrightarrow MCO_3\downarrow + 2NaCl$$

$$MSO_4 + Na_2CO_3 \longrightarrow MCO_3\downarrow + Na_2SO_4$$

where, M = Ca and Mg

Advantages and Disadvantages of Soft Water and Hard Water

Following are advantages and disadvantages of soft water and hard water

Advantages

(i) Soft water is used for drinking purpose.

(ii) Soft water is free from dissolved salts and has pleasent taste.

(iii) The presence of salts in hard water make it tasty, therefore, it is used in the preparation of beverages and wines.

(iv) Calcium and magnesium salts present in hard water are essential for the growth of our bones and teeth.

(v) To check the poisoning of water in lead pipes, hard water is used. When hard water flow inside the lead pipe, some lead salts dissolved in water to make it poisonous calcium sulphate, present in hard water forms insoluble lead sulphate in the form of a layer inside the lead pipe. It checks the lead poisoning.

Disadvantages

(i) The hard water cannot be used for washing clothes because it contains Ca^{2+} and Mg^{2+} ions, which react with soap (*i.e.*, sodium stearate, $C_{17}H_{35}COONa$ or other sodium or potassium salt of higher fatty acids) to form scum or precipitate of Ca/Mg stearate.

$$\underset{\text{Sodium stearate (soap)}}{2C_{17}H_{35}COO^-Na^+} + \underset{\text{From hard water}}{M^{2+}} \longrightarrow \underset{\text{Metal stearate (Curdy white ppt.)}}{(C_{17}H_{35}COO)_2M\downarrow} + 2Na^+$$

(where, M = Ca or Mg)

However, after the precipitation of all the Ca^{2+} and Mg^{2+} ions present in the water, the water becomes soft and gives lathers with soap. Thus, lots of soap get wasted if clothes are washed with hard water. Hence, it is unsuitable for laundry.

(ii) Hard water is also harmful for boiler as the salts present in hard water get deposited in the form of scale and thus, reduce the efficiency of the boilers.

(iii) It cannot be used for domestic purposes as it spoils the utensils lustre and results in scale formation.

(iv) It is also harmful for industries like dying, printing, textiles, sugar, etc., as plenty of water is needed.

CHECK POINT 03

1 Define soft and hard water.

2 Why hard water do not form lather with soap?

3 What is the cause of hardness in water?

4 Complete the following.

$$CaCl_2 + 2C_{17}H_{35}\overset{-}{C}O\overset{-}{O}\ Na^+ \longrightarrow$$

5 Which method is used for the removal of permanent hardness?

6 How hard water can be used to check the lead poisoning?

SUMMARY

- Water is most abundant compound; about 80% of earth surface is covered with water. It can exist in solid, liquid and gaseous states.
- The composition of water is hydrogen and oxygen atoms combined together in the ratio of 2 : 1. Due to high dielectric constant, it is regarded as universal solvent.
- A solution is a homogeneous mixture of two or more substances, whose composition can be varied within certain limits. In such a mixture, a solute which is substance dissolved in another substance, known as solvent, which is present in large quantity.
- Solution is of many types on different basis as
  - Dilute Solution Solute is very less as compared to solvent.
  - Concentrated Solution Solute dissolved is relatively more as compared to the amount of solvent.
  - Saturated Solution No more solute dissolved at the given temperature.
  - Unsaturated Solution More solute can be dissolved at the given temperature.
  - Gaseous Solution Solvent must be gas and solute may be present in any state.
  - Liquid Solution Solvent must be liquid and solute may be present in any state.
  - Solid Solution Solvent must be solid and solute may be present in any state.
- Solubility of a substance is its maximum amount that can be dissolved in a specified amount of solvent (100g) at a specified temperature.
- Solubility of a solid in a liquid does not have any significant effect of pressure while, it may increase or decrease, with increase in temperature. NaCl increases very little but potassium nitrate and potassium sulphate increases considerably with the increase in temperature.
- Certain substances contain water molecules are called hydrated substances while those substance which do not contain any water along with the salts are said to be anhydrous substances.
- Water of Crystallisation It is the fixed amount of water that is associated with hydrated crystal which is an integral part of the crystal.
- Efforescence It is the phenomenon in which a compound loses its water of crystallisation on exposure to dry air.
- Deliquescence It is the phenomenon in which stubstance absorb moisture from atmosphere and get converted into their saturated solution.
- Hygroscopy It is the phenomenon in which substance absorb moisture from the air substance absorb moisture from the air.
- Drying Agent The substance that can readily absorb moisture from other substance without chemically reacting with them is called drying agent.
- Dehydrating Agent The substance that can remove even the chemically combined water molecules from compound is called dehydrating agent.
- Soft and Hard Water Water free from soluble salts of calcium and magnesium is called soft water. Hard water contains soluble salt of calcium or magnesium.
  There are two types of hardness
- Temporary Hardness Due to the presence of bicarbonates of magnesium and calcium.
- Permanent Hardness Due to the presence of sulphates and chlorides of calcium and magnesium.

EXAM PRACTICE

Fill in the Blanks

1. Water forms about …… of human body and almost …… of some plants.

Sol. 65%, 95%

2. A.L. Lavoisier, in the year (i) …… showed that water is a compound of (ii) …… and (iii) …… atoms combined together in the ratio of (iv) …… .

Sol. (i) 1781 (ii) hydrogen (iii) oxygen (iv) 2 : 1.

3. A solution of iodine in alcohol known as …… .

Sol. tincture of iodine

4. Air is the example of …… solution.

Sol. gaseous

5. Washing soda contains …… molecules of water of crystallisation.

Sol. ten

6. Anhydrous substance lack their …… .

Sol. water of crystalisation

7. The higher the temperature of the air, the …… the efflorescence.

Sol. higher

8. Concentrated (i) …… remove water of molecules from blue vitriol. It is a (ii) …… agent.

Sol. (i) sulphuric acid (ii) dehydrating

9. …… is used for drinking purpose.

Sol. Soft water

Multiple Choice Questions

10. Consider the following statement regarding true solution.

I. It is homogeneous and consist of single phase.

II. The particles of solute do not settle down even after long time.

III. The size of particle of solute > 1 nm.

Choose the correct options.

(a) Only II (b) II and III

(c) I and III (d) All of these

Sol. (d)

11. Which of the following salt contain water of crystallisation?

(a) Potash alum (b) Plaster of paris

(c) Epsom salt (d) All of these

Sol. (d)

12. The condition of efflorescence is

(a) Vapour pressure of hydrated crystal < atmospheric vapour pressure

(b) Vapour pressure of hydrated crystal < atmospheric vapour pressure

(c) Vapour pressure of hydrated crystal = atmospheric vapour pressure.

(d) Vapour pressure of hydrated crystal ≥ atmospheric vapour pressure

Sol. (d)

13. Hot aluminium oxide (Al_2O_3) is a

(a) drying agent

(b) dehydrating agent

(c) hygroscopic substance

(d) deliquescent substance

Sol. (b)

14. Hardness of water is due to

(a) chloride of calcium

(b) bicarbonate of magnesium

(c) sulphate of aluminium

(d) Both (a) and (b)

Sol. (d)

15. $CaSO_4 + Na_2CO_3 \longrightarrow X + Y$

What is the X and Y is the above reaction?

(a) $X = CaCO_3; Y = H_2SO_4$

(b) $X = H_2SO_4, Y = CaCl_2$

(c) $X = CaCO_3; Y = Na_2SO_4$

(d) $X = CaCl_2; Y = NaCl$

Sol. (c)

Match the Following

16. Match the following columns.

	Column I (Occurrence of water)		Column II (Examples)
(i)	Hydrated salt	(a)	Mist and fog
(ii)	Solid state	(b)	$CuSO_4 \cdot 5H_2O$
(iii)	Liquid state	(c)	Ice, frost
(iv)	Gaseous state	(d)	Well water, sea water

Sol. (i)→(b), (ii)→(c), (iii)→(d), (iv)→(a)

a 1 Mark Questions

17. Define dilute and concentrated solutions.

Sol. The solution in which amount of solute is very less as compared to the amount of solvent is called **dilute solution**. The solution in which amount of solute is relatively more as compared to the amount of solvent is called **concentrated solution**.

18. Give one example of each of gaseous and solid solutions.

Sol. The example of gaseous solution is mixture of nitrogen and oxygen gases in air and solid solution is alloys.

19. Why efflorescence increase with increase in temperature.

Sol. The higher the temperature of the air, the higher the efflorescence. This is due to the air absorbs more water with increase in temperature and decrease in moisture.

20. Write two examples of deliquescent substance.

Sol. Caustic soda (NaOH) and calcium chloride ($CaCl_2$) are two examples of deliquescent substance.

21. What is the cause of hardness of water?

Sol. The cause of hardness of water is due to the presence of bicarbonates, sulphates and chlorides of calcium and magnesium.

22. Write one advantage of soft water

Sol. Soft water is used for drinking pupose.

b 2 Marks Questions

23. (i) Why water is called universal solvent?
(ii) What is the particle size of solution?

Sol. (i) Water has tendency to dissolve almost all the substances. Thus, it is regarded as universal solvent. Because of its high dielectric constant (78.39), it dissolve ionic compound as well as some covalent compound.

(ii) The particle of a solution are smaller than 1 nm (10^{-9} m) is diameter. Therefore, they cannot be seen by naked eyes. *[2]*

24. What is the effect of temperature on the solubility of the following compounds in water?
(i) $CaSO_4$ (ii) KNO_3

Sol. (i) The solubility of $CaSO_4$ in water decreases with the increase in temperature. *[1]*

(ii) The solubility of KNO_3 in water increases with the increase in temperature. *[1]*

25. Write any two difference between deliquescent substance and hygroscopic substance.

Sol.

Deliquescent substance	Hygroscopic substance
These are crystalline solid is nature.	These may be crystalline solids or liquids.
These substance absorb moisture from the atmosphere and form saturated solution.	These substance also absorb moisture from the atmosphere and become wet but do not form saturated solution.

[2]

c 3 Marks Questions

26. Write the name of two compounds whose solubility
(i) decreases with the rise in temperature.
(ii) increases with the rise in temperature.
(iii) remains unaffected with the rise in temperature.

Sol. (i) Sodium nitrate : $NaNO_3$
Potassium nitrate : KNO_3 *(2 × ½ = 1)*

(ii) Calcium sulphate : $CaSO_4$
Calcium hydroxide : $Ca(OH)_2$ *(2 × ½ = 1)*

(iii) Potassium chloride : KCl
Sodium chloride : NaCl *(2 × ½ = 1)*

27. What is water of crystallisation? Among the following, choose the salt containing water of crystallisation.
Epsom salt, potash alum, blue vitriol, white vitriol, dolomite, quicklime, phosphorous pentaoxide.

Sol. The fixed amount of water that is associated with hydrated crystals which is an integral part of the crystal is said to be water of crystallisation.

The salts containing water of crystallisation are
Epsom salt — $MgSO_4 \cdot 7H_2O$
Potash alum — $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$
White Vitriol — $ZnSO_4 \cdot 7H_2O$
Blue Vitriol — $CuSO_4 \cdot 5H_2O$ *[3]*

d 4 Marks Questions

28. Write the name of one substance whose solubility
(i) increases slightly with rise of temperature.
(ii) decreases with rise of temperature.
(iii) increases gradually with rise of temperature.
(iv) increases rapidly with rise of temperature.

Sol. (i) **Sodium chloride** (NaCl) Solubility increases slightly with rise of temperature.
(ii) **Calcium sulphate** ($CaSO_4$) Solubility decreases with rise of temperature.
(iii) **Potassium chloride** (KCl) Solubility increases gradually with rise of temperature.
(iv) **Potassium nitrate** (KNO_3) Solubility increases rapidly with rise of temperature. *[1 × 4 = 4]*

29. Explain the following with suitable reason.
(i) The level of conc. H_2SO_4 is the jar increases when exposed to atmosphere.
(ii) Common salt becomes wet during rainy season.
(iii) Ferric chloride is stored in airtight bottles.
(iv) Washing soda loses its weight when exposed to atmosphere.

Ans (i) Conc. sulphuric acid is hygroscopic in nature. Hence, when exposed to atmosphere it absorbs moisture and the level of sulphuric acid in the jar increases.
(ii) Common salt (NaCl) contains the impurities of magnesium chloride which is deliquescent in nature. Thus, common salt becomes wet during rainy season. Sodium chloride is not deliquescent in nature.
(iii) Ferric chloride is highly deliquescent in nature and from saturated solution. Hence, it should be stored in airtight bottles.
(iv) Washing soda is an efforescent salt and in loses weight when exposed to atmosphere. *[4]*

e 5 Marks Question

30. Among the following salt, write which increases in weight, decrease in weight or remain same when exposed to atmosphere.
(i) Green vitriol
(ii) Soda ash
(iii) Magnesium chloride
(iv) Conc. sulphuric acid
(v) Sodium hydroxide
(vi) Washing soda
(vii) Glauber's salt
(viii) Common salt
(ix) Ferric chloride
(x) Sodium chloride

Sol. (i) Decreases
(ii) Remains same
(iii) Increases
(iv) Increases
(v) Increases
(vi) Decreases
(vii) Decreases
(viii) Increases
(ix) Increases
(x) Remains same *[5]*

CHAPTER EXERCISE

Fill in the Blanks

1. The homogeneous mixture of solute in a solvent is known as …… .
2. The component which dissolves is known as …… .
3. Soft water is free from …… .
4. Hard water is used to check …… .
5. Hard water cannot be used for (i) ……, harmful for (ii) …… and (iii) …… purpose.
6. Permanent hardness is removed by adding …… .

Multiple Choice Questions

7. The factors affecting solubility of a solid in a liquid is/are

   (I) Nature of solute (II) Nature of solvent
   (III) Temperature (IV) Pressure

   Choose the correct option.
   (a) Only III (b) Only IV
   (c) I, II and IV (d) All of these
8. Which of the following is drying agent?
   (a) Anhydrous $ZnCl_2$ (b) Phosphorus pentaoxide
   (c) Dry sodium sulphate (d) All of these
9. Hard water is harmful for
   (a) insect (b) domestic purpose
   (c) bones (d) lead pipe

Match the Following

10. Match the following columns.

	Column I (Chemical name)		Column II (Chemical formula)
(i)	Caustic potash	(a)	CaO
(ii)	Quicklime	(b)	$MgCO_3$
(iii)	Limestone	(c)	$CaCO_3$
(iv)	Dolomite	(d)	$CaSO_4 \cdot \frac{1}{2} H_2O$
(v)	Plaster of Paris	(e)	KOH

1 Mark Questions

11. Consider the following statement.

    'The solubility of sodium chloride at 40°C is 36.5 g.'
    What is meant by the above statement?
12. Why hard water is unfit for drinking purpose?
13. What is the chemical formula of soap?

2 Marks Questions

14. Write the effect of increasing and decreasing temperature on the solubility of the gas in a liquid.
15. What are the cause for
    (i) temporary hardness;
    (ii) permanent hardness?
16. Explain with equation, when permanet hard water is treated with wasing soda.
17. State the two disadvantages of using hard water.

3 Marks Questions

18. The molecular formula of water is H_2O.

    Write the information do you get from this formula.
19. How can temporary hardness of water remove? Explain with equation.
20. Write a short note on advantage of soft and hard water.

4 Marks Questions

21. Define the following.
    (i) Dilute solution
    (ii) Saturated solution
    (iii) Unsaturated solution
    (iv) Concentrated solution
22. Write one word for the following statements.
    (i) What is the dielectric constant of water?
    (ii) Those substance which do not contain any water along with it is said to be?
    (iii) The vapours are condense to form which state.
    (iv) Write one method by which anhydrous substance is obtained.
23. (i) Why hard water is not suitable for washing clothes? Explain with equation.
    (ii) How the permanent hardness is removed?

5 Marks Question

24. Explain in brief the advantages and disadvantages of soft water and hard water.

CHALLENGERS*

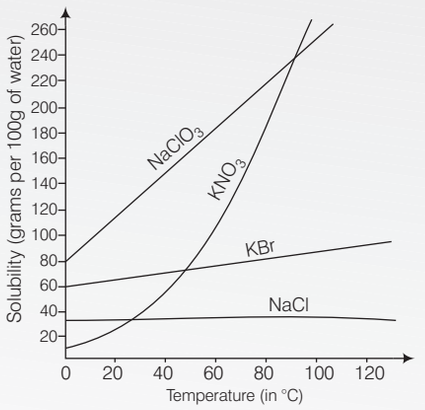
1 Water exhibit unusual properties in the condensed phase *i.e.,* liquid state and solid state. This is due to the
(a) presence of hydrogen and covalent bonding between the water molecules
(b) presence of covalent bonding between the water molecules
(c) presence of extensive hydrogen bonding between water molecules
(d) presence of ionic bonding

2 A sample of water containing some dissolved sugar and table salt is passed through an organic ion exchange resins. The resulting water will be
(a) sweet (b) tasteless (c) bitter (d) salty

3 Some of the mixtures are given below.
I. Air II. Sea water III. Cold drink IV. Milk
Which of the above mixtures are considered as true solutions?
(a) I, II and III (b) I and IV (c) I and III (d) All of these

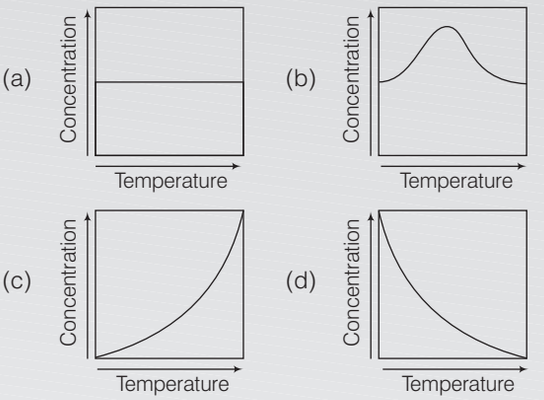
4 Consider the following statement regarding Henry's law.
I. The solubility of solid in a liquid is directly proportional to the partial pressure of the solid present above the surface of liquid solution.
II. The solubility of a gas in a liquid is directly proportional to the partial pressure of gas present above the surface of liquid or solution.
III. The solubility of a liquid in a gas is directly proportional to the partial pressure of liquid present above the surface of gas.
IV. The solubility of a gas in solid is directly proportional to the partial pressure of gas present above the surface of solid.
Choose the correct statement (s).
(a) Only I (b) Only II (c) III and IV (d) II and III

5 Solubility of salts increases with an increase in temperature. The graph given below shows the solubility of different salts at different temperature.



From the information given in the graph, which salt is almost equally soluble at all temperature?
(a) $NaClO_3$ (b) KBr (c) KNO_3 (d) NaCl

6 Which one of the following graph shows solubility of a gas in a liquid?



7 A solution conains 35 g of common salt in 300 g of water. The concentration of the solution is
(a) 11.6% (b) 88.3%
(c) 10.45% (d) 89.5%

8 *X* is a hydrate of calcium. On heating, it gives an another hydrate, *Y* which is used for setting fractured bones. The ratio of water molecules in *X* and *Y* (*X* : *Y*) is
(a) 4 : 1 (b) 2 : 1
(c) 1 : 1 (d) 1 : 4

9 One mole of a sample of hydrated sodium sulphide contains 162 g of water of crystallisation. What is the correct formula of this compound?
(a) $Na_2S \cdot 3H_2O$ (b) $Na_2S \cdot 5H_2O$
(c) $Na_2S \cdot 7H_2O$ (d) $Na_2S \cdot 9H_2O$

10 A compound *X* of sodium is commonly used in kitchen to make cripsy pakoras. It is also an active ingredient for curing acidity in the stomach. What is the product formed when solution of *X* is heated and the obtained product is recrystallised?
(a) Sodium bicarbonate
(b) Washing soda
(c) Soap
(d) Hydrogen chloride

Answers

1. (c) **2.** (a) **3.** (c) **4.** (b) **5.** (d) **6.** (d) **7.** (c) **8.** (a) **9.** (d) **10.** (b)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 112.

CHAPTER

4

Atomic Structure and Chemical Bonding

We have learnt that atoms and molecules are the fundamental building blocks of matter. The existence of different kinds of matter around us is due to different types of atoms and molecules present in them. **John Dalton** assumed that atom is indivisible *i.e.,* it has no constituent particles. But a series of experimental evidences revealed that an atom is not the smallest particle but some other particles smaller than the atom are also present, which are called **subatomic particles** *i.e.,* electrons, protons and neutrons. The atoms of different elements differ in the number of electrons, protons and neutrons.

In this chapter, we will describe how electrons, protons and neutrons were discovered and the various models that have been proposed to explain how these particles are arranged within the atom. But before going into the details of subatomic particles, we will start with understanding element and its constituent particle *i.e.,* atom.

Chapter Objectives

- Atom
- Constituents of an Atom
- Structure of an Atom
- Atomic Number
- Mass Number
- Distribution of Electrons in Different Orbits (Shells)
- Reason for Chemical Activity of an Atom
- Different Atomic Species
- Chemical Bonding
- Electrovalent Bond or Ionic Bond

Atom

An atom is the smallest particle of an element that exhibit all the properties of that element. This means that all the atoms of an element are similar to each other in every aspect and different from the atoms of different element. Atoms are further divisible into three subatomic particles *viz* electron, proton and neutron. Though these subatomic particles do not possess the characteristics possessed by the element.

Constituents of an Atom

An atom consist of three fundamental particles; electron, proton and neutron.

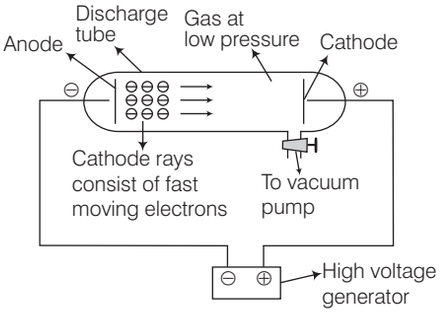
Various experiments that lead to the discovery of fundamental particles of an atom are as follows

1. Discovery of Electrons

It was known by 1900, that the atom was not a simple, indivisible particle but contained atleast one sub-atomic particle—the electron, which was identified by **J. J. Thomson**, when he performed cathode ray experiment using a discharge tube.

In the experiment, a gas at low pressure was taken in a discharge tube made up of glass. At the ends of the discharge tube two electrodes (metal plates) were placed, connected to a battery for high voltage supply.

The electrode connected to the negative end was known as cathode and that to the positive as anode.



Cathode rays experiment

During this experiment, he found a beam of negatively charged particles, called **cathode rays,** as they were originated from the cathode. Cathode rays were consisted of negatively charged particles, called as **electrons**.

Properties of Electrons

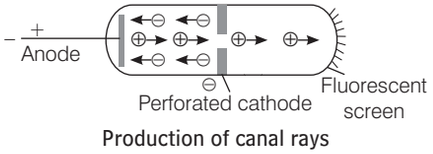
(i) Electrons are negatively charged particles and are denoted by 'e^-'.

(ii) The charge present on an electron is equal to -1.6×10^{-19} coulomb. Since, this charge is considered to be the smallest, therefore, charge on e^- is taken as -1.

(iii) The mass of an electron is equal to 9.1×10^{-31} kg.

2. Discovery of Protons

Before the identification of electron, **E. Goldstein** in 1886, discovered the presence of new radiations known as **canal rays** or **anode rays**. These are the positively charged rays which are seen moving from the anode towards cathode in a specially designed discharge tube (with a porous cathode), when a high voltage is applied across the electrodes. Porous cathode is used to provide the path for passing anode rays. It led to the discovery of another sub-atomic particle, the **proton**.



Production of canal rays

Properties of Protons

(i) Protons are positively charged particles and are denoted as 'p^+'.

(ii) The charge present on proton is equal to $+1.6 \times 10^{-19}$ coulomb and it is considered as $+1$.

(iii) The mass of a proton is equal to 1.6×10^{-27} kg.

(iv) The mass of proton is approximately 2000 times as that of the electron.

3. Discovery of Neutrons (n)

These are another subatomic particles, discovered by **J Chadwick** in 1932. It is represented by n.

He bombarded beryllium (Be) or boron (B) sheet with high speed alpha particles and noticed the emission of neutral particles.

$$_4Be^9 + {}_2He^4 \longrightarrow {}_6C^{12} + \underset{\text{Neutron}}{{}_0n^1}$$

Properties of Neutrons

(i) Neutrons are electrically neutral particles and are as heavy as protons (*i.e.*, their mass is 1.67493×10^{-27} kg).

(ii) Neutrons are present in the nucleus of all atoms except hydrogen.

Properties of the Electron, Proton and Neutron

Properties	Proton (p)	Neutron (n)	Electron (e^-)
Mass	1.67262×10^{-27} kg	1.67495×10^{-27} kg	9.1094×10^{-31} kg
Charge	1.6022×10^{-19} C	0	1.6022×10^{-19} C
Mass relative to the electron	1836	1839	1
Spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Charge relative to the proton	+1	0	–1
Discovery	E. Goldstein	J. Chadwick	J.J. Thomson

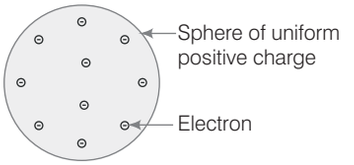
Structure of an Atom

According to **Dalton's atomic theory**, atom was indivisible and indestructible. Now, the discovery of two fundamental particles (electrons and protons) inside the atom, led to the failure of this aspect of Dalton's theory. To know the arrangement of electrons and protons within an atom, many scientists proposed various atomic models.

These are as follow

Thomson's Model of an Atom

J.J. Thomson was the first scientist to propose a model for the structure of an atom. The electrons in a sphere of positive charge, were like currants (dry fruits) in a spherical Christmas pudding. It can also be compared to a watermelon, in which, the positive charge of an atom is spread all over like the red edible part, while the electrons studded in the positively charged sphere, like the seeds in watermelon.



Thomson's model of an atom

Following are the postulates of this model

(i) Electrons are embedded in a sphere of positive charge.

(ii) The negative and positive charges are equal in magnitude. Therefore, the atom as a whole is electrically neutral.

(iii) The mass of an atom is assumed to be uniformly distributed throughout the atom.

Limitations of Thomson's Model of an Atom

Limitations of J.J. Thomson's model of an atom are

(i) J.J. Thomson's model could not explain the experimental results of other scientists such as Rutherford, as there is no nucleus in the atomic model proposed by Thomson.

(ii) It could not explain the stability of an atom *i.e.*, how positive and negative charges could remain, so close together.

Rutherford's Model of an Atom

Ernest Rutherford, with the help of Geiger and Marsden designed an experiment to know how the electrons are arranged within an atom. He bombarded thin sheets of gold foil with fast moving α-particles (these are doubly charged helium ions having a mass of 4u). He selected a gold foil because he wanted a layer as thin as possible (most malleable). This gold foil was about 1000 atoms thick.

The following observations were made by Rutherford

(i) Most of the fast moving α-particles passed straight through the gold foil.

(ii) Some of the α-particles were deflected by the foil by small angles.

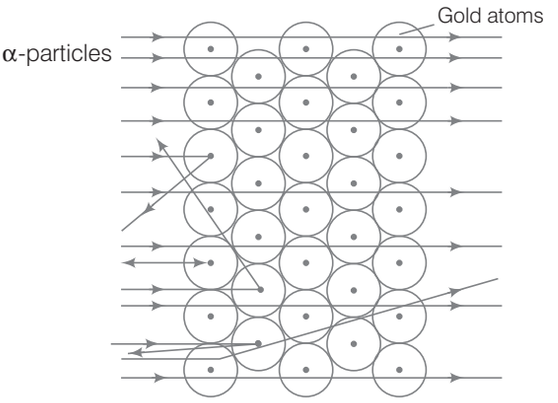
(iii) Very few α-particles (one out of 12000) appeared to rebound.

On the basis of his experiment, Rutherford concluded that

(i) Most of the space inside the atom is empty because most of the α-particles passed through the gold foil without getting deflected.

(ii) Very few particles were deflected from their path, indicating that the positive charge of the atom occupies very little space.

(iii) A very small fraction of α-particles were deflected by 180° (*i.e.*, they rebound), indicating that all the positive charge and mass of atom were concentrated in a very small volume within the atom.



Scattering of α-particles by a gold foil

On the basis of his experiment, Rutherford put forward the nuclear model of an atom, having the following features

(i) There is a positively charged, highly densed centre in an atom, called **nucleus**. Nearly, the whole mass of the atom resides in the nucleus.

(ii) The electrons revolve around the nucleus in circular path.

(iii) The size of the nucleus (10^{-15} m) is very small as compared to the size of the atom (10^{-10} m).

Note Rutherford suggested that his model of atom was similar to that of our solar system. In the solar system, the different planets are revolving around the Sun. In the same manner, in an atom the electrons are revolving around the nucleus. So, these electrons are also called **planetary electrons**.

Limitations of Rutherford's Model of an Atom

Limitations of Rutherford's model of an atom are

(i) Any charged particle when accelerated is expected to radiate energy. To remain in a circular orbit, the electron would need to undergo acceleration. Therefore, it would radiate energy.

Thus, the revolving electron would lose energy and finally fall into the nucleus. If this were so, the atom should be highly unstable. Therefore, matter would not exist, but we know matter exists. It means that atoms are quite stable.

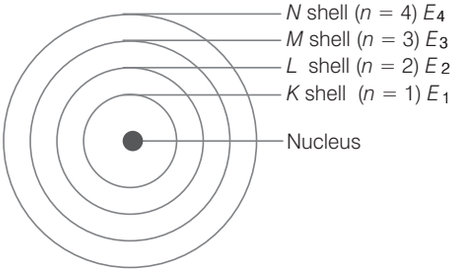
Thus, it could not explain the stability of an atom when charged electrons are moving under the attractive force of positively charged nucleus.

(ii) Rutherford's model could not explain the distribution of electrons in the extra nuclear portion of the atom.

Bohr's Model of an Atom

To overcome the objections raised against Rutherford's model of the atom, *Neils Bohr put forward the following postulates about the model of an atom*

(i) Atom consists of positively charged nucleus around which electrons revolve in **discrete orbits** *i.e.*, electrons revolve in certain permissible orbits and not just in any orbit.



A few energy levels in an atom

(ii) Each of these orbits are associated with certain value of energy. Hence, these orbits are called **energy shells** or **energy levels**. As the energy of an orbit is fixed (stationary), orbit is also called **stationary state**.

(iii) Starting from nucleus, energy levels (orbits) are represented by numbers (1, 2, 3, 4, etc.) or by alphabets (*K*, *L*, *M*, *N*, etc.).

(iv) Normally, the electrons present in first energy level (E_1) have lowest energy. Energies increase on moving towards outer energy levels.

(v) Energy of an electron remains same as long as it remains in discrete orbit and it does not radiate energy while revolving.

(vi) When energy is supplied to an electron, it can go to higher energy levels. While an electron falls to lower energy level, when it radiates energy.

CHECK POINT 01

1. Name all the fundamental particles of atom.
2. Write the name of discoveror of electrons, protons and neutrons.
3. What conclusion would be drawn by Rutherford when he observed that most of the fast moving α-particles passed straight through the gold foil?
4. Nucleus of an atom is positively charged and electrons around it are negatively charged, then why do electrons not just fall to the nucleus out of attraction?
5. What do you understand by the term 'discrete orbit'?
6. Draw a sketch of Bohr's model of an atom with four shells.

Atomic Number

It is defined as the number of protons present in the nucleus of an atom. It is also equal to the number of electrons in the neutral atom. It is denoted by Z and written as a subscript towards the left of the symbol.

Atomic number = Number of protons in the nucleus = Number of electrons

e.g., $^{4}_{2}He$, $^{7}_{3}Li$; Z = 2 and 3 for He and Li respectively.

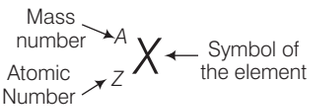
Mass Number

It is defined as the sum of number of protons and neutrons present in the nucleus of an atom. Protons and neutrons together called as nucleons. Mass number is denoted by 'A'.

Mass number (*A*) = Number of protons + Number of neutrons.

Number of neutrons = Mass number − Atomic number

Mass number is written as a superscript towards the left of the symbol. In the notation for an atom, the atomic number, mass number and symbol of the element are to be written as



e.g., For nitrogen, the notation is $^{14}_{7}N$,

i.e., its atomic number is 7 and mass number is 14.

Note

- If number of electrons < number of protons, the atom carries positive charge and called **cation**.
- If number of electrons > number of protons, the atom carries negative charge and called **anion**.
- If number of electrons is equal to number of protons, the atom carries no charge i.e., it is **neutral**.

Distribution of Electrons in Different Orbits (Shells)

The distribution of electrons into different orbits of an atom was suggested by **Bohr** and **Bury**. For writing the number of electrons in different energy levels or shells, some rules are followed.

These are

(i) The maximum number of electrons present in a shell is given by the formula $2n^2$, where n is the orbit number or energy level, 1, 2, 3, ...

Therefore, the maximum number of electrons in different shells are as follow

First orbit or *K*-shell $= 2 \times (1)^2 = 2$

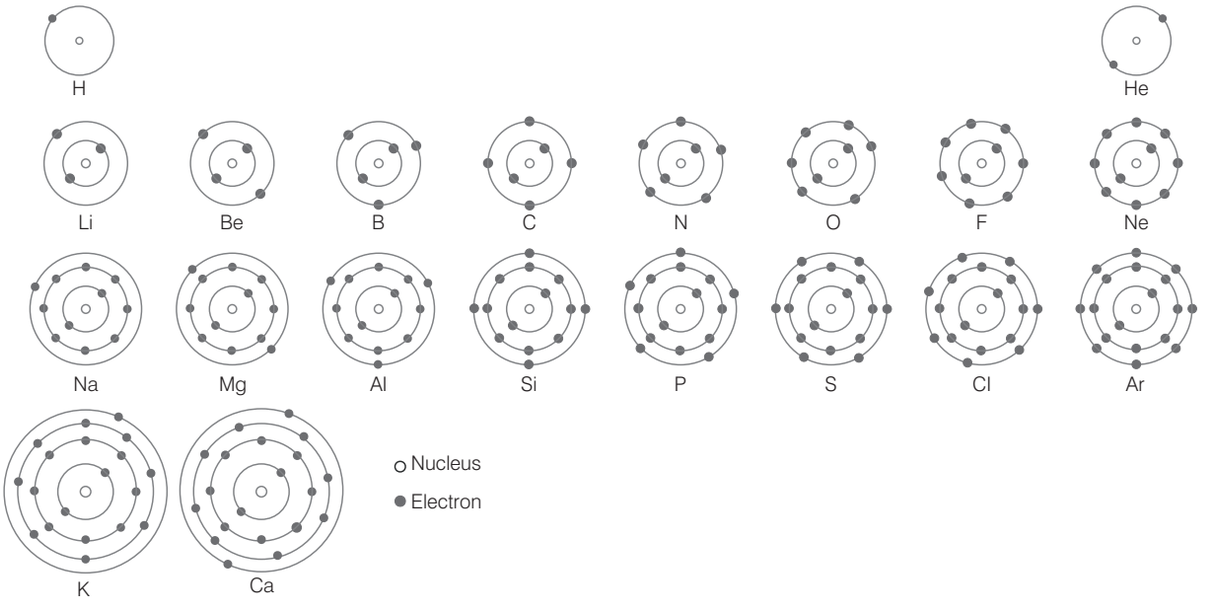
Second orbit or *L*-shell $= 2 \times (2)^2 = 8$

Third orbit or *M*-shell $= 2 \times (3)^2 = 18$

Fourth orbit or *N*-shell $= 2 \times (4)^2 = 32$ and so on.

(ii) The maximum number of electrons that can be accommodated in the outermost orbit is 8.
(iii) Electrons are not accommodated in a given shell, unless the inner shells are filled (*i.e.*, the shells are filled in a stepwise manner).

Representation of Atomic Structure (First Twenty Elements)



Atomic structures of elements with atomic numbers in the range Z = 1 (hydrogen) to Z = 20 (calcium).

Valency

The electrons present in the outermost shell of an atom are known as **valence electrons.** They govern the chemical properties of elements as they take part in chemical reactions. The elements with same number of electrons in the valence shell show similar properties and with different number of valence electrons show different chemical properties. The tendency to react with atoms of the same or different elements to form molecules is an attempt to attain fully-filled outermost shell. It means, atoms react with other atoms in order to attain fully-filled outermost shell. An outermost shell, which had eight electrons is called an **octet**. This is known as **octet rule.**

This can be achieved by sharing, gaining or the loss of electrons.

The number of electrons lost or gained or shared by an atom to become stable or to achieve an octet in the outermost shell is known as valency of that element.

In other words, valency is the combining capacity of the atom of an element with the atom(s) of other element(s) in order to complete its octet.

e.g., Hydrogen, lithium, sodium and potassium atoms contain one electron each in their outermost shell, therefore each one of them can lose one electron to become stable. Hence, their valency is 1.

Nitrogen and phosphorus each has 5 valence electrons and their valency is 3 because they can gain 3 electrons (instead of losing five electrons) to become stable.

All the inert elements *i.e.,* He, Ne, Ar, etc., have completely filled outermost shells. Therefore, their valency is zero.

Note For metals, valency = Number of valence electrons and for non-metals, valency = 8 – number of valence electrons.

Composition of Atoms of the First Twenty Elements with Electron Distribution in Various Shells

S. No.	Name of elements	Symbol	Atomic number	Number of protons	Number of neutrons	Number of electrons	Distribution of electrons				Valency
							K	*L*	*M*	*N*	
1.	Hydrogen	H	1	1	–	1	1	–	–	–	1
2.	Helium	He	2	2	2	2	2	–	–	–	0
3.	Lithium	Li	3	3	4	3	2	1	–	–	1
4.	Beryllium	Be	4	4	5	4	2	2	–	–	2
5.	Boron	B	5	5	6	5	2	3	–	–	3
6.	Carbon	C	6	6	6	6	2	4	–	–	4
7.	Nitrogen	N	7	7	7	7	2	5	–	–	3
8.	Oxygen	O	8	8	8	8	2	6	–	–	2
9.	Fluorine	F	9	9	10	9	2	7	–	–	1
10.	Neon	Ne	10	10	10	10	2	8	–	–	0
11.	Sodium	Na	11	11	12	11	2	8	1	–	1
12.	Magnesium	Mg	12	12	12	12	2	8	2	–	2
13.	Aluminium	Al	13	13	14	13	2	8	3	–	3
14.	Silicon	Si	14	14	14	14	2	8	4	–	4
15.	Phosphorus	P	15	15	16	15	2	8	5	–	3, 5
16.	Sulphur	S	16	16	16	16	2	8	6	–	2
17.	Chlorine	Cl	17	17	18	17	2	8	7	–	1
18.	Argon	Ar	18	18	22	18	2	8	8		0
19.	Potassium	K	19	19	20	19	2	8	8	1	1
20.	Calcium	Ca	20	20	20	20	2	8	8	2	2

Reason for Chemical Activity of an Atom

The chemical activity of an atom depends upon the number of electrons in the valence shell of its atom. Chemically active atoms have an incomplete octet *i.e.*, less than 8 electrons or less than 2 electrons in their valence shell. The valence electrons of atoms contribute to the formation of molecules.

Note All the six inert gases namely, helium (He), neon (Ne), agron (Ar), krypton (Kr), xenon (Xe) and radon (Rn) are non-reactive i.e., inert. They do not combine with other atoms to form molecules. So, their combining capacity is zero.

CHECK POINT 02

1. How can you denote the atomic number of any element?
2. What do you understand by mass number?
3. What can be the maximum number of electrons in the outermost orbit?
4. Find out the number of electrons present in last shell of an atom having atomic number 15.
5. In an atom first four shells (*K*, *L*, *M* and *N*) are completely filled, then what is the total number of electrons in that atom?
6. A non-metal has six electrons in its outermost shell. Predict its valency.

Different Atomic Species

Different atomic species are as given below

Isotopes

Isotopes are defined as the atoms of the same element, having the same atomic number (or number of protons) but different mass numbers (or number of neutrons).

In other words, it can be said that isotopes have same number of protons but differ in the number of neutrons. Each isotope of an element is a pure substance. They have same chemical properties but different physical properties and occupy same position in the periodic table.

Examples of Isotopes

(i) **Hydrogen** It has three isotopes all having atomic number equal to one but mass numbers as 1, 2 and 3.

Isotopes	Atomic number	Mass number	No. of electrons	No. of protons	No. of neutrons
Protium $^{1}_{1}H$	1	1	1	1	0
Deuterium $^{2}_{1}H$ or $^{2}_{1}D$	1	2.	1	1	1
Tritium $^{3}_{1}H$ or $^{3}_{1}T$	1	3	1	1	2

(ii) **Carbon** *It has three isotopes as listed below*

Isotopes	Atomic number	Mass number	No. of electrons	No. of protons	No. of neutrons
C-12 or $^{12}_{6}C$	6	12	6	6	6
C-13 or $^{13}_{6}C$	6	.13	6	6	7
C-14 or $^{14}_{6}C$	6	14	6	6	8

(iii) **Chlorine** It has many isotopes found in traces. *Two major isotopes of it are listed below*

Isotopes	Atomic number	Mass number	No. of electrons	No. of protons	No. of neutrons
Cl-35 or $^{35}_{17}Cl$	17	35	17	17	18
Cl-37 or $^{37}_{17}Cl$	17	37	17	17	20

Properties of Isotopes

(i) Isotopes have similar chemical properties.

(ii) They differ in physical properties that depend on the atomic mass such as density, boiling point, light scattering, etc.

Applications of Isotopes

(i) An isotope of uranium (U-235) is used as a fuel for the production of electricity in nuclear reactors.

(ii) U-238 is used to determine the age of very old rocks and even the age of the earth.

(iii) An isotope of cobalt (Co-60) is used in the treatment of cancer.

(iv) An isotope of carbon (C-14) is used to determine the age of old specimens of wood or old bones of living organisms.

(v) An isotope of iodine (I-131) is used in the treatment of goitre.

(vi) P-32 is used in agricultural research.

(vii) Na-24 is used to detect blood clots.

Isobars

Atoms of different elements with different atomic numbers but same mass number are known as **isobars.**

In other words, isobars are the atoms of different elements that have same number of nucleons (protons + neutrons) but differ in the number of protons.

e.g., $^{40}_{18}Ar$ and $^{40}_{20}Ca$ are **isobars.**

Since, isobars have different atomic number as well as different electronic configuration. Thus, they also have different chemical properties.

Isotones

Atoms of different elements having the same number of neutrons are called **isotones.** *e.g.*, $^{14}_{6}C$ and $^{16}_{8}O$ are isotones, as both have 8 neutrons [(14 – 6 = 8) and (16 – 8 = 8)].

Example 1. Consider the following pairs.

(i) $^{58}_{26}A$, $^{58}_{28}B$

(ii) $^{79}_{35}X$, $^{80}_{35}Y$

(a) Which of the above pairs are isotopes and isobars?

(b) What factors are responsible for the change in superscripts, 79, 80 (in case II), though the element is the same?

(c) Give the nuclear composition of $^{58}_{26}A$.

Sol. (a) **Isobars** $^{58}_{26}A$ and $^{58}_{28}B$ **Isotopes** $^{79}_{35}X$ and $^{80}_{35}Y$

(b) X and Y are pair of isotopes. Isotopes have same number of protons but differ in the number of neutrons (hence, their mass number differs, from each other because mass number is the sum of number of protons and neutrons).

(c) Number of protons = 26

Number of electrons = 26

Number of neutrons = 58 – 26 = 32

CHECK POINT 03

1 Identify the isotopic pair(s) out of the following species.
$_{8}C^{16}, _{6}C^{14}, _{7}N^{14}, _{8}O^{18}, _{7}N^{16}$

2 Which isotope of hydrogen contain same number of electrons, protons and neutrons?

3 How many isotopes of carbon found in nature?

4 Name the isotope used as a fuel in nuclear reactors.

5 Give an example of isotone.

Chemical Bonding

A chemical bond is a kind of attraction which holds two or more constituents (atoms, molecules or ions) together. The process of their combination is called **chemical bonding**.

Types of Chemical Bond

There are mainly three types of chemical bond which are as follows

(i) Electrovalent bond or ionic bond
(ii) Covalent bond or molecular bond
(iii) Coordinate bond or dative bond

Electrovalent Bond or Ionic Bond

The bond formed as a result of electrostatic force of attraction which holds the array of oppositely charged ions *i.e.*, positive and negative ions together is termed as the **electrovalent** or **ionic bond**. The compounds in which ionic bond is present are called **electrovalent or ionic compounds.** It is formed by the complete transfer of electrons from one atom to another, such, that all the combining atoms complete their octet (or duplet in case of H, Li, etc.). This type of bond is formed between an electropositive (metal) element and an electronegative (non-metal) element.

Important Terms to Understand the Formation of Electrovalent Bonds

(i) **Electrovalency** The number of electrons donated or accepted by the valence shell of an atom of an element, to achieve the stable electronic configuration is called electrovalency.

(ii) **Electropositive Elements** Atoms are electrically neutral, they possess equal number of protons and electrons. On losing an electron, an atom becomes positively charged because number of protons exceeds the number of electrons (cation is formed).

e.g., Na^+, K^+, Ca^{2+}, Mg^{2+}, Al^{3+}, etc.

$$Na \longrightarrow \underset{\text{(Cation)}}{Na^+} + e^-$$

(iii) **Electronegative Elements** When an atom gains an electron, the number of electrons exceed the number of protons and thus, atom becomes negatively charged (anion is formed).

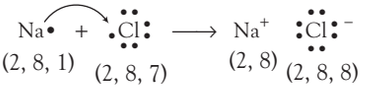
e.g., Cl^-, Br^-, I^-, F^-, O^{2-}, S^{2-}, N^{3-}, etc.

$$Cl + e^- \longrightarrow \underset{\text{(Anion)}}{Cl^-}$$

Note Group 1 elements are most electropositive. The metallic nature increases down the group (Cs is the most electropositive element). In same way, group 17 elements are most electronegative and electronegativity decreases down the group (F is the most electronegative element). Therefore, CsF is ionic in nature.

Formation of Electrovalent Bonds

Electrovalent bond is formed only when one of an atom can easily lose electron(s) while other can gain easily to acquire the stable electronic configuration (or arrangement) of nearest noble gas. *e.g.*, Formation of sodium chloride.



Structure of Some Electrovalent Compounds

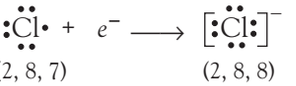
The structure of some electrovalent compounds are as follows

A. Sodium Chloride (NaCl)

The electronic configuration of sodium (atomic number is 11) is 2, 8, 1. It loses one electron from its outermost shell and acquires the inert gas configuration of nearest noble gas (*i.e.*, neon), thus cation is formed.

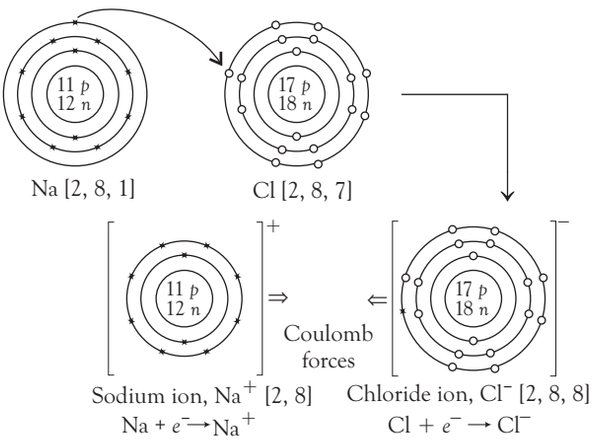
$$\underset{(2,8,1)}{Na} \longrightarrow \underset{(2,8)}{Na^+} + e^-$$

The electronic configuration of chlorine (atomic number is 17) is 2, 8, 7. It can accept one electron (which was released by sodium) and, thus anion is formed.



The above two oppositely charged ions (*i.e.*, chloride and sodium ions) approach each other.They are held together by the strong electrostatic force of attraction. In this way, formation of sodium chloride takes place.

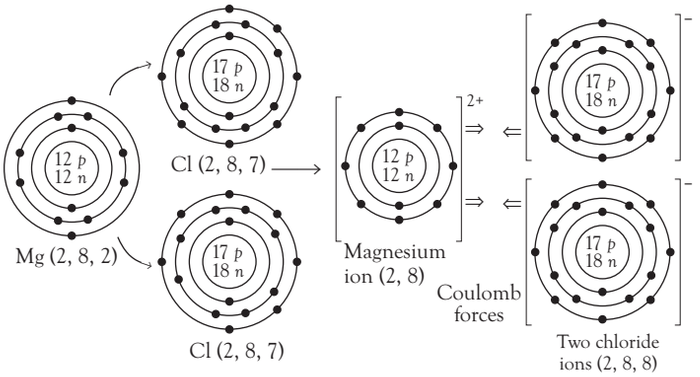
Orbit Structure of NaCl



B. Magnesium Chloride ($MgCl_2$)

The number of valence electrons in magnesium atom (atomic number is 12) and chlorine atom (atomic number is 17) are 2 and 7, respectively. Therefore, magnesium atom loses its two electrons, acquire a stable noble gas configuration (2, 8) and attains +2 charge (cation). Each chlorine atoms containing seven electrons in its valence shell can accept one-one electron of the two electrons that are donated by the magnesium atom. Therefore, two chloride ions will combine with one magnesium ion (Mg^{2+}) to form magnesium chloride molecule ($MgCl_2$).

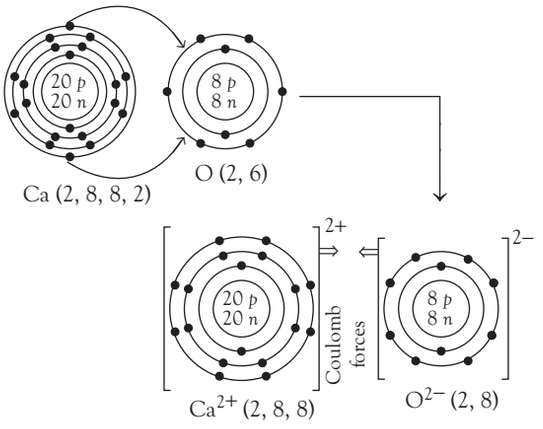
Orbit Structure of $MgCl_2$



C. Calcium Oxide (CaO)

Calcium (atomic number is 20, electronic configuration = 2, 8, 8, 2) loses two electrons and attains +2 charge by forming calcium ion and acquires stable noble gas electronic configuration (*i.e.*, argon). On the other hand, oxygen (atomic number is 8, electronic configuration = 2, 6) gain two electrons to forms oxide ion and acquires stable configuration of nearest noble gas (*i.e.*, neon).

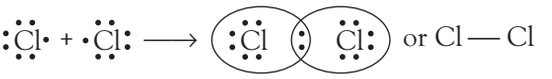
Orbit Structure of CaO



Covalent Bond or Molecular Bond

A chemical bond formed by the mutual sharing of electrons between the combining atoms of the same or different elements is called the **covalent bond.** This bond is generally formed between two electronegative *i.e.*, non-metallic elements.

The number of electrons shared by an atom in order to complete its octet is called the **covalency** of that atom *e.g.*, Formation of chlorine molecule.



Covalent bond between two Cl-atoms

Note Number of covalent bonds formed depend upon the number of shared pair of electrons between the two atoms.

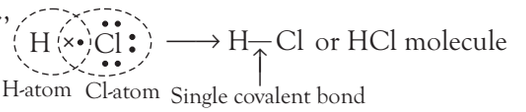
Types of Covalent Bonds

Covalent bonds are broadly classified into following types

(A) On the Basis of Sharing of Electrons

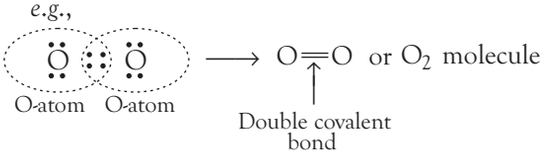
(i) **Single Covalent Bond** It is formed by the sharing of one pair of electrons between two atoms. It is represented by a single line (—).

e.g.,

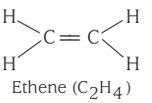


(ii) **Double Covalent Bond** It is formed by the sharing of two pair of electrons between two atoms. It is represented by a double line (═).

e.g.,



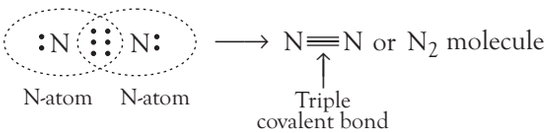
Note Some molecules like C_2H_4 (ethene) have the combination of one double covalent bond and four single covalent bonds.



Ethene (C_2H_4)

(iii) **Triple Covalent Bond** It is formed by the sharing of three pair of electrons between two atoms. It is represented by a triple line (≡).

e.g.,



Note Some molecules like C_2H_2 (ethyne) have the combination of one triple and two single covalent bonds.

Ethyne (C_2H_2)

(B) On the Basis of Polarity

(i) **Polar Covalent Bond** A polar covalent bond is formed when the combining elements have significant difference in their electronegativity. They are generally gases, liquids or soft solids.

These compounds have high melting and boiling point. These compound have free ions therefore, these are soluble in polar solvents. *e.g.,* Water (H_2O) and ammonia (NH_3).

(ii) **Non-polar Covalent Bond** A covalent bond is formed when the combining elements have no or very slight difference in their electronegativity. They are generally gases, liquids or solids. These compounds have low melting and boiling points.

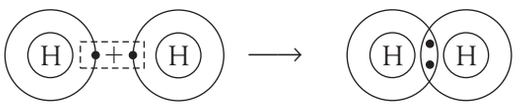
These compounds do not ionise in water due to lack of charge separation. *e.g.,* Hydrogen (H_2), chlorine (Cl_2), nitrogen (N_2), etc. All hydrocarbons are non-polar covalent compounds because their electronegativity difference is little and pair of electrons are equally shared by the linked atoms.

Atomic Orbital Structure of Some Covalent Compounds

The structures of some covalent compounds are as follows

A. Hydrogen Molecule (H_2) (Non-polar Covalent Compound)

A hydrogen atom has one electron in its outermost shell. It needs one more electron to complete its duplet. Thus, hydrogen atom shares its electron with another hydrogen atom to form H_2 molecule.

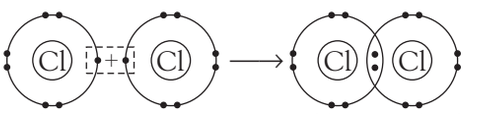


H—H or H_2 molecule

B. Chlorine Molecule (Cl_2) (Non-polar Covalent Compound)

Electronic configuration of Cl-atom is 2, 8, 7. So, it needs one electron to complete its octet. Hence, it shares one electron with another Cl-atom to form Cl_2 molecule.

e.g.,



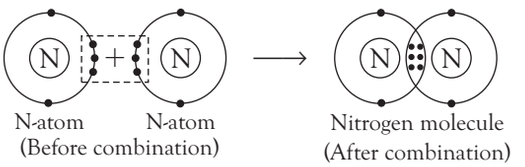
Cl—Cl or Cl_2 molecule

Single covalent bond

C. Nitrogen Molecule (N_2) (Non-polar Covalent Compound)

Electronic configuration of N is 2, 5. To complete its octet, nitrogen needs three electrons. Hence, two N-atoms share three pair of electrons to form N_2 molecule.

e.g.,



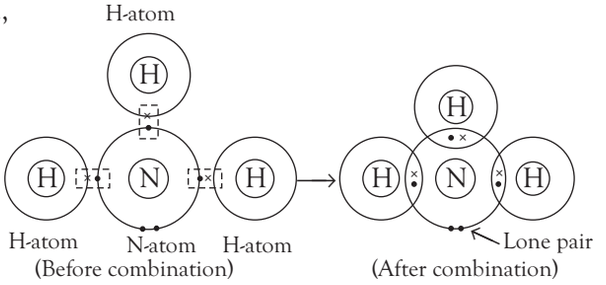
N≡N or N_2 molecule

Triple covalent bond

D. Ammonia Molecule (NH_3) (Polar Compound)

Electronic configuration of N is 2, 5 and H is 1. Nitrogen needs three electrons to complete its octet while hydrogen needs one electron to complete its duplet. Number of covalent bonds in NH_3 = 3

e.g.,



H—N—H or NH_3 molecule

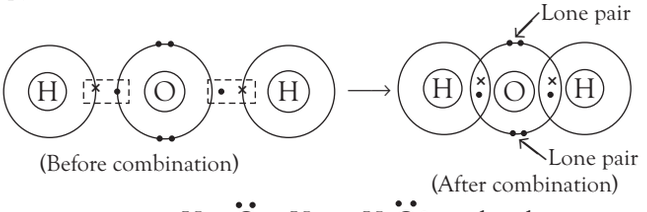
3 single covalent bonds

E. Water Molecule (H_2O) (Polar Compound)

Electronic configuration of H is 1 and O is 2, 6.

Hydrogen needs one electron to complete its duplet while oxygen needs two electrons to complete its octet. Hence, one O-atom shares its two electrons with two H-atoms,

e.g.,



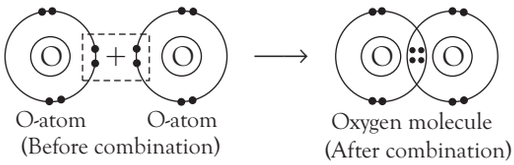
H—O—H or H_2O molecule

Two single covalent bonds

F. Oxygen Molecule (O_2) (Non-Polar Covalent Compound)

Electronic configuration of O is 2,6. To complete its octet, oxygen needs two electrons. Hence, two O-atoms share two pair of electrons to form O_2 molecule.

e.g.,



$O=O$ or O_2 molecule

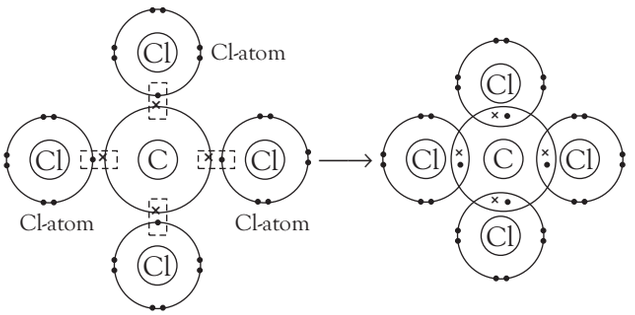
Double covalent bond

G. Carbon Tetrachloride Molecule (CCl_4) (Non-polar Compound)

Electronic configuration of C = 2, 4 and Cl = 2, 8, 7.

Carbon needs 4 electrons while Cl requires one more electron to attain the stable electronic configuration of nearest noble gas by completing their octet.

e.g.,



Cl
|
Cl—C—Cl or CCl_4 molecule
|
Cl

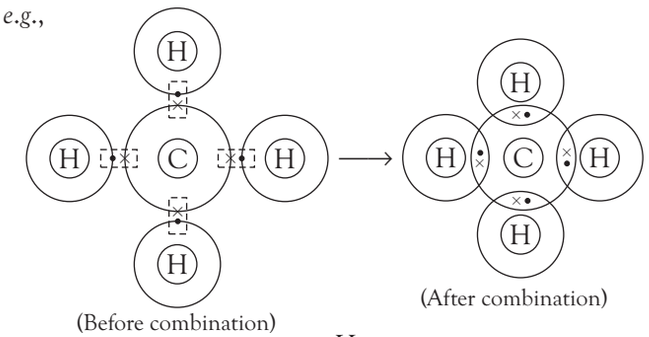
4 single covalent bond

H. Methane (CH_4) (Non-polar Compound)

Carbon atom has four electrons in its valence shell.

In order to complete octet, it shares four electrons, one each with four hydrogen atoms.

e.g.,



H
|
H—C—H or Ch_4 molecule
|
H

4 single covalent bond

Note In covalent bond formation, only valence electrons participate in bond formation.

CHECK POINT 04

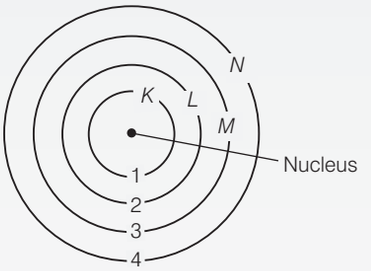
1. Give one example of electropositive and electronegative elements.
2. Write the electronic configuration of the ions of the electrovalent products of the following reaction.

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

3. Name the type of covalent bonds formed on the basis of sharing of electrons.
4. Name a non-polar covalent compound containing two pair of electrons.
5. How many covalent bonds are formed during the formation of water molecule?

SUMMARY

- An atom is the smallest particle, which exhibit the characteristic properties of respective element. There are three sub-atomic particles present in an atom i.e., electrons, protons and neutrons.
- Discovery of Electrons In 1990, J.J. Thomson discovered cathode rays (or electrons) originating or emitting from the cathode in a gas discharge tube. Electrons are the fundamental particles of all atoms.
- Cathode rays travel in a straight line. In the presence of electric field, these get deflected towards the positive electrode. They produce fluorescence when strike on the walls of discharge tube.
- Charge and mass of electron are 1.6×10^{-19} C and 9.11×10^{-31} kg, respectively.
- Discovery of Protons In 1886, E. Goldstein discovered the presence of new radiations known as canal rays or anode rays passing through holes or 'canals' of cathode and moving towards cathode in a discharge tube.
- Anode rays consist of positively charged particles, known as protons.
- Protons have a charge equal in magnitude but opposite in sign to that of electron. Its mass is about 1840 times to that of the electron.
- Discovery of Neutrons In 1932, J. Chadwick discovered another sub-atomic particle called neutrons. They are electrically neutral and are as heavy as protons. They are present in the nucleus of all atoms, except hydrogen.
- Thomson's Model of an Atom The mass of an atom is assumed to be uniformly distributed throughout atom. An atom is considered to be a sphere of uniformly distributed positive charge in which electrons are embedded. The negative and positive charge balance each other, therefore atom as a whole is neutral.
- Rutherford's Model of an Atom After performing α-particle experiment, he suggested that: There is a positively charged, highly densed centre in an atom, called the nucleus. Nearly the whole mass of atom resides in it. The electrons revolve around the nucleus in well defined orbits.
- Bohr's Model of an Atom Only certain special orbits called discrete orbits or energy levels of electrons are allowed inside the atom. While revolving in discrete orbits, the electrons do not radiate energy. The orbits are represented by letters K, L, M, N or the numbers 1, 2, 3, 4.



Bohr's model

- Atomic Number It is defined as the number of protons present in a nucleus of an atom. It is also equal to the number of electrons in case of neutral atom. It is denoted by Z and written as subscript e.g., ${}_6C$.
- Mass Number It is defined as the number of protons and neutrons in the nucleus. It is denoted by A and written as superscript e.g., ${}^{14}N$.
- Bohr and Bury Scheme for Distribution of Electrons in Different Energy Levels The maximum number of electrons in an energy level is equal to $2n^2$, where n is the energy level or orbits or shells.
- Valency It is the combining capacity of an element with the atom(s) of other element(s) in order to complete its octet.
- Chemical Activity of an Atom It depends upon the number of electrons in the valence shell of its atom. Chemically active atoms have an incomplete octet.
- Isotopes They have same atomic number but different mass number or same number of protons but different number of neutrons. e.g., ${}_1H^1$, ${}_1H^2$, ${}_1H^3$. Their chemical properties are same due to same atomic number.
- Electrovalent bond is formed between an electropositive (metal) element and an electronegative (non-metal) element.
- Covalent bond is generally formed between two electronegative i.e., non-metallic elements.

EXAM PRACTICE

Fill in the Blanks

1. The size of an atom is decided by the number of …… .

Sol. electrons

2. Neutron has mass roughly equal to …… .

Sol. proton

3. Almost all the mass of an atom is concentrated in a small region, called …… .

Sol. nucleus

4. Rutherford's α-particle scattering experiment was responsible for the discovery of …… .

Sol. nucleus

5. According to Bohr's model, an atom has discrete …… levels.

Sol. energy

6. …… is an element with atomic number three.

Sol. Lithium

7. Mass number is the sum of number of …… and …... .

Sol. proton, neutron

8. First energy level can have maximum …… electrons.

Sol. 2

9. Electronic configuration of neon atom is …… .

Sol. 2, 8

10. Maximum number of electrons occupied by *L*-shell is …… .

Sol. eight

11. An element having atomic number 13 has valency equal to …… .

Sol. three

12. Isotopes has same …… numbers but has different …… numbers.

Sol. atomic, mass

13. Isotope of …… is used to determine the age of old specimens of wood.

Sol. carbon

14. In covalent compounds, the bond is formed due to the …… of electrons.

Sol. sharing

Multiple Choice Questions

15. A pure substance, constituted of only one type of atom is called an

(a) atom (b) element
(c) compound (d) None of these

Sol. (a)

16. Name of the smallest particle which can take part in a chemical reaction independently is

(a) atom (b) proton (c) neutron (d) electron

Sol. (a)

17. The constituent particle of an element having properties similar to those of element is

(a) electron (b) proton (c) atom (d) molecule

Sol. (c)

18. Cathode rays are composed of

(a) proton (b) neutron (c) electron (d) nucleus

Sol. (c)

19. J.J. Thomson, in his atomic model, assigned positive charge to

(a) electron (b) proton
(c) neutron (d) atomic sphere

Sol. (d)

20. In christmas pudding model, the currants were compared with

(a) electrons (b) protons (c) neutrons (d) atoms

Sol. (a)

21. Who discovered that positive charge in an atom is concentrated at nucleus?

(a) Thomson (b) Rutherford
(c) Goldstein (d) Chadwick

Sol. (b)

22. Which scientist proposed that electrons revolve in distinct energy level, around nucleus?

(a) Rutherford (b) Bohr
(c) Chadwick (d) Thomson

Sol. (b)

23. Number of valence electrons in Cl^- ion are
(a) 16 (b) 8 (c) 17 (d) 18
Sol. (b)

24. Which one of the following is a correct electronic configuration of sodium?
(a) 2, 8 (b) 8, 2, 1 (c) 2, 1, 8 (d) 2, 8, 1
Sol. (d)

25. How many energy levels are present in sodium atom?
(a) 1 (b) 2 (c) 3 (d) 4
Sol. (c)

26. The valency of fluorine atom is
(a) 1 (b) 2 (c) 3 (d) 0
Sol. (a)

27. Isotopes of an element have
(a) the same physical properties
(b) different chemical properties
(c) different number of neutrons
(d) different atomic numbers
Sol. (c)

28. Which of the following is not an isotope of hydrogen?
(a) ^1_1H (b) ^2_1H (c) ^3_1H (d) ^4_1H
Sol. (d)

29. The bond formed between nitrogen atoms in a molecule is
(a) single covalent bond (b) double covalent bond
(c) ionic bond (d) triple covalent bond
Sol. (d)

Match the Following

30. Match the following columns.

	Column I (Experiments)		**Column II** (Conducted by)
(i)	Cathode rays experiment	(a)	Mulliken
(ii)	Gold foil experiment	(b)	Goldstein
(iii)	Anode rays experiment	(c)	Thomson
		(d)	Rutherford
		(e)	Neils Bohr

Sol. (i) → (c), (ii) → (d), (iii) → (b)

31. Match the following columns.

	Column I (Discoverer or scientist)		**Column II** (Related discovery or theory)
(i)	John Dalton	(a)	Nucleus
(ii)	E Goldstein	(b)	Electron
(iii)	J Chadwick	(c)	Proton
(iv)	J.J. Thomson	(d)	Neutron
		(e)	Indivisiblity of atom

Sol. (i) → (e), (ii) → (c), (iii) → (d), (iv) → (b)

32. Match the following columns.

	Column I (Element)		**Column II** (Valency)
(i)	Oxygen	(a)	1
(ii)	Potassium	(b)	2
(iii)	Nitrogen	(c)	3
(iv)	Silicon	(d)	4

Sol. (i) → (b), (ii) → (a), (iii) → (c), (iv) → (d)

a 1 Mark Questions

33. Atomic models have been improved over the years. Arrange the following atomic models in the order of their chronological order. Rutherford's atomic model, Thomson's atomic model, Bohr's atomic model.
Sol. (i) Thomson's atomic model
(ii) Rutherford's atomic model
(iii) Bohr's atomic model

34. Why did Rutherford select a gold foil in his α-ray scattering experiment?
Sol. Because gold is the most malleable metal. A very thin foil (≈1000 atoms thick) can be made from gold, so that the observations are very clear.

35. If Mg^{2+} has 12 protons and 12 neutrons, what is its atomic number and mass number?
Sol. Atomic number = Number of protons = 12
Mass number = Number of protons + Number of neutrons
= 12 + 12 = 24

36. Which subatomic particles of an atom are responsible for mass number?
Sol. Protons and neutrons

37. Calculate the number of neutrons present in the nucleus of an element X, which is represented as ${}^{31}_{15}X$.

Sol. Mass number of $X = 31$

Atomic number of $X = 15$

Number of neutrons = Mass number − Atomic number

$= 31 - 15 = 16$

38. Define the term electrovalent bond.

Sol. Electrovalent or ionic bond is the bond formed as a result of electrostatic force of attraction which holds the array of oppositely charged ions *i.e.*, positive and negative ions together.

b 2 Marks Questions

39. When α-particles are bombarded on a gold sheet, only few of them got deflected, whereas mostly go straight and undeflected? Give reason.

Sol. This occurs because volume of nucleus is very small as compared to the atom *i.e.*, most of the part of atom is empty. Therefore, mostly α-particles go undeflected. *[2]*

40. For the symbols He^4 and He^5 tabulate the two subatomic particles, present in the nucleus of each of them.

Sol.

Elements	Electrons	Protons	Neutrons
${}_2He^4$	2	2	2
${}_2He^5$	2	2	3

Only neutrons and protons are present in the nucleus. *[2]*

41. In the atom of an element X, 6 electrons are present in the outermost shell. If it acquires noble gas configuration by accepting requisite number of electrons, then what would be the charge on the ion so formed?

Sol. In order to complete its octet, element X require 2 electrons. So, the charge on the anion (X^{2-}) formed is −2. *[2]*

42. Which of the two would be chemically more reactive: element 'A' with atomic number 18 or element 'D' with atomic number 16 and why?

Sol. Electronic configuration of ${}_{18}A = 2, 8, 8$

It would be chemically inert due to its complete octet.

Electronic configuration of ${}_{16}D = 2, 8, 6$

To complete its octet, it will gain 2 electrons, therefore it will be more reactive. *[2]*

43. Elements from A to F have the distribution of electrons, protons and neutrons in the following way.

Atom/Ion	Number of electrons	Number of protons	Number of neutrons
A	4	3	4
B	10	11	12
C	17	17	18
D	17	17	20
E	18	18	22
F	19	19	21

From the table, find

(i) a pair of ions

(ii) a pair of isobars

(iii) a pair of isotopes

Sol. (i) A and B, because number of electrons and protons are different for these elements. *[1]*

(ii) E and F, because these have same mass number (number of protons + number of neutrons) but different atomic number. *[1/2]*

(iii) C and D, because these have same atomic number (number of protons) but different mass number. *[1/2]*

44. Answer the following questions.

(i) The electronic configuration of an element is $2(K), 8(L), 2(M)$. Predict its valency.

(ii) Name of the element.

(iii) Determine the number of protons and neutrons in the element.

Sol. (i) M-shell has 2 electrons therefore, its valency is 2. *[1/2]*

(ii) The element has atomic number $= 2 + 8 + 2 = 12$

$\therefore$ The element is magnesium. *[1/2]*

(iii) Number of protons = Number of electrons = 12

Number of neutrons = $A - Z = 24 - 12 = 12$

(as mass number of magnesium is 24) *[1]*

45. In the following table, the mass number and the atomic number of certain elements are given below.

Elements	A	B	C	D	E
Mass number	1	7	14	40	40
Atomic number	1	3	7	18	20

(i) Select a pair of isobars from the above table.

(ii) What would be the valency of element B listed in the above table?

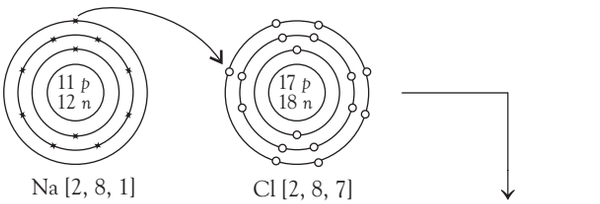
Sol. (i) D and E *[1]*

(ii) Electronic configuration of the element B is 2, 1. Therefore, its valency is 1. *[1]*

c 3 Marks Questions

46. Draw the appropriate orbit structure of sodium chloride and state the type of bond present in it.

Sol.



$Na + e^- \rightarrow Na^+$ $\quad Cl + e^- \rightarrow Cl^-$ ***[2]***

The above two oppositely charged ions are held together by electrovalent bond or ionic bond. ***[1]***

47. Answer the following questions.

(i) What was Thomson's model of an atom?

(ii) Write any two observations of Rutherford's model of an atom.

(iii) Draw the sketch of Bohr's model of an atom with three shells.

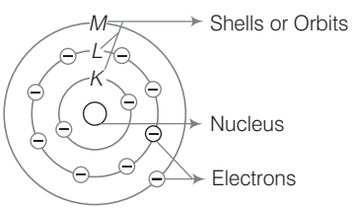
Sol. (i) Thomson's model of an atom was compared to Christmas pudding. The electrons in a sphere of positive charge were like currants (dry fruits) in a spherical Christmas pudding. ***[1]***

(ii) *Observations of Rutherford's model are*

(a) Most of the fast moving α-particles passed straight through the gold foil.

(b) Some of the α-particles were deflected by the foil by small angles. ***[1]***

(iii)



[1]

Bohr's model for sodium atom (Na) [$_{11}Na = 2, 8, 1$]

48. Answer the following questions.

(i) What is the number of electrons in Cl^- ion? (Cl = 17)

(ii) What is the electronic configuration of sodium? (Na = 11)

(iii) Which isotope of uranium is used in nuclear fuel?

Sol. (i) Cl^- ion 17 + 1 (gained) = 18 electrons (because negative charge shows gain of electrons.) ***[1]***

(ii) Atomic number of sodium = 11

K L M

Electronic configuration = 2, 8, 1 ***[1]***

(iii) Uranium-235 isotope. ***[1]***

d 4 Marks Questions

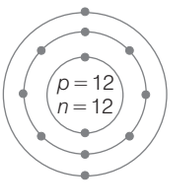
49. Answer the following questions.

(i) What is an octet? How do elements reach an octet?

(ii) Make a schematic atomic structure of magnesium and phosphorus.
(Given number of protons of magnesium = 12 and that of phosphorus = 15)

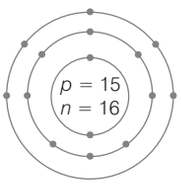
Sol. (i) An outermost shell, which has eight electrons is said to possess an octet. Elements reach their octet by sharing, gaining or losing electrons. ***[2]***

(ii) **Atomic structure of Mg**



$_{12}Mg = 2, 8, 2$ ***[1]***

Atomic structure of P



$_{15}P = 2, 8, 5$ ***[1]***

50. Write down the electronic configuration of first four elements in the periodic table mentioning their energy levels.

Sol. (i) Hydrogen, atomic number = 1
Outermost shell $\quad K$
Electronic configuration = 1 ***[1]***

(ii) Helium, atomic number = 2
Outermost shell $\quad K$
Electronic configuration = 2 ***[1]***

(iii) Lithium, atomic number = 3
Outermost shell K and L
Electronic configuration = 2, 1 *[1]*

(iv) Beryllium, atomic number = 4
Outermost shells K and L
Electronic configuration = 2, 2 *[1]*

e 5 Marks Questions

51. Answer the following questions.

(i) State the three observations made by Rutherford on his α-particle scattering experiment.

(ii) Write the electronic configuration of an element whose mass number is 31 and atomic number is 15. What is its valency?

Sol. (i) *The three observations made by Rutherford are*

(a) Most of the α-particles passed undeviated, which shows that 'most part of an atom is hollow'. *[1]*

(b) Some α-particles were scattered with large angular deviations which shows that 'the centre of an atom is positively charged'. *[1]*

(c) A few of these particles were reflected back, which shows that they had direct collision with the entire mass and the whole mass of the atom is concentrated in the nucleus. *[1]*

(ii) Electronic configuration of an element (15) = 2, 8, 5 *[1]*

Valency = 8 − 5 = 3 *[1]*

52. How are the electrons distributed in different orbits (Shells)?

Sol. *The electrons are distributed in different orbits in the following ways*

(i) The maximum number of electrons present in a shell is given by the formula $2n^2$, where n is the orbit number or energy level, 1, 2, 3..... .
Therefore, the maximum number of electrons in different shells are as follow

First orbit or K-shell $= 2 \times 1^2 = 2$

Second orbit or L-shell $= 2 \times 2^2 = 8$

Third orbit or M-shell $= 2 \times 3^2 = 18$

Fourth orbit or N-shell $= 2 \times 4^2 = 32$ and so on. *[2]*

(ii) The maximum number of electrons that can be accommodated in the outermost orbit is 8.

(iii) The penultimate shell (*i.e.,* the second last shell) cannot accommodate more than 18 electrons.

(iv) The anti-penultimate shell (*i.e.,* the third last shell) can have a maximum of 32 electrons.

(v) Electrons are not accommodated in a given shell, unless the inner shells are filled *i.e.,* the shells are filled in a stepwise manner. *[3]*

CHAPTER EXERCISE

Fill in the Blanks

1. Electrons revolve around the …… in well defined orbits.

2. The extranuclear part of the atom in which electrons are revolving, is known as …… .

3. In a neutral atom, the atomic number is equal to the number of …… .

4. Helium has …… valence electrons and has valency of …… .

5. Deuterium and tritium are …… of hydrogen.

6. …… bond is formed by the mutual sharing of electrons between the combining atoms of the same or different elements.

Multiple Choice Questions

7. Which of the following rays is deflected under electric field?

(a) X-rays (b) Cathode rays (c) γ-rays (d) UV-rays

8. Thomson's atomic model is also called

(a) Christmas pudding model
(b) Plum pudding model
(c) Both (a) and (b)
(d) None of the above

9. Distribution of electrons into different shells of an atom was suggested by

(a) J.J. Thomson (b) Rutherford
(c) Bohr and Bury (d) Neil Bohr

10. The formula used to represent the maximum number of electrons present in a shell

(a) $2n^2$ (b) n^2 (c) $2n$ (d) n

11. Which isotope of hydrogen is used in making heavy water?

(a) Protium (b) Deuterium
(c) Tritium (d) Both (b) and (c)

Match the Following

12. Match the following columns.

Column I (Properties of Chlorine)		Column II (Value)
(i) Atomic number	(a)	1
(ii) Total number of shells	(b)	3
(iii) Atomic mass (approx.)	(c)	7
(iv) Valency	(d)	17
(v) Number of valence electrons	(e)	35

1 Mark Questions

13. Name the scientist who performed cathode ray experiment using a discharge tube.

14. Name the scientist and experiment that led to the discovery of proton.

15. Define charge to mass (e/m) ratio.

16. When magnesium atom changes to its ion, what is the change in atomic number?

17. Name the particles, which determine the mass of an atom.

18. Uranium-235 has 92 protons in its atom. Give the number of neutrons.

19. What is the order of energy in energy shells?

20. Write electronic configuration of an inert gas having three shells.

2 Marks Questions

21. Comment about the combining capacity of ${}^{40}_{18}\text{Ar}$.

22. An ion M^{3-} contains 10 electrons and 7 neutrons. What is the atomic number and mass number of the element M? Name the element.

23. The atom of an element has 9 protons, 9 electrons and 10 neutrons.

(i) What is the atomic number of the element?
(ii) Predict the valency of the element.

24. Give any two applications of radioisotopes.

3 Marks Questions

25. Compare the properties of electrons, protons and neutrons.

26. The electronic configuration of elements is given. Name the elements.

(i) 2, 8, 5 (ii) 2, 8, 8, 2 (iii) 2, 8, 1

27. An atom X has 4 protons and 5 neutrons with electronic configuration 2, 2.
Give information about its

(i) atomic number (ii) mass number (iii) valency

28. Explain the formation of calcium oxide and magnesium chloride with the help of orbit diagram. (Atomic number : Ca = 20, O = 8, Mg = 12, Cl = 17)

4 Marks Question

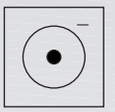
29. Write four characteristics properties of cathode rays.

5 Marks Question

30. Write the rules suggested by Bohr and Bury for the distribution of electrons in an atom giving suitable examples.

CHALLENGERS*

1 Consider the following information.



Mass = 1 amu

Ramana wants to neutralise it but the available particles with her are neutron, electron, proton and helium nuclei.

Which will be the best item to fulfill the Ramana's need?

(a) A neutron (b) A proton
(c) An electron (d) A helium nucleus

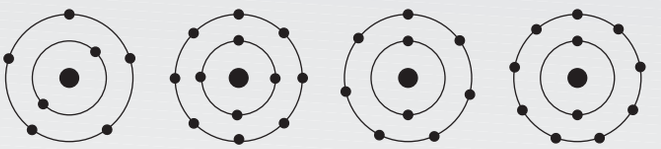
2 Which of the following will not show deflection from the path on passing through an electric field?

(a) Proton (b) Cathode rays (c) Electron (d) Neutron

3 Which of the following ion has the maximum shells containing electrons?

(a) S^{2-} (b) Be^{2+} (c) N^{3-} (d) Al^{3+}

4 Which of the following figures do not represent Bohr's model of an atom correctly?



I II III IV

(a) Both I and II (b) Both II and III (c) Both II and IV (d) Both I and IV

5 An element X is converted into its positive ion as $X \longrightarrow X^{3+}$. Mass number of the atom is 27 and the number of neutrons is 14. What is the number of electrons in the ion?

(a) 13 (b) 10 (c) 14 (d) 16

6 An element X has two isotopes, which may be represented as ^{238}X and ^{235}X.

How does ^{238}X differ from ^{235}X?

(a) It has 3 more protons and 3 more electrons
(b) It has 3 more protons, but same no. of electrons
(c) It has 3 more neutrons and 3 more electrons
(d) It has 3 more neutrons, but same no. of electrons

7 Among the following, the electrovalent linkage is present in

(a) CH_4 (b) NH_3 (c) H_2O (d) $MgCl_2$

8 The maximum number of covalent bonds by which the two atoms can be bonded to each other is

(a) four (b) two (c) three (d) None of these

9 Elements A, B and C have respectively 1,3 and 5 electrons in valence shell. Ionic compound is not formed from

(a) A and C (b) A and B (c) B and B (d) B and C

10 Multiple covalent bond exists in a molecule of

(a) N_2 (b) F_2 (c) CH_4 (d) H_2

Answers

1. (b) **2.** (d) **3.** (a) **4.** (c) **5.** (b) **6.** (d) **7.** (d) **8.** (c) **9.** (d) **10.** (a)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 112-113.

CHAPTER

5

The Periodic Table

Elements are the building blocks of all substances. There are 118 elements known at present, out of which 98 are naturally occurring. In order to study the properties of all these elements separately, scientists felt the necessity to group elements having similar characteristics together. So, all the elements are divided into a few groups in such a way that elements in the same group have similar properties.

In this chapter, we will study various attempts which have been made to classify the elements from time to time and finally we will study the present form classification.

Chapter Objectives

- Earlier Attempts to Classify Elements
- Mendeleev's Periodic Table (1834-1907)
- Atomic Number as the Basis for Modern Periodic Law
- Trends in the Modern Periodic Table
- Study of Some Specific Groups

Earlier Attempts to Classify Elements

Several attempts are made to classify the elements according to their properties. *Some important of them are discussed below*

Lavoisier's Classification (1789)

It is one of the earliest attempt to classify elements. Lavoisier divided elements into two main groups, called **metals** and **non-metals.**

Döbereiner's Triads (1817)

In the year 1817, **Johann Wolfgang Döbereiner,** a German chemist; has made an attempt to arrange the elements with similar properties into groups having three elements each. He called these groups as **triads.** Döbereiner showed that when the three elements in a triad were arranged in the order of increasing atomic masses, the atomic mass of the middle element was roughly the average of the atomic masses of the other two elements.

Dobereiner's Triads

Elements	Atomic mass	Average atomic mass of first and third elements
Li Na K	7 23 39	$\frac{7+39}{2}=23$
Cl Br I	35.5 80 127	$\frac{35.5+127}{2}=81.25$
Ca Sr Ba	40 88 137	$\frac{40+137}{2}=88.5$

The given classification of elements into triads had a great significance in predicting atomic mass and properties of middle element.

Limitation All the elements discovered at that time are not able to classified into triads. Döbereiner could identify only three triads from the elements known at that time. *These are*

Li, Na, K; Ca, Sr Ba; Cl, Br, I

Newlands' Law of Octaves (1866)

In 1866, **John Newlands',** an English scientist, arranged the known elements in the order of increasing atomic masses and found that every eighth element had properties similar to that of the first. He compared this to the octaves found in music *i.e.,* sa, re, ga, ma, pa, da, ni. And in the west, they use the notations – do, re, mi, fa, so, la, ti. Therefore, he called it the **law of octaves.** This is known as Newlands' Law of Octaves. *A part of the original form of Newlands' octaves is given in table below.*

Notes of Music						
sa (do)	**re** (re)	**ga** (mi)	**ma** (fa)	**pa** (so)	**da** (la)	**ni** (ti)
H	Li	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe
Co and Ni	Cu	Zn	Y	In	As	Se
Br	Rb	Sr	Ce and La	Zr	–	–

Limitations

- This law was applicable only upto calcium. After calcium, every eighth element do not possess the same properties to that of the first.
- Newland assumed that there were only 56 elements existed in nature and no more elements would be discovered in the future. But, later on, several new elements were discovered, whose properties did not fit into the Law of Octaves.
- One more drawback is that, in order to fit elements into his table, Newlands' adjusted two elements in the same slot and also put some unlike elements under the same column.

  e.g., Cobalt and nickel are in the same slot and these are placed in the same column as fluorine, chlorine and bromine which have very different properties than these elements. Iron, which resembles cobalt and nickel in properties, has been placed far away from these elements.

Mendeleev's Periodic Table (1834-1907)

Dmitri Ivanovich Mendeleev, a Russian chemist, arranged the element on the basis of their fundamental property 'atomic mass' and also on the similarity of chemical properties. On this basis, he arranged the elements in a tables, known as **periodic table**.

He then arranged 63 elements (known at that time) in the increasing order of their atomic masses and found that the elements with similar and chemical properties occur at regular intervals. He observed that elements with similar properties fall in the same vertical column. These vertical columns are called **groups** and horizontal rows of elements are called **periods**. On this basis, Mendeleev gave a periodic law, which states that "the properties of elements are a periodic function of their atomic masses".

Mendeleev's Periodic Table (Published in a German journal in 1872)

Group	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Oxide Hydride	R_2O RH	RO RH_2	R_2O_3 RH_3	RO_2 RH_4	R_2O_5 RH_3	RO_3 RH_2	R_2O_7 RH	RO_4
Periods	A B	A B	A B	A B	A B	A B	A B	Transition series
1	H 1.008							
2	Li 6.939	Be 9.012	B 10.81	C 12.011	N 14.007	O 15.999	F 18.998	
3	Na 22.99	Mg 24.31	Al 29.98	Si 28.09	P 30.974	S 32.06	Cl 35.453	
4 **First series**	K 39.102	Ca 40.08	Sc 44.96	Ti 47.90	V 50.94	Cr 50.20	Mn 54.94	Fe Co Ni 55.85 58.93 58.71

Group	I	II	III	IV	V	VI	VII	VIII
Second series	Cu 63.54	Zn 65.37	Ga 69.72	Ge 72.59	As 74.92	Se 78.96	Br 79.909	
5 First series	Rb 85.47	Sr 87.62	Y 88.41	Zr 91.22	Nb 92.91	Mo 95.94	Tc 99	Ru 101.07 Rh 102.91 Pd 106.4
Second series	Ag 107.87	Cd 112.40	In 114.82	Sn 118.69	Sb 121.75	Te 127.60	I 126.90	
6 First series	Cs 132.90	Ba 137.34	La 138.91	Hf 178.49	Ta 180.95	W 183.85		Os 190.2 Ir 192.2 Pt 195.09
Second series	Au 196.97	Hg 200.59	Tl 204.37	Pb 207.19	Bi 208.98			

Note In the formula of oxides and hydrides at the top of the columns, the letter 'R' is used to represent any of the elements in the group.

Features of Mendeleev's Periodic Table

The important features of this table are

(i) This table contains 8 vertical columns, called **groups** and 6 horizontal rows, called **periods.**

(ii) In the table, Mendeleev's left gaps for the elements not discovered at that time. He named such elements by prefixing a Sanskrit numeral *Eka* (one), *divi* (two), *tri* (three) etc., to the name of the preceding similar (analogous) element in the same group. e.g. *Eka*-boron, *Eka*-aluminium, *Eka*-silicon, which after their discovery were named as scandium, gallium and germanium, respectively.

(iii) He also predicted the atomic masses and properties of several elements that were not known at that time. Elements like scandium, gallium and germanium have properties similar to those predicted by Mendeleev.

(iv) In order to group the elements having similar properties together, at some places, Mendeleev had to place an element with a slightly greater atomic mass before an element with a slightly lower atomic mass.

(v) **Noble gases** like helium (He), neon (Ne), argon (Ar), etc., were discovered very late because they are very inert and present in extremely low concentrations in our atmosphere. One of the strengths of **Mendeleev's periodic table** was that, when these gases were discovered, they could be placed in a new group without disturbing the existing order.

Limitations of Mendeleev's Periodic Table

Although this table was greatly helpful for the study of elements but a few anomalies could not be explained on the basis of this table. *These anomalies are*

(i) **Position of Hydrogen** The electronic configuration of hydrogen resembles with alkali metals. It combines with halogen, oxygen and sulphur to give similar type of compounds as given by alkali metals, *e.g.*, (HCl, NaCl), (H_2O, Na_2O) and (H_2S, Na_2S). But just like halogen it exists in diatomic form and combines with metals and non-metals to form covalent compounds. Thus, its position was not fixed in the Mendeleev's periodic table but it was kept with alkali metals.

(ii) **Position of Isotopes** Isotopes of the elements, have similar chemical properties but different atomic masses. In Mendeleev's periodic table, no place was given to these elements *e.g.*, .The element chlorine has two isotopes, Cl-35 and Cl-37, having atomic masses of 35 and 37, respectively.

The placing of these two isotopes of chlorine (having different atomic masses) in the same group of periodic table could not be explained by Mendeleev's periodic law.

(iii) **Uncertainty in Atomic Masses** Another problem was that the atomic masses do not increase in a regular manner on moving from one element to the next.

So, it was not possible to predict how many elements could be discovered between two elements especially when we consider the heavier elements.

(iv) **Placing of Heavier Element before the Lighter One** Few elements, those possess higher atomic mass were placed before elements having a lower atomic mass. *e.g.*, Argon (39.9) was placed before potassium (39.1), cobalt (58.9) before nickel (58.6), tellurium (127.60) before iodine (126.9).

CHECK POINT 01

1 Write an example of Dobereiner's triad.
2 What is the basis of Newland's law of octaves?
3 What was the reason for the failure of Newland's law of octaves?
4 How many periods and groups are there in Mendeleev periodic table?
5 Write any one limitation of Mendeleev's periodic table.

Atomic Number as the Basis for Modern Periodic Law

In 1913, Henry Moseley measured the frequencies of X-rays emitted by different elements when bombarded with high speed electrons. He observed that the square root of the frequency of X-rays emitted by an element was proportional to its atomic number and not the atomic mass of an element.

Hence, **Henry Moseley** showed that the atomic number of an element is a better fundamental property and on the basis of this, he modified **Mendeleev's periodic law** as "physical and chemical properties of the elements are a periodic function of their atomic number". This is called **modern periodic law.**

Modern Periodic Table

When the elements were arranged in the increasing order of their atomic number, the obtained table is called **modern periodic table.**

Explanation of the Anomalies of Mendeléev's Periodic Table

Different anomalies of Mendeleev's periodic table can be explained with the help of modern periodic table as

- The fundamental basis for modern periodic table is atomic number, not atomic mass, hence it is more accurate.
- Since, the table is based on atomic number and isotopes have same atomic number and chemical properties, so they can be put at one place in the same group of the periodic table.
- In this periodic table, a unique position has been given to hydrogen. It is kept at the top left corner because of its unique characteristics.
- The position of cobalt and nickel is justified itself because atomic number of cobalt is less than atomic number of nickel.

Long Form of Periodic Table

It is an extension of modern periodic table. It is based upon the electronic configuration of elements as it was concluded that electronic configuration of element is also a periodic function. Bohr and Bury scientists made this extension. Therefore, this table is also called Bohr's periodic table.

Features of Modern Periodic Table

This table has 18 vertical columns, known as **groups** and 7 horizontal rows, known as **periods.**

Features of Groups

Important features of the elements present in groups are as follow

- The groups are not divided into sub-groups.
- The elements present in a group have the same number of valence or similar electrons.
- The elements present in a group have the same valency.
- The number of shells increases as we go down the group.
- The physical properties of the elements such as melting point, boiling point, density in a group vary gradually.
- The elements present in a group have identical chemical properties.

Features of Periods

Important features of the elements present in period are as follow

- Elements of a period do not have the same number of valence electrons but they contain the same number of shells.
- The number of valence shell electrons increases by one unit as the atomic number increases by one unit on moving from left to right in a period. Therefore, the atoms of different elements with same number of shells are placed in the same period.
- As the number of valence shell electrons changes, the chemical properties of the elements also change.

Number of Elements in a Period

We can explain the number of elements in the periods based on how electrons are filled into various shells

Maximum number of electrons that can be accommodated in a shell is given by the formula $2n^2$, where n = number of given shell from the nucleus.

e.g.,

- *K*-shell – $2 \times (1)^2 = 2$, hence the first period has 2 elements and is called **very short period.**
- *L*-shell – $2 \times (2)^2 = 8$, hence the second period has 8 elements and is called **short period.**
- M-shell – $2 \times (3)^2 = 18$, but the outermost shell can have only 8 electrons, so the third period also has only 8 elements thus, it is also called **short period.**Fourth and fifth periods have 18 elements and are called **long periods**.
- Sixth and seventh periods have 32 elements and are also called **long periods.**

Long Form of Periodic Table

Metals | Metalloids | Non-metals

The *zig-zag* line separates the metals from the non-metals.

s-block or representative elements — GROUP NUMBER 1, 2

d-block or transition elements — GROUP NUMBER 3 to 12

p-block or representative elements — GROUP NUMBER 13, 14, 15, 16, 17, 18

PERIODS 1 to 7

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.0																	2 He Helium 4.0
2	3 Li Lithium 6.9	4 Be Beryllium 9.0											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
3	11 Na Sodium 23.0	12 Mg Magnesium 24.3											13 Al Aluminium 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulphur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 39.9
4	19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 45.0	22 Ti Titanium 47.8	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.9	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
5	37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium (99)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.3	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
6	55 Cs Caesium 132.9	56 Ba Barium 137.3	57 La* Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 181.0	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192. 2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (210)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac** Actinium (227)	104 Rf Rutherfordium (267)	105 Db Dubnium (268)	106 Sg Seaborgium (271)	107 Bh Bohrium (272)	108 Hs Hassium (277)	109 Mt Meitnerium (276)	110 Ds Darmstadium (281)	111 Rg Roentgenium (280)	112 Cn Copernicium (285)	113 Nh Nihonium (---)	114 Fl Flerovium (287)	115 Mc Moscovium (---)	116 Lv Livermorium (291)	117 Ts Tennessine (---)	118 Og Oganesson (---)

f-block or inner-transition elements

*Lanthanoides	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Leutetium 175.5
**Actinoides	90 Th Thorium 232.0	91 Pa Protactinium (231)	92 U Uranium 238.1	93 Np Neptunium (237)	94 Pu Plutonium (242)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (245)	98 Cf Californium (251)	99 Es Einsteinium (254)	100 Fm Fermium (253)	101 Md Mendelevium (256)	102 No Nobelium (254)	103 Lr Lawrencium (257)

Blocks of Periodic Table

The periodic table is divided into four blocks

(i) s-**block elements** It includes group 1 (alkali metals) and group 2 (alkaline earth metals) elements.

(ii) p-**block elements** It includes group 13 to 18 elements.

(iii) d-**block elements** It includes group 3 to group 12. These are also called transition elements (in between s-block and p-block elements).

(iv) f-**block elements** It includes 14 elements after lanthanum (La, 57), called **lanthanoides** and 14 elements after actinium (Ac, 89), called **actinoides**.

Position of the Elements in the Long Form of Periodic Table

In order to find the position of an element in the periodic table, first write its electronic configuration and *then find period and group number from its electronic configuration in the following ways*

- The **period number** of an element is equal to the number of electron shells in its atom.
  e.g., If the atom of an element has 2 electron shells (*K* and *L*), then it belongs to 2nd period.
- If two (or more) elements have the same number of valence shells, then they belong to the same period of the periodic table.
- The **group number** of an element having upto two valence electrons is equal to the number of valence electrons.
- The **'group number'** of an element having more than 2 valence electrons is equal to the number of valence electrons plus 10'.
  e.g., If an element has 1 valence electron, it belongs to group 1 while element with 3 valence electrons has group number 3 + 10 = 13.
- If two (or more) elements have the same number of valence electrons then they belong to the same group of the periodic table.

Note

- Position of elements in the periodic table also tell us about their **chemical reactivity.** If they are present at extreme left or extreme right, they are highly reactive metals and non-metals, respectively.
- **Ionic bond** is formed when there is transfer of electrons from metal to non-metal and **covalent bond** is formed when there is sharing of electrons between two non-metals.
- Lanthanoides and actinoides are kept at the bottom of the periodic table because they resemble each other but do not resemble with other group elements.

CHECK POINT 02

1. What is the basis of modern periodic table?
2. Write other name of long form of periodic table.
3. What is the position of hydrogen in modern periodic table?
4. Why lanthanide and actinides are kept at the bottom of the periodic table?
5. Give a term which is used for horizontal rows and vertical columns of the periodic table, respectively.

Trends in the Modern Periodic Table

In this table, some properties show a regular trend when we move along a period from left to right or in a group from top to bottom.

These properties are

1. Valency

It is the combining capacity of an atom of an element to acquire noble gas configuration and depends upon the number of valence electrons *i.e.*, the electrons present in the outermost shell of its atom.

- For the elements of group 1, 2, 13 and 14, valency = number of valence electron(s),
- For the elements of group 15 onwards, valency = 8 – valence electrons.

Thus, the valencies of elements of different groups are as follow

Valency of group 1 elements is 1;	Valency of group 2 elements is 2
Valency of group 13 elements is 3;	Valency of group 14 elements is 4
Valency of group 15 elements is 3;	Valency of group 16 elements is 2
Valency of group 17 elements is 1;	Valency of group 18 elements is 0

Variation Along a Group

In a group, outer electronic configuration is same for all the elements, so all have the same number of valence electrons and the valency. *e.g.*, All the elements of group 1 have valency = 1.

Group 1 element	Symbol	Electronic configuration	No. of valence electrons
Lithium	Li	2, 1	1
Sodium	Na	2, 8, 1	1
Potassium	K	2, 8, 8, 1	1

Similarly, for the elements of group 17, valency = 8 – 7 = 1

Group 17 element	Symbol	Electronic configuration	No. of valence electrons
Fluorine	F	2, 7	7
Chlorine	Cl	2, 8, 7	7
Bromine	Br	2, 8, 18, 7	7
Iodine	I	2, 8, 18, 18, 7	7

Variation Along a Period

The valency increases from 1 to 4 (till group 14) and then decreases to zero from group 15 to 18.

Group	1	2	13	14	15	16	17	18
Valency	1	2	3	4	3	2	1	0

2. Atomic Size

It refers to the radius of an atom. It may be visualised as the distance between the centre of the nucleus and the outermost shell of an isolated atom. It is measured in picometres. [1 pm (picometre) = 10^{-12} m].

e.g., Atomic radius of hydrogen atom is 37 pm (or 37×10^{-12} m).

Variation Along a Group

The atomic size increases down the group. This is because new shells are being added as we go down the group. This increases the distance between the outermost electrons and the nucleus such that the atomic size increases inspite of the increase in nuclear charge.

	Group 1	Atomic radii (pm)	
Lithium	Li	152	Li
Sodium	Na	186	Na
Potassium	K	231	K
Rubidium	Rb	244	Rb
Caesium	Cs	262	Cs
Francium	Fr	270	Fr

Smallest atom

Atomic size increases on going down a group

Biggest atom

Variation Along a Period

The atomic radius decreases on moving from left to right along a period. This is due to an increase in nuclear charge which tends to pull the valence electrons closer to the nucleus and reduces the size of the atom.

e.g.,

Third period elements	Na	Mg	Al	Si	P	S	Cl
Atomic radii (pm)	186	160	143	118	110	104	99

Size of atoms decreases →

Na Mg Al Si P S Cl

3. Metallic and Non-metallic Properties

The tendency of elements to lose electrons is called their **metallic character.** Because of the formation of positive ions, these are also called **electropositive elements.**

Non-metals are the elements which have a tendency to gain one or more electrons to form negative ions. Thus, these are **electronegative elements**. These are present on the right side in the periodic table. The non-metallic character of the elements is due to their electron accepting tendency.

There are some elements which exhibit the properties of both metals and non-metals. These are called **metalloids.** In the modern periodic table, a *zig-zag* line separates metals from non-metals. The borderline elements—boron, silicon, germanium, arsenic, antimony, tellurium and polonium are intermediate in properties so they are called **metalloids** or **semi-metals.**

Variation Along a Period and a Group

As the effective nuclear charge acting on the valence shell electrons increases across a period, the tendency to lose electrons will decrease. Down the group, the effective nuclear charge experienced by valence electrons decreases because the outermost electrons are farther away from the nucleus.

Therefore, these can be lost easily. Hence, metallic character decreases across a period and increases down a group. Non-metallic character, however increases across a period and decreases down a group.

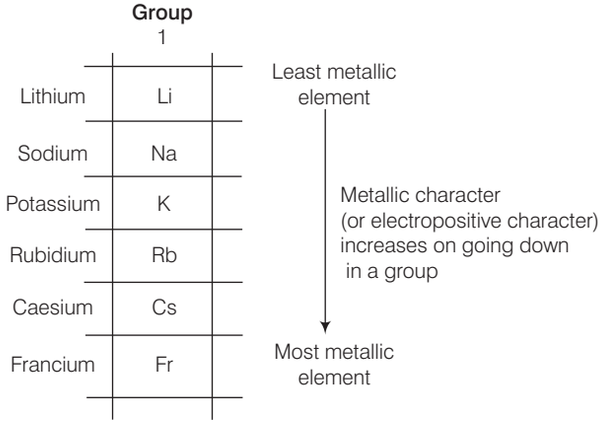
e.g., In case of elements of third period, metallic and non-metallic character vary in the following manner.

Third period elements	Na	Mg	Al	Si	P	S	Cl
Nature of elements	Metals			Metalloid		Non-metals	

Metallic character decreases →

Non-metallic character increases

However, in groups, the order of variation of metallic and non-metallic character is as follows



Note Reactivity of metals increases on moving down a group while that of non-metals decreases.

4. Nature of Oxides

Oxides of the metals are of basic nature while those of non-metals are acidic.

Variation Along a Period and a Group

Along a period, the basic character of the oxides of the elements decreases while their acidic character increases.

On going down in a group of the periodic table, the order is reversed *i.e.*, basic character of oxides increases and acidic character of oxides decreases.

e.g., In case of oxides of elements of group 2, the nature varies as

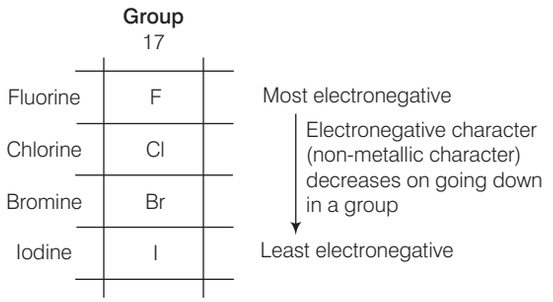
Oxide	Nature
MgO	Least basic
CaO	↓
SrO	
BaO	Most basic

5. Electronegativity

It may be defined as the relative electron attracting tendency of an atom for a shared electron pair in a covalent bond with other atom.

Variation Along a Period and a Group

The electronegativity of the elements increases along a period since the non-metallic character increases. Similarly, it decreases down the group, since the non-metallic character decreases.



Example 1. A group of elements in the periodic table are given below (boron is the first member of the group and thallium is the last).
(Boron, aluminium, gallium, indium, thallium)
Answer the following questions in relation to the above group of elements.

(i) Which element has the most metallic character?

(ii) Which element would be expected to have the highest electronegativity?

(iii) Will the elements in the group to the right of boron be more metallic or less metallic in character? Justify your answer.

Sol.

(i) Thallium has the most metallic character. Metallic character increases down in a group.

(ii) Boron has the highest electronegativity because electronegativity decreases down a group.

(iii) Less metallic in character because on moving across a period, metallic nature decreases.

Example 2. An element X (atomic number = 17) reacts with an element Y (atomic number = 20) to form a divalent halide.

(i) Where does the elements X and Y placed in the periodic table?

(ii) Classify X and Y as metal (s), non-metal (s) or metalloid (s).

(iii) What will be the nature of oxide of element Y? Identify the nature of bonding in the compound formed.

Sol. (i) The electronic configuration of element X with atomic number 17 is 2, 8, 7. Since, it has 7 valence electrons. Therefore, it lies in group 17 (10 + 7). Further, since in element X, third shell is being filled, it lies in third period. In other words, X is chlorine.

The electronic configuration of element Y with atomic number 20 is 2, 8, 8, 2. Since, it has 2 valence electrons, it lies in group 2. Further, since in element Y, fourth shell is being filled, it lies in 4th period. In other words, Y is calcium.

(ii) Since, element X (*i.e.,* Cl) has seven electrons in the valence shell and needs one more electron to complete its octet. Therefore, it is a **non-metal**. Further, the element Y has two

electrons in the valence shell which it can easily lose to achieve the stable electronic configuration of the nearest inert gas, therefore, it is a **metal**.

(iii) Since, element *Y* (*i.e.,* Ca) is a metal, therefore its oxide (*i.e.,* CaO) must be basic in nature. Further, metals and non-metals form ionic compounds, therefore the nature of bonding in calcium oxide is ionic.

CHECK POINT 03

1 What is the most important cause of periodicity?
2 What is the valency of group 13?
3 Arrange F, Cl, Br and I in increasing order of their atomic size down the group.
4 Write the name of any two metalloids.
5 Define electronegativity and how it vary along the period?

Study of Some Specific Groups

The elements present in a group exhibit similar properties, as they have same number of valence electrons and same electronic configuration. The properties of some groups, group 1 (alkali metals), group 2 (alkaline earth metals), group 17 (halogens) and group 18 (zero group) are discussed below.

Alkali Metals (Group 1)

The elements which belong to the group 1 of the periodic table are called as alkali metals. The elements such as lithium (Li), sodium (Na), potassium (K), rubidium (Rb), caesium (Cs) and francium (Fr) have one electron in their outermost orbit and show one valency. So, they are placed in group 1 of the periodic table.

General Characteristics of Alkali Metals

(i) **Electronic Configuration**

Element	*K*	*L*	*M*	*N*	*O*	*P*	*Q*
$_{3}$Li	2	1					
$_{11}$Na	2	8	1				
$_{19}$K	2	8	8	1			
$_{37}$Rb	2	8	18	8	1		
$_{55}$Cs	2	8	18	18	8	1	
$_{87}$Fr	2	8	18	32	18	8	1

(ii) **Occurrence** Highly reactive elements and occur in the combined state only.

(iii) **Nature** Soft in nature (can be cut with a knife) and have low melting and boiling points.

(iv) **Bonding** Alkali metals have one electron in the valence shell *i.e.,* their valency is 1, so they form ionic bond by donating electrons.

$$M - e^- \longrightarrow M^+$$

(v) **Action of Air** On exposure to moist air, they react rapidly with oxygen and form metal oxide. Hence, these metals (Na and K) are kept immersed in kerosene.

$$4M + O_2 \longrightarrow 2M_2O \text{ (where, M = any alkali metal)}$$

(vi) **Action of Water** React violently with water to produce alkali and hydrogen gas.

$$2M + 2H_2O \longrightarrow \underset{\text{Alkali}}{2MOH} + H_2\uparrow$$

(where, M = any alkali metal)

(vii) **Action of Acids** React violently with dil. HCl and dil. H_2SO_4 and produce H_2 gas.

$$2M + 2HCl \longrightarrow 2MCl + H_2\uparrow$$

$$2M + 2H_2SO_4 \longrightarrow M_2SO_4 + H_2\uparrow$$

(where, M = any alkali metals)

(viii) They are strong reducing agents.

(ix) They have very low ionisation energy which means that they can easily form unipositive ions.

$$M(g) - e^- \longrightarrow M^+(g)$$

(x) They are generally soft when freshly cut, show typical silvery white metallic lustre but on exposure to the air, they turn into dull black colour.

(xi) They impart colour to the flame *e.g.,* Lithium (crimson red), sodium (golden yellow), potassium (pale violet).

(xii) Alkali metals are obtained by the electrolysis of their molten salts *e.g.,* Na metal can be easily obtained from NaCl salt.

$$NaCl \rightleftharpoons Na^+ + Cl^-$$

At cathode $Na - e^- \longrightarrow Na^+$

At anode $Cl + e^- \longrightarrow Cl^-$

Alkaline Earth Metals (Group 2)

The elements which belong to the group 2 of the periodic table are known as alkaline earth metals. The elements such as beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba) and radium (Ra) are known as alkaline earth metals because their oxides occur in the earth's crust and their hydroxides are alkalies.

General Characteristics of Alkaline Earth Metals

(i) **Electronic Configuration**

Element	*K*	*L*	*M*	*N*	*O*	*P*	*Q*
$_{4}$Be	2	2					
$_{12}$Mg	2	8	2				
$_{20}$Ca	2	8	8	2			
$_{38}$Sr	2	8	18	8	2		
$_{56}$Ba	2	8	18	18	8	2	
$_{88}$Ra	2	8	18	32	18	8	2

(ii) **Occurrence** The reactive element occur in the combined state only.

(iii) **Nature** They are slightly harder than alkali metals.

(iv) **Bonding** They possess two electrons in the valence shell hence form dipositive cations and shows ionic bonding.

$$M - 2e^- \longrightarrow M^{2+}$$

(where, M = any alkaline earth metals)

(v) **Action of Air** On exposure to moist air, they react slowly. Upon heating in the presence of air they form oxide and nitrides.

e.g., $2M + O_2 \longrightarrow 2MO$

$3M + N_2 \longrightarrow M_3N_2$

(where, M = any alkaline earth metals)

(vi) **Action of Water** They react with water to produce alkali and hydrogen gas.

$$\underset{\text{Alkaline earth metal}}{M} + 2H_2O \longrightarrow \underset{\text{Alkali}}{M(OH)_2} + H_2\uparrow$$

(vii) **Action of Acids** They react with dil. HCl and dil. H_2SO_4, respectively to produce hydrogen gas.

$$M + 2HCl \longrightarrow MCl_2 + H_2\uparrow$$

$$\underset{\text{Alkaline earth metal}}{M} + H_2SO_4 \longrightarrow MSO_4 + H_2\uparrow$$

(viii) They act as reducing agents.

(ix) They have low ionisation energy (higher than alkali metals) and forms dipositive ion.

$$M - 2e^- \longrightarrow M^{2+}$$

(where, M = any alkaline earth metal)

(x) Melting and boiling points are comparatively low but higher than the alkali metals.

(xi) Generally, all the alkaline earth metals impart colour to the flame (except beryllium and magnesium), *e.g.*, Ca (Brick red), Sr (Crimson), Ba (Apple green), Ra (Crimson).

(xii) They are also obtained by the electrolysis of their molten salts.

e.g., $MgCl_2 \rightleftharpoons Mg^{2+} + 2Cl^-$

At cathode $Mg^{2+} + 2e^- \longrightarrow Mg$

At anode $2Cl^- - 2e^- \longrightarrow 2[Cl]$

$2[Cl] \longrightarrow Cl_2$

Halogens (Group 17)

Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I) and Astatine (At) belongs to group 17 and are collectively known as halogens.

The name halogens greek is derived from word 'halo' means 'salt' and 'genes' means 'born' *i.e.*, salt producers. The elements of group 17 show great similarity amongst themselves, like group 1 and 2 elements.

General Characteristics of Halogens

(i) **Electronic Configuration**

Element	*K*	*L*	*M*	*N*	*O*	*P*
$_9F$	2	7				
$_{17}Cl$	2	8	7			
$_{35}Br$	2	8	18	7		
$_{35}I$	2	8	18	18	7	
$_{85}At$	2	8	18	32	18	7

(ii) **Occurence** They are highly reactive non-metallic elements

(iii) **Nature** Flourine and Chlorine are gases, bromine is liquid and iodine is solid.

(iv) **Bonding** Halogens due to the presence of seven electrons in their valence shell, are highly reactive and form ionic compounds with highly electropositive metals, readily.

However, with weakly electropositive metals and non-metals, they form covalent bonds.

(iv) All these halogens are coloured. F_2 is yellow, Cl_2 is greenish yellow, Br_2 is reddish brown and I_2 is violet in colour.

(v) Halogen having high electron affinity and low bond enthalpy, can react with most of elements in the periodic table.

However, the order of reactivity of the group members decreases down the group as

$$F > Cl > Br > I$$

(vi) Most of the metals react with halogens to form metal halides as

$$2M + nX_2 \longrightarrow 2MX_n$$

(here, M = metal, *n* = oxidation state of metal X = F, Cl, Br or I)

Noble Gases (Group 18 or Zero Group)

Group 18 or zero group of periodic table contains six elements collectively known as noble gases. These elements are helium (He), neon (Ne), argon (Ar), Krypton (Kr), Xenon (Xe) and due to their inertness, these gases were discovered on the basis of study of their physical properties such as density.

Note W. Ramsay was awarded by Noble prize in chemistry for the discovery of the inert gases in air.

General Characteristics of Noble Gases

(i) **Electronic Configuration**

Element	*K*	*L*	*M*	*N*	*O*	*P*
$_{2}$He	2					
$_{10}$Ne	2	8				
$_{18}$Ar	2	8	8			
$_{36}$Kr	2	8	18	8		
$_{54}$Xe	2	8	18	18	8	
$_{86}$Rn	2	8	18	32	18	8

(ii) **Occurence** Due to inert nature of these gases, they always occur in free state.

(iii) **Nature** These are colourless, odourless and tasteless gases.

(iv) These are monoatomic gases and are sparingly soluble in water.

(v) Noble gases have low melting and boiling points due to weak dispersion forces. Helium has the lowest boiling point of any known substance.

(vi) Helium, is a *s*-block element but has been placed in group 18, at the top, as its chemical inertness is similar to the rest of the members of group 18.

(vii) Helium is used in filling balloons for meteorological observations as it is a non-inflammable and light gas. Neon is used in discharge tubes. Neon bulbs are used in botanical gardens and in greenhouses. Argon because of its inert nature is used to provide an inert atmosphere in high temperature metallurgical process.

CHECK POINT 04

1. What happens when alkali metals are exposed to the air?
2. How do alkali metals and alkaline earth metals differ from each other in respect to the formation of metallic ions?
3. Arrange the halogens in increasing order of reactivity towards other group members.
4. Why do noble gases have low melting and boiling point?
5. Noble gases occur in free state. Comment.

SUMMARY

- Dobereiner grouped the three elements in a triad which were written in the order of increasing atomic masses; the atomic mass of the middle element was roughly the average of the atomic masses of the other two elements.
- In Newlands's law of octaves, elements are arranged in increasing order of atomic masses and found that every eighth element had properties similar to that of the first. This law is based on the octaves found in music.
- Mendeleev's periodic table (1834-1907) is based on Mendeleev's periodic law, which states that the properties of the elements are the periodic functions of their atomic weights. This table contains 8 groups and 6 periods and containing gaps for the elements which are not discovered at that time.
- Mendeleev predicted the atomic masses and properties of several elements that were not known at that time. He also corrected the atomic mass of some elements such as Be from 13 to 9.
- There are some limitations of Mendeleev's periodic table such as
  - → Position of hydrogen is not fixed.
  - → No place was given to isotopes.
  - → Atomic masses do not increase in a regular manner.
  - → Placing of heavier element before the lighter one.
- Long form of periodic table (1913) is based on modern periodic law which states that the properties of the elements are the periodic function of their atomic numbers. This table contains 18 groups and 7 periods.
- The periodic table is divided into four blocks as follows
  - → s-block : Group 1 (alkali metals) and 2 (alkaline earth metals) elements
  - → p-block : Group 13 to 18 elements
  - → d-block (transition elements) : Group 3 to group 12 elements
  - → f-block : 14 elements after lanthanum (lanthanoids) and 14 elements after actinium (actinoids)
- Properties showing regular gradation along the period and group. These can be properties like valency, atomic size, metallic and non-metallic properties, electronegativity and nature of oxides, etc.
- Valency It is the combining capacity of an atom to acquire noble gas configuration. It is same for all the elements in group but increases along a period.
- Atomic size (atomic radius) It is the distance between the centre of the nucleus and the outermost shell of an isolated atom. It decreases along a period but increases on moving down the group.
- Metallic and non-metallic character Metallic character of the elements are tendency to lose their electrons while, non-metallic character of the element is due to their electron accepting tendency. Metallic character increases on moving down the group and decreases along a period. Reverse is true for non-metallic character.
- Nature of oxides Acidic nature of oxides increases along a period from left to right but decreases on moving down the group. Opposite is true for basic nature.
- Electronegativity It is the electron attracting power of a element in a compound. It decreases in the group and increases along a period from left to right.
- The elements present in a group exhibit similar properties as they have same number of valence electrons and same electronic configuration.
- Alkali and alkaline earth metals are reactive elements and occur in combined state only.
- Halogens are highly reactive non-metallic elements and are placed in group 17 of the periodic table.
- Group 18 elements because of their inert nature is known as inert gases.

EXAM PRACTICE

Fill in the Blanks

1. Dobereiner's relationship referred to as the ..... .

Sol. law of triads

2. John Newlands in 1866, arranged the elements in the increasing order of their (i)..... .
He noted that every eighth element had properties similar to the (ii)..... element. The relationship was just like every (iii)..... that resembles the first in (iv)..... of music. It is seemed to be true only for elements upto (v)..... .

Sol. (i) atomic weight (ii) first
(iii) eighth note (iv) octaves
(v) calcium

3. Mendeleev arranged elements in horizontal rows and ..... .

Sol. vertical columns

4. In Mendeleev's periodic table, *eka*-silicon and *eka*-aluminium were .....and ..... , respectively.

Sol. germanium, gallium

5. Second period of modern periodic table has 8 elements which is called..... .

Sol. short period

6. Strontium belongs to group ..... and ..... period.

Sol. second, fifth

7. The number of valence shell electrons (i)..... by one unit as the (ii)..... increases by one unit on moving in a period and (iii)..... of the elements also change.

Sol. (i) increases
(ii) atomic number
(iii) chemical properties

8. Boron is ..... than beryllium in size.

Sol. smaller

9. Elements, having a tendency to lose one or more electrons and form positive ions are called (i)..... . The tendency of these elements to lose electrons is called their (ii)..... Because of the formation of positive ions, these are also called (iii).....

Sol. (i) metals
(ii) metallic character
(iii) electropositive elements

10. ..... metals reacts rapidly with air to form oxides.

Sol. Alkali

Multiple Choice Questions

11. Which of the following is the correct set of elements to Dobereiner's triads?

(a) Li Na K (b) Br Cl I
7 23 39 80 35.5 127
(c) Fe Ni Co (d) Data is insufficient
55.85 58.71 58.93

Sol. (a)

12. Which of the following is correct?

(a) Law of triads seemed to work only for large elements
(b) John Newlands (law of octaves) arranged the elements in the increasing order of their atomic weights
(c) Dobereiner arranged elements by the help of triads method
(d) Both (b) and (c)

Sol. (d)

13. Which of the following statement(s) about the modern periodic table are incorrect?

I. The elements in the modern periodic table are arranged on the basis of their decreasing atomic number.
II. The elements in the modern periodic table are arranged on the basis of their increasing atomic masses.
III. Isotopes are placed in adjoining group(s) in the periodic table.
IV. The elements in the modern periodic table are arranged on the basis of their increasing atomic number.

(a) Only I (b) I, II, and III
(c) I, II and IV (d) Only IV

Sol. (b)

14. Which of the elements *A, B, C, D* and *E* with atomic number 2, 3, 7, 10 and 30, respectively belong to the same period?

(a) *A, B, C* (b) *B, C, D*

(c) *A, D, E* (d) *B, D, E*

Sol. (b)

15. In the modern periodic table, tungsten, *W* (atomic number = 74) is surrounded by the elements with atomic numbers 73, 42, 75, 106

	Mo	
Ta	W	Re
	Sg	

Which of the following will have physical and chemical properties similar to it?

(a) 42, 106 (b) 42, 73, 106

(c) 73, 106 (d) 42, 73

Sol. (a)

16. Two elements *M* and *N* belong to group 2 and 3, respectively in the same period. The formulae of their oxides are

(a) MO, N_2O_3

(b) M_3O_2, N_3O_2

(c) M_2O_3, N_3O_2

(d) M_3O_2, N_2O_3

Sol. (a)

17. Which one among the following is an alkaline earth metal ?

(a) Potassium (b) Calcium

(c) Lead (d) Copper

Sol. (b)

Match the Following

18. Match the following columns.

	Column I		Column II
(i)	Law of triads	(a)	Give the relationship of atomic masses and physical, chemical properties.
(ii)	Law of octaves	(b)	Periodic law
(iii)	Mendeleev	(c)	1866
		(d)	1817

Sol. (i) → (d), (ii) → (c), (iii) → (a, b)

19 Match the following columns.

	Column I (Group)		Column II (Block)
(i)	1 and 2	(a)	*p*-block
(ii)	3 to 12	(b)	*d*-block
(iii)	13 to 18	(c)	*s*-block
		(d)	*f*-block

Sol. (i) → (c), (ii) → (b), (iii) → (a)

a 1 Mark Questions

20 Chlorine, bromine and iodine form a Dobereiner's triad. The atomic masses of chlorine and iodine are 35.5 and 126.9, respectively. Predict the atomic mass of bromine.

Sol. Atomic mass of bromine = Average of atomic masses of chlorine and iodine

$$= \frac{35.5 + 126.9}{2} = \frac{162.4}{2} = 81.2$$

21. In Mendeleev's periodic table the elements were arranged in the increasing order of their atomic masses. However, cobalt with atomic mass of 58.93 amu was placed before nickel having an atomic mass of 58.71 amu. Give reason for the same.

Sol. The sequence was inverted so that elements with similar properties could be grouped together. Hence, cobalt (58.9) is placed before nickel (58.7).

22. Arrange the following metals with increasing order of their atomic number.

Li, N, Al, H, Na

Sol. H < Li < N < Na < Al

(1) (3) (7) (11) (13)

23. An atom has electronic configuration 2, 8. Predict the group in which it should be placed.

Sol. Zero group or 18th group. This group has elements having completely filled outermost shell. These are known as inert gases.

24. A metal *M* belongs to 13th group in the modern periodic table. Write the valency of the metal.

Sol. 3, as it possess three valence electrons in its outermost shell (2, 8, 3).

25. An element *X* is present at the left corner of modern periodic table. State whether it would be a metal or a non-metal.

Sol. It would be a metal.

26. Why alkali metals are good reducing agents ?

Sol. Alkali metals have greater tendency to lose or donate electrons which make them good reducing agents.

b 2 Marks Questions

27. Can the following groups of elements be classified as Dobereiner's triad?

(i) Na, Si, Cl (ii) Be, Mg, Ca

(Atomic mass of Be 9; Na 23; Mg 24; Si 28; Cl 35; Ca 40)

Explain by giving reason.

Sol. (i) No, because Si has an average atomic mass than that of Na and Cl. But they do not resemble in their properties. Na (23); Si (28); Cl (35)

$$\text{Atomic mass of Si} = \frac{23+35}{2} = \frac{58}{2} = 29$$ *[1]*

(ii) Yes, Be (9); Mg (24); Ca (40)

$$\text{Atomic mass of Mg} = \frac{9+40}{2} = \frac{49}{2} = 24.5$$

It can be classified as Dobereiner's triads because the middle element of the triad had both atomic mass and properties similar to average of the two other elements of the triad. *[1]*

28. Elements have been arranged in the following sequence on the basis of their increasing atomic masses.

F, Na, Mg, Al, Si, P, S, Cl, Ar, K

(i) Pick two sets of elements which have similar properties.

(ii) The given sequence represents which law of classification of elements?

Sol. (i) Here, the elements are arranged in the order of increasing atomic masses, so according to Newland's law of octaves there is a repetition of properties in every eighth element as compared to the given element.

The two sets of elements which have similar properties are

Set I → F, Cl Set II → Na, K *[1]*

(ii) The given sequence represents Newland's law of octaves. *[1]*

29. "Hydrogen occupies a unique position in the modern periodic table". Justify the statement.

Sol. In electronic configuration, hydrogen (1) resembles with alkali metals. Moreover, it combines with halogen, oxygen and sulphur to give similar type of compounds as given by alkali metals. *e.g.,* (HCl, NaCl), (H_2O, Na_2O), (H_2S, Na_2S). *[1]*

But just like halogens, it exists in diatomic form and combines with metals and non-metals to form covalent compounds. In this periodic table, a unique position has been given to the hydrogen. It is kept at the top left corner because of its unique characteristic. *[1]*

30. Compare the radii of two species *X* and *Y*. Give reasons for your answer.

(i) *X* has 12 protons and 12 electrons

(ii) *Y* has 12 protons and 10 electrons

Sol. The radii of species *Y* will be smaller than species *X* because *Y* is formed when *X* loses 2 electrons. Hence, *Y* is the cation and protons are more than electrons in *Y*, so electrons are strongly attracted by the nucleus and are pulled inward. Hence, the size decreases. *[2]*

31. Arrange the following elements in the increasing order of their atomic radii.

(i) Li, Be, F, N (ii) Cl, At, Br, I

Sol. (i) F < N < Be < Li (ii) Cl < Br < I < At *[1]*

Because atomic radii decreases along a period and increases on moving down a group. *[1]*

32. A metal *M* forms an oxide having the formula, *M*O. It belongs to 2nd period in the modern periodic table. Write its atomic number and valency.

Sol. Since, the metal form *M*O type oxide, it belongs to second group and have configuration 2, 2 because have two shells. Thus, atomic number of the element is 4 and its valency is 2. *[2]*

33. Write a reaction of alkaline earth metal with

(i) oxygen (ii) water

Sol. (i) Alkaline earth metals reacts with oxygen to form respective oxides

$$2M + O_2 \longrightarrow 2MO$$

(where, M = any alkaline earth metals) *[1]*

(ii) They reacts with water to produce alkali and hydrogen gas

$$\underset{\text{Alkaline earth metal}}{M} + 2H_2O \longrightarrow \underset{\text{Alkali}}{M(OH)_2} + H_2\uparrow$$ *[1]*

34. Give one use of (a) Argon gas (b) neon gas.

Sol. (a) Argon gas because of its inert nature is used to provide an inert atmosphere in high temperature metallurgical process. *[1]*

(b) Neon gas is used in discharge tubes. *[1]*

C 3 Marks Questions

35. The three elements *A, B* and *C* with similar properties have atomic masses *X, Y*, and *Z* respectively. The mass of *Y* is approximately equal to the average mass of *X* and *Z*. What is such an arrangement of elements called as? Give one example of such a set of elements.

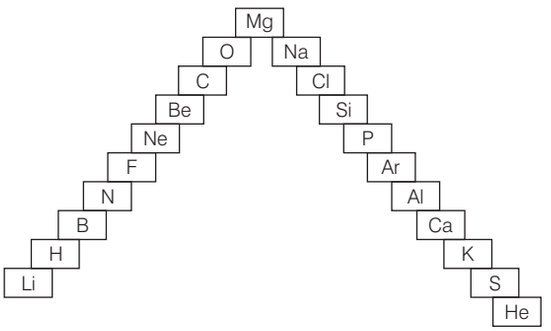
Sol. The arrangement of elements in which the atomic mass of middle element is almost the mean of atomic masses of first and third element is known as triads.

e.g., Ca (40), Sr (88), Ba (137) *[2]*

$$Sr = \frac{40 + 137}{2} = 88.5$$ *[1]*

36. (i) In this ladder (Figure) symbols of elements are jumbled up. Rearrange these symbols of elements in the increasing order of their atomic number in the periodic table.

(ii) Arrange them in the order of their group, also.



Sol. (i) H < He < Li < Be <B < C < N < O < F < Ne < Na < Mg < Al < Si < P < S < Cl < Ar < K < Ca. *[1½]*

(ii)

Group	1	2	13	14	15	16	17	18
	H	Be	B	C	N	O	F	He
	Li	Mg	Al	Si	P	S	Cl	Ne
	Na	Ca						Ar
	K							

[1½]

37. Consider the part of periodic table given below and answer the following questions.

Group / Period	1	2	13	14	15	16	17	18
I	*a*							*j*
II	*b*	*e*				*g*	*h*	*k*
III	*c*			*f*			*i*	*l*
IV	*d*							

(i) The atom of which element is smaller in size '*e*' or '*b*'?

(ii) Which element is most electropositive in nature?

(iii) Which element has only one proton in its atom?

(iv) What is the valency of '*g*'?

(v) How many valence electrons does '*g*' have?

(vi) Name the element which is a metalloid.

Sol. (i) *b* (ii) *d*

(iii) *a* (iv) 2

(v) 6 (vi) *f* *[½ × 6]*

38. Three elements *A, B* and *C* have 3, 4, and 2 electrons, respectively. Give the group number to which they belong in the modern periodic table. Also, give their valencies.

Sol. Electronic configuration of element $A = 2, 1$

$B = 2, 2$

$C = 2$ *[1]*

Thus, element *A* belongs to group 1

B belongs to group 2

C belongs to group 18

Valency of *A* — 1

B — 2

C — 0 *[2]*

39. An element *X* (atomic number 17) reacts with an element *Y* (atomic number 20) to form a divalent halide.

(i) What is the position of elements *X* and *Y* in the periodic table?

(ii) What will be the nature of oxide of element *Y*? Identify the nature of bonding in the compound formed.

Sol. *X* is the non-metal while *Y* is the metal.

Divalent halide = YX_2 *[1]*

(i) Position of *X* (2, 8, 7) - Group - 17, Period - 3

Position of *Y* (2,8, 8, 2)- Group - 2, Period - 4 *[1]*

(ii) Oxide of element *Y* (*YO*) is basic in nature. It forms ionic bond. *[1]*

40. Mention any three characteristics of halogens.

Sol. (i) They are highly reactive non-metallic elements. *[1]*

(ii) All the halogens are coloured. F_2 is yellow, Cl_2 is greenish yellow, Br_2 is reddish brown and I_2 is violet in colour. *[1]*

(iii) Most of the metals react with halogens to form metal halides as

$$2M + nX_2 \longrightarrow 2MX_n$$

(here, *M* = metal, *n* = oxidation state of metal, *X* = F, Cl, Br or I) *[1]*

d 4 Marks Questions

41. (i) The three elements *X, Y* and *Z* with similar chemical and physical properties have atomic masses *A, B* and *C*. Mass of *Y* (*i.e., B*) is approximately equal to the average atomic masses of *X* (*i.e., A*) and *Z* (*i.e., C*). What will you call such an arrangement of elements? Also give an example.

(ii) Which group of elements could be placed in Mendeleev's periodic table without disturbing the original order? Give reason.

Sol. (i) This arrangement of elements is called Dobereiner's triad. *e.g.,* Potassium (K), barium (Ba) and iodine(I). *[2]*

(ii) The noble gases could be placed in a new group without disturbing the existing order because they were very inert and present in extremely low concentrations in our atmosphere. *[2]*

42. Mendeleev predicted the existence of certain elements not known at that time and named two of them as *eka*-silicon and *eka*-aluminium.

(i) Name the elements which have taken the place of these elements.

(ii) Mention the group and the period of these elements in the modern periodic table.

(iii) Classify these elements as metals or non-metals or metalloids.

(iv) How many valence electrons are present in each one of them?

Sol. (i) Germanium and gallium have taken the place of these elements. *[1]*

(ii) Germanium — Group 14, Period 4
Gallium — Group 13, Period 4 *[1]*

(iii) They are metalloids. *[1]*

(iv) In germanium, the number of valence electrons is 4 and in gallium it is 3. *[1]*

43. A part of the periodic table has been shown below:

Group / Period	1	2			13	14	15	16	17	18
1										
2	A	C							E	G
3	B					D			F	

Answer the following questions on the basis of position of elements in the given table.

(i) Which element is a noble gas? Give reason.

(ii) Which element is most electronegative? Give reason.

(iii) Write the electronic configuration of (a) *B* and (b) *E*.

Sol. (i) *G* is a noble gas because it is present in group 18 and has zero valency. *[1]*

(ii) *E* is the most electronegative element due to its smallest atomic size and more electron affinity. *[1]*

(iii) (a) Electronic configuration of *B* – *K L M*
2, 8, 1 *[1]*

(b) Electronic configuration of *E* – *K L*
2, 7 *[1]*

e 5 Marks Questions

44. The position of three elements *A*, *B* and *C* in the periodic table are shown below.

Group 16	Group 17
–	–
–	A
–	–
B	C

(i) State whether *A* is a metal or non-metal.

(ii) State whether *C* is more reactive or less reactive than *A*.

(iii) Will *C* be larger or smaller in size than *B*?

(iv) Which type of ion, cation or anion, will be formed by *A* ?

Sol. (i) Since, *A* belongs to group 17 and has 7 valence electrons so, it is a non-metal because it will gain electrons to complete its octet. *[1]*

(ii) *C* lies below A and in the same group. As we move down in a group, the size increases and electronegative character decreases. With the increase in electronegative character, the electron adapting tendency and hence the reactivity decrease, so *C* is less reactive than *A*. *[2]*

(iii) *C* is smaller than *B* in size because as we move left to right in a period atomic size decreases due to increased effective nuclear charge. *[1]*

(iv) As discussed in part (i) that element *A* has a tendency to gain electron to complete its octet. It needs to take up one electron, so it will form anion (A^-). *[1]*

45. Properties of the elements are given below. Where would you locate the following elements in the periodic table?

(i) A soft metal stored in kerosene.

(ii) An element with variable (more than one) valency stored in water.

(iii) An element which is tetravalent and forms the basis of organic chemistry.

(iv) An element which is an inert gas with atomic number 2.

(v) An element whose thin oxide layer is used to make other elements corrosion resistant by the process of 'anodising'.

Sol. (i) Group 1, period 3 (Na) *[1]*

(ii) Group 15, period 3 (P) *[1]*

(iii) Group 14, period 2 (C) *[1]*

(iv) Group 18, period 1 (He) *[1]*

(v) Group 13, period 3 (Al) *[1]*

46. Atomic number of a few elements are given below.

10, 20, 7, 14

(i) Identify the elements.

(ii) Identify the group number of these elements in the periodic table.

(iii) Identify the periods of these elements in the periodic table.

(iv) What would be the electronic configuration for each of these elements?

(v) Determine the valency of these elements.

Sol. (i) The elements are 10 – Neon
20 – Calcium
7 – Nitrogen
14 – Silicon *[1]*

(ii) Group number of Neon – 18
Calcium – 2
Nitrogen – 15
Silicon – 14 *[1]*

(iii) The periods are 2, 4, 2, 3. *[1]*

(iv) Electronic configuration of Neon – K L
2, 8

Calcium – K L M N , Nitroge n – K, L
2, 8, 8, 2 2, 5

Silicon – K, L, M
2, 8, 5 *[1]*

(v) Valency – Neon – 0
Calcium – 2
Nitrogen – 3
Silicon – 4 *[1]*

CHAPTER EXERCISE

Fill in the Blanks

1. Law of octaves is systematic relationship between the …… and repetition of …… of elements.

2. The physical and chemical properties of elements are the periodic function of their atomic masses are known as …… .

3. Around the year 1800, the number of known elements were (i) …… but later the number gradually (ii) …… . At present, (iii) …… elements are known to us, out of which (iv) …… are naturally occurring.

4. Mendeleev's periodic table is based on (i)…… which states that the physical and chemical properties of elements are the periodic function of their (ii)…… . This table contains (iii)…… vertical column called …… and …… horizontal rows, called …… .

5. Modern periodic table has …… groups and …… periods.

Multiple Choice Questions

6. Newland's law of octaves seemed to be true only for elements upto …*A*… . Here, *A* refers to

(a) calcium (b) argon

(c) potassium (d) zinc

7. Which of the following is incorrect explanation about Mendeleev's periodic law?

(a) Mendeleev arranged elements in horizontal rows only

(b) Mendeleev arranged elements with increasing atomic weight

(c) Mendeleev's system of classifying elements was more elaborated

(d) Both (a) and (b)

8. The element with atomic number 14 is hard and forms acidic oxide and a covalent halide. To which of the following categories does the element belong?

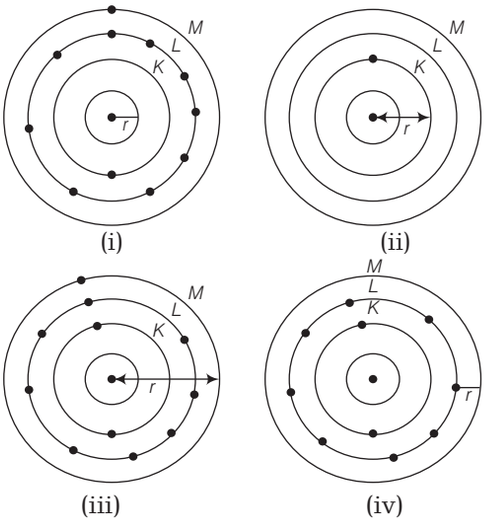
(a) Metal

(b) Metalloid

(c) Non-metal

(d) None of the above

9. Which one of the following depicts the correct representation of atomic radius (*r*) of an atom?



(a) (i) and (ii) (b) (ii) and (iii)

(c) (iii) and (iv) (d) (i) and (iv)

Match the Following

10. Match the following columns.

	Column I		Column II
(i)	*Eka*-boron	(a)	Henry Moseley
(ii)	Modern periodic table	(b)	Long and incomplete
(iii)	Seventh period	(c)	$2n^2$
(iv)	Maximum number of electron in a shell	(d)	Scandium

11. Match the following columns.

	Column I (Characteristics)		Column II (Trends in the modern periodic table)
(i)	Valency	(a)	Increase in group, decrease in period
(ii)	Atomic size	(b)	Decrease in group, increase in period
(iii)	Non-metallic properties	(c)	Same in group, increase in period
(iv)	Electronegativity		

1 Mark Questions

12. Arrange the following metals with increasing order of their atomic number

Li, N, Al, H, Na.

13. If an element *X* is placed in group 14, what will be the formula and the nature of bonding of its chloride?

14. Name an element of group 18 which can form compounds.

2 Marks Questions

15. An atom of an element has electronic configuration 2, 8, 6.

(i) What is the atomic number of this element?

(ii) Name the element that shows chemical similarity.

16. Explain the increase in chemical reactivity of metals as we go down the group.

17. An element *X* belongs to the second period and group 15 of the periodic table. Find out

(i) the number of valence electrons in its atoms.

(ii) valency of the element.

18. Explain by giving example, how alkali metals are obtained by electrolysis of their molten salts?

3 Marks Questions

19. (i) Why is it necessary to classify the elements?

(ii) Give an example of Dobereiner's triad.

(iii) On what basis Newland proposed his classification?

20. Arrange the following elements according to the instructions written in paranthesis.

(i) Cu, Mn, Ge, Sc (increasing atomic size)

(ii) Fe, Hs, Ru, Os (increasing number of valence shells)

(iii) Hf, Cs, Ba, Tl (increasing valency)

21. Explain the variation of metallic character down the group along with examples.

4 Marks Questions

22. Compare and contrast the arrangement of elements in Mendeleev's periodic table and the modern periodic table.

23. Write short note on the following.

(i) Atomic radii (ii) Electronegativity

(iii) Valency (iv) Metallic character

24. Write a reactions showing action of acids on alkaline earth metal.

5 Marks Questions

25. Which element has

(i) two shells, both of which are completely filled with electrons?

(ii) the electronic configuration 2, 8, 2?

(iii) a total of three shells with four electrons in its valence shell?

(iv) a total of two shells, with three electrons in its valence shell?

(v) twice as many electrons in its second shell as in its first shell?

26. (i) Nitrogen (atomic number = 7) and phosphorus (atomic number = 15) belong to group 15 of the periodic table. Write the electronic configuration of these two elements. Which will be more electronegative and why?

(ii) In the modern periodic table, calcium (atomic number = 20) is surrounded by elements with atomic numbers 12, 19, 21 and 38. Which of these have physical and chemical properties resembling calcium?

27. Identify the elements.

(i) Two shells with atomic number less than two than that of N.

(ii) Three shells which are completely filled.

(iii) Atomic number-1.

(iv) Group 15, period 4

(v) Liquid with atomic number one less than that of Tl.

CHALLENGERS*

1 Consider the following statements.

I. Dobereiner's triads had a great significance in predicting atomic mass and properties of middle element.

II. Law of octaves is based upon octaves found in music.

III. *Eka*-boron and *eka*-aluminium were named as scandium and gallium, later on.

Identify the correct statements.

(a) I and II (b) II and III

(c) I and III (d) All of these

2 *X*, *Y* and *Z* are three members of a Dobereiner's triad. If the atomic mass of *X* is 7 and that of *Z* is 39. What is the atomic mass of *Y*?

(a) 27 (b) 25

(c) 32 (d) 23

3 Mendeleev's periodic table is based upon the atomic masses. This periodic table is upset by the fact that

(a) many elements have several isotopes

(b) noble gases do not form compounds

(c) some groups are divided into two sub groups *A* and *B*.

(d) atomic weights of elements are not always whole numbers

4 In terms of period and group where would you locate the element with $Z = 114$?

(a) 7th period, 14th group

(b) 6th period, 14th group

(c) 6th period, 4th group

(d) 7th period, 4th group

5 According to IUPAC nomenclature, a newly discovered element has been named as Uun. This atomic number of the element is

(a) 111 (b) 112

(c) 109 (d) 110

6 A trend common to both of group I and VII element in the periodic table as atomic number increases is

(a) atomic radius increases

(b) maximum valency increases

(c) oxides become basic

(d) metallic character increases

7 Match the correct atomic radius with the element.

	Element		**Atomic radius** (pm)
A.	Be	(i)	74
B.	C	(ii)	88
C.	O	(iii)	111
D.	B	(iv)	77
E.	N	(v)	66

Codes

	A	B	C	D	E
(a)	(iii)	(iv)	(v)	(i)	(ii)
(b)	(iii)	(iv)	(v)	(ii)	(i)
(c)	(iv)	(iii)	(v)	(ii)	(i)
(d)	(v)	(iii)	(iv)	(i)	(ii)

8 Consider the following statements regarding periodic classification of elements.

I. The properties of elements are periodic functions of their atomic numbers.

II. Non-metallic elements are less in number than metallic elements.

Which is correct statement(s)?

(a) Only I (b) Only II

(c) Both I and II (d) Neither I nor II

9 An element *X* which occurs in the first short period has an outer electronic structure, s^2p^1. What are the formula and acid-base character of its oxides?

(a) XO_3, basic (b) X_2O_3, basic

(c) X_2O_3, amphoteric (d) XO_2, acidic

10 Which one of the following order represents the correct sequence of the increasing basic nature of the given oxides?

(a) $Al_2O_3 < MgO < Na_2O < K_2O$

(b) $MgO < K_2O < Al_2O_3 < Na_2O$

(c) $Na_2O < K_2O < MgO < Al_2O_3$

(d) $K_2O < Na_2O < Al_2O_3 < MgO$

Answers

1. (d) **2.** (d) **3.** (a) **4.** (a) **5.** (d) **6.** (a) **7.** (b) **8.** (c) **9.** (c) **10.** (a)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 113.

CHAPTER

6

Study of First Element–Hydrogen

Hydrogen is the lightest element known to us, it is thus placed at the first position in the periodic table. The atomic number of hydrogen is one (1) and it is the only element, which occurs without a neutron in its nucleus. It is represented by the symbol H.

Chapter Objectives

- Discovery
- Occurrence
- Isotopes of Hydrogen
- Position of Hydrogen in the Periodic Table
- General Methods of Preparation of Hydrogen Gas
- Laboratory Preparation of Hydrogen Gas
- Industrial Preparation of Hydrogen Gas By Bosch Process
- Tests for Hydrogen
- Uses of Hydrogen Gas

Discovery

Hydrogen was discovered by **Henry Cavendish** in 1766 by the action of acid on metal. The name hydrogen was given by **Antoine Lavoisier**, which means water producer (Greek word: *Hydro-* water, *gen-*to produce).

Occurrence

In nature, hydrogen occurs in free as well as in combined state. In elemental form, it exists as a diatomic (H_2) molecule and forms 90% of sun's atmosphere.

Combined State Most of the hydrogen on earth occurs in combined state as in water, living masses, fossil fuels and many organic and inorganic compounds. In water, hydrogen is 11.1% by weight.

Isotopes of Hydrogen

Hydrogen is known to exist in three isotopes, which are listed below in the table

Isotopes	**Protium** ($^{1}_{1}H$)	**Deuterium** ($^{2}_{1}D$ or $^{2}_{1}H$)	**Tritium** ($^{3}_{1}T$ or $^{3}_{1}H$)
Atomic number	1	1	1
Mass number	1	2	3
Number of electrons	1	1	1
Number of protons	1	1	1
Number of neutrons	0	1	2
Natural abundance (%)	99.98	0.01	Traces

Note Heavy water (D_2O) consist of deuterium. Tritium $^{3}_{1}H$ is known to be radioactive.

Position of Hydrogen in the Periodic Table

Hydrogen resembles with alkali metals (Group 1) and halogens (Group 7). It also differs from them as well. Thus, it is unique in behaviour and is, therefore best placed separately in the periodic table.

1. Resemblance with Alkali Metals

Hydrogen resembles with alkali metals in the following ways

(i) **Electronic Configuration** The electronic configuration of hydrogen ($1s^1$) is same as the outer electronic configuration of alkali metals, which is ns^1.

Hydrogen, H $1s^1$

Lithium, Li $1s^2, 2s^1$

Sodium, Na $1s^2, 2s^2, 2p^6, 3s^1$

(ii) **Electropositive Nature (Ion Formation)** Just like alkali metals, hydrogen readily loses its one electron to form unipositive hydrogen ion *i.e.*, H^+ which is also called proton. It shows that it is an electropositive element.

$$H \longrightarrow H^+ + e^-, \qquad Na \longrightarrow Na^+ + e^-$$

(iii) **Valency and Oxidation State** Hydrogen exhibits +1 oxidation state in most of its compounds just like alkali metals. Both alkali metal and hydrogen have one valence electron.

(iv) **Burning** Hydrogen burns in oxygen with a pop sound to form neutral oxide (water).

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Alkali metals also burn vigorously when heated in oxygen to form their respective oxides.

$$4Li + O_2 \longrightarrow 2Li_2O$$

2. Resemblance with Halogens

Hydrogen resembles with halogens in the following ways

(i) **Electronic Configuration** Like halogens, hydrogen requires only one electron to achieve the nearest inert or noble gas configuration. *e.g.*,

- H ($1s^1$) have one electron less than He ($1s^2$).
- F ($1s^2, 2s^2, 2p^5$) have one electron less than Ne ($1s^2, 2s^2, 2p^6$).

(ii) **Electronegative Character (Ion Formation)** Like halogens, hydrogen also have a tendency to accept one electron to form uninegative, hydride ion (H^-).

$$H + e^- \longrightarrow H^-, \quad Cl + e^- \longrightarrow Cl^-$$

(iii) **Valency** Both halogen and hydrogen have valency 1. They both can accept one electron to attain the nearest noble gas configuration.

(iv) **Atomicity and Non-metallic Character** Hydrogen exists as a diatomic molecule (H_2) like halogens (F_2, Cl_2, Br_2 and I_2). Further, it is a non-metal like halogens.

(v) **Physical State** Like halogens, hydrogen is a gas at room temperature.

As we have studied that hydrogen resembles with both the alkali metal and the halogen group. This leads to confusion about the placing of it in the periodic table.

But considering its electronic configuration and fact that it has 1 valence electron like alkali metals, it has been placed in the group I of the periodic table.

CHECK POINT 01

1 Write the name of scientist, who discovered hydrogen.
2 Which isotope of hydrogen is radioactive?
3 Write the name of that isotope of hydrogen, which has no neutron.
4 In which form hydrogen molecule exist?
5 Why hydrogen has been placed in the group 1 of the periodic table?

General Methods of Preparation of Hydrogen Gas

Some of the methods for the preparation of hydrogen gas are as follows

1. Preparation of Hydrogen from Water

Action of metals on water in different states or at different temperature produces hydrogen gas.

The reactions of different metals, in different conditions with water are as follow

(i) Action of Active Metals with Cold Water

Active metals like sodium, potassium and calcium being highly reactive, react with cold water producing bases (hydroxides of metals) and releasing hydrogen gas.

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2 \uparrow$$

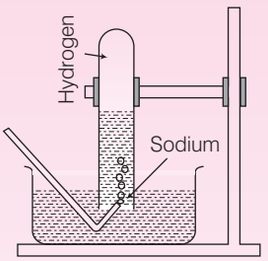
$$2K + 2H_2O \longrightarrow 2KOH + H_2 \uparrow$$

$$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2 \uparrow$$

The above reactions are exothermic and the reactions of sodium and potassium is violent and may result in explosion.

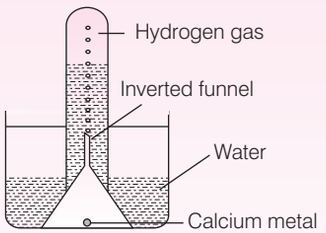
Action of Sodium and Calcium on Water in Laboratory

(i) The action of sodium on water is shown below. Bubbles of hydrogen gas are produced and the solution formed is colourless, soapy, slightly warm and alkaline.



Action of sodium on water

(ii) The action of calcium on water is shown below. Bubbles of hydrogen are liberated and the solution turns milky, turbid and alkaline. If red litmus is introduced in solution, it turns blue.



Action of calcium on water

(ii) Action of Magnesium on Hot Water

Magnesium react with hot water slowly to produce metal hydroxides and evolving hydrogen gas.

$$Mg + 2H_2O \xrightarrow{\Delta} Mg(OH)_2 + H_2 \uparrow$$

(iii) Action of Metals on Steam

Metals like magnesium, aluminium, iron and zinc react with steam to form oxides of metals and evolve hydrogen gas.

$$Mg + H_2O(g) \xrightarrow{\Delta} MgO + H_2 \uparrow$$

$$2Al + 3H_2O(g) \xrightarrow{800°C} Al_2O_3 + 3H_2 \uparrow$$

$$3Fe + 4H_2O(g) \rightleftharpoons Fe_3O_4 + 4H_2 \uparrow$$

The reaction between iron and water is irreversible. If the hydrogen formed is not removed, the iron oxide formed is reduced back to iron.

$$Zn + H_2O(g) \xrightarrow{\Delta} ZnO + H_2 \uparrow$$

(iv) Action of Steam on Non-metals

When steam is passed over red hot coke, water gas ($CO + H_2$) is formed.

$$C + H_2O \longrightarrow \underbrace{CO + H_2}_{\text{Water gas}}$$

Application of Activity Series in the Preparation of Hydrogen

In activity series, metals are arranged in decreasing order of reactivity.

Reactivity series of metals with respect to hydrogen is given below

K	–	Potassium	Highly reactive
Na	–	Sodium	↑
Ca	–	Calcium	↑
Mg	–	Magnesium	↑
Al	–	Aluminium	↑
Zn	–	Zinc	↑
Fe	–	Iron	↑
Sn	–	Tin	↑
Pb	–	Lead	↑
H	–	Hydrogen	↑
Cu	–	Copper	↑
Hg	–	Mercury	↑
Ag	–	Silver	↑
Pt	–	Platinum	↑
Au	–	Gold	Less reactive

Metal present on the top of the series are active metals. The ability of metals to reduce water to hydrogen decreases on going down the series.

$$K > Na > Ca > Mg > Al > Zn \ldots\ldots$$

2. Displacement of Hydrogen from Acids

Few metals which are more active than hydrogen in activity series (or reactivity series) displace hydrogen from acids. Metals such as Zn, Fe, Al and Mg (above hydrogen in the activity series) react with dil. H_2SO_4 or HCl at room temperature liberating hydrogen and forming their respective salts.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2 \uparrow$$

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2 \uparrow$$

$$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2 \uparrow$$

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2 \uparrow$$

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2 \uparrow$$

$$Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2 \uparrow$$

$$2Al + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 3H_2$$

While metals which are less reactive than hydrogen like copper and silver (below hydrogen in the activity series) has no effect on acid.

$$Cu + H_2SO_4 \longrightarrow \text{No reaction}$$

$$Cu + HCl \longrightarrow \text{No reaction}$$

Note

(i) Potassium, sodium and calcium react with dilute H_2SO_4 and dilute HCl but the reaction is explosive and thus not feasible.

$$2Na + 2HCl \longrightarrow 2NaCl + H_2\uparrow$$

$$2K + 2HCl \longrightarrow 2KCl + H_2\uparrow$$

$$Ca + 2HCl \longrightarrow CaCl_2 + H_2\uparrow$$

(ii) Nitric acid should not be used to form hydrogen because nitric acid reacts with only magnesium and manganese to liberate hydrogen. If it reacts with rest of the metals it produces oxides of nitrogen or ammonium nitrate and not hydrogen as it is an oxidising agent.

$$Mg + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2\uparrow$$

$$Mn + 2HNO_3 \longrightarrow Mn(NO_3)_2 + H_2\uparrow$$

3. Displacement of Hydrogen from Alkalies

Powdered form of active metals like aluminium, zinc and lead, when boiled with alkalies (like NaOH, KOH) evolve hydrogen gas.

$$2Al + 2NaOH + 2H_2O \longrightarrow \underset{\text{Sodium meta aluminate}}{2NaAlO_2} + 3H_2\uparrow$$

$$2Al + 2KOH + 2H_2O \longrightarrow \underset{\text{Potassium meta aluminate}}{2KAlO_2} + 3H_2\uparrow$$

$$Zn + 2NaOH \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2} + H_2\uparrow$$

$$Zn + 2KOH \longrightarrow \underset{\text{Potassium zincate}}{K_2ZnO_2} + H_2\uparrow$$

$$Pb + 2NaOH \longrightarrow \underset{\text{Sodium plumbate}}{Na_2PbO_2} + H_2\uparrow$$

Metals like zinc, lead and aluminium react with both acids and alkalies to produce hydrogen and salts. This is unique nature of these metals. Their oxides and hydroxides have both basic and acidic nature. Hence, react with both base and acid therefore, they are called **amphoteric oxides** or **hydroxides.**

CHECK POINT 02

1. Why copper cannot produce hydrogen gas from acids?
2. Write the name of two elements which are least reactive.
3. How is hydrogen obtained from dilute sulphuric acid?
4. Give one reaction to prepare dihydrogen from a substance other than water.
5. Define amphoteric oxides and give an example.

Laboratory Preparation of Hydrogen Gas

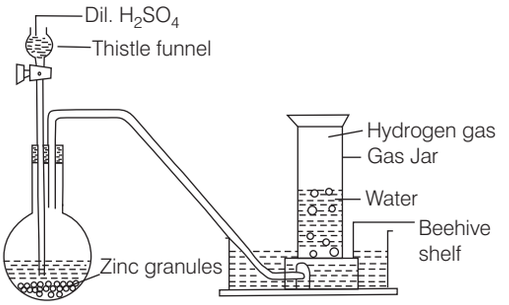
In laboratory, hydrogen is mainly prepared by treating zinc granules either with dilute sulphuric acid or with aqueous alkali (NaOH).

$$Zn + \underset{\text{Dilute}}{H_2SO_4} \longrightarrow ZnSO_4 + H_2\uparrow$$

Use of Zinc Zinc metal is preferred over other active metals as hydrogen gas produced slowly and hence, easy to collect in this case.

Procedure

Take few granules of zinc metal in a round bottom flask fixed with air tight cork having two holes. Through one hole pass a thistle funnel with a long stem which allow dil. H_2SO_4 to pass in round bottom flask, and through the other, a long delivery tube. The setup as shown below in the figure.



Laboratory preparation of hydrogen

Observation

A brisk effervescence is produced and hydrogen gas is collected. Wait until all the air from the setup is expelled and finally hydrogen gas is collected in the jar.

Collection of Hydrogen

Hydrogen is collected by **downward displacement of water** because

(i) it is virtually insoluble in water.

(ii) it forms an explosive mixture with air and hence, cannot be collected by downward displacement of air even though it is lighter than air.

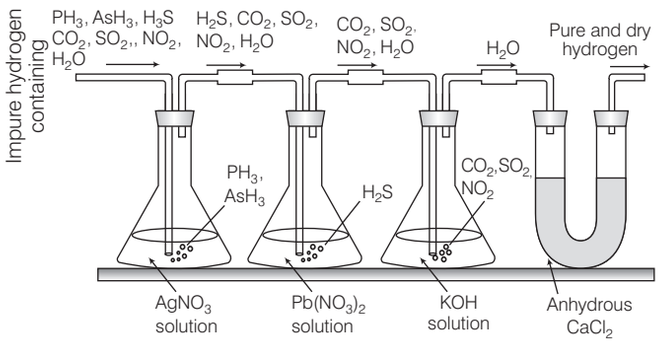
Impurities Present in Hydrogen Gas

Presence of impurities in the zinc granules (like As, P, S, C, etc) and air inside the setup results in the formation of many other gases as impurities. Main impurities usually found are phosphine (PH_3), arsine (AsH_3), hydrogen sulphide (H_2S), sulphur dioxide (SO_2), oxides of nitrogen, carbon dioxide (CO_2), water vapour (H_2O), etc.

Removal of Impurities

To remove the impurities, hydrogen gas is treated with following compounds or reagents

Reagents/Compounds	Impurities removed
Silver nitrate solution (*aq.* $AgNO_3$) *e.g.*, $AsH_3 + 6AgNO_3 \longrightarrow Ag_3As + 3AgNO_3 + 3HNO_3$ $PH_3 + 6AgNO_3 \longrightarrow Ag_3P + 3AgNO_3 + 3HNO_3$	PH_3, AsH_3
Lead nitrate solution (*aq.* $Pb(NO_3)_2$) *e.g.*, $Pb(NO_3)_2 + H_2S \longrightarrow PbS + 2HNO_3$	H_2S
Potassium hydroxide solution (*aq.* KOH) *e.g.*, $SO_2 + 2KOH \longrightarrow K_2SO_3 + H_2O$ $CO_2 + 2KOH \longrightarrow K_2CO_3 + H_2O$ $2NO_2 + 2KOH \longrightarrow KNO_2 + KNO_3 + H_2O$	SO_2, CO_2 and oxides of nitrogen
Anhydrous calcium chloride ($CaCl_2$) as a drying agent	Water vapour



Purification of hydrogen

Precautions

Following precautions must be taken while preparing the gas

(i) The apparatus used should be airtight, otherwise gas will leak from the set up.

(ii) Hydrogen gas being highly inflammable should be devoid of any flame or lighting object.

(iii) Make sure all the air has been escaped from the setup as the mixture of hydrogen gas and air is highly explosive.

(iv) The end of the thistle funnel must be dipped in sulphuric acid otherwise gas will also escape through the thistle funnel.

Industrial Preparation of Hydrogen Gas By Bosch Process

Various steps involved in this process are as follow

Production of Water Gas: Coal Gasification

On passing super-heated steam over red hot coke or coal at 1000° C in the presence of Ni as catalyst, a mixture of carbon monoxide (CO) and dihydrogen (H_2) is obtained.

$$C(s) + H_2O(g) \xrightarrow{1000°C} \underbrace{CO(g) + H_2(g)}_{\text{Water gas}}$$

This endothermic process of producing water gas from coke or coal is called **coal gasification**.

Reduction of Steam by Water Gas: Water Gas Shift Reaction

In order to remove CO and to increase the production of hydrogen from water gas, CO of the water gas is oxidised to CO_2 by mixing it with more steam at 673 K in the presence of iron chromate or ferric oxide and little chromium oxide (at 450°C) as catalyst.

$$\underbrace{CO(g) + H_2(g)}_{\text{Water gas}} + \underset{\text{Steam}}{H_2O(g)} \xrightarrow[\substack{FeCrO_4 \text{ or} \\ Fe_2O_3 + Cr_2O_3}]{450°\,C} CO_2(g) + 2H_2(g)$$

This exothermic chemical reaction in which carbon monoxide of the water gas reacts with steam to give carbon dioxide and more hydrogen gas is called water gas **shift reaction**.

Separation of Carbon Dioxide (CO_2) and Carbon Monoxide (CO)

(i) Carbon dioxide can be removed either by passing through cold water under high pressure or by reacting with KOH (alkali).

(ii) Carbon monoxide is removed by passing hydrogen gas into ammoniacal solution of cuprous chloride.

$$CO_2 + H_2O \xrightarrow{30\ atm} H_2CO_3$$

$$CuCl + CO + 2H_2O \longrightarrow CuCl \cdot CO \cdot 2H_2O$$

Thus, hydrogen gas is left behind.

Tests for Hydrogen

Following tests are used to detect the hydrogen gas

(a) Hydrogen gas burns with a pop sound.

(b) It burns in air with pale blue flame to form colourless liquid water, which turns anhydrous copper sulphate white to blue.

Uses of Hydrogen Gas

Some of the important applications of hydrogen gas are as follow

(i) It is used in the manufacture of ammonia (by Haber's process).

(ii) It is used for hardening of oil and in the synthesis of many important compounds like metallic hydrides, hydrogen chloride, methanol (an organic compound), etc.

$$\underset{\text{Carbon monoxide}}{CO(g)} + \underset{\text{Dihydrogen}}{2H_2(g)} \xrightarrow[\text{Catalyst}]{\text{Cobalt}} \underset{\text{Methanol}}{CH_3OH(l)}$$

(iii) It is used in oxy-hydrogen and oxy-atomic hydrogen torches for cutting and welding.

Oxidation and Reduction Reactions

The process of oxidation and reduction; and the various oxidation and reduction reactions are as follows

Oxidation

Oxidation is defined as a chemical process which involves either the addition of oxygen or electronegative element to the substance or removal of hydrogen or electropositive element from the substance.

(i) **Addition of Oxygen**

$$2Mg + O_2 \longrightarrow 2MgO$$
$$2CO + O_2 \longrightarrow 2CO_2$$

(ii) **Addition of Electronegative Element**

$$2FeCl_2 + Cl_2 \longrightarrow 2FeCl_3$$

(iii) **Removal of Hydrogen**

$$H_2S + Cl_2 \longrightarrow 2HCl + S$$

(iv) **Removal of Electropositive Element**

$$2KI + H_2O_2 \longrightarrow 2KOH + I_2$$

Note If a substance gains oxygen or loses hydrogen during reaction, it is oxidised.

Oxidising Agents Those substances that brings oxidation in a chemical process is known as oxidising agents. They itself gets reduced.

Reduction

Reduction is defined as a chemical process which involves either the addition of hydrogen or electropositive element to the substance or removal of oxygen or electronegative element from the substance.

(i) **Addition of Hydrogen**

$$2Na + H_2 \longrightarrow 2NaH$$

(ii) **Addition of Electropositive Element**

$$2HgCl_2 + SnCl_2 \longrightarrow Hg_2Cl_2 + SnCl_4$$

(iii) **Removal of Oxygen**

$$2KClO_3(s) \xrightarrow{\Delta} 2KCl(s) + 3O_2(g)$$

(iv) **Removal of Electronegative Element**

$$2FeCl_3 + H_2S \longrightarrow 2FeCl_2 + 2HCl + S$$

Note If a substance loses oxygen or gains hydrogen during a reaction, it is reduced.

Reducing Agents Those substances that brings reduction in a chemical process is known as reducing agents. They itself gets oxidised.

Redox Reactions

Those reactions in which oxidation and reduction take place simultaneously, are called redox reactions.

e.g., In the following reaction, the copper (II) oxide is losing oxygen and is being reduced. Whereas oxygen is added to hydrogen and is being oxidised.

$$\overset{\text{Reduction}}{\overbrace{CuO + H_2 \xrightarrow{\Delta} Cu + H_2O}}$$
$$\underset{\text{Oxidation}}{\underbrace{\phantom{CuO + H_2 \xrightarrow{\Delta} Cu + H_2O}}}$$

CHECK POINT 03

1. Give the laboratory preparation of hydrogen gas.
2. Name the constituents of water gas.
3. Write the reaction to prepare hydrogen using Bosch process.
4. Write the use of oxy-hydrogen torch.
5. Identify the substance that are oxidised and substance that are reduced in the following reactions.
   (i) $4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$
   (ii) $CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$

SUMMARY

- Hydrogen is the lightest element and placed separately due to its resemblance with elements of group 1 and 17.
- It was discovered by Henry Cavendish in 1766.
- Hydrogen occurs in free state (minerals, rocks, sun and many other stars) as well in combined state (water, living masses and fossil fuels).
- Hydrogen is the only element which does not have neutrons in its nucleus. It exists in three isotopes such as protium ($_1H^1$), deuterium ($_1H^2$ or D) and tritium ($_1H^3$ or T).
- General methods of preparation of hydrogen gas
  (i) Reaction with water

$$2Na + 2H_2O\,(\text{cold water}) \longrightarrow 2NaOH + H_2\uparrow$$

$$Mg + 2H_2O\,(\text{boiling water}) \xrightarrow{\Delta} Mg(OH)_2 + H_2\uparrow$$

$$Mg + H_2O(g, \text{steam}) \xrightarrow{\Delta} MgO + H_2\uparrow$$

  (ii) Reaction with acid
  There are few metals (such as Zn, Fe and Mg) which are more reactive than hydrogen in reactivity series and hence, displace hydrogen from acids.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\uparrow$$

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2\uparrow$$

  (iii) Reaction with alkalies

$$2Al + 2NaOH + 2H_2O \longrightarrow 2NaAlO_2 + 3H_2\uparrow$$

$$Zn + 2NaOH \longrightarrow Na_2ZnO_2 + H_2\uparrow$$

- Laboratory preparation of hydrogen gas
  Hydrogen is mainly prepared by treating zinc granules either with dilute sulphuric acid or with aqueous alkali (NaOH).

  Industrial preparation of hydrogen gas (Bosch process)

$$C(s, \text{red hot coke}) + H_2O(g) \xrightarrow{1000^\circ C} \underbrace{CO(g) + H_2(g)}_{\text{water gas}} + H_2O \xrightarrow[450^\circ C]{Fe_2O_3} CO_2(g) + 2H_2(g)$$

- Uses of hydrogen gas Hydrogen gas is used as/in
  (i) Haber's process (ii) hardening of oil (iii) reducing agent
  (iv) atomic hydrogen torch and oxy-hydrogen torch (v) rocket fuel in space research
- Oxidation It is defined as a chemical process which involves either the addition of oxygen to the substance or removal of hydrogen from the substance.
- Reduction It is defined as a chemical process which involves either the addition of hydrogen to the substance or removal of oxygen from the substance.

EXAM PRACTICE

Fill in the Blanks

1. Hydrogen literally means ..... producer.

Sol. water

2. Heavy water is made up of ..... isotope of hydrogen.

Sol. deuterium

3. Hydrogen is placed in same group as the ..... metals.

Sol. alkali

4. ..... is the least reactive metal.

Sol. Gold

5. Zinc metal form oxides having both acidic and ..... nature.

Sol. basic

6. Water gas is a mixture of ..... and hydrogen.

Sol. carbon monoxide

7. $CuCl + CO + 2H_2O \longrightarrow$ ..... .

Sol. $CuCl \cdot CO{\cdot}2H_2O$

8. Carbon dioxide present as impurities in hydrogen gas is removed using ..... solution.

Sol. *aq*. KOH

9. Hydrogen alongwith ..... is used in flame for welding metals.

Sol. oxygen

10. Hydrogen in ..... state along with oxygen is used as rocket fuel.

Sol. liquid

Multiple Choice Questions

11. Which of the following isotopes make heavy water?

(a) ${}_1^1H$ (b) ${}_1^2H$

(c) ${}_1^3H$ (d) Both (b) and (c)

Sol. (b)

12. Which of the following metal oxide would reduced by hydrogen?

(a) MgO (b) Na_2O (c) CuO (d) CaO

Sol. (c)

13. Which of the following would displace hydrogen from acid?

(a) Copper (b) Mercury

(c) Platinum (d) None of these

Sol. (d)

14. Water upon reaction with sodium metal produce

(a) acidic solution

(b) basic solution

(c) amphoteric solution

(d) neutral solution

Sol. (b)

15. Zinc metal reacts with sulphuric acid

(a) explosively (b) fast

(c) slowly (d) does not react

Sol. (c)

16. Carbon dioxide, in Bosch process is separated as

(a) $CaCO_3$ (b) $NaHCO_3$

(c) Na_2CO_3 (d) H_2CO_3

Sol. (d)

17. Hydrogen is collected through

(a) air displacement method

(b) water displacement method

(c) Both (a) and (b)

(d) Neither (a) nor (b)

Sol. (b)

18. Solubility of hydrogen in water is

(a) very low

(b) moderate

(c) high

(d) cannot be determined

Sol. (a)

19. Which of the statement about the reaction below is incorrect?

$$2PbO(s) + C(s) \longrightarrow 2Pb(s) + CO_2(g)$$

(a) Lead is getting reduced

(b) Carbon is getting oxidised

(c) Lead oxide is getting reduced

(d) Cannot be predicted

Sol. (a)

Match the Following

20. Match the following columns.

	Column I		Column II
(i)	An isotope of hydrogen	(a)	Aluminium
(ii)	Less reactive metal than hydrogen	(b)	Potassium
(iii)	Form amphoteric oxides	(c)	Tritium
(iv)	Form alkali	(d)	Platinum

Sol. (i) → (c), (ii) → (d), (iii) → (a), (iv) → (b)

21. Match the following columns.

	Column I		Column II
(i)	Aluminium	(a)	does not displace hydrogen
(ii)	Copper	(b)	used in laboratory preparation of hydrogen
(iii)	Potassium	(c)	form amphoteric oxide
(iv)	Zinc	(d)	most reactive metal
(v)	Tritium	(e)	radioactive in nature

Sol. (i) → (c), (ii) → (a), (iii) → (d), (iv) → (b), (v) → (e)

a 1 Mark Questions

22. Name an isotope of hydrogen which
(i) has same number of proton and neutron
(ii) is most abundant on earth

Sol. (i) Deuterium (^2_1D or ^2_1H)
(ii) Protium (^1_1H) – 99.98%.

23. What happens when steam is passed over red hot coke?

Sol. When steam is passed over red hot coke then water gas ($CO + H_2$) is formed.

$$C + H_2O \xrightarrow{1270K} \underbrace{CO + H_2}_{\text{Water gas}}$$

24. Name two metals, which can displace hydrogen from acid as well as alkali.

Sol. Aluminium and zinc.

25. Define redox reaction.

Sol. Refer to text on page 87.

b 2 Marks Questions

26. Write the chemical reactions showing amphoteric nature of zinc.

Sol. Zinc reacts with both acid and base hence shows its amphoteric nature.

Reaction with Acid

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2\uparrow$$ *[1]*

Reaction with Base

$$Zn + 2NaOH \longrightarrow Na_2ZnO_2 + H_2\uparrow$$ *[1]*

27. Complete the following reactions.
(i) $CuO(s) + H_2(g) \longrightarrow$
(ii) $CH_4(g) + H_2O(g) \longrightarrow$

Sol. (i) $CuO(s) + H_2(g) \longrightarrow H_2O(g) + Cu(s)$ *[1]*

(ii) $CH_4(g) + H_2O(g) \xrightarrow[Ni]{1270\ K} CO(g) + 3H_2(g)$ *[1]*

28. How can production of hydrogen from water gas be increased by using water gas shift reaction?

Or

How can the production of hydrogen, obtained from coal gasification, be increased?

Sol. In order to remove CO and to increase the production of hydrogen from water gas, CO of the water gas is oxidised to CO_2 by mixing it with more steam at 673 K in the presence of iron chromate or ferric oxide and little chromium oxide (at 450°C) as catalyst.

$$\underbrace{CO(g) + H_2(g)}_{\text{Water gas}} + \underset{\text{Steam}}{H_2O(g)} \xrightarrow[\substack{FeCrO_4 \text{ or} \\ Fe_2O_3 + Cr_2O_3}]{450°C} CO_2(g) + 2H_2(g)$$ *[2]*

29. How does the atomic hydrogen or oxy-hydrogen torch function for cutting and welding purposes? Explain.

Sol. Atomic hydrogen atoms, produced by dissociation of hydrogen with the help of an electric arc, are allowed to recombine on the surface to be welded. In this process, a large amount of energy is liberated, which is used to generate a temperature of 4000 K for cutting and welding purpose in the form of atomic hydrogen or oxy-hydrogen torches. **[2]**

30. Give an example each of oxidation and reduction reaction on the basis of electronegative and electropositive element.

Sol. **Oxidation**

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$
(addition of electronegative element)

$$2K + H_2O_2 \longrightarrow 2KOH + I_2$$
(removal of electropositive element) *[1]*

Reduction

$2HgCl_2 + SnCl_2 \longrightarrow Hg_2Cl_2 + SnCl_4$

(Addition of electropositive element)

$2FeCl_3 + H_2S \longrightarrow 2FeCl_2 + 2HCl + S$

(removal of electronegative element) *[1]*

C 3 Marks Questions

31. Justify the position of hydrogen in the periodic table on the basis of its electronic configuration.

Sol. *The electronic configuration of hydrogen can be compared as follows*

(i) The electronic configuration of hydrogen ($1s^1$) is similar to the outer electronic configuration of alkali metals, which is ns^1.

	K	L	M
Hydrogen (H) : $1s^1$	1		
Lithium (Li) : $1s^2, 2s^1$	2,	1	
Sodium (Na) : $1s^2, 2s^2, 2p^6, 3s^1$	2,	8,	1

[1]

(ii) Like halogens, hydrogen requires only one electron to achieve the nearest inert or noble gas configuration. *e.g.*,

$H(^{K}_{1})$ has one electron less than $He(^{K}_{2})$

$F(^{K\ L}_{2\ 7})$ has one electron less than $Ne(^{K\ L}_{2\ 8})$

$Cl(^{K\ L\ M}_{2\ 8\ 7})$ has one electron less than $Ar\ (^{K\ L\ M}_{2\ 8\ 8})$ *[1]*

As we can see hydrogen resembles with both the alkali metal group and the halogen group.

This arises confusion about the placing of it in the periodic table. But considering its electronic configuration and fact that it has one valence electron like alkali metals it has been placed in the group-I of the periodic table. *[1]*

32. Why is it safe to store acid in a copper container but not to store in an iron container?

Sol. Iron lies above hydrogen in the activity series, hence, it displaces hydrogen from an acid when the acid is kept in an iron container.

$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2\uparrow$

In this process iron corrodes and hence, wall of container deplete. *[1½]*

On the other side, copper is less reactive than hydrogen, hence it cannot react with acid to displace hydrogen.

And thus, the copper container remains harmless.

$Cu + H_2SO_4 \longrightarrow$ No reaction *[1½]*

33. How is hydrogen obtained from

(i) dilute sulphuric acid

(ii) sodium hydroxide

(iii) water?

Give one equation in each case.

Sol. (i) When metal reacts with dilute sulphuric acid, hydrogen is obtained along with metal salts.

$Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$ *[1]*

(ii) When zinc reacts with sodium hydroxide, sodium zincate is formed and hydrogen gas is evolved.

$Zn(s) + 2NaOH(aq) \longrightarrow Na_2ZnO_2(aq) + H_2(g)$ *[1]*

(iii) When acidified water is electrolysed using platinum electrodes, hydrogen gas is evolved at cathode.

$H_2O \longrightarrow H^+(aq) + OH^-(aq)$

At cathode $2H^+ + 2e^- \longrightarrow 2H \longrightarrow H_2$

At anode $OH^-(aq) \longrightarrow OH + e^-$

$4OH + 4e^- \longrightarrow 2H_2O + O_2$ *[1]*

34. (a) Describe the industrial applications of hydrogen dependent on the heat liberated when its atoms are made to combine on the surface of a metal.

(b) Give the difference between oxidation and reduction with examples.

Sol. (a) Due to this property hydrogen is used in atomic hydrogen torch for welding/cutting. *[1]*

(b) Oxidation is defined as a chemical process which involves either the addition of oxygen to the substance or loss of hydrogen from the substance.

e.g.,

(i) $\overset{\text{Oxidation}}{\overbrace{H_2S}} + Cl_2 \longrightarrow 2HCl + S$

(ii) $\overset{\text{Oxidation}}{\overbrace{2Cu}} + O_2 \longrightarrow 2CuO$ *[1]*

Reduction is defined as a chemical process which involves either the addition of hydrogen to the substance or loss of oxygen from the substance.

e.g., $\overset{\text{Reduction}}{\overbrace{2Na}} + H_2 \longrightarrow 2NaH$

$\overset{\text{Reduction}}{\overbrace{ZnO}} + H_2 \longrightarrow Zn + H_2O$ *[1]*

d 4 Marks Questions

35. (i) (a) How would you prepare dihydrogen from water by using a reducing agent?

(b) How would you prepare dihydrogen from a substance other than water?

(ii) Write the names of isotopes of hydrogen. What is the mass ratio of these isotopes?

Sol. (i) (a) Sodium metal is a good reducing agent.

It reduces water to hydrogen (or dihydrogen).

$$2H_2O + 2Na \longrightarrow 2NaOH + H_2(g)$$ *[1]*

(b) Dihydrogen can be obtained by treating zinc with dilute HCl.

$$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$ **[1]**

(ii) Protium ^1_1H, deuterium ^2_1H or D, tritium ^3_1H or T.

The mass ratio of protium: deuterium : tritium = 1 : 2 : 3. *[2]*

36. (i) Complete the following reactions:

(a) $H_2(g) + Al_2O_3(s) \xrightarrow{\Delta}$

(b) $C(s) + H_2O(g) \xrightarrow[\text{Catalyst}]{\Delta}$

(c) $Zn(s) + NaOH(aq) \xrightarrow{\text{Heat}}$

(ii) What do you understand by the term 'water gas'?

Sol. (i) (a) $3H_2(g) + Al_2O_3(s) \xrightarrow{\Delta} 2Al(s) + 3H_2O(l)$ *[1]*

(b) $C(s) + H_2O(g) \xrightarrow{\text{Ni, 1270 K}} CO(g) + H_2(g)$ *[1]*

(c) $Zn(s) + 2NaOH(aq) \xrightarrow{\text{Heat}} \underset{\text{Sodium zincate}}{Na_2ZnO_2(aq)} + H_2(g)$ *[1]*

(ii) **Water gas** Mixture of CO and H_2 is known as synthesis gas or water gas. Reaction of steam on hydrocarbons or coke at high temperatures in the presence of catalyst yields water gas. *e.g.,*

$$CH_4(g) + H_2O(g) \xrightarrow[\text{Ni}]{1270\ K} CO(g) + 3H_2(g)$$ *[1]*

e 5 Marks Question

37. When a neutral gas *A* which burns with popping sound is passed through boiling yellow non-metal *B'* it forms gas *C*.

(i) Identify *A, B* and *C*.

(ii) Give balanced chemical equation for the reaction.

(iii) Give the characteristic odour of gas *C*.

(iv) Give equation for the preparation of water gas.

(v) Write a balanced chemical equations for the reaction of hydrogen with oxygen.

Sol. (i) *A* = Hydrogen

B = Sulphur

C = Hydrogen sulphide *[1]*

(ii) $\underset{\text{'}A\text{'}}{H_2} + \underset{\text{Boiling 'B'}}{S} \longrightarrow \underset{\text{'}C\text{'}}{H_2S}$ *[1]*

(iii) Rotten egg smell *[1]*

(iv) $\underset{\text{Hot charcoal}}{C} + \underset{\text{Super heated steam}}{H_2O} \xrightarrow{170^\circ C} \underbrace{CO + H_2}_{\text{Equivolume mixture of CO and } H_2 \text{ (water gas)}}$ *[1]*

(v) $2H_2 + O_2 \longrightarrow 2H_2O$ *[1]*

CHAPTER EXERCISE

Fill in the Blanks

1. Both alkali metals and hydrogen act as ..... .
2. The reaction of calcium and water is ..... .
3. ..... metal lies below hydrogen but above mercury in the activity series.
4. Main products of water gas shift reaction are ..... and ..... .
5. Acidulated water has more ..... than pure (distilled) water.
6. The substance that brings oxidation in a chemical process and itself gets reduced is called ..... .

Multiple Choice Questions

7. The radioactive isotope of hydrogen has ...*I*..... neutron in the nucleus of its atom. Here, *I* refers to
   (a) 1 (b) 2 (c) 3 (d) 0
8. Which of the following differs in terms of valency as that of hydrogen?
   (a) Na (b) Mg (c) Cl (d) K
9. Which one of the following is least reactive?
   (a) Zinc (b) Iron (c) Copper (d) Tin
10. Which of the following is not amphoteric?
    (a) Mg (b) Pb (c) Al (d) Zn
11. Which of the following impurity is removed by $Pb(NO_3)_2$ solution?
    (a) PH_3 (b) AsH_3
    (c) SO_2 (d) H_2S
12. Hydrogen gas acts as
    (a) reducing agent (b) oxidising agent
    (c) Both (a) and (b) (d) Neither (a) nor (b)
13. Hydrogen gas, now a days, is not preferred to be used
    (a) as rocket fuel (b) in balloon
    (c) in oxyflame for welding (d) All of these

Match the Following

14. Match the following columns.

	Column I		Column II
(i)	Action of metals on cold water	(a)	Oxygen
(ii)	Action of metals on acids	(b)	Hydroxides of metals
(iii)	Electrolysis	(c)	Oxides of carbon
(iv)	Bosch process	(d)	Salts of metal

1 Mark Questions

15. Compare the electronic configurations of the three isotopes of hydrogen.
16. Name solutions used to separate PH_3 and SO_2 respectively from hydrogen gas prepared in laboratory.
17. Give at least one example each for reduction by hydrogen and hydrogen getting reduced.

2 Marks Questions

18. Give two properties in which hydrogen neither resembles with alkali metals nor with halogens.
19. Give four uses of hydrogen gas.

3 Marks Questions

20. Which of the following metals can be used for liberating hydrogen from dilute hydrochloric acid? Write reactions as well.
    (i) Zinc (ii) Copper (iii) Iron
    (iv) Silver (v) Magnesium
21. What do you understand by "water gas shift reaction"? Discuss its use in the preparation of hydrogen.
22. Write reactions for the preparation of hydrogen from
    (i) action of a reducing agent on an acid
    (ii) Bosch process (including reactions for separation)
23. Consider the following reactions.

$$MnO_2(s) + 4HCl \longrightarrow MnCl_2(aq) + Cl_2(g) + 2H_2O$$

    (i) Identify the oxidation and reduction reaction in the above equation.
    (ii) Give the term used for such reactions.

5 Marks Questions

24. Justify the position of hydrogen in the periodic table on the basis of similarity and dissimilarity with alkali metals and halogens.
25. (i) Describe the procedure to prepare and collect hydrogen gas in a laboratory, with suitable diagrams.
    (ii) Why Bosch process is preferred over laboratory method for industrial production of hydrogen?

CHALLENGERS*

1 Hydrogen resembles halogens in many respects for which several factors are responsible. Which one is most important in this respect?
(a) Its small size
(b) Its low negative electron gain enthalpy value
(c) Its tendency to lose an electron to form a cation
(d) Its tendency to gain a single electron in its valence shell to attain stable electronic configuration

2 H^+ ion always get associated with other atoms in molecules because
(a) loss of an electron from hydrogen atom results in a nucleus of very small size as compared to other atoms or ions. Due to small size it cannot exist free
(b) its reactivity is similar to halogens
(c) it resembles both alkali metals and halogens
(d) physical properties resembles with alkali metals

3 Radioactive elements emit α, β and γ-rays and are characterised by their half lives. The radioactive isotope of hydrogen is
(a) hydronium
(b) protium
(c) deuterium
(d) tritium

4 Consider the following statement(s) regarding the preparation of hydrogen gas:
I. Reaction of potassium with cold water.
II. Reaction of calcium with boiling water.
III. Reaction of aluminium with steam
IV. Reaction of iron with boiling water or steam
The incorrect statement is
(a) I and III
(b) Only II
(c) Only IV
(d) III and IV

5 Which of the following matching is correct?

	Reagents/Compounds	Impurities removed
(a)	Anhydrous $CaCl_2$	Impurities removed are PH_3, AsH_3
(b)	Aq·KOH solution	Water vapour
(c)	Aq·$Pb(NO_3)_2$ solution	H_2S
(d)	Aq·$AgNO_3$ solution	SO_2, CO_2

6 Hydroxides of metals are formed upon reaction of metals with
(i) cold water (ii) hot water
(iii) steam (iv) sulphuric acid
Choose the correct option(s) from the above.
(a) (i) and (ii) (b) (i), (ii) and (iii)
(c) (iii) and (iv) (d) (ii), (iii) and (iv)

7 Consider the following statements.
(i) The most common isotope of hydrogen is protium.
(ii) Water gas shift reaction is a multistep reaction.
(iii) D_2O has higher boiling point than H_2O.
Which of the above statements is/are true?
(a) (i) and (iii) (b) (ii) and (iii)
(c) (i) and (ii) (d) All of these

8 Which of the following reactions is an example of use of water gas in the synthesis of other compounds?
(a) $C_nH_{2n+2} + nH_2O(g) \xrightarrow{1270\ K} n\,CO + (2n+1)H_2$
(b) $CO(g) + 2H_2(g) \xrightarrow[\text{catalyst}]{\text{cobalt}} CH_3OH(l)$
(c) $CO(g) + H_2O(g) \xrightarrow[\text{catalyst}]{673\ K} CO_2(g) + H_2(g)$
(d) $CH_4(g) + H_2O(g) \xrightarrow[Ni]{1270\ K} CO(g) + H_2(g)$

Answers

1. (d) **2.** (a) **3.** (d) **4.** (b) **5.** (c) **6.** (a) **7.** (a) **8.** (b)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 113-114.

CHAPTER

7

Study of Gas Laws

Chapter Objectives

- Gaseous State
- Gas Laws
- Absolute Zero
- Absolute or Kelvin Scale of Temperature
- Ideal Gas

Matter generally exists in solid, liquid and gaseous states. In these states, the chemical composition and hence, the chemical properties of a substance remains the same but their rate to undergo a chemical reaction is different. The state of matter is decided by the net effect of intermolecular forces *i.e.,* forces present in between the particles, molecular interactions and thermal energy. These are the characteristic parameters which constitute the concept of kinetic molecular theory of gases.

Gaseous State

It is the simplest state of matter. Only eleven elements, out of the total 118 elements known until today, exist in gaseous state under normal conditions of temperature and pressure. These eleven elements are H, He, N, O, F, Ne, Cl, Ar, Kr, Xe and Rn.

Kinetic Molecular Theory of Gases

The molecular details about the gases can be visualised with the help of a theory, called the kinetic molecular theory of gases. This theory provides a microscopic model of gases to explain their behaviour.

The main assumptions of this theory are as follows

(i) **Composition of Gases** Gases are aggregation of large number of identical tiny particles
(*i.e.,* atoms or molecules), which are so far apart that their combined volume is almost negligible as compared to empty space present between them.

(ii) **Gases are Highly Expandable** The intermolecular forces of attraction between the particles of a gas at ordinary temperature and pressure are negligible. That's why, gases expand and occupy all the available space. Thus, gases do not have definite volume.

(iii) **Gases have no Definite Shape** Particles of the gases are always in a state of constant and random motion. That's why, shape of gases is not definite.

(iv) **Gases Exert Same Pressure in all Directions** The particles of the gas move in all possible directions in straight lines and collide with each other and also with the walls of the container. Thus, they exert same pressure on the walls of the container.

(v) **Gases are Highly Compressible** There are large intermolecular (interparticle) space between gas molecules. On applying the pressure, the intermolecular space between the molecules is very much decreased. Thus, the gases are highly compressible.

(vi) **Gases have Low Density** Gases have large intermolecular space between their molecules, so that the number of molecules per unit volume in a gas is very small. Thus, gases have very low density.

(vii) **Gases show Diffusion** Diffusion is the process in which gradual mixing of two substances occurs. When two gases are brought in contact with each other, their molecules move into intermolecular space of each other forming homogeneous mixture.

(viii) **Gases can be Liquefied** Upon cooling and applying pressure on a cooled gas, the intermolecular space gets reduced and there is an increase in the molecules per unit volume occurs. Thus, the gas liquefies.

(ix) **Average KE of Gases Depends upon Absolute Temperature** Because of their different speeds, the kinetic energy of gas particles is called the **average kinetic energy** (*E*) and is directly proportional to the absolute temperature (*T*).

Measurable Properties of Gases

The physical behaviour of gases can be explained on the basis of four measurable variables called standard variables. *These variables are as follows*

1. Mass

Gases have definite masses. It can be expressed in grams or moles.

$$\text{Number of moles of a gas} = \frac{\text{Mass of the gas in grams}}{\text{Molecular mass of the gas}}$$

2. Volume

It is measurable space occupied by a gas. The space occupied by a gas is equal to volume of its container.

It can be expressed in mL or cc and dm^3 or L

1 L = 1000 cc = 1000 mL

1 mL (millilitre) = $1\,cm^3$ or cc (cubic centimetre)

1 L or l (litre) = $1\,dm^3$ (cubic decimetre)

3. Temperature

It is defined as the degree of hotness or coldness. Several scales are used to measure temperature, common three scales are °C (degree Celsius), K (Kelvin) and °F (degree Fahrenheit).

4. Pressure

Force exerted by the gas per unit area on the walls of the container is called pressure. It can be expressed in mm of Hg, cm of Hg, Atmosphere or kPa.

1 atmosphere (atm) = 76 cm of Hg

= 760 mm of Hg

= 760 torr of Hg = 101.325 kPa

Molecular Motion : Relationship with Temperature, Pressure and Volume

According to the kinetic molecular theory of gases, molecules of gases are in constant random motion and thus, they possess kinetic energy.

The effect of temperature, pressure and volume on molecular motion of particle is as follows

1. Temperature

The average kinetic energy of a particle (molecule) is directly proportional to the absolute temperature. In other words, molecular motion of a particle increases with increase in temperature and decreases with decrease in temperature.

2. Pressure

A gas enclosed in a vessel, exerts uniform pressure on the walls of the vessel. This is because inside the vessel large number of particles of gas collide with the walls and hence an appreciable force acts on the walls. The force exerted on a unit area of the wall of the vessel is equal to the pressure of the gas *i.e.*,

Pressure = Force per unit area

3. Volume

On increasing the temperature of a gas, the force exerted on the walls of the vessel also increases, which causes the increase in the pressure exerted by the gas.

If one of the walls of the vessel is flexible, then the gas expands, which also causes increase in volume with the increase in molecular motion.

Standard Temperature and Pressure

Changes in volume of a gas with respective change in the temperature and pressure take place thus, it becomes necessary to choose standard values of temperature and pressure. The abbreviation of standard temperature and standard pressure is STP, whereas for normal temperature and normal pressure it is NTP.

Standard or normal temperature = 0°C = 273 K

Standard or normal pressure = 760 mm of Hg

= 76 cm of Hg = 1 atm

Significance

For comparing the masses or densities of the gases their temperatures and pressures are taken at STP or NTP. This is due to the volume of a given mass of a gas depends upon pressure as well as temperature. At STP, one mole of any gas occupies 22.4 L (22400 mL) of volume. This is called molar volume of a gas at STP.

CHECK POINT 01

1. According to kinetic theory of gaseous state, "there is no force of attraction between the molecules of a gas". Then, how does a gas liquefy?
2. What are the measurable properties of gases?
3. How is molecular motion related with pressure?
4. What is the importance of standard temperature and standard pressure?
5. What is the molar volume of a gas at STP condition?

Gas Laws

Gas laws are actually the relationships between measurable properties of gases. These relationships are of great importance as they describe the state of the gas and give quantitative relationships between any two variables when others are kept constant.

Boyle's Law (Pressure-Volume Relationship)

This law was given by Robert Boyle in 1662 which states that at constant temperature, the pressure of a fixed amount (*i.e.*, number of moles, n) of a gas varies inversely with its volume.

Mathematical Expression of Boyle's Law

Suppose a gas occupies volume V at temperature T and pressure p, then

$$p \propto 1/V \quad \text{or} \quad p = k_1 (1/V)$$

Here, k_1 = proportionality constant, value of which depends upon the amount of the gas, temperature of the gas and units of pressure and volume.

Another form of the expression is $pV = k_1$.

Thus, the law can also be given as, at constant temperature, the product of pressure and volume of a fixed amount of a gas is constant. Let V_1 be the volume of a given mass of gas at pressure p_1 and at a given temperature T. When the pressure is changed to p_2 at the same temperature, let the volume becomes V_2 then, according to Boyle's law,

$$p_1 V_1 = k \qquad \text{...(i)}$$

$$p_2 V_2 = k \qquad \text{...(ii)}$$

From Eqs. (i) and (ii), we get,

$$p_1 V_1 = p_2 V_2 = \text{constant (at constant temperature)}$$

or

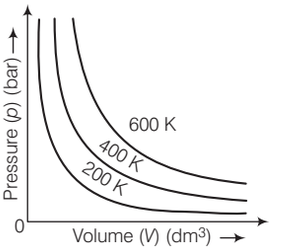
$$\boxed{\frac{p_1}{p_2} = \frac{V_2}{V_1}}$$

Graphical Representation of Boyle's Law

There are following conventional ways to show Boyle's law graphically

1. Pressure *versus* Volume Graph

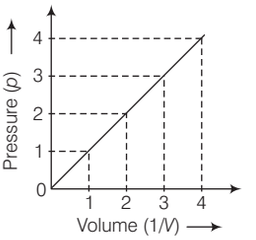
When volume of a given mass of a gas is plotted against pressure at different constant temperatures, the equilateral hyperbola is obtained for each temperature as shown in figure.



Graph of pressure, *p versus* volume, *V* of a gas at different constant temperatures

2. Pressure *versus* 1/Volume Graph

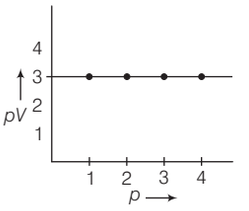
On plotting reciprocal of volumes of a fixed mass of a gas against pressure, we get straight line passing through the origin as shown in figure.



Graph of pressure *p versus* 1/*V* at constant temperature

3. *pV versus p* Graph

When the product of pressure and volume (*i.e.*, pV) is plotted against pressure, at different fixed temperatures, the straight line parallel to pressure axis (X-axis) is obtained as shown in figure.



Graph of *pV versus p* at constant temperature

Explanation of Boyle's Law Based upon Kinetic Molecular Theory of Gases

It has been observed that, if the volume of the gas is reduced to one-half at constant temperature, the number of molecules striking per unit area of the walls of the vessel become doubled, thus, pressure is doubled *i.e.*, it becomes 2 *p*. The reverse process also happens when volume is doubled.

Importance of Boyle's Law

It correlates pressure and volume and thus, proves that the gases are compressible. As we know,

$$\text{pressure} \propto \frac{1}{\text{volume}}$$

$$\text{Density} \propto \text{Pressure} \qquad \text{(at constant temperature)}$$

Note At high altitudes, the atmospheric pressure is low thus, air is less denser this result in less avilability of oxygen for breathing. Therefore, a mountaineer has to carry oxygen cylinders with them.

Example 1. A gas occupies 1500 cm^3 at pressure of 720 mm of Hg. Find the pressure at which its volume will be 1000 cm^3. Assume that temperature remains constant.

Sol. Initial pressure, $p_1 = 720$ mm of Hg

Initial volume , $V_1 = 1500\,cm^3$

Final volume, $V_2 = 1000\,cm^3$

Final pressure, $p_2 = ?$

According to Boyle's law, $p_1V_1 = p_2V_2$

$$720 \times 1500 = p_2 \times 1000$$

$$\Rightarrow \quad p_2 = \frac{720 \times 1500}{1000} = 1080 \text{ mm of Hg}$$

Example 2. A gas occupies a volume of 250 mL at 745 mm Hg and 25°C. What additional pressure is required to reduce the gas volume to 200 mL at the same temperature?

Sol. Given, initial volume, $V_1 = 250$ mL

Initial pressure, $p_1 = 745$ mm Hg

Final volume, $V_2 = 200$ mL

Final pressure, $p_2 = ?$

Additional pressure $p = ?$

$$\therefore \quad p_1V_1 = p_2V_2$$

$$745 \text{ mm Hg} \times 250 \text{ mL} = p_2 \times 200 \text{ mL}$$

$$p_2 = \frac{745 \text{ mm Hg} \times 250 \text{ mL}}{200 \text{ mL}} = 931.25 \text{ mm Hg}$$

Additional pressure $= p_2 - p_1$

$$= 931.25 - 745 = 186.25 \text{ mm Hg}$$

Note Always write the units along with the value in calculations as the remaining units help us to find out the correctness of our results.

Charles' Law (Temperature-Volume Relationship)

Jacques Charles observed that at a fixed pressure, the volume of a given mass of a gas increases or decreases by 1/273 of its volume at 0°C for each one degree rise or fall in temperature, respectively.

Mathematical Expression of Charles' Law

If at 0°C, the volume of a gas is V_0 and at *t*°C, it becomes V_t then according to Charles'

$$V_t = V_0\left[1 + \frac{t}{273}\right] \qquad \text{(at constant } p\text{)}$$

or

$$\boxed{V_t = V_0\left(\frac{273 + t}{273}\right)} \qquad \ldots\text{(i)}$$

At this condition, a new scale of temperature called the Kelvin temperature scale or absolute temperature scale or thermodynamic scale is used. On this scale, $273 + t = T$.

Thus, if temperature is 0°C, then $T_0 = 273$ K or 0°C on the Celsius scale is equal to 273 K at the Kelvin scale and if temperature on the Celsius scale is *t*°C, then

$$T = 273 + t\,°C = T_t\,(K)$$

On replacing $273 + t$ and 273 in the equation (i) by T_t and T_0, respectively, we get

$$V_t = V_0\left(\frac{T_t}{T_0}\right) \quad \text{or} \quad \frac{V_t}{V_0} = \frac{T_t}{T_0}$$

Thus, the general form of the equation can be written as

$$\frac{V_2}{V_1} = \frac{T_2}{T_1} \text{ or } \frac{V_1}{T_1} = \frac{V_2}{T_2} \text{ or } \frac{V}{T} = \text{constant} = k_2$$

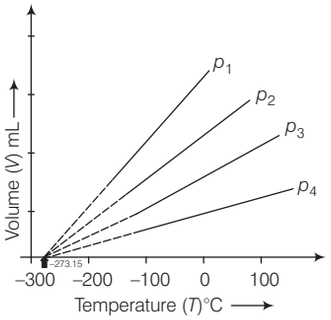
Thus, $$V = k_2T \qquad \ldots\text{(ii)}$$

Here, k_2 is a constant, value of which depends upon the pressure of the gas, its amount and the units in which volume *V* is expressed. Eq. (ii) is the mathematical expression for Charles' law, according to which at a constant pressure, the volume of a given mass of a gas is directly proportional to its absolute temperature. At very low pressure and high temperature, this law is obeyed by all gases.

Graphical Representation of Charles' Law

The plot of volume *vs* temperature at constant pressure are called **isobars** or **isoplestics**. When volume of fixed mass of a gas is plotted with temperature at different constant pressures, we get straight line in each case.

$$p_1 > p_2 > p_3 > p_4$$



Graph of volume *(V) versus* temperature *(T)* at different constant pressure

Explanation of Charles' Law Based upon Kinetic Molecular Theory of Gases

As, average KE ∝ temperature

When the temperature of a gas is increased at constant pressure, the molecules will move with higher velocities and hence, with greater momentum and so volume must increase in order to keep pressure constant.

Importance of Charles' Law

As we know that,
volume of given mass of gas ∝ temperature

$$\text{Density} \propto \frac{1}{\text{Temperature}}$$

Thus, density decreases with increase in temperature and *vice-versa*. Due to this, hot air is filled into balloons used for meterological purposes.

Example 3. A gas occupies a volume of 120 cm^3 at 27.3 K . What volume it will occupy at 0° C; pressure remaining constant?

Sol. Given, initial volume, $V_1 = 120 cm^3$
Initial temperature, $T_1 = 27.3$ K
Final volume, $V_2 = ?$
Final temperature, $T_2 = 0°C = 273K$
By Charles' law, $\frac{V_1}{T_1} = \frac{V_2}{T_2} \Rightarrow \frac{120}{27.3} = \frac{V_2}{273}$

$$\Rightarrow V_2 = \frac{120 \times 273}{27.3} = 1200 \text{ cm}^3$$

Example 4. At what temperature in centigrade will the volume of a gas at 0°C double itself on remaining pressure constant?

Sol. Let the volume of the gas at 0° C = V mL
Thus, we have $V_1 = V$ mL, $V_2 = 2V$ mL
$T_1 = 0 + 273 = 273$ K
$T_2 = ?$
By Charles' law, $\frac{V_1}{V_2} = \frac{T_1}{T_2} \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$

On substituting the corresponding values, we get

$$\frac{V}{273} = \frac{2V}{T_2} \Rightarrow T_2 = \frac{2V \times 273}{V} = 546 \text{ K}$$

$$\therefore \quad T_2 = 546 - 273 = 273°C$$

Absolute Zero

The temperature at which all molecular motions are ceases and thus the gases are liquefied. This temperature (– 273.15° C) is called absolute zero. Thus, the lowest hypothetical temperature at which the gases are supposed to occupy zero volume is called absolute zero.

Note Temperature below – 273.15° C is not possible because it corresponds to negative volume which is meaningless.

Absolute or Kelvin Scale of Temperature

With –273° C as its zero, a new scale of temperature has been built up, which is called Kelvin scale or absolute scale of temperature.

Important facts of Kelvin Scale of Temperature

(i) It starts with –273° C as its zero.
(ii) All temperatures on kelvin scale are positive.
(iii) The magnitude of each degree on Kelvin scale is same as on centrigrade scale.

Conversion of Temperature from Celsius Scale to Kelvin Scale and *Vice-Versa*

(i) The temperature value present on the Celsius scale can be converted to kelvin scale by adding 273 to it.
e.g., 25°C = 25 + 273 = 298 K

(ii) The temperature value present on the Kelvin scale can be converted to Celsius scale by substracting 273 from it.
e.g., 25 K = 25 – 273 = – 248° C

Note The unit size of the temperature on Kelvin scale (i.e., 1 K) is equal to the unit size on celsius scale (i.e., 1 °C).

$$\therefore \quad 1 \text{ K} = 1 °C$$

Example 5. Convert the following.
(a) 37 K to °C (b) 27°C to K
(c) –27°C to K (d) 0°C to K

Sol. (a) 37 K = 37 – 273 = – 236° C
(b) 27°C = 27 + 273 = 300 K
(c) –27° C = –27 + 273 = 246K
(d) 0°C = 0 + 273 = 273 K

Ideal Gas

A gas which follows Boyle's law, Charles' law and Avogadro's law ($V \propto n$) in all conditions of temperatures and pressures is called an **ideal gas**. In actual practice such gas is only hypothetical.

Ideal Gas Equation

On combining Boyle's law and Charles' law, we get a single equation, which is called **ideal gas equation.** This equation gives the simultaneous effect of pressure and temperature on the volume of a gas.

Mathematical Expression of Ideal Gas Equation

At constant T and n; $V \propto 1/p$ (Boyle's law)

At constant p and n; $V \propto T$ (Charles' law)

On combining the above two relations, we get

$$V \propto (T/p) \text{ or } V = R(T/p)$$

(here, R = proportionality constant or gas constant whose value in SI unit is 8.314 $JK^{-1}mol^{-1}$).

On rearranging the above equation, we get

$$\boxed{pV = RT}$$

This equation is called **ideal gas equation** and is applicable for all gases that behave ideally. It describes the state of any gas, so it is also called **equation of state.** In this equation, if we know any three variable then we can calculate the value of remaining fourth variable.

Let the volume of a certain mass of a gas changes from V_1 to V_2 when the pressure is changed from p_1 to p_2 and temperature from T_1 to T_2.

Then, for initial condition, ideal gas equation is

$$p_1V_1 = RT_1 \text{ or } (p_1V_1/T_1) = R \quad ...(i)$$

For final condition ideal gas equation is

$$p_2V_2 = RT_2 \text{ or } p_2V_2/T_2 = R \quad ...(ii)$$

From Eqs. (i) and (ii), we get

$$\boxed{p_1V_1/T_1 = p_2V_2/T_2}$$

This equation is called **combined gas law.** In this relation, if out of six, the values of five variables are known, the value of remaining variable can be calculated.

Example 6. At 25°C and 760 mm of Hg pressure, a gas occupies 600 mL volume. What will be its pressure at a height where temperature is 10°C and volume of the gas is 640 mL?

Sol. Given, p_1 = 760 mm Hg, V_1 = 600 mL, T_1 = 25 + 273 = 298 K

V_2 = 640 mL and T_2 = 10 + 273 = 283 K

According to combined gas law,

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2} \Rightarrow p_2 = \frac{p_1V_1T_2}{T_1V_2}$$

On substituting the corresponding values, we get

$$p_2 = \frac{(760 \text{ mm Hg}) \times (600 \text{ mL}) \times (283 \text{ K})}{(640 \text{ mL}) \times (298 \text{ K})} = 676.6 \text{ mm Hg}$$

CHECK POINT 02

1. What type of graph is obtain when pressure is plotted against volume?
2. In terms of Charles' law, explain why – 273°C is the lowest possible temperature?
3. How is the pressure of a gas related to its density at a particular temperature?
4. Convert –38°C into Kelvin scale.
5. What will be the minimum pressure required to compress 500 dm^3 of air at 1 bar to 200 dm^3 at 30°C?

SUMMARY

- Matter generally exists in solid, liquid and gaseous states.
- The states of matter is decided by intermolecular forces and thermal energy.
- The molecular details about the gases can be visualised with the help of kinetic molecular theory of gases.
- Gases have neither definite shape nor definite volume, are highly compressible, have minimum density, undergo easily diffusion, exert pressure in all direction.
- The physical behaviour of gases can be explained on the basis of four measurable variables called standard variables.
- The standard variables are mass, volume, pressure and temperature.
- Gas laws describe the behaviour of a gas under the conditions of pressure, volume and temperature.
  (i) Boyle's law $p \propto (1/V)$ (at constant T and n)
  (ii) Charles' law $V \propto T$ (at constant p and n)
- Ideal Gas equation $pV = nRT$
- At standard temperature and pressure (STP) i.e., at 273K (0°C) and 1 atm (76 cm of Hg) of pressure, one mole of any gas occupies 22.4L of volume.
- Absolute zero is the lowest hypothetical temperature at which the gases are supposed to occupy zero volume.

EXAM PRACTICE

Fill in the Blanks

1. The average kinetic energy of the molecules of a gas is directly proportional to the …… .

Sol. absolute temperature

2. The force exerted on a unit area of the wall of the vessel is equal to the …… of the gas.

Sol. pressure

3. The SI unit of pressure is …… .

Sol. pascal (Pa)

4. If the temperature is reduced to half, the volume would also reduce to …… .

Sol. half

5. If the temperature is doubled, the pressure would be …… .

Sol. doubled

6. As temperature increases, molecular motion (i) …… and when temperature decreases, molecular motion (ii) …… . But when the temperature becomes (iii) …… molecular motion (iv) …… . It is a (v) …… concept. This fact is defining (vi) …… scale of temperature.

Sol. (i) increases (ii) decreases, (iii) zero (iv) ceases (v) theoretical (vi) Kelvin

7. The different molecules possess different velocities and hence different …… .

Sol. energies

8. The melting point of ice is …… .

Sol. 273 K

9. Standard temperature is …… .

Sol. 0°C

10. Kelvin zero is equal to …… .

Sol. −273°C

11. The magnitude of each degree on kelvin scale is same as on …… scale.

Sol. centigrade

12. All temperature on Kelvin scale are …… .

Sol. positive

13. The temperature on the Kelvin scale at which molecular motion completely stop is called …… .

Sol. absoulte zero

14. The (i) …… of a gas is the force exerted by the gas per unit area on the walls of a vessel or container. The pressure of a gas can be expressed in …… of Hg or …… of Hg or …… or …… .

Sol. (i) pressure (ii) mm, (iii) cm, (iv) atmosphere, (v) kPa.

Multiple Choice Questions

15. The theory that attempts to elucidate the behaviour of gases is known as …… of gases.

(a) valence bond theory
(b) kinetic molecular theory
(c) Both (a) and (b)
(d) None of the above

Sol. (b)

16. Gases expand and occupy all the space available to them. Which of the following assumption explain this behaviour correctly?

(a) There is no force of attraction between gas molecules
(b) Gas molecules are considered as negligible masses
(c) Collisions of the gas molecules are perfectly elastic
(d) All of the above

Sol. (a)

17. On applying the pressure, the intermolecular spaces can be reduced. This assumption explains the

(a) fixed volume of gases
(b) partial pressure exerted by the gases
(c) compressibility of gases
(d) All of the above

Sol. (c)

18. The pressure exerted by the gas is due to

(a) the repulsion between gas molecules
(b) the attraction between gas molecules
(c) collision of the particles with the wall of the container
(d) Both (a) and (b)

Sol. (c)

19. In kinetic molecular theory, it is assumed that average kinetic energy of the gas molecules is directly proportional to the …*A*… . Here, *A* refers to

(a) absolute pressure (b) absolute volume
(c) absolute temperature (d) None of these

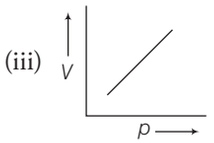
Sol. (c)

20. 6 atmosphere = …*X*… torr of Hg. Here *X* is
(a) 5760 (b) 3876
(c) 2769 (d) 4560
Sol. (d)

21. The first reliable measurement on the properties of gases was made by scientist ..... .
(a) Dalton (b) Robert Brown
(c) Robert Boyle (d) Jacques Charles'
Sol. (c)

22. Which of the expression represent the Boyle's law?
(a) $p \propto \frac{1}{V}$ (at constant T and n)
(b) $p \propto \frac{1}{T}$ (at constant V and n)
(c) $p \propto V$ (at constant T and n)
(d) All of the above
Sol. (a)

23. "At constant temperature, the pressure of a fixed amount of gas varies inversely with its volume".
This law is known as …*A*… . Here, *A* refers to
(a) Charles' law (b) Boyle's law
(c) Newton's law (d) Dalton's law
Sol. (b)

24. Boyle's is valid for
(i) $pV = \text{constant}$ (ii) $\frac{p_1}{V_2} = \frac{p_2}{V_1}$
(iii) 

Which of the following is the correct option?
(a) (i) and (iii) (b) (i) and (ii)
(c) (ii) and (iii) (d) (i), (ii) and (iii)
Sol. (b)

25. Volume temperature relationship is given by
(a) Gay-Lussac's (b) Boyle's
(c) Charles' (d) Dalton
Sol. (c)

26. The graph of pV *vs* p for a gas is
(a) straight line passing through origin
(b) straight line parallel to *X*-axis
(c) hyperbolic
(d) parabolic
Sol. (b)

27. When the temperature is raised through 1°C, the volume is increased by $\frac{1}{273}$ th times of the original volume. This is
(a) Boyle's law
(b) Charles' law
(c) Avogadro's law
(d) Graham's law
Sol. (b)

28. Charles' law is represented mathematically as
(a) $pV = \text{constant}$ (b) $V_t = V_0\left(1 + \frac{273}{t}\right)$
(c) $V_t = V_0\left(1 + \frac{t}{273}\right)$ (d) $\frac{V_t}{V_0} = \frac{T_0}{T_t}$
Sol. (c)

29. If the pressure is doubled for a fixed mass of a gas its volume will become
(a) 2 times (b) $\frac{1}{2}$ times
(c) 4 times (d) No change
Sol. (b)

30. Point out the correct relationship regarding ideal gas law
(a) $\frac{pV}{T} = \text{constant}$ (b) $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$
(c) Both (a) and (b) (d) None of these
Sol. (c)

31. The STP (standard temperature and pressure) condition stands for
(a) 273°C (temperature) and 1 atm (pressure)
(b) 273 K (temperature) and 1 atm (pressure)
(c) 273 K (temperature) and 1 bar (pressure)
(d) 273°C (temperature) and 1 bar (pressure)
Sol. (b)

32. What will be the minimum pressure required to compress 2 L of gas at 1 bar to 1 L at 25°C?
(a) 1 bar (b) 2 bar
(c) 4 bar (d) 6 bar
Sol. (b)

33. Which of the following options represent an ideal gas equation?
(a) $pV = RT$ (b) $p = VRT$
(c) $pRT = V$ (d) $pVT = R$
Sol. (a)

34. An ideal gas equation is also called the …*I*… . Here, *I* refers to
(a) equation of state (b) equation of variable
(c) equation of parabola (d) Either (a), (b) or (c)
Sol. (a)

35. On the basis of theoretical concept, the temperature at which the molecular motion completely stop is said to be
(a) 273°C (b) absolute zero
(c) 273 K (d) – 173 K
Sol. (a)

36. The Kelvin temperature scale is known as
(i) absolute temperature scale
(ii) thermodynamic scale
Choose the correct option.
(a) Only (i) (b) Only (ii)
(c) Both (i) and (ii) (d) Neither (i) nor (ii)
Sol. (c)

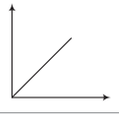
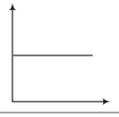
Match the Following

37. Match the following columns.

	Column I		Column II
(i)	Boyle's law	(a)	$-273°C$
(ii)	Charles' law	(b)	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
(iii)	Ideal gas equation	(c)	$p_1V_1 = p_2V_2$
(iv)	Absolute zero	(d)	$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$

Sol. (i) → (c), (ii) → (b), (iii) → (d), (iv) → (a)

38. Match the following columns.

	Column I (Graphical representation)		Column II (X and Y coordinates)
(i)		(a)	pV *vs* V
(ii)		(b)	p *vs* V
(iii)		(c)	p *vs* $\frac{1}{V}$

Sol. (i) → (b), (ii) → (c), (iii) → (a)

39. Match the following columns.

Column I (Temperature in Celsius)	Column II (Temperature in Kelvin)
(i) 17°C	(a) 273 K
(ii) 20°C	(b) 0 K
(iii) –273°C	(c) 290 K
(iv) 273°C	(d) 293 K
(v) 0°C	(e) 546 K

Sol. (i) → (c), (ii) → (d) (iii) → (b) (iv) → (e) (v) → (a).

1 Mark Questions

40. How can you define the gas?
Sol. Gas is that state of matter which has definite mass but has neither definite shape nor definite volume.

41. Write the properties of gases.
Sol. Gases move in all possible directions with their all possible speeds. The molecules are negligibly small in size as compared to the volume occupied by the gas.

42. What are the factors upon which the behaviour of gases do not depend?
Sol. The behaviour of gases do not depend upon chemical nature or colour or odour.

43. One of the assumptions of kinetic theory of gases is that there is no force of attraction between the molecules of a gas. State and explain the evidence that shows that the assumption is not applicable for real gas.
Sol. Real gases can be liquefied by cooling and compression of the gas. This proves that forces of attraction exist among the molecules.

44. Boyle's law states that at constant temperature, if pressure is increased on a gas, volume decreases and *vice-versa*. But when we fill air in a balloon, volume as well as pressure increase. Why?
Sol. The law is applicable only for a definite mass of the gas. As we fill air into the balloon, we are introducing more and more air into the balloon.

45. In terms of Charles' law explain why –273° C is the lowest possible temperature?
Sol. According to Charles' law, $V_t = V_0\left[1 + \frac{t}{273}\right]$

At $t = -273°C$, $V_t = V_0\left[1 - \frac{273}{273}\right] = 0$

Thus, at –273°C, volume of a gas becomes zero and below this temperature the volume becomes negative, which is meaningless.

46. On Kelvin scale, what is the freezing point of water?

Sol. Freezing point of water = 0° C = 0 + 273 K = 273 K

47. What do you understand by absolute zero?

Sol. Absolute zero is the hypothetical temperature *i.e.,* –273° C at which all gases may be assumed to occupy zero volume.

48. Is it possible to change the temperature and pressure of a certain mass of a gas, without changing its volume?

Sol. It is possible by increasing the pressure on the enclosed volume of a gas, its volume decreases while by increasing temperature its volume also increases. Therefore, by keeping an equilibrium between the increase in pressure and increase in volume, it is possible to keep the volume constant.

b 2 Marks Questions

49. Whenever there is experiment in the laboratory, hydrogen sulphide gas (offensive odour) is prepared for some test. There is smell of the gas which we can observe 50 metres away. Name the phenomenon.

Sol. This is because of the mixing of hydrogen sulphide gas with air. This property is called diffusion. It is because, gas molecules are always in random motion and there are large vacant spaces between the molecules of a gas. *[2]*

50. One of the assumptions of kinetic theory of gases states that "there is no force of attraction between the molecules of a gas." How far is this statement correct? Is it possible to liquefy an ideal gas? Explain.

Sol. This statement is correct only for ideal gases. It is not possible to liquefy an ideal gas because there is no intermolecular forces of attractions between the molecules of an ideal gas. *[2]*

51. The molecular theory accounts for the pressure exerted by a gas in a closed vessel as a result of the gas molecules striking on the walls of the vessel. How will the pressure change, if

(i) the volume is made half of original value, maintaining the temperature constant?

(ii) temperature is doubled maintaining the volume constant?

Sol. (i) When the volume is halved, the number of gas molecules striking per unit area of the walls of the vessel is doubled. Thus, the pressure is doubled. *[1]*

(ii) When the temperature is doubled, the average kinetic energy of the gas molecules is doubled. Thus, the pressure is doubled. *[1]*

52. Explain, why

(i) temperature – 273°C is a theoretical temperature, but cannot be achieved?

(ii) Kelvin temperature is always positive?

Sol. (i) At –273°C, volume of a gas becomes zero. But it is not possible because gas is a state of matter and cannot have zero volume. Thus, –273°C is a theoretical temperature, which cannot be achieved. *[1]*

(ii) Kelvin scale of temperature starts from zero, which is equal to –273°C. Temperature below –273°C is not possible. Thus, Kelvin temperature is always positive. *[1]*

53. Why while stating the volume of a gas, the temperature and pressure should also be given?

Sol. The volume of a fixed mass of a gas depends upon the temperature as well as pressure. Thus, while stating the volume of a gas, the temperature and pressure should be specified. *[2]*

54. (i) What is STP or NTP denoted?

(ii) Why is it necessary to compare gases at STP?

Sol. (i) STP stands for standard temperature and standard pressure. NTP denotes normal temperature and normal pressure. *[1]*

(ii) The volume of a fixed mass of dry enclosed gas depends upon the pressure of the gas and temperature of the gas in Kelvin, hence to express the volume of the gases, we need to compare these to STP. *[1]*

c 3 Marks Questions

55. Write important characteristics of a gas based upon kinetic theory of gases.

Sol. (i) Gases have neither fixed shape nor fixed volume.

(ii) Gases have negligible attractive forces between the molecules of a gas.

(iii) Gases exert pressure in all the direction.

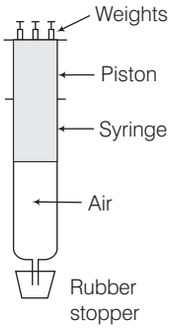
(iv) Gases have low density.

(v) Gases have high compressibility.

(vi) Gases easily undergo diffusion. *[½ × 6]*

56. Mention an experiment to show the pressure-volume relationship of gas.

Sol. Take a 10 mL syringe fitted with a piston and move upward the piston to 10 mL mark.
Cover the adhesive tape over its nozzle. Fit this nozzle tightly into a hole in the rubber stopper as shown in given figure.



On putting some weight on the piston (for pressure), the piston moves downward and volume of the air in the syringe decreases. Then put some more weight, the piston moves further downwards and the volume of the air is further reduced. Similarly, if the weights on the piston are gradually decreased, the piston moves upwards and volume of air starts increasing. ***[3]***

57. State the following.
(i) The volume of a gas at 0 K.
(ii) The STP conditions
(iii) The absolute temperature of a gas at 7°C

Sol. (i) Zero ***[1]***
(ii) 1 atmospheric pressure and 0°C (273 K) temperature. ***[1]***
(iii) 280 K ***[1]***

58. Write the value of
(i) Standard pressure in
(a) mm of Hg (b) cm of Hg
(c) atm (d) torr
(ii) Standard temperature in
(a) °C (b) K

Sol. (i) Standard pressure
(a) 760 mm of Hg (b) 76 cm of Hg
(c) 1 atmosphere (d) 760 torr ***[2]***
(ii) Standard temperature
(a) 0°C (b) $273 + 0 = 273\,K$ ***[1]***

59. The product of pressure and volume of an enclosed dry gas at a given temperature is always a constant quantity. Explain it.

Sol. According to Boyle's law, temperature remaining constant, volume of a fixed mass of a dry gas is inversely proportional to the pressure exerted on it.

Mathematically, $V \propto \frac{1}{p}$ (T is kept constant)

where, V is the volume of a certain mass of a gas at pressure p and temperatue T.

$\therefore \quad V = \frac{k}{p}$

(where, k is a constant of proportionality)

$\therefore \quad pV = k$

Thus, the product of pressure and volume of an enclosed dry gas at a given temperature is always a constant quantity. ***[3]***

60. How did Charles' law state the concept of absolute scale of temperature?

Sol. From the Charles' law, at constant pressure, the volume of a given mass of a gas increases or decreases by $\frac{1}{273}$ of its volume at 0°C for each 1°C rise or fall in temperature.

Suppose V_0 be the volume of a fixed mass of a gas at 0°C and its pressure is p.

$\therefore$ At constant pressure, volume of gas (V) at t°C is

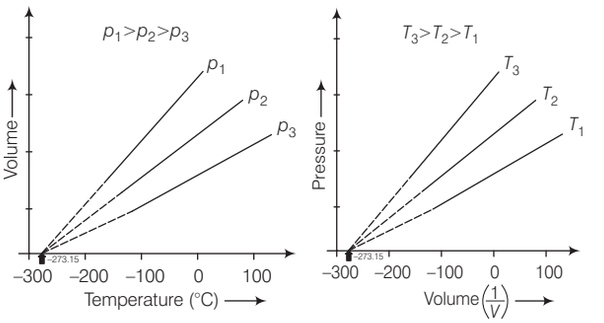
$$V = V_0 + \frac{1}{273} \times V_0\, t$$

Volume of a gas at −273°C (at constant pressure),

$$V_{-273\,°C} = V_0 + \frac{1}{273} \times V_0\,(-273)$$
$$= V_0 - V_0 = 0$$

The temperature, −273°C is called absolute zero. ***[3]***

61. State the laws which are represented by the given graphs.



Sol. (i) **Charles' law** $V \propto T$ (n, p constant)
(ii) **Boyle's law** $p \propto \frac{1}{V}$ (n, T constant) ***[3]***

d 4 Marks Questions

62. Give reasons for the following statements.
(i) It is necessary to specify its temperature and pressure while stating volume of a gas.
(ii) Gas fills the vessel completely in which it is kept.
(iii) Inflating a balloon seems to violate Boyle's law.
(iv) Mountaineers carry oxygen cylinders with them.

Sol. (i) This is due to volume of a gas changes with the change in temperature or pressure. *[1]*
(ii) The molecules in a gas are far apart and are in a state of rapid motion in all possible directions with greater speeds. They move throughout the vessel in which they are kept. Therefore, a gas fills the vessel completely. *[1]*
(iii) Because of inflation of a balloon though the volume and pressure inside the balloon is increased while Boyle's law is valid for a definite mass of a gas in a closed container. Thus, in this case the mass of the ballon is also rapidly increased as the air is blown into the ballon. Hence, it is not violating the Boyle's law. *[1]*
(iv) This is because at higher altitudes (at mountains) the density of oxygen is less. Thus, lesser volume of oxygen is available for breathing. *[1]*

63. Give one line/one word to answer the following:
(i) Volume of a gas compared to the solid state.
(ii) Standard temperature of a gas in Kelvin.
(iii) Standard pressure of a gas in mm of Hg.
(iv) Celsius temperature of a gas at 300 K.
(v) Volume of a gas at −273°C.

Sol. (i) Volume of a gas is very large as compared to the volume of solid.
(ii) Standard temperature of a gas = 273 K
(iii) Standard pressure of a gas = 760 mm of Hg
(iv) Celsius temperature of a gas at 300 K
$= 300 - 273 = 27°C$
(v) Volume of a gas at $-273°C$ = Zero *[4]*

64. (i) State one difference and similarity between the Celsius scale and Kelvin scale.
(ii) What are the two fixed points normally used to calibrate the instrument used to measure temperature? Write its value on absolute scale.
(iii) What are STP and NTP? Write its significance.

Sol. (i) The temperature on Kelvin scale are always positive while temperature on celsius scale may be negative, zero or positive. The magnitude of each degree on celsius scale is same as on Kelvin scale. *[1]*
(ii) The two fixed points to calibrate the instrument to measure temperature are
Freezing point of water = 0°C = 273K.
Boiling point of water = 100°C = 273 + 100 = 373K. *[1]*
(iii) STP stands for standard temperature and standard pressure. It is equal to 0°C to 273 K. NTP stands for normal temperature and normal pressure. It is equal to 760 mm or 7.6 nm of Hg or 1 atmosphere.
Significance For comparing the masses or densities of the gases, their temperature and pressure are taken at STP or NTP. This is due to volume of a given mass of a gas depends upon pressure as well as temperature. *[2]*

65. What is general gas equation or perfect gas equation? How will you derive it?

Sol. Refer to text on page 100.

e 5 Marks Questions

66. (i) State and explain Boyle's law.
(ii) Give its mathematical form.
(iii) What is its significance?

Sol. (i) Refer to text on Page 97.
(ii) Refer to text on Page 97.
(iii) Refer to text on page 98.

67. (i) State and explain Charles' law.
(ii) Give its mathematical form.
(iii) How can you explain the Charles' law based upon kinetic molecular theory of gases?

Sol. (i) Refer to text on Page 98.
(ii) Refer to text on Page 98.
(iii) Refer to text on Page 99.

Numerical Based Questions

68. What will be the minimum pressure required to compress 500 dm^3 of air at 1 bar to 200 dm^3 at 30°C?

Sol. Given, $p_1 = 1$ bar, $p_2 = ?$, $V_1 = 500\ dm^3$, $V_2 = 200\ dm^3$
$\therefore \quad p_1V_1 = p_2V_2$
$\Rightarrow \quad p_2 = \dfrac{p_1V_1}{V_2} = \dfrac{1\ \text{bar} \times 500\ dm^3}{200\ dm^3}$
$= 2.5$ bar *[2]*

69. A balloon filled with an ideal gas is taken from the surface of the sea to a depth of 100 m. What will be its volume in terms of its original volume?

Sol. Pressure at the surface = 76 cm = 76 × 13.6 cm Hg
= 1033.6 cm of Hg
= 10.3 m of Hg
$\therefore$ Pressure at 100 m depth = 100 + 10.3 m
= 110.3 m

Applying, $p_1V_{1,\text{(at surface)}} = p_2V_{2,\text{(at 100 m depth)}}$

$$10.3 \times V = 110.3 \times V_2$$

or $$V_2 = 0.093\,V = 9.3\%\text{ of } V$$ [2]

70. Calculate the temperature of 4.0 moles of a gas occupying 5 dm^3 at 3.32 bar. (Take, $R = 0.083$ bar dm^3 K^{-1} mol^{-1}).

Sol. Apply ideal gas equation, $pV = nRT$

$$\Rightarrow T = \frac{pV}{Rn} = \frac{3.32 \text{ bar} \times 5 \text{ dm}^3}{0.083 \text{ bar dm}^3 \text{ K}^{-1} \text{ mol}^{-1} \times 4 \text{ mol}}$$

$$T = 50 \text{ K}$$ [2]

71. Determine the pressure of a gas, when its volume is 250 mL initially, the gas is expanded to volume of 1000 mL and the pressure of 0.4 atmosphere. Assume that temperature during the reaction remains constant.

Sol. Given, initial volume, $V_1 = 250$ mL

Final volume, $V_2 = 1000$ mL

Initial pressure, $p_1 = ?$

Final pressure, $p_2 = 0.4$ atm

Applying Boyle's law,

$$p_1V_1 = p_2V_2$$

$$p_1 \times 250 = 0.4 \times 1000$$

$$\Rightarrow p_1 = \frac{0.4 \times 1000}{250} = 1.6 \text{ atm}$$ [2]

72. The volume occupied by a given gas was 5.6 dm^3 when the pressure was 2 atmosphere. If the pressure is increased by 20%, calculate the new volume of the gas.

Sol. Initial volume of gas, $V_1 = 5.6$ dm^3

Final volume, $V_2 = ?$

Initial pressure of gas, $p_1 = 2$ atm

20% of initial pressure $= 2 \times \frac{20}{100} = \frac{4}{10} = 0.4$

Final pressure, $p_2 = 0.4 + 2 = 2.4$ atm

Applying Boyle's law,

$$p_1V_1 = p_2V_2$$

$$2 \times 5.6 = 2.4 \times V_2$$

$$\Rightarrow V_2 = \frac{5.6 \times 2}{2.4} = 4.67 \text{ dm}^3$$ [2]

73. A gas is enclosed in a vessel at standard temperature. Find out the temperature at which the volume of enclosed gas will be 1/6 of its initial volume. (Given that the pressure remain constant)

Sol. Suppose that the initial volume of gas, $V_1 = x$

Final volume, $V_2 = x/6$

Initial temperature, $T_1 = 0°\text{C} = 0 + 273\text{ K} = 273\text{ K}$

Final temperature, $T_2 = ?$

Applying Charles' law,

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{x}{273} = \frac{x}{6 \times T_2}$$

$$T_2 = \frac{273x}{6 \times x} = 45.5 \text{ K}$$ [2]

74. 6 dm^3 of dry gas is present at temperature of 27°C and pressure of 700 mm of Hg. Determine the volume of gas at STP

Sol. Initial volume, $V_1 = 6\text{dm}^3$

Final volume, $V_2 = ?$

Initial pressure, $p_1 = 700$ mm of Hg

Final pressure, $p_2 = 760$ mm of Hg

Initial temperature, $T_2 = 27 + 273 = 300\text{ K}$

Final temperature, $T_2 = 273\text{ K}$

Applying ideal gas equation,

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$\frac{700 \times 6}{300} = \frac{760 \times V_2}{273}$$

or $$V_2 = \frac{700 \times 6 \times 273}{300 \times 760}$$

$$= 5.02 \text{ dm}^3$$ [3]

75. Moist nitrogen at a pressure of 700 mm of Hg and temperature of 300 K is found to occupy a volume of 100 cm^3. Determine the volume of dry nitrogen gas at STP. (Take, aqueous tension at 27°C is 15 mm of Hg)

Sol. Initial pressure, $p_1 = 700 - 15 = 685$ mm of Hg

Final pressure, $p_2 = 760$ mm of Hg

Initial volume, $V_1 = 100\text{ cm}^3$

Final volume, $V_2 = ?$

Initial temperature, $T_1 = 300\text{ K}$

Final temperature, $T_2 = 273\text{ K}$

Applying ideal gas equation,

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$\frac{685 \times 100}{300} = \frac{760 \times V_2}{273}$$

or $$V_2 = \frac{685 \times 100 \times 273}{300 \times 760}$$

$$= 82.01 \text{ cm}^3$$ [3]

CHAPTER EXERCISE

Fill in the Blanks

1. There are large vacant space between the molecules known as …… .
2. All gases are made up of large number of …….. .
3. According to kinetic molecular theory of gases, average …… of molecules of a gas depends upon its …… temperature, therefore if its temperature is increased at constant pressure, the molecules will move with …… velocities.
4. There is no effect of …… on the motion of the molecules of a gas.
5. Boyle's law equation : …… = …… .
6. Charles' law states that at constant ……, volume of a given mass of a gas is directly proportional to its …… .
7. The melting point of ice is …… on Kelvin scale.
8. 1 litre = …… cm^3 = …… mL.
9. The mathematical equation which gives us the effect of simultaneous change of …… and …… on the volume of a given mass of a gas. This equation is called …… or perfect gas law or …… .

Multiple Choice Questions

10. At any particular time different particles in the gas have …I… speed and hence …II… kinetic energies.
    Here, I and II refer to
    (a) I → same, II → same
    (b) I → different, II → same
    (c) I → different, II → different
    (d) I → same, II → different
11. According to the Boyle's law, as the pressure increases volume
    (a) decrease (b) increases
    (c) remains same (d) first increases then decreases
12. The absolute temperature value that corresponds to 27°C is
    (a) 273 K (b) 300 K (c) 373 K (d) 246 K
13. The values of celsius scale can be converted to Kelvin scale by
    (a) subtracting 273 (b) adding 273
    (c) subtracting 373 (d) adding 373
14. On converting 25°C, 38°C and 66°C to Kelvin scale, the correct sequence of temperature will be
    (a) 273 K, 278 K and 543 K
    (b) 298 K, 310 K and 338 K
    (c) 298 K, 300 K and 543 K
    (d) 298 K, 311 K and 339 K
15. The Kelvin scale of temperature is always
    (a) negative
    (b) positive
    (c) sometimes positive sometimes negative
    (d) None of the above
16. The pressure, volume and temperature relationship is
    (a) $\frac{T_1}{p_1V_1} = \frac{T_2}{p_2V_2}$
    (b) $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$
    (c) $\frac{p_1T_1}{V_1} = \frac{p_2T_2}{V_2}$
    (d) $p_1V_1T_1 = p_2V_2T_2$

Match the Following

17. Match the following columns.

	Column I		Column II
(i)	Pressure	(a)	Atmospheric pressure low
(ii)	At high altitudes	(b)	Gas variables
(iii)	Kelvin zero	(c)	Molecular motion ceases

1 Mark Questions

18. Gases do not settle at the bottom of a container. Explain.
19. State diffusion. Why do gases show the property of diffusion?
20. Mention the relationship between the Celsius scale and the Kelvin scale of temperature.
21. Give the graphical representation of Charles' law.

2 Marks Questions

22. Explain, why
(i) volume of a gas is always equal to the volume of container in which it is held?
(ii) gases can be liquefied?

23. Give reason for the following statement.
(i) It is necessary to specify its pressure and temperature while stating volume of a gas.
(ii) It is necessary to choose the standard values of temperature and pressure.

3 Marks Questions

24. Explain the following.
(i) Gases show diffusion
(ii) Gases are highly compressible
(iii) Gases exert same pressure in all direction.

25. Mention whether the volume of a given mass of a gas increases or decreases if
(i) pressure is reduced, temperature remaining constant.
(ii) temperature is decreases, pressure remaining constant.

26. Convert the following temperature on the Kelvin scale to the Celsius scale.
(i) 426 K (ii) 105 K
(iii) 250 K (iv) 338 K
(v) 285 K (vi) 728 K

4 Marks Questions

27. Give one word for the following.
(i) When molecules strike against each other.
(ii) Movement of one gas molecule into another gas.
(iii) Space occupied by a gas.
(iv) Measure of kinetic energy possessed by the gas molecules

28. Write the observable properties or variable of gases and explain it.

29. (i) State absolute zero or Kelvin zero.
(ii) What is Kelvin scale of temperature?

5 Marks Questions

30. Explain briefly.
(i) The Kelvin scale has been adopted for chemical calculation.
(ii) The need for the Kelvin scale of temperature.

Numerical Based Questions

31. The volume of a certain mass of a gas was found to be 800 cc when pressure was 760 mm of Hg. If the pressure increases by 50%. Calculate the new volume of the gas, assuming that temperature remains constant.

32. 2 L of a gas is enclosed in a vessel when the pressure is 760 mm. If the temperature remains constant, find the pressure, if
(i) the volume changes to 4 dm^3.
(ii) the volume is increased by one and half times.

33. 1800 cc of a gas was collected at 650 mm pressure. At what pressure would the volume of the gas be reduced by 40% of its original volume, if the temperature remaining constant.

34. 77 cm^3 of nitrogen is at a pressure of 880 mm of mercury. The pressure is then raised to 770 mm. Determine by how much the volume would diminish, if the temperature remains constant.

35. At constant pressure, a gas at $-27°C$ is heated to 127°C. Find the percentage increase in the volume of the gas.

36. To what temperature a gas at 227°C must be cooled such that its volume is reduced to 1/5 of the initial volume pressure remaining constant?

37. A certain mass of a gas occupies 4 L at 27°C and 200 pascal. Calculate the temperature when the volume and pressure become half of their initial value.

38. 150 cm^3 of hydrogen is collected over water at 27°C and 750 mm pressure. Find the volume of dry gas at STP if the vapour pressure at 27°C is 48 mm.

39. 370 cc of moist hydrogen measured at 19°C and 859 mm pressure. Calculate the volume of dry hydrogen at NTP. The vapour pressure of water at 19°C is 9 mm.

40. A gas occupies a volume of 800 cc. On heating to 127°C, its volume becomes 3200 cc. Calculate the initial temperature of gas on Celsius scale assuming that pressure remains constant.

CHALLENGERS*

1 Which description fits best for a gas?
(a) Definite shape and volume; strong intermolecular attractions
(b) Definite volume and shape; moderate intermolecular attractions
(c) Definite volume and shape; weak intermolecular attractions
(d) Volume and shape are not definite; negligible intermolecular attractions

2 Which of the assumptions of the kinetic-molecular theory best explains the observations that a gas can be compressed?
(a) Gas molecules move at random motion with no attractive forces between them
(b) The velocity of gas molecules is proportional to their Kelvin temperature
(c) The amount of space occupied by a gas is much greater than the space occupied by the actual gas molecules
(d) In collisions with the walls of the container or with other molecules, energy is conserved

3 What weight of hydrogen at STP could be contained in a vessel that holds 3.36 L O_2 gas at STP?
(a) 0.21 g (b) 4.8 g (c) 0.30 g (d) 3.36 g

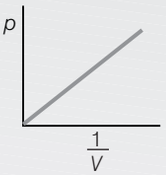
4 Volume of oxygen measured at STP obtained by heating 2.16 g of HgO (Hg = 200) is

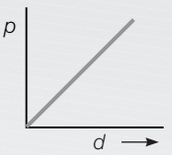
$$2HgO \xrightarrow{\Delta} 2Hg + O_2$$

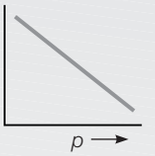
(a) 2400 mL (b) 224 mL (c) 112 mL (d) 448 mL

5 A flask of gaseous CCl_4 was weighed at measured temperature and pressure. CCl_4 was replaced by O_2 at the same temperature and pressure. The mass of the CCl_4 vapour will be
(a) five times as heavy as O_2 (b) one fifth heavy as compared to O_2
(c) same as that of O_2 (d) twice as heavy as O_2

6 Which is not a correct representation of Boyle's law?

(a) 

(b) 

(c) 

(d) 

7 A quantity of gas is collected in a graduated tube over the mercury. The volume of gas at 18°C is 50.0 mL and the level of mercury in the tube is 100 torr above the outside mercury level. The barometer reads 750 Torr. Hence, volume at STP is approximately
(a) 22 mL (b) 40 mL (c) 20 mL (d) 44 mL

8 What percent of a sample of nitrogen must be allowed to escape if its temperature, pressure and volume are to be changed as given below,

$$\boxed{273°C,\ 3.00\ atm\ 1.65\ L} \longrightarrow \boxed{0°C,\ 0.75\ atm\ 0.55\ L}$$

(a) 16.67% (b) 83.33% (c) 75.00% (d) 25.00%

9 Which of the assumptions of the kinetic molecular theory best explains the observation that a balloon collapses when exposed to liquid nitrogen (which is much colder than a cold winter day)?
(a) Gas molecules move at random with no attractive forces between them
(b) The velocity of gas molecules is proportional to their Kelvin temperature
(c) The amount of space occupied by a gas is much greater than the space occupied by the actual gas molecules
(d) Collisions with the walls of the container or with other molecules are elastic

10 On a ship sailing in pacific ocean where temperature is 23.4° C, a balloon is filled with 2 L air. What will be the volume of the balloon when the ship reaches the Indian ocean, where temperature is 26.1°C?
(a) 1.98 L (b) 2.02 L (c) 2.18 L (d) 5.12 L

Answers

1. (d) **2.** (c) **3.** (c) **4.** (c) **5.** (a) **6.** (c) **7.** (b) **8.** (b) **9.** (b) **10.** (b)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 114.

CHAPTER

8

Atmospheric Pollution

Earth is surrounded by a covering of various gases (air), called atmosphere, which extends to a height of about 1600 km above the earth surface. Dry air contains roughly (by volume) nitrogen (78.08%), oxygen (20.95)%, argon (0.93%), carbon dioxide (0.033%) and trace amount of other gases such as Ne (18 ppm), He (5.2 ppm), methane (1.3 ppm), Kr (1 ppm), H_2 (0.5 ppm), CO (0.10 ppm), O_3 (0.02 ppm), SO_2 (0.001 ppm) etc.

Addition of some undesirable substances into the troposphere or stratosphere (either due to some natural phenomenon or due to human activity), which have adverse effect on plants and animals including human being is called **atmospheric pollution**. Thus, atmospheric pollution is mainly concerned with pollution of troposphere and stratosphere.

Troposphere It is lowest portion of the earth's atmosphere. It contains approximately 75% of earth's atmosphere and 99% of its water vapour and aerosol.

Stratosphere It is the second major layer of earth's atmosphere, just above the troposphere.

Chapter Objectives

- Acid Rain
- Global Warming
- Ozone Depletion

Acid Rain

In simple words, the rain water (pH = 5.6) which is acidic in nature due to presence of certain pollutants in the air is called **acid rain** (pH = below 5.6)

It is the deposition of wet acidic solutions or dry acidic particles in the water droplets present in the air. Rain, snow, fog or dew is made acidic by the presence of sulphuric acid (H_2SO_4) and nitric acid (HNO_3) that results when sulphur and nitrogen oxides combine with O_2 and H_2O in the atmosphere.

These oxides are formed in bulk from burning of fossil fuels, electrical power generation and other industrial activities. Combustion engines of automobiles also contribute in increasing the amount of these oxides in atmosphere.

$$H_2O + CO_2 \longrightarrow H_2CO_3$$

Note The term acid rain was put forth by **Robert Augus.**

Composition of Acid Rain

Acid rain results from acids such as sulphuric acid and nitric acid present in polluted air. These acids are formed when oxides of sulphur and nitrogen, respectively come into contact with rain water.

Causes of Acid Rain

Acid rain is caused by a chemical reaction that starts when compounds like sulphur dioxide and nitrogen oxides are released into the air. These substances can rise very high into the atmosphere where they mix and react with water, oxygen and other chemicals to form more acidic pollutants. The main cause of acid rain is due the formation of mineral acids like nitric acid, carbonic acid and sulphuric acid during rains.

Formation of Nitric Acid

Oxides of nitrogen are introduced into the atmosphere by the burning of the fossil fuels in internal combustion engines which results in the production of a very high temperature and thus, nitrogen and oxygen of air combine to form nitric oxide.

$$N_2 + O_2 \xrightarrow{\text{High temperature}} \underset{\text{Nitric oxide}}{2NO}$$

Nitrogen monoxide combines with more of oxygen to form nitrogen dioxide.

$$2NO + O_2 \longrightarrow 2NO_2$$

Further, nitrogen dioxide (NO_2) dissolves with rain water and oxygen to form nitric acid.

$$4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$$

Formation of Sulphuric Acid

Sulphur is a non-metallic element found in coal and fuel oil. When these fuels are burned, sulphur combines with oxygen in presence of air to form sulphur dioxide.

$$S + O_2 \longrightarrow SO_2$$

Sulphur dioxide is oxidised by atmospheric oxygen to form sulphur trioxide.

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

Further, SO_3 combines with water to form sulphuric acid.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

Harmful Effects of Acid Rain

Acid rain causes the following adverse effects

(i) **Acid Rain Affects Soil Chemistry** Acid rain causes harmful effects to the soil such as nutrient leaching, accumulation of toxic metals and the release of toxic aluminium.

When acid rain adds hydrogen ions to the soil which interact chemically with existing minerals causes nutrient leaching.

It displaces important minerals such as Ca, Mg and K from soil particles and deprives nutrition of trees. It washes a number of essential minerals from soil and the later depleted of these minerals cause harmful effect on the growth of plants. Due to acid rain, damage of trees at large number and loss of leaves occur (brown and fall off). Acid rain increases the acidity of the soil causes adverse effect on the plants.

(ii) Acid rain damages the buildings and other structures made up of limestone or marble, i.e. $CaCO_3$. Sulphuric acid and nitric acid dissolve calcium carbonate to form calcium sulphate and calcium nitrate, respectively.

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + CO_2 \uparrow + H_2O$$

$$CaCO_3 + 2HNO_3 \longrightarrow Ca(NO_3)_2 + CO_2 \uparrow + H_2O$$

(iii) In human beings and animals, it causes seveal respiratory diseases.

(iv) When acid rain water is mixed with river of lakes, it affects the aquatic life adversely. The acids dissolved the heavy metals such as Al, Mn, Pb, Zn, etc., that are present on the lake. These metal salts are extremely harmful to fish and the other animals living under the water.

Taj Mahal and Acid Rain

In the city of Agra, the air is highly contaminated with oxides of nitrogen and sulphur since a large number of industries and power plants are present around it and coal, kerosene and fire wood of poor quality are widely used as fuel for domestic purposes. This leads to acid rain, due to which the marble of a wonderful monument Taj Mahal, situated in Agra, is getting discoloured and lustreless.

$$\underset{\text{Marble}}{CaCO_3} + \underset{\text{From acid rain}}{H_2SO_4} \longrightarrow CaSO_4 + H_2O + CO_2 \uparrow$$

Methods to Reduce Formation of Acid Rain

Acid rain occurs because of the oxides of nitrogen and sulphur, so the methods by which these oxides can be removed, also reduce the formation of acid rain.

Some such methods are as follows.

(i) By using less vehicles working on fossil fuels.

(ii) By using fossil fuels having less sulphur content for power plants and industries, i.e. using natural gas which is a better fuel as compared to coal or using coal with less sulphur content.

(iii) By using catalytic converters in cars to reduce the effect of exhaust on the atmosphere, e.g. NO_x and CO present in the exhaust gases are converted into N_2 and CO_2 respectively at 573 K. The main component of the converter is a ceramic honey-comb coated with precious metals like Pt, Pd and Rh.

(iv) By adding powdered limestone to neutralise the acidic soil.

(v) By spreading information about the harmful effects of oxides of N and S.

CHECK POINT 01

1. Write the name of two constituent of troposphere.
2. Who discovered the term acid rain.
3. Mention the balanced chemical equation for the formation of acid rain.
4. Write only the chemical reation for the formation of sulphuric acid.
5. How the acid rain damages the building made up of marble?
6. Write any two methods to reduce the formation of acid rain.

Global Warming

About three-fourth of the solar energy reaching the earth is absorbed by the earth's surface. Due to which the temperature of earth increases. The rest of the heat radiates back to atmosphere.

Some of the heat is trapped by gases such as CO_2, CH_4, CFCs and water vapour in the atmosphere.

Thus, they add to the heating of the atmosphere and causes global warming.

Green-House Effect

The process by which heating of earth takes place due to solar radiation trapped by atmospheric gases like carbon dioxide, water vapours, etc. The gases which traps solar radiation to produce heating effect is called green house gases.

Green house effect is very essential for existence of life and vegetation because in its absence, the earth would be converted into extremely cold planet.

This effect is called green house effect because of glass structures called glass houses that are used to grow green plants in colder regions. The glass houses allow sunlight to enter but does not allow the radiated heat to escape, results in heating up of the green houses.

Green-House Gases and their Sources

As discussed earlier, the gases that contribute to green house effect are called green house gases. Various green house gases and their sources are given below:

(i) **Water Vapours** The main sources of water vapour are industrial exhaust, vehicular exhaust, burning of fuels and volcano eruptions.

Hydrocarbon + Oxygen → Carbon dioxide + Water vapour

(ii) **Carbon Dioxide** (CO_2) Respiration, burning of fossil fuels for energy, decomposition of limestone for cement manufacturing, volcanic eruptions etc., all processes proceed with the liberation of carbon dioxide into the atmosphere. Thus, a large amount of carbon dioxide is released into the atmosphere which is removed by green plants on account of photosynthesis and in turn they release oxygen and maintain an appropriate level of CO_2 (i.e. 0.03%) in the troposphere (or atmosphere).

Source Deforestation and excessive burning of fossil fuels increase the level of CO_2 and disturb the atmospheric balance.

Bhopal Gas Tragedy

On December 1984, in which about 3000 people were killed and about 50,000 are still suffering from respiratory, lung and eye diseases, was due to leakage of methyl isocyanate (MIC) vapours.

(iii) **Hydrocarbons (Methane)** These are the compounds of only carbon (C) and hydrogen (H). Among various hydrocarbons, methane (CH_4) or **marsh gas** is the most abundant hydrocarbon pollutant.

Source These are obtained by the incomplete combustion of fossil fuels in automobile engines and by anaerobic decomposition of organic matter or vegetation. From paddy fields, coal mines, and rotting garbage dumps, large amounts of methane are released.

(iv) **Oxides of Nitrogen** Among the various oxides of nitrogen, nitric oxide (NO), a colourless, odourless gas and nitrogen dioxide (NO_2), a brown gas with pungent odour, are the two oxides that act as tropospheric pollutants.

Source At high altitudes when lightening strikes or thunderstorm, the two major constituents of air, i.e. dinitrogen and dioxygen which do not react with each other at normal temperature combine to give these oxides. Other sources of these oxides are combustion of fossil fuels such as coal, oil, gasoline etc., in automobile engines, (at high temperature as given by the reaction below), tobacco smoke, denitrifying bacteria and many industrial processes.

$$N_2(g) + O_2(g) \xrightarrow{1483\,K} 2NO(g)$$

Actually NO, itself is not a strong pollutant but reacts readily with oxygen in the troposphere to give NO_2. The reaction with ozone is much faster in stratosphere than the reaction with oxygen.

$$2\,NO(g) + O_2(g) \longrightarrow 2NO_2(g)$$
$$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$$

NO_2 gets further oxidised to nitrate ion, NO_3^- which is washed into the soil, where it acts as a fertiliser.

Effects of Global Warming

Global warming is the main consequence of disturbance of green house effect. Global warming had a drastic effect on climatic conditions. It may cause melting of polar ice caps and glaciers which result in floods of low lying areas. Moreover global warming also increases the incidence of several infectious diseases such as malaria, sleeping sickness, dengue, yellow fever etc.

Methods of Reducing Global Warming

Following are the methods of reducing global warming:

(i) Use of solar energy, hydrogen or atomic energy,hydroelectricity can help in reducing green house effect.

(ii) Deforestation must be stop and afforestation should be made to develop new forests by encouraging tree planting programmes as it act as CO_2 sinks.

(iii) Educating the masses to use cleaner fuels, not the coal, fire wood, etc.

(iv) Use of precipitators, wet scrubbers made obligatory for the factories to remedial measures.

(v) Advanced technologies are used in the automobiles to initiate complete combustion of fuels.

(vi) Use public transport where possible, as well as pooling of cars can be practised. A lot of pollutants are caused due to automobiles.

CHECK POINT 02

1. What is the role of CO_2 in the 'green-house effect'?
2. What is the percent (%) composition of CO_2 in the pure dry air ?
3. List gases which are responsible for green-house effect.
4. What is the main constituent of methane gas?
5. State one source and effect of carbon dioxide and methane in the atmosphere.
6. Write any method by which global warming can reduced.

Ozone Depletion

Ozone is an allotropic form of oxygen which is found in the upper layer of atmosphere about 20 km away from the surface of earth. It is formed from oxygen in the presence of sunlight. It protects earth's surface from UV–radiations.

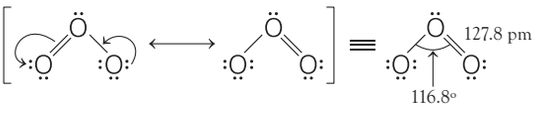
Formation of Ozone

It is prepared by subjecting pure and dry oxygen to silent electric discharge in Siemen's ozoniser. 10-15% of O_2 is converted to O_3. The product so formed is called ionised oxygen.

$$3O_2(g) \longrightarrow 2O_3(g),\ \Delta H = +142\text{kJ mol}^{-1}$$

Structure of Ozone

The structure of ozone is given below:



Resonance hybrid

Function of Ozone in the Atmosphere

The upper stratosphere consists or considerable amount of ozone (O_3) which protect us from the harmful ultraviolet (UV) radiations coming from the sun.

These radiations cause skin cancer in humans.

Therefore, it is important to maintain the ozone shield.

When UV rays interact with dioxygen molecule (O_2), it gets split up into free oxygen atoms (O), which combine with molecular oxygen to give ozone.

$$O_2(g) \xrightarrow{UV} O(g) + O(g)$$

$$O(g) + O_2(g) \underset{}{\overset{UV}{\rightleftharpoons}} O_3(g)$$

The obtained ozone absorbs UV-radiations of comparatively longer wavelength which, decomposes to give molecular oxygen back. Thus, there is a dynamic equilibrium between the formation and decomposition of ozone layer.

Depletion or Destruction of Ozone Layer

Decrease in quantity of ozone in the upper layer of atmosphere (stratosphere) is called depletion of ozone layer or destruction of the ozone layer. Depletion of ozone layer is being caused by certain compounds such as chlorofluorocarbon compounds (CFCs), oxides of nitrogen, etc., obtained from various human activities.

Chemicals Responsible for Destruction of Ozone layer

The various chemicals responsible for destruction of ozone layer are as follows

Nitric Oxide

It is released into upper atmosphere from engine of supersonic transport planes.

When it reaches into the stratosphere, it reacts with ozone and causes its depletion.

Chlorofluorocarbon Compounds

(CFCs) i.e. freons being non–reactive, non–inflammable, non–toxic organic molecules, are widely used in air conditioners, refrigerators, in electronic industry for cleaning computer parts etc.

Due to very long life time (CF_2Cl_2 or CFC-12 has life time of 139 yr and $CFCl_3$ or CFC-11 has life time of 77yr), these compounds ultimately reach the stratosphere where they get broken down by powerful UV radiations and release chlorine free radical.

The reaction, once start, continues for a long time. Thus, a single chlorine free radical is able to convert about one lakh ozone molecules into oxygen and hence, it may lead to massive ozone depletion.

Note Now a days, some chlorine free substituted CFCs such as **hydrofluoro carbons** (HFC-1349), hydrochlorofluoro carbons (HCFCs), methyl cyclohexane (MCH) are widely used, in place of CFCs.

Ozone Hole

A large scale depletion in the concentration of O_3 observed over Antarctica is called ozone hole.

They found that for the depletion of ozone layer unique set of conditions was responsible.

During summer season, there exists nitrogen dioxide and methane which act as sink for chlorine free radicals and prevent much ozone depletion.

$$\underset{\text{Chlorine nitrate}}{\dot{Cl}O(g) + NO_2(g) \longrightarrow ClONO_2(g)}$$

$$\dot{Cl}(g) + CH_4(g) \longrightarrow \underset{\text{Methyl free radical}}{\dot{C}H_3(g)} + \underset{\text{Hydrogen chloride}}{HCl(g)}$$

While in winters, there exist special type of clouds, called **polar stratospheric clouds** (PSCs) over Antarctica.

These clouds convert chlorine nitrate ($ClONO_2$) and hydrochloric acid (HCl) formed in the above reactions, into HOCl and Cl_2.

$$ClONO_2(g) + H_2O(g) \longrightarrow HOCl(g) + HNO_3(g)$$

$$ClONO_2(g) + HCl(g) \longrightarrow Cl_2(g) + HNO_3(g)$$

PSCs also result in the formation of **polar vortex** (a tight whirlpool of wind) which unables the ozone rich air of the non-polar regions to reach in Antarctica.

Thus, ozone hole remains unfilled. During spring season, the sunlight returns to the Antarctica and breaks up the clouds and cause photolysis of HOCl and Cl_2.

$$HOCl(g) \xrightarrow{h\nu} \dot{O}H(g) + \dot{C}l(g)$$

$$Cl_2(g) \xrightarrow{h\nu} 2\dot{C}l(g)$$

The chlorine free radicals, thus formed, again start the chain reaction for ozone depletion. However, after spring, the high intensity sunlight breaks down these vortex and ozone rich air from surroundings rushes in and replenishes the ozone hole.

Effects of Depletion of the Ozone Layer

Following problems are caused by the effect of depletion of the ozone layer

(i) Depletion of ozone layer results in entering of ultraviolet rays into the atmosphere causing skin cancer.

(ii) Ultraviolet rays causes weakening of eye-sight and finally lead to blindness. It has been estimated that decrease in 1% ozone concentration in stratosphere will lead to blind almost 1 lakh people.

(iii) Ultraviolet radiations lead to weakening of the human immune system (immuno suppression).

(iv) Several of the world's major crop species are particularly vulnerable to increased UV-radiations resulting in reduced growth, photosynthesis and flowering.

List of Major air pollutants : Their origin and health impact

	Pollutants	Origin	Health impact
(i)	Carbon monoxide (CO)	Produced due to incomplete burning of petrol, diesel and wood.	Reduces oxygen in blood resulting into retardation and dizziness.
(ii)	Carbon dioxide (CO_2)	Produced on burning of coal, oil and natural gases.	Reduces oxygen levels.
(iii)	Chloro - fluorocarbons (CFCs)	Released from refrigerators and air-conditioning systems.	Reduces ozone layer that protects us from the harmful ultraviolet radiations of the sun.
(iv)	Ozone (O_3)	Emitted from vehicles and industries.	Burning, itching, watery eyes and lowered resistance to respiratory diseases.
(v)	Lead (Pb)	Present in petrol, diesel, paints and batteries.	Damages the nervous and digestive systems and can cause cancer
(vi)	Sulphur dioxide (SO_2)	Produced from burning of coal, petrol and diesel.	Smog and acid rain containing sulphuric acid make children more susceptible to respiratory diseases.
(vii)	Oxides of nitrogen (NO_x)	Produced on burning of petrol, diesel and coal.	Smog (combination of fog and smoke) produces acid rain that makes children more susceptible to respiratory diseases.
(viii)	Suspended particulate matter (SPM)	Solids suspended in smoke, dust and vapour.	Small particles get lodged in the lungs and gradually damage the functioning of lungs.

CHECK POINT 03

1. Write the chemical equation for the formation of ozone in the atmosphere.
2. Draw the resonating structure of ozone.
3. Name the chemical responsible for ozone layer destruction ?
4. Name the gas that caused the Bhopal gas tragedy.
5. Which disease is caused due to hole in the ozone layer and why?
6. How many percent (%) decrease in ozone concentration in stratosphere cause blindness?

SUMMARY

- Atmospheric pollution is alteration in the composition of air due to the addition of foreign materials (i.e. pollutants).
- Atmospheric pollution is mainly concerned with pollution of troposphere (lowest portion of earth's atmosphere) and stratosphere (second major portion of earth's atmosphere).
- Acid rain is defined as the deposition of wet and dry acidic components. Its pH is less then 5.6.
- Acid rain results from acid like nitric acid and sulphuric acid present in polluted air.
- Formation of nitric acid

$$N_2 + 2O_2 \longrightarrow 2NO + O_2 \longrightarrow 2NO_2,$$
$$4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$$

- Formation of sulphuric acid

$$S + O_2 \longrightarrow SO_2$$
$$2SO_2 + O_2 \longrightarrow 2SO_3$$
$$SO_3 + H_2O \longrightarrow H_2SO_4$$

- Acid rain has many adverse effects on soil chemistry, water bodies, damages the buildings, corrodes metal pipes, nutrients leaching, causes respiratory diseases.
- Methods to reduce formation of acid rain is by using less vehicles, fossil fuels having less sulphur content, catalytic converters in cars to reduce the effect of exhaust.
- Green house effect is heating up of earth due to trapping of IR radiation (thermal radiations) by CO_2, CH_4, O_3, NO, CFCs, water vapour, etc.
- Global warming is increase in the temperature of earth due to increased concentration of green-house gases. It may cause melting of ice-caps and glaciers, several infectious disease like malaria, sleeping sickness, etc.
- Green house gases and their sources:
- Water vapours (main source-industrial exhaust, vehicular exhaust, burning of fuel, volcano eruption).
- CO_2 (main source -deforestation and excessive burning of fossil fuel).
- Hydrocarbons (main source - automobile engines and vegetation).
- NO and NO_2 (main source - lightening strikes, automobile engines, etc).
- Methods for reducing global warming are use of solar energy, afforestation, use of precipitations, wet scrubbers, car pooling.

Ozone layer is the upper layer of atmosphere about 20 km away from the surface of the earth. It protects earth's surface from UV-radiations. It is prepared by subjecting pure and dry oxygen to silent electric-discharge in Siemen's ozoniser as.

$$3O_2(g) \xrightarrow{h\nu} 2O_3(g)$$

- Depletion (destruction) of ozone layer is the decrease in quantity of ozone in the stratosphere. This depletion of ozone layer is caused by certain compounds such as chlorofluorocarbon compounds (CFCs), oxides of nitrogen, etc., obtained from various human activities.
- Ozone hole observed due to the depletion of ozone layer in Antarctica over South pole in 1980.
- Effect of depletion of the ozone layer leads to skin cancer, adverse effect on immune system, loss of sight (blindness).

EXAM PRACTICE

Fill in the Blanks

1. The percent proportion of nitrogen in dry air is ..... .

Sol. 78.08%

2. Acid rain is slightly ..... due to dissolution of atmospheric ..... in water.

Sol. acidic, gases.

3. ..... is referred to the various ways by which accumulated acid falls from the ..... in wet or dry forms.

Sol. Acid rain, atmosphere

4. The acid rain results into the damaging of plants and retard the growth of ..... .

Sol. leaves

5. Carbon dioxide, water vapour, oxides of nitrogen, CH_4, O_3, CFCs, etc. are called ..... .

Sol. green houses gases.

6. ..... affects yield of crops and cause damage to lungs.

Sol. Sulphur dioxide

7. Rise in average temperature of the earth's surface is called ..... .

Sol. global warming.

8. Ozone is an ..... of oxygen.

Sol. allotrope

9. ..... are responsible for depletion of ozone layer in upper strata of the atmosphere.

Sol. Freons

10. Depletion of ozone leads to the formation of an ..... .

Sol. ozone hole

Multiple Choice Questions

11. Which of the following is not a green house gas?

(a) CO (b) CO_2

(c) CH_4 (d) H_2O/vapour

Sol. (a)

12. Consider the following measures regarding way to reduce the presence of greenhouse gases.

I. Afforestation

II. Use of solar energy

III. Pooling of cars can be practised

The correct option is

(a) Only I (b) Only II

(c) I and III (d) I, II and III

Sol. (b)

13. The major sources of water vapours are

(a) industrial and vehicular exhaust

(b) burning of fuels

(c) volcanic eruptions

(d) All of the above

Sol. (d)

14. For the preparation of ozone, the commonly used ozoniser is/are

(a) Siemen's ozoniser (b) Brodie's ozoniser

(c) Both (a) and (b) (d) None of these

Sol. (c)

Match the Following

15. Match the reactions given in Column I with the products given in Column II.

	Column I		Column II
A.	$4NO_2 + 2H_2O + O_2 \longrightarrow$	(i)	$2SO_3$
B.	$2SO_2 + O_2 \xrightarrow{\text{Particulate}}$	(ii)	H_2SO_4
C.	$SO_2 + H_2O \longrightarrow$	(iii)	$O_3(g)$
D.	$O(g) + O_2(g) \underset{\text{light}}{\overset{\text{UV}}{\rightleftharpoons}}$	(iv)	$4HNO_3$

Sol. A → (iv), B → (i), C → (ii), D → (iii)

1 Mark Questions

16. Which acid is not present in acid rain?
HNO_3, H_2SO_3, H_2SO_4, CH_3COOH, H_2CO_3, HCl

Sol. CH_3COOH (acetic acid) is not present in acid rain.

17. What is the main cause of acid rain?

Sol. The main cause of acid rain is the formation of mineral acids like HNO_3, carbonic acid and sulphuric acid.

18. Which rays cause greenhouse effect?

Sol. Greenhouse gases absorb ultraviolet radiations and this results in greenhouse effect.

19. How are NO and NO_2 formed in the atmosphere?

Sol. NO is formed by the reaction of N_2 and O_2 during lightening or combustion of fossil fuels. It is further oxidised to NO_2.

20. State any one difference between oxygen and ozone.

Sol. Oxygen is diatomic (O_2), while ozone is triatomic (O_3).

21. What is the reason behind the ozone layer getting depleted?

Sol. Excessive use of man-made compounds containing both fluorine and chlorine, e.g. CFCs, cause depletion of ozone layer.

22. Name the carbon compound, responsible for ozone hole in the atmosphere.

Sol. Chlorofluorocarbons (CFCs).

23. We are lucky that ozone is not stable near the the Earth's surface. Why?

Sol. Ozone occurring near the Earth's surface is a strong oxidant. It causes corrosion of articles, respiratory diseases and also acts as a greenhouse gas. Luckily, it is not stable near the Earth's surface and forms oxygen or oxides.

24. If all the oxygen present in the environment gets converted to ozone, what is most likely to happen?

Sol. The environment will become poisonous and ozone would kill all living forms on the Earth.

b 2 Marks Questions

25. What are the two forms of oxygen found in the atmosphere?

Sol. The two forms of oxygen found in the atmosphere are:

(i) **Elemental Oxygen** It is normally found in the form of diatomic molecule (O_2) in the lower part of atmosphere. It constitutes about 20.95% of the atmosphere and is non-poisonous. *[1]*

(ii) Ozone It is found in the stratosphere of atmosphere. It contains three atoms of oxygen (O_3). It is the poisonous form of oxygen. *[1]*

26. What is the role of CO_2 in the 'green house effect'?

Sol. Heat from the sun after being absorbed by the earth is re-emitted by the earth and absorbed by CO_2 which then radiate it back to the earth, thus, maintaining the constant temperature of the earth. *[2]*

27. Green plants use carbon dioxide for photosynthesis and return oxygen to the atmosphere, even then carbon dioxide is considered to be responsible for green house effect. Explain why?

Sol. The amount of CO_2 produced due to human activity such as burning of fossil fuels like coal, natural gas, petroleum, etc., and production of lime from limestone is much more than that consumed during photosynthesis. The consumption in photosynthesis has further decreased due to deforestation. *[2]*

28. What would have happened if the green house gases were totally missing in the earth's atmosphere? Discuss.

Sol. Carbon dioxide, methane, water vapours, nitrous oxide, CFCs and ozone are green house gases. These gases trap some of the heat radiated by the earth's near the earth's surface and keep it warm. *[1]*

This is called natural green house effect because it maintains the temperature and makes the earth perfect for life. If there were no green house gases, there would have been no vegetation and life on earth as the earth would be converted into a cold planet. *[1]*

29. What will happen, if

(i) ozone gas is present in atmosphere?

(ii) all plants become extinct from the Earth?

Sol. (i) If ozone gas is present in atmosphere, then living organisms cannot survive because it is highly poisonous gas and harmful for living organisms. *[1]*

(ii) We will not be able to survive on Earth, if all plants become extinct because plants are the only source of oxygen in the atmosphere. *[1]*

c 3 Marks Questions

30. Statues and monuments in India are affected by acid rain. How?

Sol. The air around the statues and monuments in India contains fairly high levels of oxides of sulphur and nitrogen. It is mainly due to a large number of industries and power plants around the areas. Oxides of nitrogen and sulphur are acidic in nature. SO_2 and NO_2 after oxidation and reaction with water are major contributors to acid rain.

$$2\,SO_2(g) + O_2(g) + 2\,H_2O(l) \longrightarrow 2\,H_2SO_4(aq)$$

$$4\,NO_2(g) + O_2(g) + 2\,H_2O(l) \longrightarrow 4\,HNO_3(aq)$$

This acid rain reacts with marble of statues and monuments causing damage to these. *[2]*

$$CaCO_3(s) + H_2SO_4(aq) \longrightarrow CaSO_4(s) + H_2O(l) + CO_2(g)$$ *[1]*

31. Oxidation of sulphur dioxide into sulphur trioxide in the absence of a catalyst is a slow process but this oxidation occurs easily in the atmosphere. Explain how does this happen? Give chemical reaction for the conversion of SO_2 into SO_3.

Sol. The presence of particulate matter in polluted air catalyses the oxidation of SO_2 to SO_3.

The oxidation of sulphur dioxide into sulphur trioxide can occur both photochemically or non-photochemically. In the near ultraviolet region, the SO_2 molecules react with ozone photochemically.

$$SO_2 + O_3 \xrightarrow{h\nu} SO_3 + O_2$$
$$2SO_2 + O_2 \xrightarrow{h\nu} 2SO_3 \quad \textit{[2]}$$

Non-photochemically, SO_2 may be oxidised by molecular oxygen in presence of dust and soot particles.

$$2SO_2 + O_2 \xrightarrow{\text{Particulates}} 2SO_3 \quad \textit{[1]}$$

d 4 Marks Questions

32. (i) List any four methods used to reduce formation of acid rain?

(ii) List any four methods that be used to reduce global warming?

Sol. (i) (a) By using less vehicles working on fossil fuels.

(b) By using catalytic converters in cars to reduce the effect of exhaust.

(c) By adding powdered limestone to neutralise the acidic soil.

(d) By spreading information about the harmful effects of oxides of N and S. *[2]*

(ii) The methods that can be used to reduce the global warming are as follows :

(a) Use of solar energy.

(b) Afforestation

(c) Use of wet scrubbers.

(d) Use of public transport. *[2]*

e 5 Marks Questions

33. What is green house effect and what are its sources?

Sol. **Greenhouse effect** is a naturally occurring phenomenon that is responsible for heating of Earth's surface and atomosphere due to the presence of certain gases in the atmosphere.

In the absence of greenhouse effect, the average temperature of Earth would have been chilly −18°C rather than the present average temperature of 15°C. *[2]*

Various sources are as follows:

(a) **Oxides of Sulphur** These are produced when sulphur containing fossil fuel is burnt. SO_2 gas is poisonous to both animals and plants.

(b) **Oxides of Nitrogen** These are produced by the reaction of nitrogen and oxygen at high altitudes when lightening strikes.

$$N_2(g) + O_2(g) \xrightarrow{1483\ K} 2\,NO(g)$$
$$2\,NO(g) + O_2(g) \longrightarrow 2\,NO_2(g)$$
$$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$$

(c) **Hydrocarbons** Incomplete combustion of fuel used in automobiles is the major source for the release of hydrocarbons. These are carcinogenic and cause cancer. They also harm plants.

(d) **Oxides of Carbon** Carbon monoxide is one of the most serious air pollutants. It is highly poisonous to living beings because it blocks the supply of oxygen to the organs and tissues. It is produced due to the incomplete combustion of carbon. Carbon dioxide is the main contributor for global warming. It is released into the atmosphere by respiration, burning of fossil fuels and by decomposition of limestone during cement manufacturing. *[3]*

34. What do you mean by global warming? State the causes and effects of global warming.

Sol. The gradual and continuous rise in average temperature of the Earth's surface is called **global warming**. *[1]*

Causes of Global Warming

(i) High levels of gases, such as carbon dioxide (CO_2), methane (CH_4), ozone (O_3), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) are responsible for global warming.

(ii) Burning of fossil fuels in homes and industries, deforestation, etc., increases the level of carbon dioxide and methane in atmosphere. *[2]*

Effects of Global Warming

(i) An increase in temperature would lead to melting of polar ice caps and consequent rise in sea levels.

(ii) Increase in temperature of Earth can cause change in weather and precipitation patterns on the Earth. *[2]*

CHAPTER EXERCISE

Fill in the Blanks

1. The percent proportion of gaseous components in pure air is …… .

2. pH of acid rain usually ranges between …… and …… .

3. …… causes extensive damage to buildings and sculptural materials.

4. Absence of green house gases will result in decreasing the surface temperature to …… .

5. Ozone has (i) …… bonds with bond angle (ii) …… and bond length is about (iii) …… pm.

Multiple Choice Questions

6. The main sources of global warning is/are
(a) water vapours (b) CO_2
(c) methane (d) All of these

7. Ozone hole refers to
(a) increase concentration of ozone in the atmosphere
(b) decrease of thickness of ozone in troposphere
(c) decrease in thickness of ozone layer in stratosphere
(d) black hole

8. Chlorofluorocarbons (CFCs) are widely used in air conditioners, refrigerators etc. because they are
(a) highly reactive (b) flammable
(c) non-reactive (d) All of these

Match the Following

9. Match the phenomenon/pollutants gives is Column I with example given is Column II

	Column I		Column II
A.	Gaseous	(i)	Oxides of Nitrogen and CO_2
B.	Acid rain	(ii)	CO_2, CH_4, CFC's
C.	Global warming	(iii)	N_2O, CH_4, H_2S

1 Mark Questions

10. Write the composition of air.

11. Write the two major causes for the destruction of ozone layer.

2 Mark Questions

12. How is carbon dioxide harmful for our environment ?

13. What ate sources of nitrogen oxide and methane as air pollutants?

3 Mark Questions

14. Define acid rain and what are its causes?

15. Why should the CFCs be banned ? Write any one substance that can replace chlorofluorocarbon.

16. Write the ways that can be used to reduce the presence of green house gases.

4 Mark Questions

17. Write the sources of following gases:
(a) Water vapour
(b) Carbon dioxide
(c) Methane
(d) Oxides of nitrogen

18. (i) Write the functions of ozone in the atmosphere (any two).
(ii) How ozone can be prepared?

5 Mark Questions

19. Give one name for the following :
(i) Another name of green-house effect
(ii) An allotrope of oxygen which causes green-house effect.
(iii) The oxide of nitrogen that causes green-house effect.
(iv) Two gases that causes acid rain.
(v) Major contributor of green-house effect.

20. (i) What is ozone hole ?
(ii) Give the name of chemicals that are responsible for the depletion of ozone layer.
(iii) Why depletion of ozone is considered as a threat to human beings. Explain.

CHALLENGERS*

1 Consider the following sectors:

I. Agriculture II. Aquatic ecosystem. III. Buildings and other structures

Among the given options, which is affected by the acid rain?

(a) I and II (b) II and III (c) I and III (d) I, II and III

2 Catalytic converters are fitted into automobiles to reduce emission of harmful gases. Catalytic converters changes unburnt hydrocarbons into

(a) carbon dioxide and H_2O(b) carbon monoxide

(c) methane (d) carbon dioxide and methane

3 Which of the following green-house gas is released in paddy field?

I. CFCs II. CH_4 III. SO_2

(a) Only I (b) Only II (c) Both I and II

4 Which of the following gases cause global warming?

I. CO_2 II. O_3 III. CO IV. Chlorofluorocarbons

Choose the correct option

(a) I, II and III (b) II, III and IV (c) I, II and IV (d) I, II, III and IV

5 Global warming causes increase in temperature of earth too much. It can be controlled by

(a) reducing deforestation, decreasing the use of fossil fuels

(b) reducing reforestation, increasing the use of fossil fuel

(c) increasing deforestation, slow down the growth of population

(d) increasing deforestation, reducing efficiency of energy usage

6 How do CFCs causes thinning of ozone layer in stratosphere?

(a) CFCs are transporting agents that generate chlorine radicals into stratosphere

(b) CFCs are transporting agents that generate fluorine radicals into stratosphere

(c) Both (a) and (b)

(d) In the presence of UV, CFCs forms stable compound which degrade the ozone layer.

7 Which of the following is the correct consequence of global warming.

I. Increase in average temperature of earth. II. Melting of Himalayan glaciers.

III. Increased biological oxygen demand. IV. Eutrophication

Choose the correct option

(a) I and III (b) II and IV (c) I and II (d) I and IV

8 Consider the following statement(s) regarding O_3 layer.

I. O_3 layer is found in troposphere.

II. O_3 layer absorbs IR-radiation

III. O_3 layer absorbs UV-radiation

Identify the correct statement.

(a) Only III (b) Only I (c) Both I and II (d) II and III

Answers

1. (d) **2.** (a) **3.** (b) **4.** (c) **5.** (a) **6.** (a) **7.** (c) **8.** (a)

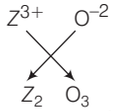
* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 115.

Explanations to Challengers

Chapter 1. The Language of Chemistry

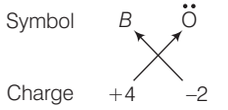
1. (c) Valency of one atom of oxygen = 2

Z has valency equal to 3.

$\because$ 

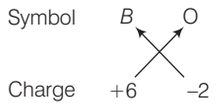
2. (c) If element B shows valency = 4

then formula of its oxide will be



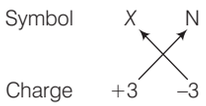
B_2O_4 or BO_2

Similarly,



B_2O_6 or BO_3

3. (c) From the formula of the sulphate $[X_2(SO_4)_3]$ it is clear that the valency of metal X is +3.



On crossing the valencies, we get

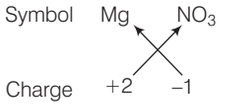
$X_3N_3 = XN$

4. (b) Hydrogen sulphide + air → water + sulphur dioxide

$2H_2S(g)+3O_2(g) \longrightarrow 2H_2O(l)+2SO_2(g)$

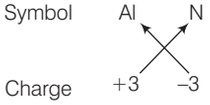
(Balanced equation)

5. (a) Magnesium nitrate



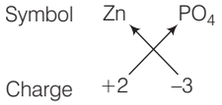
$\Rightarrow Mg(NO_3)_2$

Aluminium nitride



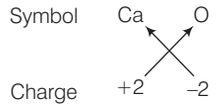
$\Rightarrow Al_3N_3$ or AlN

Zinc phosphate



$\Rightarrow Zn_3(PO_4)_2$

Calcium oxide



$\Rightarrow Ca_2O_2$ or CaO

So, option (a) is incorrect.

6. (d) Calcium carbonate + phosphoric acid ⟶ calcium phosphate + water + carbon dioxide

$$\underset{\downarrow X}{3\,CaCO_3} + \underset{\downarrow Y}{2\,H_3PO_4} \longrightarrow$$

$$Ca_3(PO_4)_2 + 3H_2O + 3CO_2 \text{ (Balanced Equation)}$$

here $X = 3, Y = 2$.

7. (d) Importance of a chemical equations:

(i) A chemical equation gives us information about the substance involved in a reaction.

(ii) It gives information about the symbol and formulae of all the substances involved in a particular reaction.

(iii) It tells about the atoms or molecules of the reactants and products involved in a reaction.

(iv) It tells us about the physical state of the reactants and products.

(v) It gives information about whether heat is evolved or absorbed during a chemical reaction.

8. (d) $\underset{\text{Lead nitrate}}{Pb(NO_3)_2\,(aq)} + \underset{\text{Potassium iodide}}{2KI(aq)} \longrightarrow$

$$\underset{\substack{\text{Lead iodide}\\\text{(yellow ppt.)}\\[w]}}{PbI_2(s)(\downarrow)} + \underset{\substack{\text{Potassium}\\\text{nitrate}\\[x]}}{2KNO_3(aq)}$$

$$\underset{\substack{\text{Zinc}\\[y]}}{Zn(s)} + \underset{\substack{\text{Sulphuric acid}\\\text{(dilute)}}}{H_2SO_4\ (aq)} \rightarrow \underset{\substack{\text{Zinc}\\\text{sulphate}}}{ZnSO_4(aq)} + \underset{\substack{\text{Hydrogen}\\[z]}}{H_2\ (g)\uparrow}$$

So, here $w = (s)$, $x = (aq)$, $y = (s)$, $z = (g)$

Chapter 2. Chemical Changes and Reactions

1. (b) Liquid A(oil) contains carbon and hydrogen as a main component and is inflammable in nature. While liquid B (water) contains hydrogen and oxygen and is used to extinguish fire. Hence, they differ in their chemical composition.

2. (c) For an exothermic reaction, heat releases during reaction so temperature increases whereas endothermic reactions proceeds with absorption of heat which decreases the temperature of reaction.

3. (c) Change in colour occurs due to acidic medium of $K_2Cr_2O_7$.

$$K_2Cr_2O_7 + 6FeSO_4 + 7H_2SO_4 \longrightarrow \underset{\text{Orange}}{} \underset{\text{Green}}{Cr_2(SO_4)_3} + 3Fe_2(SO_4)_3 + K_2SO_4 + 7H_2O$$

4. (c) $6CO_2(g) + 12H_2O(l) \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6(aq) + 6O_2(aq) + 6H_2O(l)$

So, the correct option is c.

$$x = 6,\ y = (g),\ z = 12,\ p = (aq)$$

5. (c) From the information given in question.

As, $K_2SO_4 \longrightarrow$ soluble; $Ba(OH)_2 \longrightarrow$ soluble

$KOH \longrightarrow$ soluble; $BaSO_4 \longrightarrow$ insoluble

Hence, insoluble product is barium sulphate ($BaSO_4$). So, option (c) is correct.

6. (c) On the basis of their relative tendency to lose electron and their reactive nature, the correct order of reactivity of element is Na > Mg > Zn > Pb > H > Ag

7. (a) When $FeSO_4$ crystals are heated, they form their anhydrous $FeSO_4$ and hence, their colour changes from green to white.

$$FeSO_4 \cdot 7H_2O \xrightarrow{\Delta} FeSO_4 + 7H_2O$$

$$2FeSO_4 \xrightarrow{\Delta} Fe_2O_3 + SO_2 + SO_3$$

$\therefore$ First crystals of $FeSO_4$ looses the water of crystallisation and then decomposes.

8. (a) Metal X is lead which forms carbonate ($PbCO_3$)

$$\underset{\text{Lead carbonate (white solid)}}{PbCO_3\ (s)} \xrightarrow{\Delta} \underset{\text{Lead oxide (yellow solid)}}{PbO\ (s)} + \underset{\text{Carbon dioxide}}{CO_2\ (g)}$$

9. (b) As lead acetate $(CH_3COO)_2Pb$ will give yellow ppt. of PbI_2 on mixing with KI solution. Hence, sonu can use lead acetate in place of lead nitrate solution for performing the given activity.

10. (c) When mercury (II) thiocyanate is heated, it forms carbon nitride (C_3N_4), mercury sulphide and carbon disulphide.

$$2Hg(SCN)_2 \longrightarrow 2HgS + CS_2 + C_3N_4$$

Chapter 3. Water

1. (c) Due to high electronegativity difference between hydrogen and highly electronegative elements (like F, O and N) extensive hydrogen bonding is established between such (i.e. water) molecules. Such type of bonding is responsible for the liquid and solid state of water.

2. (a) Organic ion exchange resins can remove only ionic impurities (NaCl). So, the resulting water will be sweet due to presence of sugar.

3. (c) A homogeneous mixture of two or more substances is called true solution. Here, particles of air and cold drink are evenly distributed in the solution and hence are considered as true solutions.

4. (b) According to Henry's Law, at a constant temperature, the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas present above the surface of liquid or solution.

5. (d) From the information given in the graph, salt of NaCl is almost equally soluble at all temperature. Since, solubility of salt NaCl is not increase with temperature.

6. (d) $pV = nRT,\ p = n/V\,(RT) \quad \therefore \quad (n/V = C)$

$\therefore \quad T \propto 1/\text{concentration}$

Thus, with an increases temperature concentrations of thegas decreases.

7. (c) Mass of salt = 35 g; Mass of water = 300g

Mass of the solution = 300 + 35 = 335 g

Hence, conc. of the solution is

$$= \frac{\text{mass of salt}}{\text{mass of solution}} \times 100 = \frac{35}{335} \times 100 = 10.45\%$$

8. (a) $\underset{\text{Gypsum}\ (X)}{CaSO_4 \cdot 2H_2O} \xrightarrow{\Delta} \underset{\text{Plaster of Paris}\ (Y)}{CaSO_4 \cdot \frac{1}{2}H_2O} + \frac{3}{2}H_2O$

The ratio of water molecules in X and Y is 4:1.

9. (d) According to question, one mole of a simple of hydrated sodium sulphide contains 162g of water of crystallisation. It means nine molecules of water present in it.

$\because$ Mass of one water molecule $(H_2O) = 2 \times 1 + 16 = 18$

$\therefore$ Mass of nine water molecules $= 18 \times 9 = 162$ g

10. (b) X = Sodium bicarbonate or sodium hydrogen carbonate.

Its formula is $NaHCO_3$.

$$\underset{(X)}{2NaHCO_3\ (s)} \xrightarrow{\text{Heat}} Na_2CO_3\ (s) + H_2O\ (l) CO_2\ (g)$$

$$Na_2CO_3 + 10H_2O \xrightarrow{\text{Recrystallisation}} \underset{\text{Washing soda}}{Na_2CO_3 \cdot 10H_2O}$$

Chapter 4. Atomic Structure and Chemical Bonding

1. (b) Since, the given species has one –ve charge, it will be neutralised by one positive charge i.e. proton.

2. (d) Neutron is a neutral particle. It means that there is no charge on neutron. So, it will not show deflection from the path on passing through an electric field.

3. (a) S^{2-} ion has $18e^-$. So, its electronic configuration is $K(2), L(8), M(8)$.

Hence, S^{2-} ion has the maximum shells containing electrons.

4. (c) According to Bohr's model of an atom, first shell (K) contains only 2 electrons and second shell (L) contains maximum 8 electrons.

Maximum number of e^- in shell $= 2n^2$

where, n = number of shell

For K, $n=1$

$\therefore$ Maximum number of e^- in K shell $=2\times(1)^2=2e^-$

For L, $n=2$

$\therefore$ Maximum number of e^- in L shell $=2\times(2)^2=8e^-$

So, option (c) is correct.

5. (b) $X \longrightarrow X^{+3}$

Mass number

= Number of protons + Number of neutrons

27 = Number of protons $+14$

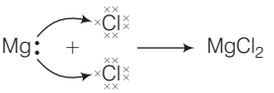
$\therefore$ Number of protons $=27-14=13$

In neutral atom, no. of protons = no. of electrons

But here, element X contains three unit positive charge. So, no. of electrons $=13-3=10e^-$

6. (d) Elements X has two isotopes ^{238}X and ^{235}X. Atoms of the same elements, having the same atomic number, but different mass numbers are called isotopes of the element. Therefore, ^{238}X has 3 more neutrons, but same no. of electrons.

7. (d) A chemical bond formed by the complete transfer of electrons from one atom to another is called electrovalent bond.



8. (c) The maximum number of covalent bonds by which the two atoms can be bonded to each other is three.

Single covalent bond → —C—C—

Double covalent bond → —C=C—

Triple covalent bond → —C≡C—

9. (d) As given species have 1, 3 and 5 valence electrons in A, B and C respectively. Only combination of B and C will not give an ionic compound.

10. (a) Multiple covalent bond exists in a molecules of N_2.

$:N\equiv N:$

N_2 molecule contains three covalent bonds.

Chapter 5. The periodic Table

1. (d) All of the given statements are correct.

2. (d) In a Dobereiner's triad, the atomic mass of the middle element is roughly the average of the atomic masses of the other two elements. Thus, in the given triad.

The atomic mass of Y

$$=\frac{\text{Atomic mass of } X + \text{Atomic mass of } Z}{2}$$

$=7+39/2=46/2=23$ u

3. (a) Isotopes are the elements having similar chemical properties but different atomic masses. In Mendeleev's periodic table, no place was given to these elements.

4. (a) Elements with atomic numbers from $Z=87$ to $Z=114$ are present in the 7th period of the periodic table. Thus, the element with $Z=114$ (flerovium) is present in the 7th period and 14th group of the periodic table.

5. (d) The atomic number of the element Uun is 110.

Number → 1, 1, 0; Name → un, un, nil

Symbol → u, u, n

So, the element name is Ununnilium (Uun) and atomic number is 110.

6. (a) As, we move down the group I and VII, respectively the number of shell will be added.

This increases the distance between the outermost electrons and the nucleus. So, the atomic size increases inspite of the increase in nuclear charge.

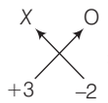
7. (b) According to modern periodic table, as we move left to right atomic radius decreases across the period.

Be=111 pm, B=88 pm, C=77 pm, N=74 pm, O=66 pm

8. (c) According to Henry-Mosely statement "physical and chemical properties of the elements are a periodic function of their atomic number".

Non-metallic elements are about 17 including halogen and noble gas while there are 101 metallic elements in periodic table.

9. (c) Here, element X has an outer electronic structure, s^2p^1. Therefore, its valency is 3 and formula of its oxide will be



$\Rightarrow X_2O_3$

X_2O_3 oxide such as Al_2O_3 is amphoteric in nature. Metal oxides which react with both acids as well as bases to produce salts and water are known as amphoteric oxides.

10. (a) When we move left to right across the periods in the periodic table, acidic character increases and basic character decreases. So, the correct order of basic oxide is $Al_2O_3 < MgO < Na_2O < K_2O$ (Increasing order of basic oxide)

Chapter 6. Study of First Element-Hydrogen

1. (d) Halogen have the tendency to gain one electron and acquire inert gas configuration. Hydrogen also accepts one electron and acquires helium configuration, which is an inert gas.

$F \underset{2s^2 2p^5}{\longrightarrow} Ne \underset{2s^2 2p^6}{}$, $Cl \underset{3s^2 3p^5}{\longrightarrow} Ar \underset{3s^2 3p^6}{}$, $H \underset{1s^1}{\longrightarrow} He \underset{1s^2}{}$

2. (a) $H \rightarrow H^+ + e^-$

H^+ has a very small size ($\sim 1.5\times10^{-3}$ pm) compared to normal atomic and ionic sizes of 50 to 220 pm. It does not exist freely and is always associated with other atoms or molecules.

3. (d) Tritium is one of the radioactive isotope of hydrogen. It has a half-life of about 12.32 years. Tritium is the most stable radioisotope of hydrogen.

4. (b) (i) Reaction of potassium with cold water.

$$2K(s) + \underset{\text{Cold water}}{2H_2O(l)} \longrightarrow 2KOH(aq) + H_2(aq)\uparrow$$

(ii) Calcium does not react with boiling water.

(iii) Metal like Al, Zn, Fe do not react with hot/cold water, they react only with steam to form a metal oxide and hydrogen gas.

$$\underset{\text{(Steam)}}{2Al(s) + 3H_2O(g)} \longrightarrow Al_2O_3(s) + 3H_2(g)\uparrow$$

(iv) Reaction of with boiling water or steam

$$\underset{\text{(Steam)}}{3Fe(s) + 4H_2O(g)} \longrightarrow Fe_3O_4(s) + 4H_2(g)$$

5. (c) Aqueous $Pb(NO_3)_2$ solution is used to remove impurity, H_2S.

6. (a) Hydroxides of metals are formed upon reaction of metals with cold water and hot water.

$$\text{Metal} + \underset{\text{(Cold or hot)}}{H_2O} \longrightarrow \text{Metal hydroxide} + H_2\ (g)$$

7. (a) (i) Protium, the most common isotope of hydrogen, consists of one proton and one electron.

(ii) Water gas shift reaction is a multistep reaction.

(iii) D_2O has lower boiling point than H_2O. It is because H_2O has intermolecular hydrogen bonding.

8. (b) The water gas shift reaction is the reaction of CO and H_2O to form CO_2 and H_2 (the mixture of CO and hydrogen (H_2) is known as water gas).

$$CO(g) + H_2O(g) \xrightarrow{673\text{ K, catalyst}} CO_2(g) + H_2(g)$$

So, here the option (b) is an examples of use of water gas in the synthesis of other compounds.

Chapter 7. Study of Gas Laws

1. (d) Gases neither have definite shape or definite volume. In gaseous state, intermolecular space is maximum while intermolecular forces of attraction is minimum.

2. (c) Pressure $(p) \propto \dfrac{1}{V(\text{volume})}$

But according to van der Waals equation,

$$[p + a(n/V)^2]\ (V - nb) = nRT$$

As, co-volume is the additional volume to give the ideal gas equation. Hence, the amount of space occupied by a gas is much greater than the space occupied by the actual gas molecules.

3. (c) At STP, 1 mole gas = 22.4.

$\because$ 1 mole = gram molecular mass

$\therefore$ 22.4 L of O_2 gas holds = 2 g of H_2 gas

$\therefore$ 3.36 L of O_2 gas holds $= \dfrac{2}{22.4} \times 3.36 = 0.3$ g H_2 gas

4. (c) At STP, 1 mole of gas = 22.4 L.

$$2HgO \xrightarrow{\Delta} 2Hg + O_2$$

2 mol 1 mol

2×216 g 22.4 L or 22400 mL

2×216 g HgO produced = 22400 mL of O_2 gas.

$\therefore$ 2.16 g HgO produced $= \dfrac{22400}{2 \times 216} \times 2.16 = 112$ mL

5. (a) According to deal gas equation, $pV = nRT$

$$\therefore \quad pV = \frac{W}{M}RT \Rightarrow M(CCl_4) = (12 + 142 = 154)$$

$M(O_2) = 32$

Since, V, p and T are constants.

$$\therefore \quad \frac{W_{CCl_4}}{W_{O_2}} = \frac{M_{CCl_4}}{M_{O_2}} = \frac{154}{32} = 4.81 \simeq 5 \Rightarrow \frac{W_{CCl_4}}{W_{O_2}} \simeq 5$$

6. (c) From Boyle's law, $p \propto \dfrac{1}{V}$ [at constant n and T]

$$pV = \text{constant}$$

Hence, option (c) is incorrect representation of Boyle's law.

7. (b) Net pressure recorded = $750 - 100 = 650$ torr

$$p_1V_1/T_1 = p_2V_2/T_2 \qquad \text{[Ideal gas equation]}$$

$$V_2 = \frac{p_1V_1T_2}{p_2T_1} = \frac{650 \times 50 \times 273}{760 \times 291} = 40 \text{ mL}$$

8. (b) From ideal gas law, $pV = nRT \quad \therefore \quad n = pV/RT$

$P_1 = 3$ atm, $V_1 = 1.65$ L, $T_1 = 273 + 273 = 546$ K

$P_2 = 0.75$ atm, $V_1 = 0.55$ L, $T_1 = 0 + 273 = 273$ K

$$\therefore n_1 = \frac{3 \times 1.65}{R \times 546} \text{ and } n_2 = \frac{0.75 \times 0.55}{R \times 273}$$

Now, % nitrogen to be released $= (n_1 - n_2/n_1) \times 100$

$$= (1 - (n_2/n_1)) \times 100$$

$$= \left(1 - \frac{0.75 \times 0.55 \times R \times 546}{R \times 273 \times 3 \times 1.65}\right) \times 100$$

$$= (1 - 0.167) \times 100 = 83.33\%$$

9. (b) As per postulates of kinetic theory of gases, velocity $\propto$ Absolute temperature.

Hence, the velocity of gas molecules is proportional to their Kelvin temperature.

10. (b) $V_1 = 2$L, $T_2 = 299.1$ K, $T_1 = 296.4$ K

From Charle's law, $V_1T_2 = V_2T_1$

$V_2 = V_1T_2/T_1 \Rightarrow V_2 = 2 \times 299.1/296.4 \Rightarrow V_2 = 2.018$ L

Chapter 8. Atmospheric Pollution

1. (d) Acid-rain contain HNO_3 and H_2SO_4 as a component of acid-rain (i.e. along with water which can damage agriculture, aquatic-ecosystem and building along with other structures.

2. (a) Catalytic converter converts the harmful gases and unburnt hydrocarbons to carbon dioxide (CO_2) and water (H_2O) which are non-poisons to human being.

3. (b) Paddy-field releases methane (CH_4) gas, which is responsible for green-house effect.

4. (c) The heating up of earth and its objects because of the trapping of radiations by CO_2 (mainly) and other green house gases such as methane. NO, O_3, CFCs, water vapour etc, in the atmosphere is called **green house effect**.

5. (a) Global warming is controlled by minimising the use of automobiles (i.e., by using bicycle, public transport system, or go for carpool), avoiding the combustion of dry leaves, wood etc., avoiding smoking at public or work places, by planting more trees (i.e. reducing deforestation and decreasing use of fossil-fuels.) and by sharing information about global warming.

6. (a) **Chlorofluorocarbon compounds**, (CFCs) i.e. freons, ultimately reach the stratosphere where they get broken down by powerful UV radiations and release chlorine free radical.

The chlorine free radicals react with ozone and cause its depletion by converting it into chlorine monoxide radical and molecular oxygen.

$$CF_2Cl_2(g) \xrightarrow{h\nu} \dot{Cl}(g) + \dot{C}F_2Cl(g)$$

$$CFCl_3(g) \xrightarrow{h\nu} CFCl_2(g) + \dot{Cl}(g) \qquad \text{(Free radical)}$$

$$Cl^{\bullet}(g) + O_3(g) \longrightarrow ClO^{\bullet}(g) + O_2(g)$$

7. (c) Global warming had a drastic effect on climatic conditions. It increases the average temperature of earth and may cause melting of polar ice caps and glaciers which result in floods of low lying areas.

8. (a) I. Ozone (O_3) layer is mainly present in stratosphere.

II. O_3 do not absorb IR-radiations.

III. O_3 absorbs UV radiations.

Internal Assessment of Practical Work

Experiment 1

Identification of Gases

S. No.	Experiment	Observations	Inferences
1.	**Detection of Hydrogen (H_2)**		
	Preparation Dilute hydrochloric acid (HCl) or dilute sulphuric (H_2SO_4) acid is added to one of the active metals (*e.g.*, Mg). Blue litmus and a burning splinter is brought near to the mouth of test tube. **Reaction** $Mg + \underset{\text{dil.}}{H_2SO_4} \longrightarrow MgSO_4 + H_2\uparrow$	A colourless, odourless gas is evolved which is neutral towards litmus.It put off the burning wooden splinter after giving a pale blue flame and producing a pop sound.	Presence of H_2 is confirmed.
2.	**Detection of Oxygen (O_2)**		
	Preparation Lead dioxide is strongly heated in a boiling tube. Blue litmus paper and a burning splinter is brought near to the mouth of test tube. **Reaction** $2PbO_2 \xrightarrow{\Delta} 2PbO + O_2\uparrow$	A colourless, odourless gas is evolved which is neutral towards litmus.It increased the glow of burning wood splinter.	Presence of O_2 is confirmed.
3.	**Detection of Carbon Dioxide (CO_2)**		
	Preparation Dilute sulphuric acid (H_2SO_4) or dilute hydrochloric acid (HCl) is added to metal carbonate. Blue litmus paper is brought near to the mouth of the test tube. **Reaction** $ZnCO_3 + \text{dil.}2HCl \longrightarrow ZnCl_2 + CO_2 + H_2O$ Pass the evolved gas through lime water,$Ca(OH)_2$	A colourless, odourless gas is evolved which turned moist blue litmus paper red. In put off the burning wooden splinter and turned lime water milky.	Presence of CO_2 is confirmed.
4.	**Detection of Chlorine (Cl_2)**		
	Preparation Concentrated HCl is added to the lead oxides (Pb_3O_4 or PbO_2) or manganese oxide (MnO_2). Blue litmus paper and moist a stach iodide paper is brough near to the mouth of test tube. **Reaction** $PbO_2 + 4HCl \longrightarrow PbCl_2 + 2H_2O + Cl_2\uparrow$ $Pb_3O_4 + 8HCl \longrightarrow 3PbCl_2 + 4H_2O + Cl_2\uparrow$ $MnO_2 + 4HCl \longrightarrow MnCl_2 + H_2O + Cl_2\uparrow$	A greenish yellow gas with pungent smell is evolved which turned moist blue litmus paper first red and then decolourised it. It turned moist starch iodide paper blue black.	Presence of Cl_2 is confirmed.

5.	**Detection of Hydrogen Chloride** (HCl)		
	Preparation Concentrated H_2SO_4 is added to sodium chloride (NaCl) or potassium chloride (KCl). Blue litmus paper and a rod dipped in ammonium hydroxide is brought near to the mouth of test tube. **Reaction** $NaCl + H_2SO_4 \longrightarrow NaHSO_4 + HCl\uparrow$ $KCl + H_2SO_4 \longrightarrow KHSO_4 + HCl\uparrow$	A colourless gas with pungent smell is evolved which turned moist blue litmus paper red. It produced dense white fumes when a glass rod dipped in ammonium hydroxide solution is brought near to it.	Presence of HCl is confirmed
6.	**Detection of Sulphur Dioxide** (SO_2)		
	Preparation Dilute HCl or dilute H_2SO_4 is added to the sodium sulphite. Blue litmus paper, a paper dipped in acidified $K_2Cr_2O_7$ and in $KMnO_4$ and *a* burning splinter is brought near to the mouth of test tube. **Reaction** $Na_2SO_3 + 2HCl \longrightarrow 2NaCl + H_2O + SO_2\uparrow$ $Na_2SO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O + SO_2\uparrow$ $K_2Cr_2O_7 + 3SO_2 + H_2SO_4 \longrightarrow K_2SO_4 + H_2O + Cr_2(SO_4)_3$ (Orange) (Green) $2KMnO_4 + 2H_2O + 5SO_2 \longrightarrow K_2SO_4 + 2MnSO_4 + 2H_2SO_4$ (Purple) (Colourless)	A colourless gas with pungent suffocating smell, similar to that of burning sulphur is evolved which turned moist blue litmus paper red. It put off burning splinter of wood, turned lime water milky, decolourised $KMnO_4$ solution and turned orange solution of acidified $K_2Cr_2O_7$ green.	Presence of SO_2 is confirmed.
7.	**Detection of Hydrogen Sulphide** (H_2S)		
	Preparation Dilute HCl or dilute H_2SO_4 is added to a metal sulphide. Blue litmus paper and paper dipped in lead acetate is brought near to the mouth of test tube. **Reaction** $Na_2S + 2HCl \longrightarrow 2NaCl + H_2S\uparrow$ $ZnS + H_2SO_4 \longrightarrow ZnSO_4 + H_2S\uparrow$	A colourless gas with smell of rotten eggs is evolved which turned moist blue litmus paper red. It also turned lead acetate paper black.	Presence of H_2S is confirmed.
8.	**Detection of Ammonia** (NH_3)		
	Preparation Ammonium salts is heated with alkalies. Red litmus paper and a rod dipped in conc. HCl is brought near to the mouth of test tube. **Reaction** $NH_4Cl + NaOH \xrightarrow{\Delta} NaCl + H_2O + NH_3\uparrow$ $(NH_4)_2SO_4 + 2KOH \xrightarrow{\Delta} K_2SO_4 + 2H_2O + 2NH_3\uparrow$	A colourless gas with pungent smell is evolved which turned moist red litmus paper blue. It produced dense fume, when brought in contact with a rod dipped in conc. HCl.	Presence of NH_3 is confirmed.

9.	**Detection of Water Vapour (H_3O)**		
	Preparation Crystals of hydrated copper sulphate is heated. Litmus paper is brought near to the mouth of test tube. The condensed liquid is dropped anhydrous copper sulphate. **Reaction** $CuSO_4 \cdot 5H_2O \xrightarrow{\Delta} CuSO_4 + 5H_2O$	A colourless, odourless gas is evolved which has no effect on litmus. It condensed to liquid state at room temperature. It turned anhydrous $CuSO_4$ (from white) to blue.	Presence of H_2O is confirmed.
10.	**Detection of Nitrogen Dioxide (NO_2)**		
	Preparation Concentrated nitric acid is added to copper turnings. The contents of the test tube is heated. Blue litmus paper and iodide paper is brought near to the mouth of test tube. The evolved gas is passed through acidified ferrous sulphate solution. **Reaction** $Cu + 4HNO_3 \longrightarrow Cu(NO_3)_2 + 2H_2O + 2NO_2\uparrow$	A reddish brown gas with pungent smell is evolved which turned moist blue litmus paper red. It also turned iodide paper blue and acidified $FeSO_4$ solution brown.	Presence of NO_2 is confirmed.

Experiment 2

Action of Heat on Given (Unknown) Substances

Heating causes both physical and chemical changes. Physical changes usually involve melting and evaporation while chemical changes involve decomposition of a substance, dehydration of hydrated crystals of substance. Observations of change in colour during the heating, gas evolved, etc., helps to identify the heated substance.

S. No.	Observations	Inferences
1.	**Action of Heat on $CuCO_3$ and $ZnCO_3$**	
	(a) Copper Carbonate ($CuCO_3$)	
	(i) The given substance is light green amorphous powder which turns black on heating.	The black residue is CuO.
	(ii) A colourless, odourless gas evolves on heating which turns lime water milky.	The gas evolved is CO_2.
	Chemical reactions	The substance heated is $CuCO_3$.
	$\underset{\text{Light green}}{CuCO_3} \xrightarrow{\Delta} \underset{\text{Black}}{CuO} + CO_2\uparrow$	
	$\underset{\text{Lime water}}{Ca(OH)_2} + CO_2 \longrightarrow CaCO_3 + H_2O$	
	(b) Zinc Carbonate ($ZnCO_3$)	
	(i) The given substance is white amorphous solid which turns to pale yellow solid on strong heating.	

S. No.	Observations	Inferences
	(ii) A colourless, odourless gas evolves which turns lime water milky.	The white residue is ZnO.
	(iii) The residue turns white on cooling. **Chemical reaction** $ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2$	The gas evolved is CO_2. The substance heated is $ZnCO_3$.
2.	**Action of Heat on $Na_2CO_3 \cdot 10\ H_2O$ and $CuSO_4 \cdot 5\ H_2O$**	
	(a) Washing Soda ($Na_2CO_3 \cdot 10\ H_2O$) **:**	
	(i) The given substance is white, crystalline solid which gives steamy vapour and subsequently melts. On cooling, the residue left is white amorphous solid.	The white residue is Na_2CO_3.
	(ii) The vapour that evolves, condenses into liquid upon cooling and turns white anhydrous $CuSO_4$ to blue hydrated $CuSO_4$. **Chemical reaction** $Na_2CO_3 \cdot 10\ H_2O \xrightarrow{\Delta} Na_2CO_3 + 10\ H_2O\uparrow$	The vapour evolved is H_2O. The substance heated is washing soda (hydrated sodium carbonate - $Na_2CO_3 \cdot 10\ H_2O$)
	(b) **Copper Sulphate Crystals** ($CuSO_4 \cdot 5\ H_2O$)	
	(i) The given substance is blue crystalline solid which produces steamy vapour and white residue on heating.	The white residue is $CuSO_4$.
	(ii) The vapour that evolves, condenses into liquid upon cooling and turns blue cobalt chloride paper pink. **Chemical reaction** $CuSO_4 \cdot 5\ H_2O \xrightarrow{\Delta} CuSO_4 + 5\ H_2O\uparrow$	The vapour evolved is H_2O. The substance heated to give white residue is copper sulphate crystal.
3.	**Action of Heat on $Zn(NO_3)_2 \cdot 6H_2O$, $Cu(NO_3)_2 \cdot 6H_2O$ and $Pb(NO_3)_2$**	
	(a) Zinc Nitrate Hexahydrate [$Zn(NO_3)_2 \cdot 6H_2O$]	
	(i) The given substance is white, crystalline, deliquescent solid which on heating, produces steamy vapour and melts to form a white viscous liquid.	
	(ii) The vapour that evolves, condenses into liquid and turns white anhydrous $CuSO_4$ to blue hydrated $CuSO_4$.	
	(iii) When the residue is heated more strongly, it produces a new pale yellow residue along with reddish brown fumes which turns moist blue litmus paper red.	The final residue is ZnO.
	(iv) On bringing a glowing wood splinter in the fumes, it inflames, which suggest the presence of oxygen in the fumes.	The initially evolved steamy vapour is H_2O.
	(v) The pale yellow residue turns white on cooling. **Chemical reactions** $Zn(NO_3)_2 \cdot 6\ H_2O \xrightarrow{\Delta} Zn(NO_3)_2 + 6\ H_2O$ $Zn(NO_3)_2 \xrightarrow{\Delta} 2\ ZnO + 4NO_2 + O_2\uparrow$	The reddish brown fumes are mixture of NO_2 and O_2. The given substance is $Zn(NO_3)_2 \cdot 6\ H_2O$.
	(b) Copper Nitrate Hexahydrate [$Cu(NO_3)_2 \cdot 6H_2O$]	
	(i) The given substance is bluish green crystalline solid which produces steamy vapour and turns to bluish green amorphous solid on heating.	
	(ii) The vapour that evolves, condenses into liquid and turns white anhydrous $CuSO_4$ to blue hydrated $CuSO_4$.	

S. No.	Observations	Inferences
	(iii) On heating the residue even more strongly, it produces a new black residue along with reddish brown fumes which turn moist blue litmus paper red.	The final residue is CuO.
	(iv) On bringing a glowing wood splinter in the fumes, it inflames, which suggest the presence of oxygen in the flame.	The initially evolved steamy vapour is H_2O. The reddish brown fumes are mixture of NO_2 and O_2.
	Chemical reactions $Cu(NO_3)_2 \cdot 6\,H_2O \xrightarrow{\Delta} Cu(NO_3)_2 + 6\,H_2O$ $2Cu(NO_3)_2 \xrightarrow{\Delta} 2\,CuO + 4NO_2 \uparrow + O_2 \uparrow$	The given substance is $Cu(NO_3)_2 \cdot 6\,H_2O$.
	(c) Lead Nitrate $[Pb(NO_3)_2]$	
	(i) The given substance is white, crystalline solid which fuses on heating to produce reddish brown residue along with reddish brown fumes which turn moist blue litmus paper red.	The residue formed is PbO.
	(ii) On bringing a glowing wood splinter in the fumes, it inflames, which suggest the presence of oxygen in the fumes.	The reddish brown fumes are mixture of NO_2 and O_2.
	(iii) The reddish brown residue changes to light yellow colour on cooling.	The given substance is $Pb(NO_3)_2$.
	Chemical reaction $2Pb(NO_3)_2 \xrightarrow{\Delta} 2PbO + 4NO_2 \uparrow + O_2 \uparrow$	
4.	**Identification of NH_4Cl, I_2 and $(NH_4)_2Cr_2O_7$**	
	(a) Ammonium Chloride (NH_4Cl)	
	(i) The given substance is white crystalline solid which sublimes to produces dense white fumes on heating, leaving no residue behind.	The fumes consist of NH_3 and HCl.
	(ii) The white fumes condenses to form white powdery solid on cooling.	The given substance is NH_4Cl.
	Chemical reaction $NH_4Cl \underset{\text{Cool}}{\overset{\Delta}{\rightleftharpoons}} NH_3 \uparrow + HCl$	
	(b) Iodine (I_2)	
	(i) The given substance is greyish brown crystalline solid, which sublimes to produce violet vapours of heating, leaving no residue behind.	The vapours and the given solid substance are I_2.
	(ii) The violet vapours turn the white filter paper, dipped in starch solution, blue.	
	(iii) The vapours condense to form greyish brown crystalline solid.	
	Chemical reaction $I_2 \xrightarrow{\Delta} 2\,I \uparrow$	
	(c) Ammonium Dichromate $[(NH_4)_2Cr_2O_7]$	
	(i) The given substance is reddish orange, crystalline solid which give steamy fumes on heating, leaving greenish grey residue.	
	(ii) On cooling, fumes produce a colourless liquid and a colourless gas.	
	(iii) The colourless liquid turns white anhydrous $CuSO_4$ to blue hydrated $CuSO_4$.	The residue formed is Cr_2O_3.
	(iv) The colourless, odourless gas neither burns nor supports combustion. It also does not have any effect on lime water.	The liquid and the gas are H_2O and N_2, respectively.
	Chemical reaction $(NH_4)_2Cr_2O_7 \xrightarrow{\Delta} Cr_2O_3 + N_2 \uparrow + 4\,H_2O \uparrow$	The given substance is $(NH_4)_2Cr_2O_7$.

Experiment 3

Action of Dilute Sulphuric Acid on Unknown Substance

S. No.	Experiment	Observations	Inferences
1.	**Action on Metals**		
	$\underset{\text{Magnesium}}{Mg} + \underset{\text{Dil. sulphuric acid}}{H_2SO_4} \rightarrow MgSO_4 + H_2\uparrow$ $\underset{\text{Zinc}}{Zn} + \underset{\text{Dil. sulphuric acid}}{H_2SO_4} \rightarrow ZnSO_4 + H_2\uparrow$ The gas evolved is brought near to burning splinter.	A brisk effervescence of colourless, odourless gas is evolved which burns with a sound of pop.	The evolved gas is hydrogen (H_2S). The given substance is a metal.
2.	**Action on Carbonate**		
	$\underset{\text{Sodium carbonate}}{Na_2CO_3} + \underset{\text{Dil. sulphuric acid}}{H_2SO_4} \longrightarrow Na_2SO_4 + H_2O + CO_2\uparrow$ The gas evolved is passed through lime water.	A brisk effervescence of colourless, odourless gas is evolved which turns lime water milky.	The evolved gas is carbon dioxide (CO_2). The given substance is a carbonate.
3.	**Action on Sulphide**		
	$\underset{\text{Sodium sulphide}}{Na_2S} + \underset{\text{Dil. sulphuric acid}}{H_2SO_4} \longrightarrow Na_2SO_4 + H_2S\uparrow$ $\underset{\text{Zinc sulphide}}{ZnS} + \underset{\text{Dil. sulphuric acid}}{H_2SO_4} \longrightarrow ZnSO_4 + H_2S\uparrow$ The gas evolved is brought near to the lead acetate paper and to a burning wooden splinter.	A colourless gas having odour of rotten eggs is evolved, which turns lead acetate paper black. It burns with a pop sound.	The evolved gas is hydrogen sulphide (H_2S). The given substance is a sulphide.
4.	**Action on Sulphite**		
	$K_2SO_3 + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O + CO_2$ The gas evolved is passed through lime water and is brought near to lead acetate paper.	A colourless gas is evolved having suffocating odour of burning sulphur, which turns lime water milky and lead acetate paper black.	The evolved gas is sulphur dioxide (SO_2). The given substance is sulphite.

Experiment 4

AIM

To apply the flame test to identify the metal in the unknown substance.

(i) a sodium salt

(ii) a potassium salt

(iii) a calcium compound

Theory

If a given salt consists metal ion then it can be detected by the flame test. In this test, certain metals impart characteristic colour to the flame, which becomes basis of their identification.

Procedure

(i) Take a thin platinum wire and make a circular loop at its end.

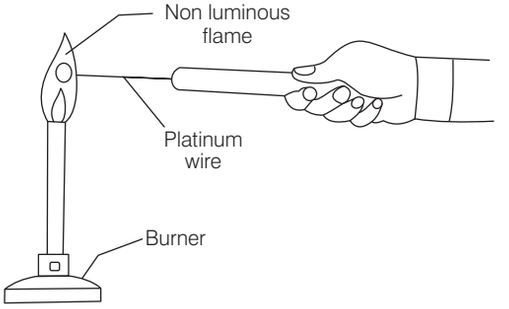
(ii) Clean it by dipping it in concentrated hydrochloric acid and subsequently heating in the non-luminous flame of the burner.

(iii) This process is repeated until the platinum wire does not impart any colour to the flame.

(iv) Make a thin paste of given salt with concentrated hydrochloric acid.

(v) Apply this paste on the loop of the wire.

(vi) Observe and note the colour imparted to the flame.



Performing flame test

Observation Table

S. No.	Observation		Inference
	Colour Imparted to the Flame		
	Colour observed with Naked Eyes	Colour seen through a blue Glass	Presence of metal ion
(i)	Golden yellow	Persistent pale yellow	Sodium ion (Na^+)
(ii)	Lilac (voilet)	Lilac (voilet)	Potassium ion (K^+)
(iii)	Brick red	Pale green	Calcium ion (Ca^{2+})

Experiment 5

AIM

To carry out simple experiments based on hard water and soft water.

Theory

On the basis of action with soaps, there are two types of water

(i) Hard Water

This kind of water does not form lather or foam with soap, easily.

e.g., Ground water, river water, sea water, etc.

(ii) Soft Water

This kind of water readily produces lather with soap.

e.g., Rain water and distilled water.

Cause of Hardness of the Water

Hard water consists of dissolved salts *viz* bicarbonates [$Ca(HCO_3)_2$, $Mg(HCO_3)_2$], chlorides ($CaCl_2$, $MgCl_2$) and sulphates ($CaSO_4$, $MgSO_4$). These salts form complex with soap molecule which prevents soap from dissolving in water and hence reduces its cleansing capacity.

Types of Hardness of Water

There are two types of hardness of water which are as follows

(i) Temporary Hardness

This kind of hardness can be removed easily by boiling the water. It is caused due to presence of Ca and Mg bicarbonates.

(ii) Permanent Hardness

This kind of hardness of water cannot be removed by boiling the water. It is caused due to presence of chlorides and sulphates of calcium and magnesium.

Identification of Soft Water and Hard Water

Procedure

(i) Take equal amount of hard water and soft water samples in two separate test tubes.

(ii) Add equal amount of soap in both test tubes and shake them thoroughly.

Observation

Note the length of lather produces in the test tubes.

Inference

The sample of water which produce more lather in the test tube is soft water while the other one is hard water.

Identification of Temporary and Permanent Hard Water

Procedure

(i) Take equal amount of temporary and permanent hard water samples in two separate test tubes.

(ii) Boil both the samples and let them cool down to room temperature.

(iii) Filter both the sample in different separate test tubes and add little but equal amount of soap to each sample.

(iv) Shake both the tubes thoroughly.

Observation

Note down the length of later formed in each case.

Inference

Heating temporary hard water removes its hardness and makes it soft, as bicarbonates convert into carbonates and sediment down.

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

Thus, the sample which formed more lather is temporarily hard while the other one is permanently hard.

Removal of Hardness of Water

Following methods can be implied to soften a hard water

(i) Boiling the Temporary Hard Water

As discussed in the previous experiment, written above, boiling a temporary hard water precipitate the bicarbonates in the form of carbonates. By filtering out the insoluble carbonates we get soft water.

(ii) Removing Temporary as well as Permanent Hardness of Water

As the discussed in the experiment, the hardness of water cannot be removed easily by boiling the water.

Procedure

(i) Take about 100 mL of permanent (or temporary) hard water in a beaker and add about 2 g of washing soda in it.

(ii) Stir the mixture well and filter out the insoluble salt from it.

(iii) Use this soften water with soap to test whether the lather is formed easily.

Observation

The soften water form lather readily with a soap.

Inference

Washing soda forms precipitate with hardening agents of hard water as follows

(a) **In case of temporary hard water**

$$\underset{\substack{\text{Bicarbonate}\\(\text{present in temporary}\\ \text{hard water})}}{Ca(HCO_3)_2} + \underset{\text{Washing soda}}{Na_2CO_3} \longrightarrow \underset{\substack{\text{Insoluble calcium}\\ \text{carbonate (precipitat)}}}{CaCO_3} \downarrow + 2\,NaHCO_3$$

(b) **In case of permanent hard water**

$$CaCl_2 + \underset{\text{Washing soda}}{Na_2CO_3} \longrightarrow \underset{\substack{\text{Insoluble calcium}\\ \text{carbonate (precipitat)}}}{CaCO_3}\downarrow + 2\,NaCl$$

Advantage of Using Detergents over Soap in Hard Water

Soaps Sodium or potassium salt of higher fatty acids are called soaps.

e.g., Sodium stearate potassium palmate etc.

Detergents Sodium salts of alkyl sulphonic acids are called detergents.

e.g., Sodium dodecyle benzene sulphonate.

The main advantage of using detergents over soap is that detergents form lather even in hard water and hence are more effective cleaning agent.

Comparision of Lather Formation by Soaps and Detergents

Procedure

(i) Take about 20 mL of hard water in each of two test tubes.

(ii) Add about 1 g of soap in one of the test tubes and about 1 g to detergent in the other test tube. Shake both the tubes properly.

(iii) Note the length of lather formed in each test tube.

Observation

The test tube consisting detergent formed lather while soap did not form lather with hard water.

Inference

Detergents form more lather in hard water in comparision to soaps hence can act as better cleansing agent.

Experiment 6

AIM

To find out the sources of pollution of water bodies in the locality suggest preventive steps to control it.

Theory

Mixing of undesirable and usually harmful substances in natural source of water is called water pollution. A polluted water can be identified by unusual colour, smell, taste and visible mixed substances. A polluted water causes serious health hazards to living beings.

Common Sources of Water Pollution

(i) Soaps and detergents used for washing clothes, utencils, etc., causes serious kind of water pollution.

(ii) Sewage and domestic wastes flushed into a river or a pond makes water unfit for creatures dependent on these water bodies.

(iii) Industries releases wastes containing heavy metals, inorganic and organic compounds are so hazardous and persistent that they enter aquatic food chains and get accumulated there.

(iv) Oil spills, usually by oil carrying ships in sea, causes death of living creatures searching for foods on water.

Quality of Water

To assess the quality of water from a water body in your locality, follow the steps written below

Procedure

(i) Take water sample from a water body (like pond, river, well, etc.)

(ii) Filter the sample and fill it in two or three different test tubes.

(iii) Add a small amount of soap in one of the test tube and shake it thoroughly.

Observation

(i) Note the colour of water.

(ii) Notice, if there are any visible suspended particles.

(iii) Note the odour of water, if any.

(iv) Dip an universal pH paper in a test tube (other than the one having dissolved soap) and note the pH of water normal (pH is 7 for pure water.)

(v) Note the length of the foam formed in the test tube having dissolved soap.

(vi) Repeat all the above observation with purified drinking water.

Inference

Any significant or noticeable deviation in observation of water sample from that of drinking water, suggests the quality of water is unfit for drinking, cooking, etc.

Preventive Steps to Control Water Pollution

(i) Proper treatment of sewage should be done, before releasing it into water bodies.

(ii) Ultraviolet radiations can be used to destroy pathogens present in water.

(iii) Methods like oxidation or precipitation can be used to remove organic matter.

(iv) Gravity settlement and screening can be used to remove heavier floating solids.

(v) Toxic substances from factories should be treated so as to reduce their toxicity.

Viva-Voce

Q 1. Name the gas evolved when dilute sulphuric acid is added to magnesium granules.

Ans. Hydrogen (H_2)

Q 2. Name a gas which increase the glowing wood splinter.

Ans. Oxygen (O_2)

Q 3. Name a metal salt which would produce carbon dioxide gas upon heating.

Ans. Zinc carbonate ($ZnCO_3$)

Q 4. Name a gas which turns lime water milky.

Ans. Carbon dioxide (CO_2)

Q 5. What effect does chlorine gas have on moist starch iodide paper?

Ans. It turns the paper blue black.

Q 6. Name the acidic gas formed upon action of common salt on concentrated sulphuric acid.

Ans. Hydrogen chloride (HCl)

Q 7. Name a gas which decolourise $KMnO_4$ solution and tuns acidified solution of $K_2Cr_2O_7$ green.

Ans. Sulphur dioxide (SO_2)

Q 8. What are the products formed upon action of acid on metal sulphides?

Ans. Metal salts (like NaCl, $ZnSO_4$) and hydrogen sulphide (H_2S) gas.

Q 9. How can the ammonia gas be prepared?

Ans. Heating ammonia salts with alkalies.

Q 10. How can we turn white $CuSO_4$ solid to blue?

Ans. By adding water to the $CuSO_4$.

Q 11. What action does a gas, produced by reaction of nitric acid on copper turning, have on iodide paper?

Ans. The gas (NO_2) turns iodide paper blue.

Q 12. What are the products formed on thermal decomposition of copper (II) carbonate?

Ans. CuO and CO_2

Q 13. How the colour changes during decomposition of $CuCO_3$?

Ans. Colour changes form light green ($CuCO_3$) to black (CuO).

Q 14. How can you distinguish between $ZnCO_3$ and $CuCO_3$?

Ans. $ZnCO_3$ is white and turns pale yellow on heating while $CuCO_3$ is light green and turns black on heating.

Q 15. How many water of crystallisation is associated with each molecule of sodium carbonate in washing soda crystal?

Ans. 10 ($Na_2CO_3 \cdot 10H_2O$)

Q 16. What colour change is observed when copper sulphate crystal is heated?

Ans. Blue crystals turn to white solid.

Q 17. Strong heating of zinc nitrate results in evolution of brown fumes. What compose(s) the brown furmes?

Ans. The brown fumes are the mixture of nitrogen dioxide (NO_2) and oxygen (O_2).

Q 18. Name a bluish green crystal which produces fumes of NO_2 and O_2.

Ans. Copper nitrate hexahydrate $[Cu(NO_3)_2 \cdot 6H_2O]$.

Q 19. Name a metal nitrate crystal which does not have any water of crystallisation.

Ans. Lead nitrate $[Pb(NO_3)_2]$

Q 20. Name the reddish brown oxide formed after thermal decomposition of a white crystalline nitrate.

Ans. Lead oxide (PbO)

Q 21. Name the process by which ammonium chloride forms ammonia and hydrogen chloride.

Ans. Sublimation

Q 22. Name a substance that sublimes into violet vapour.

Ans. Iodine (I_2)

Q 23. Name the products formed after the thermal decomposition of ammonium dichromate.

Ans. Chromium oxide (Cr_2O_3), nitrogen (N_2) and water (H_2O).

Q 24. What effect does H_2S have on lead acetate paper?

Ans. It turns lead acetate paper black.

Q 25. What is the cause of brisk effervescence, when dilute sulphuric acid is added to sodium carbonate?

Ans. Evolution of carbon dioxide gas (CO_2).

Q 26. Name the salt formed in a displacement reaction between zinc metal and dilute sulphuric acid.

Ans. Zinc sulphate

Q 27. Name the colours imparted by salts of sodium, potassium and calcium.

Ans. Salts of soidum, potassium and calcium import golden yellow, lilac and brick red colour respectively to the flame.

Q 28. Why platinum wire is used in a flame test?

Ans. Because platinum does not impart any colour to the flame.

Q 29. Name a gas that turns lime water milky and lead acetate paper black.

Ans. Sulphur dioxide (SO_2)

Q 30. Give examples of hard water and soft water.

Ans. **Hard Water** Water from pond, well, etc.

Soft Water Rain water, distilled water, etc.

Q 31. Give atleast one example each of substances which causes temporary hardness and permanent hardness.

Ans. **Temporary Hardness Calcium bicarbonate** [$Ca(HCO_3)_2$].

Permanent Hardness Calcium sulphate ($CaSO_4$).

Q 32. How can we removed temporary hardness?

Ans. By boiling the water.

Q 33. Name a method to remove temporary as well as permanent hardness of water.

Ans. Adding washing soda [$Na_2CO_3 \cdot 10\ H_2O$] into the water.

Q 34. Give examples of substance which forms soap and detergents.

Ans. **Soap** Sodium stearate

Detergent Sodium dodecyl benzene sulphonate.

Q 35. Given examples of sources that cause

(a) pollution on water surface.

(b) hazard to food chain.

Ans. (a) Oil spills

(b) Heavy metals, organic compounds, etc., released from industries.

Q 36. What is the precipitate product in the process of softening of hard water?

Ans. Calcium carbonate $CaCO_3$.

Q 37. Name a cleansing agent effective in hard water.

Ans. Detergents

Q 38. Which produces more lather in hard water soaps or detergents?

Ans. Detergent form more lather in hard water than soap, hence acts as better cleansing agent.

Q 39. Give preventive steps to control water pollution.

Ans. (i) Proper treatment of sewage should be done, before releasing it into water bodies.

(ii) Oxidation or precipitation methods can be used to remove organic matter.

Q 40. How will you distinguish hard water from soft water?

Ans. By dissolving soap in water samples. Hard water does not make lather easily while soft water does.

SAMPLE QUESTION PAPER 1

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS IX

CHEMISTRY (FULLY SOLVED)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

FULLY SOLVED

Section-A

[40 *Marks*]

1. (a) Fill in the blanks.

(i) Neutrons and protons are found in ..... of the atom.

(ii) Electrons present in outermost shell of an atom is called ..... electrons.

(iii) The number of protons present in an atom is called ..... number of an atom.

(iv) There are ..... electrons in outer shell of neon.

(v) An atom having eight electrons and eight protons can be represented by the symbol as ..... . ***[5]***

(b) Choose the most appropriate answer.

(i) What is the percentage composition of hydrogen in water ? (Relative atomic mass of H = 1, O = 16)

(a) 22.7 % (b) 18.4 %

(c) 11.1 % (d) 16.2 %

(ii) What is the chemical formula of soap ?

(a) $C_{16}H_{33}COONa$ (b) $C_{17}H_{35}COONa$

(c) $C_{15}H_{31}COONa$ (d) $C_{14}H_{29}COONa$

(iii) Which of the following is ionic compound?

(a) C_2H_4 (b) $MgCl_2$ (c) NH_3 (d) CCl_4

(iv) The correct order regarding size of atom is

(a) Li ≈ Be > C ≈ O (b) Li > Be > C ≈ O

(c) Li > Be > C > O (d) Be > Li > C > O

(v) $H_2S + Cl_2 \longrightarrow 2HCl + S$

In the above reaction, the substance shows reduction is

(a) H_2S (b) S (c) HCl (d) Cl_2 ***[5]***

(c) Correct the underlined words in each of the following cases.

(i) Washing soda is used to remove temporary hardness of water.

(ii) Hard water is used for washing purposes.

(iii) Water has low dielectric constant.

(iv) The chemical formula of ozone is O_2.

(v) An atom contains electron and proton in the nucleus. ***[5]***

(d) Write the complete balanced equation of the following.

(i) $Pb(NO_3)_2 \xrightarrow{\Delta}$

(ii) $MgO \xrightarrow{\text{Combustion}}$

(iii) $NaCl + AgNO_3 \longrightarrow$

(iv) $NH_4CNO \xrightarrow{\Delta}$

(v) $Zn + CuSO_4 \longrightarrow$ ***[5]***

(e) Name any one reactant, for each of the following reactants, that reacts to produce hydrogen gas.

(i) Cold H_2O

(ii) Hot H_2O

(iii) Steam

(iv) Acid

(v) Alkali ***[5]***

(f) (i) Write the formulae for the following.

1. Ammonium carbonate
2. Potassium sulphate
3. Cupric chloride ***[3]***

(ii) From the list of formula given, choose the most appropriate radicals to match the given description (CH_3COO^-, CO_3^{2-}, P^{3-}, $Fe(CN)_6^{4-}$)

1. Monovalent acid radical
2. Divalent acid radical **[2]**

(g) (i) Calculate the temperature at which 500 cm^3 of a gas measured at 20°C occupy half its volume. Assume pressure is remain constant. **[2]**

(ii) One litre of a gas at 10°C is heated till both its volume and pressure are triple. What is the final temperature ? **[2]**

(iii) What is standard temperature and pressure ? **[1]**

(h) Match the following columns.

	Column I		Column II
(i)	Boyle's law	(a)	373 K
(ii)	Charles's law	(b)	$V \propto T$
(iii)	Boiling point of water	(c)	$pV = K$
(iv)	Freezing point of water	(d)	−273°C
(v)	Absolute zero	(e)	273 K

[5]

FULLY SOLVED

Section-B

[40 *Marks*]

2. (a) Write the four important feature of the activity series. **[4]**

(b) Ozone gas is heavier than air. Why does ozone not settle down near the earth? **[2]**

(c) Oxidation of sulphur dioxide into sulphur trioxide in the absence of a catalyst is a slow process but this oxidation occurs easily in the atmosphere. Explain how does this happen? Give chemical reaction for the conversion of SO_2 into SO_3? **[2]**

(d) How are NO and NO_2 formed in the atmosphere? **[2]**

3. (a) A gas is enclosed in a room. The temperature and pressure are °C and *p* atm.

(i) What will be the pressure and temperature in each compartment if room is partitioned into four equal compartments?

(ii) What will be the values of pressure and temperature in each compartment if the walls between the two compartments (say 1 and 2) are removed? **[4]**

(b) Atomic number of the elements of 3 period of modern periodic table are listed below. Study the data carefully and answer the questions that follows.

Period 3 elements	Na	Mg	Al	Si	P	S	C	Ar
Atomic number	11	12	13	14	15	16	17	18

[4]

(i) What are the atomic number of sodium and phosphorus respectively? Write their respective electronic configurations.

(ii) Write down the number of valence electrons in an atom of sodium and phosphorus respectively.

(iii) What are the valencies of sodium and phosphorus?

(iv) What are the valencies of sulphur and chlorine atom?

(c) 35mL of oxygen were collected at 6°C and 758 mm pressure. Calculate its volume at NTP. **[2]**

4. (a) An experimental result shows the variation of solubility of salt with temperature as given in the table. (Variation of solubility with temperature as in 100 grams of water)

Salt	10°C	20°C	30°C	40°C	50°C	80°C
$CaSO_4$	11.0 g	9.0 g	4.0 g	3.2 g	2.0 g	1.0 g
$NaNO_3$	80.0 g	88.0 g	96.0 g	104.0 g	114.0 g	148.0 g
NaCl	35.8 g	36.0 g	36.3 g	36.6 g	37.0 g	38.0 g
K_2SO_4	9.2 g	11.1 g	13.0 g	14.8 g	16.5 g	21.4 g
KBr	59.5 g	62.2 g	70.6 g	75.5 g	80.2 g	95.0 g

From the data given above, answer the following questions.

(i) Which salt shows the greatest weight increase in solubility as the temperature increases from 10°C and 80°C?

(ii) Which salt shows a decrease in solubility with rise in temperature?

(iii) A solution of $NaNO_3$ containing 50 g of water is cooled from 30°C to form a saturated solution of 10°C. Calculate the weight of $NaNO_3$ will be precipitated.

(iv) A solution containing 100 g of water, 10 g of K_2SO_4 was heated to 50°C. How much additional weight (in g) of K_2SO_4 must be added to saturate the solution at 50°C? **[4]**

(b) Define the following.

(i) Hydrated substance (ii) Anhydrous substance

(iii) What do you understand by water of crystallisation? **[3]**

(c) By which method the solubility of gas can be increased? **[3]**

5. (a) (i) Describe the bulk preparation of hydrogen by electrolysis? **[2]**

(ii) How can the production of dihydrogen, obtained from coal gasification be increased? **[2]**

(b) How is dihydrogen obtained from

(i) dilute sulphuric acid?

(ii) sodium hydroxide?

(iii) water?

(iv) Zinc ?

Give one equation in each case. *[4]*

(c) Write the balanced chemical equation for the following.

(i) Ammonia react with oxygen in the presence of platinum.

(ii) Zinc react with dilute sulphuric acid. *[2]*

6. (a) Given a balanced equation for each of the following.

(i) Action of concentrated sulphuric acid on copper.

(ii) Action of water on iron.

(iii) Reaction of potassium iodide with hydrogen peroxide.

(iv) Reaction of quicklime with carbon dioxide. *[4]*

(b) Write the one example of the following.

(i) Anhydrous substance

(ii) Hydrated substance

(iii) Hygroscopic substance

(iv) Efflorescent substance *[4]*

(c) Give a balanced chemical equation for each of the following.

(i) Decomposition of calcium bicarbonate.

(ii) Addition of calcium bicarbonate and calcium hydroxide. *[2]*

7. (a) Make a schematic atomic structure of magnesium and phosphorus.

(Give number of protons of magnesium = 12 and that of phosphorus = 15) *[5]*

(b) What is an octet? How do elements reach an octet? *[2]*

(c) Fill in the blanks.

(i) ..... is an element whose isotope has mass number 14 and 8 neutrons.

(ii) ..... will not show deflection from the path on passing through an electric field.

(iii) ..... are the species having same number of neutrons. *[3]*

ANSWERS

1. (a) (i) nucleus (ii) valence (iii) atomic (iv) eight

(v) $^{16}_{8}O$

(b) (i) (c) The composition of water is H_2O.

Relative molecular mass of $H_2O = 1\times2 + 16 = 18$ g

$\because$ 18 g of water contains 2g of hydrogen

$\therefore$ 100 g of water contains $\frac{2}{18}\times100 = 11.11$ g of hydrogen.

Hence, the percentage of hydrogen in water is 11.1 %.

(ii) (b) Soap is chemically a sodium salt of stearic acid (an organic acid, formula $C_{17}H_{35}COOH$) and has the formula $C_{17}H_{35}COONa$. For washing purpose, soap is used.

(iii) (b) Ionic compounds are formed by ions but there also exists a repulsive force between ions for like charges. Magnesium chloride is an example of ionic compound while ethene, ammonia and carbon tetrachloride are covalent compound.

(iv) (c) Size of atom decreases when moving left to right in a period (increase in the number of protons increases nuclear pull which decreases the size).

Thus, the correct order is

$$Li > Be > C > O$$

(v) (d) In the reaction between hydrogen sulphide and chlorine, hydrogen sulphide loses its hydrogen to chlorine and is thereby oxidised to sulphur and chlorine, which gains hydrogen, is reduced to hydrochloric acid.

Oxidised

$$H_2S + Cl_2 \longrightarrow 2HCl + S$$

Reduction

(c) (i) Boiling (ii) Soft

(iii) High (iv) O_3

(v) Proton and neutron

(d) (i) $2Pb(NO_3)_2 \xrightarrow{\Delta} 2Pb + 4NO_2 + 2O_2$

(ii) $2MgO \xrightarrow{\text{Combustion}} 2Mg + O_2$

(iii) $NaCl(aq) + AgNO_3(aq) \longrightarrow AgCl(s)\downarrow + NaNO_3(aq)$

(iv) $NH_4CNO \xrightarrow{\Delta} \underset{\text{Urea}}{NH_2\overset{\overset{O}{\|}}{C}NH_2}$

(v) $Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)\downarrow$

(e) (i) Potassium (ii) Magnesium (iii) Iron

(iv) Zinc (v) Aluminium

(f) (i) 1. Ammonium carbonate

Symbol	NH_4	CO_3
Charge	+1	−2
Formula	$(NH_4)_2CO_3$	

2. Potassium sulphate

Symbol	K	SO_4
Charge	+1	−2
Formula	K_2SO_4	

3. **Cupric chloride**

Symbol	Cu	Cl
Charge	+2	−1
Formula	$CuCl_2$	

(ii) 1. **Acetate** CH_3COO^- (Monovalent electronegative acid radical)

2. **Carbonate** CO_3^{2-} (Divalent electronegative acid radical)

(g) (i) Let the required temperature be x°C.

FULLY SOLVED

$V_1 = 500\ cm^3$; $T_1 = (273 + 20)\ K = 293\ K$

$V_2 = 250\ cm^3$; $T_2 = (273 + t)\ K$

By Charles' law,

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Putting the value,

$$\frac{500}{293} = \frac{250}{273 + x}$$

or $500(273 + x) = 250 \times 293$

or $2(273 + x) = 293$

or $273 + x = \frac{293}{2} = 146.5$

or $x = 146.5 - 273 = -126.5°C$

Hence, the gas would occupy half its volumeat $-126.5°C$.

(ii) Initial condition: $p_1 = p$, $V_1 = 1\ L$, $T_1 = (273 + 10)\ K = 283\ K$

Final condition: $p_2 = 3p$, $V_2 = 3\ L$, $T_2 = ?$

From the gas equation,

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

or $$T_2 = \frac{p_2V_2T_1}{p_1V_1}$$

or $$T_2 = \frac{3p \times 3 \times 283}{p \times 1}$$

$= 2547\ K$

$= (2547 - 273)°C = 2274°C$

Hence, the final temperature is 2274°C.

(iii) Standard temperature = 0°C = 273 K

Standard pressure = 760 mm Hg

= 76 cm Hg = 1 atm

(h) (i)-(c); (ii)-(b); (iii)-(a); (iv)-(e); (v)-(d)

2. (a)
- Electropositive character decreases down in the activity series.
- Reducing power of metals decreases down in the activity series. Hence, potassium is the strongest reducing agent.
- Tendency to metal to lose valence electrons *i.e.*, oxidation, decrease down in the activity series. Hence, potassium is the most oxidised metal.
- Metal above hydrogen displace hydrogen from water and dilute acid, but metals below hydrogen do not.

(b) Ozone layer is formed in the stratosphere at an altitude of about 25-30 km from the earth's surface, because there the force of gravitation is negligible.

(c) The presence of particulate matter in polluted air catalyses the oxidation of SO_2 to SO_3.

$$2SO_2 + O_2(g) \xrightarrow{\text{Particulates}} 2SO_3(g)$$

(d) NO is formed by the reaction of N_2 and O_2 during lightening or combustion of fossil fuels. It is further oxidised to NO_2.

3. (a) (i) Pressure in each compartment is same, p.
Temperature will remain same ($t°C$)

(ii) Pressure and temperature will remain same (p atm).

(b) (i) Atomic number of sodium = 11
Atomic number of phosphorus = 15
Electronic configuration of Na = 2, 8, 1
Electronic configuration of P = 2, 8, 5

(ii) Number of valence electrons in an atom of sodium = 1
Number of valence electrons in an atom of phosphorus = 5

(iii) Valencies of Na and P are 1 and 3, respectively.

(iv) Valencies of S and Cl are 2 and 1, respectively.

(c) Given, temperature will remain same ($t°C$)

$V_1 = 35$ mL, $V_2 = ?$, $p_1 = 758$ mm, $p_2 = 760$ mm

$T_1 = 6 + 273 = 279\ K$, $T_2 = 0 + 273 = 273\ K$

By applying gas equation, we have

$$\frac{760 \times V_2}{273} = \frac{758 \times 35}{279}$$

$$\therefore \quad V_2 = \frac{758 \times 35}{279} \times \frac{273}{760} = 34.16\ mL$$

Volume of chloride gas = 34.16 mL.

4. (a) (i) $NaNO_3$ (ii) $CaSO_4$

(iii) $\frac{96}{2} - \frac{80}{2} = \frac{16}{2} = 8g$ (iv) $16.5 - 10 = 6.5\ g$

(b) (i) **Hydrated substance** The substance which contains a certain fixed number of water molecules, bound to one molecule with chemical bond is known as hydrated substance.

e.g., $CuSO_4 \cdot 5H_2O$, $FeSO_4 \cdot 7H_2O$

(ii) **Anhydrous substance** The substance which completely loses its water of crystallisation is known as anhydrous substance.

(iii) The number of water molecules, which enter in a chemical combination with one molecule of a substance during the crystallisation of substance from its hot saturated aqueous solution are said to be water crystallisation.

(c) The solubility of gas can be increased by increasing pressure of the gas above liquid.

e.g., Soda water bottle contains CO_2 dissolved in water under the pressure of 5 to 10 atmosphere.

5. (a) (i) Electrolysis of acidified water using platinum electrodes gives hydrogen.

$$2H_2O(l) \xrightarrow[\text{Traces of acid}]{\text{Electrolysis}} 2H_2(g) + O_2(g)$$

Here, the role of an electrolyte is to make water conducting.

(ii) **From water gas** (Bosch process) On passing super heated steam over red hot coke or coal at 1270 K in the presence of Ni as catalyst, a mixture of carbon monoxide (CO) and dihydrogen (H_2) is obtained.

$$C(s) + H_2O(g) \xrightarrow{1270\ K} CO(g) + H_2(g)$$

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The process of producing syn gas from coke or coal is called coal gasification. This gas now-a-days is obtained from sewage, saw-dust, scrap wood, newspaper, etc.

(b) (i) When metal such as magnesium reacts with dilute sulphuric acid, hydrogen is obtained along with metal salts.

$$Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$$

(ii) When metal such as zinc reacts with sodium hydroxide, sodium zincate is formed and hydrogen gas is evolved.

$$Zn(s) + 2NaOH(aq) \longrightarrow Na_2ZnO_2(aq) + H_2(g)$$

(iii) When acidified water is electrolysed using platinum electrodes, hydrogen gas is evolved at cathode.

$$H_2O(l) \longrightarrow H^+(aq) + OH^-(aq)$$

At cathode $H^+(aq) + e^- \longrightarrow H$

$$H + H \longrightarrow H_2(g)$$

At anode $OH^-(aq) \longrightarrow OH + e^-$

$$4OH \longrightarrow 2H_2O(l) + O_2$$

(iv) When dilute hydrochloric acid react with zinc, then zinc chloride and hydrogen are formed.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

(c) (i) $4NH_3 + 5O_2 \xrightarrow[800°C]{Pt} 4NO + 6H_2O$

(ii) $Zn + \text{dil. } H_2SO_4 \longrightarrow ZnSO_4 + H_2$

6. (a) (i) $Cu + 2H_2SO_4 \longrightarrow CuSO_4 + SO_2 + 2H_2O$

(ii) $2Fe + 3H_2O \longrightarrow Fe_2O_3 + 3H_2$

(iii) $2KI + H_2O_2 \longrightarrow 2KOH + I_2$

(iv) $CaO + CO_2 \longrightarrow CaCO_3$

(b) (i) Sugar ($C_{12}H_{22}O_{11}$)

(ii) Copper sulphate pentahydrate ($CuSO_4 \cdot 5H_2O$)

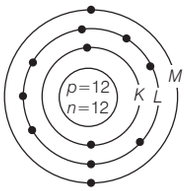
(iii) Quicklime (CaO)

(iv) Washing soda ($Na_2CO_3 \cdot 10\ H_2O$)

(c) (i) $Ca(HCO_3)_2 \longrightarrow CaCO_3 + CO_2 + H_2O$

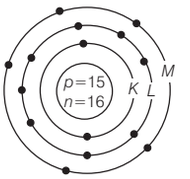
(ii) $Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 \downarrow + 2H_2O$

7. (a) **Atomic structure of Mg**



$$_{12}Mg = 2, 8, 2$$

Atomic structure of P



$$_{15}P = 2, 8, 5$$

(b) An outermost shell, which has eight electrons is said to possess an octet. Elements attain their octet by sharing, gaining or losing electrons. By gaining octet, atom achieve noble gas configuration.

(c) (i) Carbon (ii) Neutron

(iii) Isotones

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SAMPLE QUESTION PAPER 2

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS IX

CHEMISTRY (FULLY SOLVED)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

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Section-A

[40 *Marks*]

1. (a) Fill in the blanks.

(i) Atoms of same elements may differ from one another are called .....

(ii) Atoms of different elements may be similar are called .....

(iii) Atomic number is equal to number of .....

(iv) The subscript number shows the ..... of an element.

(v) Proton is discovered by ..... ***[5]***

(b) Choose the correct answer from the options given below.

(i) The relative molecular mass of blue vitriol is

(a) 345.6 (b) 249.5

(c) 272.4 (d) 268.9

(ii) $N_2 + 3H_2 \underset{\text{450-500°C, 200-900 atm}}{\overset{\text{Catalyst}}{\rightleftharpoons}} 2NH_3$

Identify catalyst in the above reaction.

(a) Platinum with carbon

(b) Palladium with carbon

(c) Iron with molybdenum

(d) Iron

(iii) Which of the following statement is incorrect?

(a) Reduction is the process in which an atom gain electrons.

(b) Oxygen is an oxidising agent.

(c) Addition of oxygen is oxidation.

(d) Addition of electropositive atom or iron is oxidation.

(iv) The number of electrons present in *N*-shell of atom is

(a) 2 (b) 8 (c) 18 (d) 32

(v) An element *X* has atomic mass is 40 while the element *Y* has atomic mass is 137. Then, the atomic mass of the intermediate element *Z* is ***[5]***

(a) 88 (b) 128 (c) 62 (d) 84

(c) Correct the underlined words in each of the following cases.

(i) The chemical name of caustic soda is <u>KOH</u>.

(ii) Washing soda is <u>deliquescent</u> substance.

(iii) Zinc react with hydrochloric acid to form <u>chlorine</u> gas.

(iv) $\underline{SO_4^{2-}}$ is an example of <u>monovalent</u> acidic radical.

(v) Hydrogen is prepared from <u>Haber's</u> process. ***[5]***

(d) Balance the following chemical equations.

(i) $Mg + HNO_3 \longrightarrow Mg(NO_3)_2 + H_2$

(ii) $NH_3 + CuO \longrightarrow N_2 + H_2O + Cu$

(iii) $H_2S + Cl_2 \longrightarrow HCl + S$

(iv) $S + HNO_3 \longrightarrow H_2SO_4 + NO_2 + H_2O$

(v) $KClO_3 \longrightarrow KCl + O_2$ ***[5]***

(e) Write the name of the following.

(i) A metal whose oxide is reduced by electrolysis.

(ii) One metal displaced by copper.

(iii) One metal which do not rust.

(iv) One oxide which is reduced.

(v) One oxide which is not reduced by common reducing agent. ***[5]***

(f) (i) Write the formula of each of the following.

1. Calcium hydrogen sulphite
2. Magnesium nitrate
3. Zinc sulphate *[3]*

(ii) From the list of formula given, choose the most appropriate radicals to match the given description. (NH_4^+, Ag^{2+}, As^{3+}, Sn^{4+})

1. Trivalent basic radical
2. Tetravalent basic radical *[2]*

(g) (i) Calculate the minimum pressure required to compress 500 dm^3 of air pressure 1 bar to 200 dm^3 at 300°C. *[2]*

(ii) A gas occupies 800 cm^3 under 760 mm of Hg pressure.

Calculate the pressure of the gas will occupy 380 cm^3, the temperature remaining same. *[2]*

(iii) What is the effect of decrease the pressure on gas? *[1]*

(h) Match the following columns.

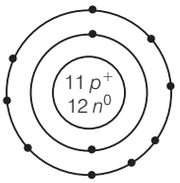
	Column I		Column II
(i)	Reducing agent	(a)	Addition of oxygen
(ii)	Oxidation	(b)	Removal of oxygen
(iii)	Reduction	(c)	Sodium zincate
(iv)	Amphoteric substance	(d)	Hydrogen sulphide
(v)	Water gas	(e)	Reaction of steam with red hot coke

[5]

Section-B

[40 *Marks*]

2. (a) Given below is the atomic structure of an atom of element $^{23}_{11}A$, according to Bohr's model of atom.



(i) Write the name of A.

(ii) What is wrong with this structure of atom?

(iii) Draw a correct representation of this atom.

(iv) Write the chemical formula of the chloride of this element. *[4]*

(b) Scrubber helps in reducing the formation of acid rain. Explain it *[2]*

(c) Write the function of ozone in the atmosphere. *[2]*

(d) Identify the state of solute and solvent in the following solution.

(i) Sugar solution (ii) Alloy *[2]*

3. (a) At a constant temperature, the gas is at a pressure of 1080 mm of Hg. Calculate the new pressure if the volume is decreased by 40%. *[4]*

(b) Discuss the unique nature of zinc and aluminium. Write the balanced chemical equations to support explanation. *[4]*

(c) Write some sources of hydrogen. *[2]*

4. (a) Write the balanced chemical equation for the following.

(i) Potassium bromide (*aq*) + Barium iodite (*aq*) ⟶ Potassium iodide (*aq*) + Barium bromide (*s*).

(ii) Zinc carbonate (*s*) ⟶ Zinc oxide (*s*) + Carbon dioxide (*g*).

(iii) Hydrogen (*g*) + Chlorine (*g*) ⟶ Hydrogen chloride (*g*)

(iv) Magnesium (*s*) + Hydrochloric acid (*aq*) ⟶ Magnesium chloride (*aq*) + Hydrogen (*s*) *[4]*

(b) When sodium hydroxide solution is added to an aqueous solution of copper sulphate, a bluish-white precipitate is obtained.

(i) How is this precipitate get separated?

(ii) Write the name and formula of the precipitate.

(iii) Write the balanced chemical equation for the reaction between copper sulphate solution and sodium hydroxide solution. *[4]*

(c) Certain salts are given below. Write their chemical formula.

(i) Potash alum

(ii) Plaster of paris *[2]*

5. (a) (i) What is the volume percent if 30 mL of alcohol is mixed with 70 mL of water to get 100 mL of solution?

(ii) Calculate the concentration of solution if 10 g of sodium chloride is added to 90 g of water? *[2]*

(b) The electronic configuration of an element X is 2, 8, 7.

Answer the following questions.

(i) What is the group of X?

(ii) What is the period of X?

(iii) What is the valency of X?

(iv) Whether 'X' is a metal or a non-metal? *[4]*

(c) What are the names of the particles represented by the following symbols?

$_1e^0$, $_0n^1$, $_1p^1$

Write the meaning of superscript and subscript number attached. *[4]*

6. (a) An aqueous solution of metal nitrate *P* reacts with sodium bromide solution to form yellow precipitate compound Q which is used in photography. Q on exposure to sunlight undergoes decomposition

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reaction to form metal present in along with a reddish brown gas. Identify *P* and *Q*. Write the balanced chemical equations for the chemical reaction. List two categories in which this reaction can be placed. *[4]*

(b) You are provided with two containers made up of copper and aluminium. You are also provided with solutions of dilute HCl, dilute HNO_3, $ZnCl_2$ and H_2O. In which of the above containers these solutions can be kept? *[4]*

(c) Give a balanced chemical equation for each of the following.

(i) Electrolysis of water

(ii) Decomposition of mercuric oxide. *[2]*

7. (a) Find out which of the following substances are oxidised or reduced?

(i) $Cl^- \longrightarrow Cl$

(ii) $Cl_2 \longrightarrow Cl^-$

(iii) $Cr^{7+} \longrightarrow Cr^{5+}$

(iv) $Mn^{5+} \longrightarrow Mn^{7+}$ *[4]*

(b) Answer the following questions.

(i) Why hydrogen is used as fuel?

(ii) Explain the role of hydrogen in the producing artificial petrol from coal. *[3]*

(c) Fill in the blanks with suitable word.

(i) Hydrogen gas is a strong .....

(ii) ..... is the strong reducing agent present in activity series.

(iii) Tendency of metal to lose electron is called ..... *[3]*

ANSWERS

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1. (a) (i) isotopes

(ii) isobars

(iii) protons

(iv) atomic number

(v) Goldstein

(b) (i) Blue vitriol is copper sulphate crystals. Its chemical formula is $CuSO_4 \cdot 5H_2O$.

The relative molecular mass of $CuSO_4 \cdot 5H_2O$

$= 63.5 + 32 + (16 \times 4) + 5(2 + 16)$

$= 159.5 + 90 = 249.5$

(Given, relative atomic mass of Cu = 63.5, S = 32, O = 16, H = 1)

(ii) $N_2 + 3H_2 \rightleftharpoons \underset{\text{(Ammonia)}}{2NH_3}$

This reaction is Haber's process. Three volumes of hydrogen and one volume of nitrogen react at temperature of 450-500°C, pressure 200-900 atm in presence of catalyst finely divided iron with molybedenum as promoter.

(iii) Addition of electropositive atom or ion is reduction. As for example,

$2HgCl_2 + SnCl_2 \longrightarrow Hg_2Cl_2 + SnCl_4$

Mercuric chloride is reduced to mercurous chloride by gain of electropositive ion Hg^+.

(iv) The maximum possible number of electrons in a particular shell is given by the formula $2n^2$, where n denotes the serial number of the shell.

N-shell has $(2 \times 4^2) = 32$ electrons

K	*L*	*M*	*N*
1	2	3	4

(v) Element, X = 40 = Calcium

Element, Y = 137 = Barium

The atomic mean of the atomic mass of calcium and barium

$$= \frac{40+137}{2} = \frac{177}{2} = 88.5$$

The atomic atomic mass of the intermediate element Z is 88.5. This is nearly the same as the atomic mass of strontium (88).

(c) (i) NaOH

(ii) Effloresecent

(iii) Hydrogen

(iv) Divalent

(v) Bosch's

(d) (i) $Mg + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2$

(ii) $2NH_3 + 3CuO \longrightarrow N_2 + 3H_2O + 3Cu$

(iii) $H_2S + Cl_2 \longrightarrow 2HCl + S$

(iv) $S + 6HNO_3 \longrightarrow H_2SO_4 + 6NO_2 + 2H_2O$

(v) $2KClO_3 \longrightarrow 2KCl + 3O_2$

(e) (i) Sodium (Na)

(ii) Mercury (Hg) can be displaced by copper

(iii) Gold (Au)

(iv) Zinc oxide (ZnO)

(v) Magnesium oxide (MgO)

(f) (i) 1. $Ca(HSO_3)_2$

2. $Mg(NO_3)_2$

3. $ZnSO_4$

(ii) 1. Arsenic - As^{3+} - Trivalent basic radical

2. Stannic- Sn^{4+} - Tetravelent basic radical

(g) (i) Initial pressure (p_1) = 1 bar

Final pressure (p_2) = ?

Initial volume (V_1) = 500 dm^3

Final volume (V_2) = 200 dm^3

Initial temperature (T_1) = 273 K

Final temperature (T_2) = 273 + 30 = 303 K

Applying ideal gas equation,

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

or $$p_2 = \frac{p_1V_1T_2}{T_1V_2}$$

$$= \frac{1 \times 500 \times 303}{273 \times 200} = 2.77 \text{ bar}$$

(ii) $p_1 = 760$ mm Hg, $V_1 = 800$ cm^3, p_2 = ?

$V_2 = 380$cm^3

From Boyle's law,

$$p_1V_1 = p_2V_2$$

Putting the values, we get

$$760 \times 800 = p_2 \times 380$$

$$p_2 = \frac{760 \times 800}{380} = 1600 \text{ mm Hg}$$

$$= 160 \text{ cm Hg}$$

Hence, required pressure is 160 cm Hg.

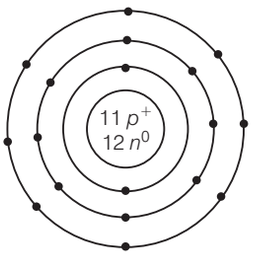
(iii) Gases increase in volume on decrease in pressure and increase in temperature.

(h) (i) → (d), (ii) → (a), (iii) → (b), (iv) → (c)

2. (a) (i) The element is sodium (Na).

(ii) The element A is Na. It has three shells *K*, *L* and M but here only 2 shells are given. Further, *L*-shell cannot have more than 8 electrons but here 9 electrons are given.

(iii) *The correct structure is*



(iv) As Na has 1 valence electron, thus it has a valency of +1 and chlorine has a valency of −1. Hence, the formula of its chloride is ACl *i.e.*, NaCl.

(b) Scrubber is a device that absorbs gaseous pollutants to reduce the formation of acid rain. Gas arising from the stack is passed through the scrubber where water absorbs SO_2. Hence, the constituents of acid rain is reduced.

(c) Ozone layer acts as blanket in the atmosphere by absorbing harmful ultraviolet rays coming from the sun and prevents them from reaching the earth. Ozone absorbs ultraviolet radiations of comparatively longer wavelength (λ) forming oxygen molecule and oxygen atom.

The reaction is

$$\underset{\text{Ozone}}{O_3} \longrightarrow O_2 + O$$

Hence, ozone protects the life on earth from harmful effect of ultraviolet radiation. Ultraviolet rays can cause skin cancer and destroy many organic species.

(d) (i) Solute-solid; solvent-liquid

(ii) Solute-solid, solvent-solid

3. (a) Initial pressure (p_1) = 1080 mm

Final pressure (p_2) = ?

Initial volume (V_1) = 100

Final volume (V_2) = 100 − 40 = 60

Applying Boyle's law,

$$p_1V_1 = p_2V_2$$

or $$1080 \times 100 = p_2 \times 60$$

or $$p_2 = \frac{1080 \times 100}{60} = 1800 \text{ mm of Hg}$$

(b) Zinc and aluminium have unique nature. Both of these react with acids as well as alkalies to produce dihydrogen. *The reaction occurs as*

$$Zn + 2NaOH \longrightarrow Na_2ZnO_2 + H_2\uparrow$$

$$Zn + 2HCl\,(dil.) \longrightarrow ZnCl_2 + H_2\uparrow$$

$$\underset{\text{Sodium aluminite}}{2Al + 6NaOH \longrightarrow 2Na_3AlO_3} + 3H_2\uparrow$$

$$2Al + 3H_2SO_4\,(dil.) \longrightarrow Al_2(SO_4)_3 + 3H_2\uparrow$$

(c) *There are two sources of hydrogen*

(i) **Free state** Earth's crust and atmosphere.

(ii) **Combined state** Plants and animal tissues, acids, alkalies, hydrocarbons, proteins, petroleum, products and fats.

4. (a) (i) $2KBr(aq) + BaI_2(aq) \longrightarrow 2KI(aq) + BaBr_2$

(ii) $ZnCO_3(s) \xrightarrow{\Delta} ZnO(s) + CO_2(g)$

(iii) $H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$

(iv) $Mg(s) + 2\,HCl(aq) \longrightarrow MgCl_2 + H_2(g)$

(b) (i) The precipitate can be separated by filtration.

(ii) Name ⟶ Copper hydroxide

Formula ⟶ $Cu(OH)_2$

(iii) $CuSO_4(aq) + 2NaOH(aq) \longrightarrow Cu(OH)_2(s) + Na_2SO_4(s)$

(c) (i) $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$

(ii) $CaSO_4 \cdot \frac{1}{2}H_2O$

5. (a) (i) Volume precent $= \frac{30}{30+70} \times 100$

$$= \frac{30}{100} \times 100 = 30\%$$

(ii) Concentration of the solution $= \frac{10}{10+90} \times 100$

$$= \frac{10}{100} \times 100 = 10\%$$

(b) (i) VII A

(ii) Third period

(iii) One

(iv) Non-metal

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(c) e = electron, n = neutron, p = proton

Superscript means the mass number of element (number of proton + number of electron)

Subscript means the atomic number of element (number of protons or number of electrons)

6. (a) P is $AgNO_3$ (silver nitrate), Q is AgBr (silver bromide).

Reaction of P with NaBr

$$\underset{P}{AgNO_3}\,(aq) + NaBr\,(aq) \longrightarrow \underset{Q}{AgBr} + NaNO_3\,(aq)$$

Decomposition of Q

$$\underset{Q}{2AgBr}\,(s) \xrightarrow{\text{Sunlight}} 2Ag(s) + Br_2\,(g)$$

The two categories in which this reaction can be placed are

(i) Decomposition reaction

(ii) Double displacement reaction

(b) The container made up of copper or aluminium is suitable for storing some solutions. This can be decided by studying their reactions with Cu and Al.

Reaction of copper with

(i) **Dilute HCl**

Cu + dilute HCl ⟶ No reaction

So, it can be stored in Cu container.

(ii) **Dilute HNO_3** Being a strong oxidising agent, dilute HNO_3 reacts with copper, so it can not be stored in copper container.

(iii) **$ZnCl_2$** Copper is less reactive than zinc so it does not react with $ZnCl_2$ solution. Therefore, it can be stored in copper container.

(iv) **H_2O** Copper does not react with water. So, its container can store H_2O in it.

Reactions of aluminium with

(i) **Dilute HCl** Al reacts with dilute HCl, so it can not be kept in aluminium container.

$$2Al + 6HCl \longrightarrow 2AlCl_3 + 3\,H_2\uparrow$$

(ii) **Dilute HNO_3** When dil. HNO_3 is kept in Al container, it forms a protective layer of aluminium oxide on it, therefore it can be kept in Al container.

(iii) **$ZnCl_2$** Al is more reactive than zinc, so it cannot keep $ZnCl_2$ solution in it.

$$2Al + 3ZnCl_2 \longrightarrow 2AlCl_3 + 3Zn$$

(iv) **H_2O** Aluminium does not react with water (hot or cold). Therefore, water can be kept in aluminium container.

Aluminium is attacked by steam to form aluminium oxide, and hydrogen.

$$2Al(s) + 3H_2O\,(g) \longrightarrow Al_2O_3\,(g) + 3H_2\,(g)$$

(c) (i) $2H_2O(l) \xrightarrow[\text{Current}]{\text{Electric}} 2H_2(g) + O_2(g)$

(ii) $2HgO(s) \xrightarrow{\Delta} 2Hg(l) + O_2(g)$

7. (a) (i) $Cl^- \longrightarrow Cl$

$Cl^- - e^-$ (Oxidation)

(ii) $Cl_2 \longrightarrow Cl^-$

$Cl_2 + 2e^- \longrightarrow 2Cl^-$ (Reduction)

(iii) $Cr^{7+} \longrightarrow Cr^{5+}$

$Cr^{7+} + 2e^- \longrightarrow Cr^{5+}$ (Reduction)

(iv) $Mn^{5+} \longrightarrow Mn^{7+}$

$Mn^{5+} - 2e^- \longrightarrow Mn^{7+}$ (Oxidation)

(b) (i) Because of its high heat of combustion, hydrogen is used as a fuel in the form of coal gas, water gas and liquid hydrogen.

(ii) Passage of hydrogen under high pressure over powdered coal in presence of a catalyst is known as hydrogenation of coal. It produces a product similar to petroleum but containing a higher proporation of hydrogen.

(c) (i) Reducing agent

(ii) Potassium

(iii) Oxidation

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SAMPLE QUESTION PAPER 3

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS IX

CHEMISTRY (FULLY SOLVED)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

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Section-A

[40 *Marks*]

1. (a) Fill in the blanks.

(i) The number of protons in the nucleus of an atom is called its.....

(ii) An atom has the mass number 35 and the atomic number 17. The number of neutrons in its nucleus are .....

(iii) The electrons have practically ..... mass as compared to the mass of nucleus.

(iv) The negatively charged particle of atom has ..... charge.

(v) All protons are identical and have a charge equal to ..... . *[5]*

(b) Choose the correct answer from the options given below.

(i) The salt which is deliquescent

(a) washing soda (b) glauber's salt

(c) iron (III) chloride (d) sodium chloride

(ii) An alkaline earth metal is

(a) potassium (b) calcium

(c) lead (d) copper

(iii) In the periodic table, alkali metals are placed in the group

(a) 1 (b) 11

(c) 17 (d) 18

(iv) The products of neutralisation reaction are

(a) salt and oxygen (b) salt and hydrogen

(c) hydrogen and oxygen (d) salt and water

(v) The reaction, $2Cu + O_2 \longrightarrow 2CuO$ is an example of

(a) oxidation reaction (b) reduction reaction

(c) redox reaction (d) None of these *[5]*

(c) State the basic and acidic radicals of the following compounds.

(i) Nickel bisulphate

(ii) Potassium manganate

(iii) Magnesium phosphate

(iv) Stannic oxide

(v) Chromium sulphate *[5]*

(d) Complete and balance the following chemical reactions

(i) $Na + H_2O \longrightarrow \ldots\ldots + \ldots\ldots$

(ii) $Zn + H_2O \longrightarrow \ldots\ldots + \ldots\ldots$

(iii) $Al + KOH + H_2 \longrightarrow \ldots\ldots + \ldots\ldots$

(iv) $Al + H_2SO_4 \longrightarrow \ldots\ldots + \ldots\ldots$

(v) $Fe + H_2O \longrightarrow \ldots\ldots + \ldots\ldots$ *[5]*

(e) Balance the following equations.

(i) $CaCO_3(s) + HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

(ii) $MgCl_2(aq) + Na_2CO_3(aq) \longrightarrow MgCO_3(s) + NaCl\ (aq)$

(iii) $Hg(NO_3)_2 \longrightarrow Hg(l) + NO_2(g) + O_2(g)$

(iv) $Na_2O_2(s) + H_2(l) \longrightarrow NaOH(aq) + O_2(g)$

(v) $NH_4Cl(s) + Ca(OH)_2(s) \longrightarrow CaCl_2(s) + NH_3(g) + H_2O(l)$ *[5]*

(f) (i) Write the formulae of each of the following.

1. Potassium nitrite 2. Ammonium acetate

3. Hydrogen peroxide *[3]*

(ii) From the list of compounds given, choose the appropriate molecules to match the given description (HCl, H_2O, Cl_2, H_2).

1. Non-polar compounds
2. Polar compound *[2]*

(g)(i) Calculate the percentage of iron in iron (III) oxide (Fe_2O_3) [O = 16, Fe = 56]. *[2]*

(ii) Element *A*, *B* and C are the members of traid. Element 'A' has atomic weigh 40 and element 'C' has 137.6. What is the atomic weight of *B*? *[2]*

(iii) Calculate the molecular mass of $ZnSO_4$. *[1]*

(h) Match the following.

	Column I (Elements)		Column II (Symbol)
(i)	Acidic radicals	(a)	K^+, Na^+
(ii)	Basic radicals	(b)	Fe^{2+}, Fe^{3+}
(iii)	Monovalent radicals	(c)	CO_3^{2-}, SO_4^{2-}
(iv)	Variable valency	(d)	Cl^-, K^+
(v)	Tetravalent element	(e)	Pb^{4+}, Pt^{4+}

[5]

Section-B

[40 *Marks*]

2. (a) Elements X, Y and Z have atomic numbers 9, 16 and 15 respectively.

Are these elements metals or non-metals? *[2]*

(b) Given reason :

(i) Group 1 elements are called alkali metals.

(ii) Group zero elements are called inert gases. *[2]*

(c) Complete the given table by identifying *A*, *B*, C and *D*

Element	Symbol	Number of Protons	Number of Electrons	Number of Neutrons
Sodium	$_{11}Na^{23}$	11	11	*A*
B	$_{9}F^{19}$	9	9	10
Chlorine	$_{17}Cl^{35}$	*C*	17	18
Uranium	*D*	92	92	146

[4]

(d) Represent the formation of covalent bonds between

(i) atoms with atomic number 9 and 16.

(ii) atoms with atomic number 16 and 16. *[2]*

3. (a) Write the effect of the following pollutants on living beings (one in each case).

(i) Nitrogen oxide (ii) Lead

(iii) Smog (iv) Smoke particles *[4]*

(b) Find out the final volume of a gas, 'Y', if the pressure originally at STP is doubled and its temperature is made three times. *[4]*

(c) Define the following.

(i) Decomposition reaction

(ii) Double displacement reaction *[2]*

4. (a) Calculate the gram of methane need to be with 32 g of oxygen to make 22 g of CO_2 and 18 g of water. *[4]*

(b) Write an example of each of the following types of reaction.

(i) A photochemical reaction involving a salt of silver

(ii) A catalytic reaction involving two gaseous reactants

(iii) A redox reaction involving two gases

(iv) An oxidation reaction involving addition of the electronegative radical *[4]*

(c) A gas occupies 400 cm^3 under 760 mm Hg pressure. Find under what pressure the gas will occupy 380 cm^3, the temperature remains constant. *[2]*

5. (a) Why water is called a universal solvent? *[2]*

(b) What is the cause of hardness of water. *[2]*

(c) State the following with reference to the elements of first and three periods of the periodic table

(i) A metalloid in period 3

(ii) The valency of elements in group 14.

(iii) Noble gas having electronic configuration 2, 8, 8.

(iv) Group whose elements have zero valency. *[4]*

(d) Name

(i) salt of calcium that causes temporary hardness of water.

(ii) salt of magnesium that causes permanent hardness of water. *[2]*

6. (a) An atom of an element is represented as $_{11}Y^{23}$.

Answer the following questions.

(i) What does the subscript 11 indicate?

(ii) What does the superscript 23 indicate?

(iii) What is the number of electrons present in Y?

(iv) What is the number of protons present in Y? *[4]*

(b) X, Y and Z are three elements in a Dobereiner's triad. If the atomic weight of X is 35.5 and Z is 127, then find out the atomic weight of Y. *[2]*

(c) State the type of bond present in

(i) non-metallic chloride

(ii) metallic chloride

(iii) chlorine molecule

(iv) nitrogen molecule *[4]*

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7. (a) What is the effect of the following, if nitrogen is absent from the air?

(i) Digestion (ii) Burning *[4]*

(b) Which gases are released in the air by following process?

(i) Respiration (ii) Combustion

(iii) Photosynthesis *[3]*

(c) (i) Nescent hydrogen is a powerful ..... agent.

(ii) Pure hydrogen burns in pure oxygen with ..... flame.

(iii) During the electrolysis of acidulated water ..... is obtained at cathode and ..... is obtained at anode. *[3]*

ANSWERS

1. (a) (i) nucleus

(ii) 18

(iii) negligible

(iv) -1.602×10^{-19} C

(v) electrons

(b) (i) (c) Iron (III) chloride salt is deliquescent.

(ii) (b) Calcium is an alkaline earth metal.

(iii) (a) In the periodic table, alkali metals are placed in the gorup 1.

(iv) (d) Neutralisation is a reaction in which acids react with bases to form salt and water.

(v) (a) Oxidation is a chemical change which involves the addition of oxygen.

(c)

	Basic radical	**Acidic radical**
(i)	Ni^{2+}	HSO_4^-
(ii)	K^+	MnO_4^{2-}
(iii)	Mg^{2+}	PO_4^{3-}
(iv)	Sn^{4+}	O^{2-}
(v)	Cr^{3+}	SO_4^{2-}

(d) (i) $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

(ii) $Zn + H_2O \longrightarrow ZnO + H_2$

(iii) $2Al + 2KOH + 2H_2O \longrightarrow 2KAlO_2 + 3H_2$

(iv) $2Al + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 3H_2$

(v) $3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2$

(e) (i) $CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

(ii) $MgCl_2(aq) + Na_2CO_3(aq) \longrightarrow MgCO_3(s) + 2NaCl(aq)$

(iii) $Hg(NO_3)_2(s) \xrightarrow{\Delta} Hg(l) + 2NO_2(g) + O_2(g)$

(iv) $2Na_2O_2(s) + 2H_2O(l) \longrightarrow 4NaOH(aq) + O_2(g)$

(v) $2NH_4Cl(s) + Ca(OH)_2(s) \longrightarrow CaCl_2(s) + 2NH_3(g) + 2H_2O(l)$

(f) (i) 1. KNO_2 2. CH_3COONH_4

3. H_2O_2

(ii) 1. Non-polar compound – Cl_2, H_2

2. Polar compound –HCl, H_2O

(g) (i) Molar mass of $Fe_2O_3 = 112 + 48 = 160$ % of $Fe = \frac{112}{160} \times 100 = 70\%$

(ii) $\frac{40 + 137.6}{2} = 88.8$

(iii) The molecular mass of $ZnSO_4 = 65 + 32 + (4 \times 16) = 161$ amu.

(h) (i) Acidic radicals – CO_3^{2-}, SO_4^{2-}

(ii) Basic radicals – K^+, Na^+

(iii) Monovalent radicals – Cl^-, K^+

(iv) Variable valency – Fe^{2+}, Fe^{3+}

(v) Tetravalent element – Pb^{4+}, Pt^{4+}

2. (a) (i) Electronic configuration of $X = 2, 7$ (non-metal)

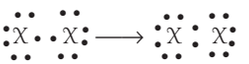
Electronic configuration of $Y = 2, 8, 6$ (non-metal)

Electronic configuration of $Z = 2, 8, 5$ (non-metal)

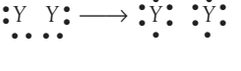
(b) (i) It is because their hydroxides are soluble in water and form strong bases.

(ii) It is because they have stable configuration following the octet rule.

(c) *Covalent bonds formed between*

(I) $\Rightarrow$ X and X 

or X—X

(II) $\Rightarrow$ Y and Y 

or Y═Y

(d) $A = 12$, $B =$ Fluorine,

$C = 17$, $D = {}_{92}U^{238}$

3. (a) (i) **Nitrogen oxide** It causes death of many plants.

(ii) **Lead** It damages the nervous and digestive systems and can cause cancer.

(iii) **Smog** It reduces visibility and induces respiratory troubles.

(iv) **Smoke particles** It causes asthma and lung diseases.

(b) Suppose that initial volume $(V_1) = x$

Final volume $(V_2) = ?$

Initial temperature $(T_1) = T_1$

Final temperature $(T_2) = 3T_1$

Initial pressure $(p_1) = 1$ atm

Final pressure $(p_2) = 2$ atm

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Applying ideal gas equation:

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

or $$\frac{1 \times x(V_1)}{T_1} = \frac{2 \times V_2}{3T_1}$$

or $$V_2 = \frac{3T_1 \times x(V_1)}{T_1 \times 2}$$

or $V_2 = 1\frac{1}{2}$ times of original volume (V_1)

(c) (i) A reaction in which a substance is broken down into two or more substances is called decomposition reaction.

(ii) A reaction in which two reacting molecules exchange their corresponding ions is called a double displacement reaction.

4. (a) *The reaction is as follows*

Methane + oxygen $\longrightarrow$ Carbon dioxide + water

From the law of conservation of mass

Total mass of reactants = Total mass of products

Mass of methane + Mass of oxygen = Mass of CO_2 + Mass of H_2O

Mass of methane + 32 g = 22 g + 18 g

or Mass of methane = 40 g − 32 g = 8 g

(b) (i) $AgBr \xrightarrow{\text{Sunlight}} Ag + \frac{1}{2}Br_2$

(ii) $N_2(g) + 3\,H_2(g) \xrightarrow{\text{Fe + Mo}} 2NH_3$

(iii) $\underbrace{H_2S + \overbrace{Cl_2}^{\text{Reduced}} \longrightarrow 2HCl + S}_{\text{Oxidised}}$

(iv) $2FeCl_2 + Cl_2 \longrightarrow 2FeCl_3$

(c) Using Boyle's law,

$$p_1V_1 = p_2V_2$$

$$760 \times 400 = p_2 \times 380$$

$$p_2 = \frac{760 \times 400}{380}$$

$$= 800 \text{ mm Hg}$$

5. (a) Water is a universal solvent as it has the capacity to dissolve a number of solute particles in it. Water is a polar covalent compound. It has a unique property of weakening the electrostatic forces of attraction in ionic compounds, thus they rapidly dissolve in water.

(b) The hardness of water is due to the presence of bicarbonates, chlorides and sulphates of calcium and magnesium.

(c) (i) $Ca(HCO_3)_2$

(ii) $MgCl_2$

(d) (i) Silicon

(ii) 4

(iii) Argon

(iv) Nable gases

6. (a) Given atom is $_{11}Y^{23}$. Then,

(i) subscript 11 indicates its atomic number

(ii) superscript 23 indicates its mass number

(iii) number of electrons present in *Y* is 11

(iv) number of protons present in *Y* is 11

(b) Triad X Y Z

Atomic weight 35.5 ? 127

Mean atomic weight $= \frac{35.5 + 127}{2} = 81.25$

Mean atomic weight is the atomic weight of *Y*. It is approximately 81.25.

(c) (i) Covalent bond

(ii) Ionic bond

(iii) Covalent bond

(iv) Covalent bond

7. (a) (i) **Digestion** Absence of nitrogen will increase oxidation and digestion will become very rapid.

(ii) **Burning** Absence of nitrogen increases the rate of burning lead to harmful effects. If fire breaks out, it becomes impossible to extinguish it.

(b) (i) O_2

(ii) O_2 and NO_2

(iii) CO_2

(c) (i) reducing

(ii) pale blue

(iii) hydrogen, oxygen.

FULLY SOLVED

SAMPLE QUESTION PAPER 4

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS IX

CHEMISTRY (UNSOLVED)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

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Section-A

[40 *Marks*]

1. (a) Fill in the blanks.

(i) The vertical columns in a periodic table are called ..... .

(ii) Actinides are elements from atomic number ..... to ..... and are radioactive.

(iii) The first period has ..... elements and is said to be ..... period.

(iv) Atomic size ..... on moving across a period from left to right.

(v) The serial number of an element in a periodic table is also its ..... . ***[5]***

(b) Choose the correct answer fromt the options given below.

(i) Ferric chloride is a

(a) deliquescent salt (b) efflorescent salt

(c) hygroscopic in nature (d) None of these

(ii) The inert gas with a complete duplet only is

(a) helium (b) argon (c) Krypton (d) neon

(iii) The percentage mass of water in washing soda crystals, $Na_2CO_3.10H_2O$ is

(a) 52.8 (b) 62.9 (c) 72.3 (d) 79.6

(iv) The relative molecular mass (or molecular weight) of $(NH_4)_2SO_4$ is

(a) 112 (b) 126 (c) 132 (d) 148

(v) The anhydrous salt which is used to test water as it changes colour when water is added to it is

(a) sodium chloride (b) magnesium sulphate

(c) zinc chloride (d) copper sulphate ***[5]***

(c) Answer the following in one or two words.

(i) The molecule containing a triple covalent bond.

(ii) Name the charged particles, which attract one another to form electrovalent compounds.

(iii) The group number of periodic table in which alkali metals are placed.

(iv) Name the phenomenon in which a compound loses its water of crystallisation on exposure to dry air.

(v) The water free from soluble salts of calcium and magnesium. ***[5]***

(d) Write the balanced chemical equation for the following.

(i) Ammonia + Oxygen $\longrightarrow$ Nitric oxide (NO) + Water

(ii) Lead monoxide + Nitric acid $\longrightarrow$ Lead nitrate + Water

(iii) Iron sulphide + Nitric acid $\longrightarrow$ Iron chloride + Hydrogen sulphide

(iv) Lime water + Carbon dioxide $\longrightarrow$ Calcium carbonate + Water

(v) Sodium nitrate + Sulphuric acid (conc.) $\longrightarrow$ Sodium sulphate + Nitric acid ***[5]***

(e) State one relavant observation for each of the following rections.

(i) Action of acidic oxides like carbon dioxide with water.

(ii) Heating of calcium hydroxide.

(iii) Action of cold water on sodium and calcium.

(iv) Addition of dilute hydrochloric acid in magnesium.

(v) The reaction of an acid (HCl) with a base (NaOH). ***[5]***

(f) (i) Write the formulae of each of the following.
1. Magnesium hydroxide 2. Chromium oxide
3. Iron (III) nitrate *[3]*

(ii) From the list of compounds given, choose the appropriate molecules to match the given description (N_2, NH_3, CCl_4, CH_4)
1. Non-polar compound 2. Polar compound *[2]*

(g) (i) Calculate the percentage composition of each element in potassium chlorate, $KClO_3$. *[2]*

(ii) Calculate the percentage of hydrogen in water (Relative atomic masses of H = 1, O = 16). *[2]*

(iii) Calculate the relative molecular mass of cane sugar, $C_{12}H_{22}O_{11}$. *[1]*

(h) Match the following.

	Column I (Element)		**Column II** (Symbol)
(i)	Titanium	(a)	K
(ii)	Scandium	(b)	Sc
(iii)	Argon	(c)	Ar
(iv)	Potassium	(d)	Si
(v)	Silicon	(e)	Ti

[5]

Section-B

[40 *Marks*]

2. (a) Explain the following statements.

(i) Chalk deposits slowly and dissolves in rain water.

(ii) Though aluminium is above to zinc in the activity series, it requires higher temperature to react with water.

(iii) Hydrogen is kept in the metal activity series of metals.

(iv) Equilibrium is reached when red hot iron reacts with steam. *[4]*

(b) (i) Define the 'atomic number of an element'. *[2]*

(c) Complete the following table

Number of protons	Number of electrons	Number of neutrons	Atomic number	Mass number
$_{17}Cl^{35}$				
$_{17}Cl^{37}$				

[2]

(d) State the electronic configuration of
(i) Chlorine atom. (ii) Chlorine ion. *[2]*

3. (a) Write the name of one suitable solvents for each
(i) wax (ii) sulphur
(iii) chlorophyll (iv) rust *[4]*

(b) State a suitable chemical test for
(i) a reducing agent (ii) an oxidising agent *[4]*

(c) A burning magnesium wire is introduced in the test tube evolving steam and then a burning candle is brought near the mouth of a test tube'.
Explain your observation and write the balanced chemical equation. *[2]*

4. (a) (i) Discuss about the chemical responsible for ozone layer destruction.

(ii) Explain how our atmosphere acts as a green house? *[4]*

(b) With suitable experimental condition, give balanced equations when hydrogen gas reacts with
(i) Sodium (ii) Chlorine
(iii) Sulphur (iv) Nitrogen *[4]*

(c) Table salt becomes sticky on exposure to humid air during rainy season. Explain. *[2]*

5. (a) Ethanoic acid + Sodium carbonate ⟶ Sodium ethanoate + Carbon dioxide + Water
If 6 g of acid reacts with 5.3 g of salt, the products will be 2.2 g of carbon dioxide, 0.9 g of water and 8.2 g of sodium ethanoate, then which law is obeyed by the above reaction? *[4]*

(b) Explain about the following help in bringing a chemical change
(i) heat (ii) light (iii) catalyst (iv) pressure *[4]*

(c) Write the name of substance which on heating leaves no residue behind. *[2]*

6. (a) When hydrogen is passed over a black solid compound X, the products are a colourless liquid and a reddish brown metal 'Y'. Metal 'Y' is divided into two parts and each placed in separate test tubes. Dilute HCl is added to one part of substance and dilute HNO_3 to the other.

(i) Write the name of substance X and Y.

(ii) Write two tests for the colourless liquid formed in the experiment.

(iii) What happen to substance X when it reacts with hydrogen?

(iv) Give the chemical equation for the reaction between carbon and the substance X. *[4]*

(b) At a constant temperature, the volume of a gas was found to be 800 cm^3 at a pressure of 76 cm of Hg. If the pressure of the gas is increased by 25%, calculate the new volume. *[3]*

(c) A sample of carbon dioxide occupies 60cm^3 at 15°C and 740 mm pressure. Calculate its volume at STP. *[3]*

7. (a) An element 'Y' belongs to the third period and group II of the periodic table then write about
(i) name of element
(ii) the number of valence electrons
(iii) valency (iv) metal or non-metal *[4]*

(b) Draw the graph between p and $1/V$ at constant temperature and explain it. *[3]*

(c) Complete and balance the following chemical equations.

(i) $Ca(NO_3)_2 \xrightarrow{\Delta}$ ..... + ...

(ii) $Cu(OH)_2 \xrightarrow{\Delta}$ ..... + ...

(iii) $KNO_3 \xrightarrow{\Delta}$ ..... + ... *[3]*

UNSOLVED

SAMPLE QUESTION PAPER 5

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS IX

CHEMISTRY (UNSOLVED)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

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Section-A

[40 *Marks*]

1. (a) Fill in the blanks.

(i) Isotopes have different ..... number because their nuclei contains different number of ..... .

(ii) Some carbon atoms have mass number 12 and some have mass number 14. These atoms of different mass numbers are said to be ..... .

(iii) An element is a ..... gas if it has ..... valence electrons.

(iv) An element ..... has one electron in *K*-shell but is a non-metal.

(v) An element ..... has two electrons in *K*-shell but is a noble gas. ***[5]***

(b) Choose the correct answer from the options given below.

(i) The property which is characteristic of an electrovalent compound is that

(a) it is easily vapourised

(b) it has a high melting point

(c) it is a weak electrolyte

(d) it often exists as a liquid.

(ii) When a metal atom becomes an ion

(a) it loses electron and is oxidised

(b) it gains electrons and is reduced

(c) it gains electrons and is oxidised

(d) it loses electrons and is reduced

(iii) The alkaline earth metal that forms ionic compounds is

(a) beryllium

(b) magnesium

(c) calcium

(d) barium

(iv) The temporary hardness of water can be removed by

(a) boiling

(b) by adding NaCl

(c) crystallisation

(d) All of these

(v) The reaction between an acid and a base that forms salt and water is an example of

(a) direct combination reaction

(b) decomposition reaction

(c) displacement reaction

(d) double decomposition reaction ***[5]***

(c) Write the name of

(i) rare gas other than neon, krypton and xenon

(ii) a non-metal having properties similar to carbon.

(iii) one halogen other than fluorine, chlorine and bromine

(iv) an alkaline earth metal except calcium, strontium and barium.

(v) an alkali metal except lithium, sodium and potassium ***[5]***

(d) Complete and balance the following chemical equations.

(i) $Pb_3O_4 \xrightarrow{\Delta}$ ..... + ...

(ii) $PCl_5 \underset{\text{Cool}}{\overset{\Delta}{\rightleftharpoons}}$ ..... + ...

(iii) $NH_3 + HCl \longrightarrow$ .....

(iv) $2H_2O \xrightarrow[\text{Current}]{\text{Electric}}$ .....

(v) $CuSO_4 + Zn \longrightarrow$ ..... + ... *[5]*

(e) State one relavant observation for each of the following reactions.

(i) Barium chloride is added to sodium sulphate solution.

(ii) Hydrogen peroxide is exposed to sunlight.

(iii) Chlorine water is exposed to sunlight.

(iv) H_2S gas is passed through copper sulphate solution.

(v) Crystals of copper (II) sulphate and iron (II) sulphate and iron (II) sulphate are separately heated in two test tubes. *[5]*

(f) (i) Write the chemical name of the following compounds.

1. Na_2SiO_3
2. $Na_4Fe(CN)_6$
3. K_2MnO_4 *[3]*

(ii) State in each case whether the following reaction represents oxidation or reduction.

1. $Al \longrightarrow Al^{3+}$
2. $Cu^{2+} \longrightarrow Cu$
3. $Ag \longrightarrow Ag^{+}$
4. $H \longrightarrow H^{+}$ *[2]*

(g) (i) Calculate the percentage of phosphorus in the fertiliser superphosphate, $Ca(H_2PO_4)_2$.

(H = 1, O = 16, P = 31, Ca = 40) *[2]*

(ii) Calculate the molecular mass of Na_2SO_4 and $MgCl_2$. *[2]*

(iii) Calculate the relative molecular mass of ammonium sulphate, $(NH_4)_2SO_4$. *[1]*

(h) Match the atomic numbers 4, 14, 8, 15 and 19 with each of the following.

(i) A solid non-metal of valency 3

(ii) A gas of valency 2

(iii) A metal of valency 1

(iv) A non-metal of valency 4 *[5]*

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Section-B

[40 *Marks*]

2. (a) K, Na, Ca, Mg, Al, Zn, Fe, Sn, Pb, H, Cu, Hg, Ag and Au constitute activity series. Then write the name of

(i) the metal which reacts fastest with cold water.

(ii) the metal which does not react with cold water, but reacts with boiling hot water slowly.

(iii) a metal which displaces hydrogen very slowly from dilute HCl.

(iv) the metal which on heating reacts with steam, but reaction is reversible. *[4]*

(b) Write the cause of air pollution by

(i) man-made sources

(ii) natural sources *[2]*

(c) What are the following groups said to be

(i) Group 17?

(ii) Group 18? *[2]*

(d) (i) What are the elements of group 17 called? *[2]*

(ii) Name all the elements of group 17.

3. (a) The effect of change of pressure on the volume of a gas was as given, keeping the temperature constant.

Pressure (atm)	**Volume** (litres)
0.90	24.9
0.85	26.3
0.75	29.9
0.65	40.2
0.55	40.7
0.45	49.8
0.30	74.7

(i) Plot the following graphs based on the above data for *p vs V*.

Interpret each graph in term of law.

(ii) The given values of pressure are correct then find the correct measurement of the volume. *[4]*

(b) The elements X and Y have electronic configuration (2, 8, 18, 2) and (2, 6) respectively, then

(i) in which period X and Y belong?

(ii) in which group X and Y belong? *[4]*

(c) Draw the orbital structure of sodium chloride and calcium oxide. *[2]*

4. (a) Calculate the gram of chlorine needed to combine with 23 g of sodium to make 58.5 g of sodium chloride. *[4]*

(b) 60 cm^3 of hydrogen is collected over water at 17°C and 750 mm of Hg pressure. Find out the volume of dry gas at STP. (Given : Vapour pressure of water at 17°C is 14 mm Hg). *[4]*

(c) Define the term 'relative atomic mass' and 'relative molecular mass.' *[2]*

5. (a) Define neutralisation reaction. Give two applications of neutralisation reactions. *[2]*

(b) Why hydrogen chloride can be termed as a polar covalent compound? *[2]*

(c) Write the formula and valency of the following

(i) cupric

(ii) aluminium

(iii) chromate

(iv) aluminate *[4]*

(d) Give an example of reaction where the following are involved. *[2]*

(i) Evolution of heat

(ii) Absorption of heat

6. (a) Explain with equation, what is noticed when permanent hard water is treated with

(i) slaked lime

(ii) washing soda *[4]*

(b) What do you understand by

(i) soft water (ii) hard water

(iii) temporary hard water

(iv) permanent hard water *[4]*

(c) What are drying or desiccating agents. Give examples. *[2]*

7. (a) The position of elements *A*, *B*, *C*, *D* and *E* in the periodic table are shown below:

Group 1	Group 2	Group 3	Group 4
—	—	—	*D*
—	*B*	*C*	—
A	—	—	*E*

(i) State which are metals, non-metals and noble gas in the above table.

(ii) Which type of ion will be formed by element *A*, *B* and C ?

(iii) Which is larger in size (i) *D* or *E* (ii) *B* or C ? *[4]*

(b) (i) *A*, *B* and C are the elements of a Dobereiner's triad. If the atomic mass of *A* is 7 and that of C is 39, what should be the atomic mass of *B* ? *[3]*

(ii) State Mendeleev's periodic law.

(c) Fill in the blanks.

(i) The alkali metal with atomic number 11 is ..... .

(ii) The horizontal rows in a periodic table are called ..... .

(iii) Going across a period from left to right, atomic size ..... . *[3]*

UNSOLVED

Latest ICSE Specimen PAPER

Chemistry (Fully Solved)

FULLY SOLVED

General Instructions

1. You will **not** be allowed to write during the first **15** minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section I** and any 4 questions from **Section II**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

Section-I

[40 *Marks*]

1. (A) Fill in the blanks with the correct choice given in brackets. (5)

(i) In an ionic compound, the bond is formed due to ..... of electrons. [sharing/transfer]

(ii) Zinc is ..... reactive than aluminium. [less/more]

(iii) The chemical reaction in which heat is absorbed is known as ..... reaction. [endothermic/exothermic]

(iv) The molecular formula of ammonium sulphate is ..... . [NH_4SO_4/$(NH_4)_2SO_4$]

(v) If an element has two electrons in its outermost shell, then it is likely to be ..... . [metallic/non-metallic]

(B) Choose the correct answer from the options given below: (5)

(i) The gas that causes the greenhouse effect

(a) oxygen

(b) ammonia

(c) methane

(d) hydrogen sulphide

(ii) According to the modern periodic law, the properties of elements are a periodic function of their

(a) atomic volume

(b) atomic number

(c) atomic weight

(d) mass number

(iii) Which of the following has water of crystallisation?

(a) Potassiumchloride

(b) Sodium chloride

(c) Sodium nitrate

(d) Washing soda crystals

(iv) The gas which has a rotten egg smell is

(a) hydrogen

(b) ammonia

(c) sulphur dioxide

(d) hydrogen chloride

(v) The temperature of 0° C on the Kelvin scale is equal to

(a) – 273 K (b) 273 K

(c) 0 K (c) 100 K

(C) Name the gas evolved in each of the following cases: (5)

(i) Copper carbonate is heated strongly.

(ii) Action of dilute hydrochloric acid on sodium sulphite.

(iii) Nitrogen combines with hydrogen.

(iv) Action of dilute sulphuric acid on sodium carbonate.

(v) Addition of sodium to cold water.

(D) Give a reason for each of the following: (5)

(i) Noble gases do not combine with other elements to form molecules.

(ii) Dilute nitric acid cannot be used in the preparation of hydrogen.

(iii) Hydrogen although lighter than air, is not collected by the downward displacement of air.

(iv) Anhydrous calcium chloride turns into a colourless solution when exposed to air.

(v) Metals form positive ions.

(E) What do you observe when (5)

(i) iodine crystals are heated in a test tube?

(ii) iron nails are added to copper sulphate solution?

(iii) lead nitrate crystals are heated strongly?

(iv) ferric chloride crystals are exposed to atmosphere for sometime?

(v) blue copper sulphate crystals are heated?

(F) (i) State Boyle's law. (5)

(ii) What is standard temperature and pressure?

(iii) Calculate the percentage of nitrogen in ammonium nitrate [NH_4NO_3] .

[N = 14 , H = 1 , O = 16]

(G) (i) Balance each of the chemical equations given below:

(a) $FeCl_3 + NH_4OH \longrightarrow NH_4Cl + Fe(OH)_3$

(b) $KI + Cl_2 \longrightarrow KCl + I_2$

(ii) Identify the substance which matches the description given below:

(a) White crystalline substance which sublimes on heating.

(b) The gas which turns lime water milky but has no effect on potassium dichromate paper.

(c) The metal that cannot displace hydrogen from dilute hydrochloric acid.

(H) Match the Column *A* with Column *B*. (5)

	Column *A*		**Column** *B*
(i)	Causes hardness in water	(a)	Calcium oxide
(ii)	Causes ozone depletion	(b)	Concentrated sulphuric acid
(iii)	Dehydrating agent	(c)	Magnesium bicarbonate
(iv)	Causes acid rain	(d)	Chlorofluoro carbon
(v)	Drying agent	(e)	Nitrogen dioxide

Section-II

[40 *Marks*]

2. (A) The formula of the chloride of a metal '*M*' is MCl_2. State the formula of its (3)

(i) carbonate (ii) nitrate

(iii) hydroxide

(B) Write balanced chemical equations for each of the following: (3)

(i) Reaction of iron with chlorine.

(ii) Addition of silver nitrate solution to sodium chloride solution.

(iii) Addition of zinc to sodium hydroxide solution.

(C) Draw the orbit structure for each of the following compounds: (4)

(i) Methane [H = 1, C = 6]

(ii) Magnesium chloride [Mg = 12, Cl = 17]

3. (A) (i) Name the industrial method for the production of hydrogen gas. (3)

(ii) Name the catalyst used in the above process.

(iii) Write the balanced chemical equation for the production of water gas.

(B) (i) What is meant by 'Group' in the Periodic Table? (3)

(ii) Explain why the elements of the same group exhibit the same chemical behaviour?

(iii) In which Group, inert gases are the placed in the Periodic Table?

(C) A part of periodic table is shown below with one element missing:

H							He
Li	Be	B	C	N	O	F	Ne
Na	Mg	Al	Si	-	S	Cl	Ar
K	Ca						

Based on the above table, answer the following questions: (4)

(i) Name the element that has duplet structure.

(ii) Name the lightest alkali metal.

(iii) Name the halogen of period 2.

(iv) Identify the missing element.

4. (A) Calculate the volume of gas X at STP, if it occupies 380 L at 300 K and 70 cm of mercury. (3)

(B) A gas occupies 70 L at 27°C.

What volume will it occupy at 273°C, pressure remaining constant? (3)

(C) Calculate the relative molecular mass of each of the following: (4)

(i) Ammonium dichromate [$(NH_4)_2Cr_2O_7$]

(ii) Hydrated copper sulphate [$CuSO_4 \cdot 5H_2O$]

[H = 1, N = 14, O = 16, S = 32, Cr = 52, Cu = 64]

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5. (A) (i) What do you understand by the term isotopes? (3)

(ii) Why do isotopes of an element possess identical chemical properties?

(iii) Name the isotope of hydrogen which does not have a neutron in it.

(B) State the type of covalent bonding in the following molecules: (3)

(i) Chlorine (ii) Nitrogen

(iii) Oxygen

(C) How would you distinguish between the following pairs of substances on the basis of the chemical tests given in brackets? (4)

(i) Sodium chloride and potassium chloride (flame test).

(ii) Zinc carbonate and lead carbonate (dry heating).

6. (A) State, if the solubility increases, decreases or remains the same with rise in temperature for each of the following compounds: (3)

(i) Calcium sulphate (ii) Potassium nitrate

(iii) Sodium chloride

(B) (i) What is the difference between temporary hard water and permanent hard water? (3)

(ii) Write a balanced chemical equation for the removal of

(a) permanent hardness

(b) temporary hardness

(C) Classify each of the following reactions as combination, decomposition, displacement or double displacement: (4)

(i) $2Al + Fe_2O_3 \longrightarrow Al_2O_3 + 2Fe$

(ii) $2KClO_3 \longrightarrow 2KCl + 3O_2$

(iii) $BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaCl$

(iv) $CaO + H_2O \longrightarrow Ca(OH)_2$

7. (A) Complete the following table: (6)

Elements	Mass number	Atomic number	Number of electrons	Number of protons	Number of neutrons
Phosphorous	31	15			
Potassium			19		20

(B) Write the electronic configuration of the following: (2)

(i) $^{40}_{20}Ca$ (ii) $^{32}_{16}S$

(C) State the valency of the element having (2)

(i) 6 electrons in the valence shell.

(ii) the electronic configuration of 2, 3.

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SOLUTIONS

Section-I

1. (A) (i) transfer

(ii) less (iii) endothermic

(iv) $(NH_4)_2SO_4$ (v) metallic

(B) (i) (c) Gases such as carbon dioxide, methane, ozone, chlorofluoro carbon compounds (CFC's) causes greenhouse effect.

(ii) (b) According to modern periodic law, the properties (physical and chemical) of elements are a periodic function of their atomic numbers, i.e. when elements are arranged in increasing order of atomic numbers, the elements having similar properties are repeated after certain regular intervals.

(iii) (d) The fixed amount of water that is associated with hydrated crystals which is an integral part of the crystal is said to be water of crystallisation. e.g. Washing soda crystal (sodium carbonate) is chemically sodium carbonate decahydrate with the formula $Na_2CO_3 \cdot 10H_2O$.

(iv) (a) Hydrogen sulphide is a colourless hydride gas of group 16 with the characteristic odour of rotten eggs.

(v) (b) The relationship between Kelvin and Celcius scale is

$$K = {}^\circ C + 273$$

Therefore, the temperature of 0°C on the Kelvin scale is equal to 273 K.

(C) (i) Copper carbonate on heating strongly, decomposes to give copper oxide and carbon dioxide.

$$CuCO_3(s) \xrightarrow{\Delta} CuO(s) + CO_2(g)$$

(ii) Sulphur dioxide gas is liberated on action of dil. HCl on sodium sulphite.

$$Na_2SO_3 + 2HCl \longrightarrow 2NaCl + H_2O + SO_2\uparrow$$

(iii) Hydrogen gas combines with nitrogen at low temperature and high pressure in the presence of iron as catalyst and Mo as promoter, to produce ammonia gas.

$$3H_2(g) + N_2(g) \xrightarrow[Fe,\ Mo]{673\ K,\ 200\ atm} 2NH_3(g)$$

This process is called Haber's process.

(iv) Dilute sulphuric acid reacts with conc. H_2SO_4 to libertate carbon dioxide gas.

$$Na_2CO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O + CO_2\uparrow$$

(v) Sodium reacts violently with cold water and produces bubbles of hydrogen gas.

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2\uparrow$$

(D) (i) The noble gases have completely filled (ns^2, np^6) electronic configuration in their valence shell. Due to this, they are chemically inert and do not combine with other elements to form molecules.

(ii) Dilute nitric acid cannot be used in the preparation of hydrogen gas, because it oxidises hydrogen gas.

(iii) Hydrogen forms an explosive mixture with air and hence cannot be collected by downward displacement of air even though it is lighter than air.

(iv) Anhydrous $CaCl_2$ being deliquescent in nature, absorbs moisture from the atmosphere when exposed to air and gets converted into colourless saturated solution.

(v) Metals are electropositive in nature, they have strong tendency to loose electrons and form positive ion (cation) to attain stable electronic configuration.

(E) (i) When iodine crystals are heated strongly in a test tube,it sublimes and forms violet vapours.

(ii) On adding, iron nails to copper sulphate solution, it displaces copper metal from aqueous copper sulphate solution because iron is more than copper. Thus, blue colour of copper sulphate fades away to give green colour of ferrous sulphate.

$$\underset{\text{Iron metal}}{Fe(s)} + \underset{\text{Copper sulphate (Blue)}}{CuSO_4(aq)} \longrightarrow \underset{\text{Ferrous sulphate (Green)}}{FeSO_4(aq)} + \underset{\text{Copper metal}}{Cu(s)}$$

(iii) On heating lead nitrate, it decomposes to give yellow lead monoxide, nitrogen dioxide and oxygen gas.

$$\underset{\text{Lead nitrate (Colourless)}}{2Pb(NO_3)_2(s)} \xrightarrow{\Delta} \underset{\text{Lead oxide (Yellow)}}{2PbO(s)} + \underset{\text{Nitrogen dioxide (Brown fumes)}}{4NO_2(g)} + \underset{\text{Oxygen}}{O_2(g)}$$

(iv) Ferric chloride crystals when exposed to atmosphere for sometime absorbs moisture from the atmosphere and gets converted into saturated solution. This phenomenon is called deliquescence.

(v) Blue copper sulphate crystals when heated, looses its water of crystallisation and gets converted to anhydrous $CuSO_4$.

$$\underset{\text{Blue crystals}}{CuSO_4 \cdot 5H_2O} \xrightarrow{\text{Heat}} \underset{\text{White powder}}{CuSO_4} + 5H_2O$$

(F) (i) Boyle's law states that at constant temperature, the pressure of a fixed amount (i.e. number of moles, n) of a gas varies inversely with its volume.

Mathematically, $p \propto \frac{1}{V}$ (at constant T and n)

$$p = k\frac{1}{V}$$

or $p_1V_1 = p_2V_2 = k$

where, k = proportionality constant.

(ii) Standard temperature and pressure (STP) means 273.15K (0°C) temperature and 1 atmospheric pressure or 760 mm or 76 cm of Hg of pressure.

(iii) Percentage of an element in a compound

$$= \frac{\text{Mass of that element in the compound}}{\text{Molar mass of the compound}} \times 100$$

In case of NH_4NO_3,

Molar mass of $NH_4NO_3 = 14\times2 + 1\times4 + 16\times3 = 80$

$\therefore$ Percentage of nitrogen in NH_4NO_3

$$= \frac{2\times14}{80} \times 100 = 35\%$$

(G) (i) (a) $FeCl_3 + 3NH_4OH \longrightarrow 3NH_4Cl + Fe(OH)_3$

(b) $D2KI + Cl_2 \longrightarrow 2KCl + I_2$

(ii) (a) Ammonium chloride (NH_4Cl).

(b) Carbon dioxide gas (CO_2). (c) Silver (Ag).

(H)

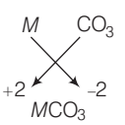
	Column *A*		Column *B*
(i)	Causes hardness in water	(c)	Magnesium bicarbonate
(ii)	Causes ozone depletion	(d)	Chlorofluoro carbon
(iii)	Dehydrating agent	(b)	Concentrated sulphuric acid
(iv)	Causes acid rain	(e)	Nitrogen dioxide
(v)	Drying agent	(a)	Calcium oxide

Section-II

2. (A) The formula of the chloride of a metal 'M' is MCl_2. Thus, the valency of M is 2.

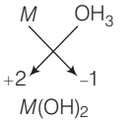
$\therefore$ The formula of its

(i) Carbonate



(ii) Nitrate

(iii) Hydroxide



(B) **Reaction of iron with chlorine**

$$\underset{\text{Iron}}{2Fe} + \underset{\text{Chlorine}}{3Cl_2} \longrightarrow \underset{\text{Iron (III) chloride}}{2FeCl_3}$$

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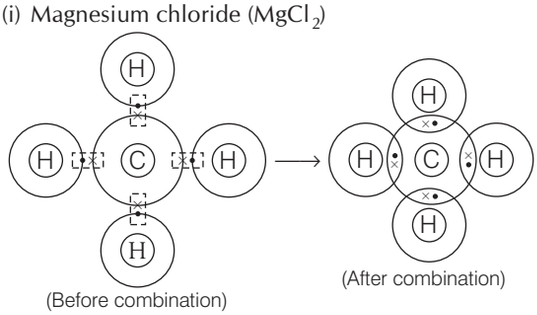
(ii) **Addition of silver nitrate solution to sodium chloride solution**

$$\underset{\text{Silver Nitrate}}{AgNO_3(aq)} + \underset{\text{Sodium chloride}}{NaCl\ (aq)} \longrightarrow \underset{\substack{\text{Silver chloride}\\ \text{(White ppt.)}}}{AgCl\downarrow} + \underset{\text{Sodium nitrate}}{NaNO_3(aq)}$$

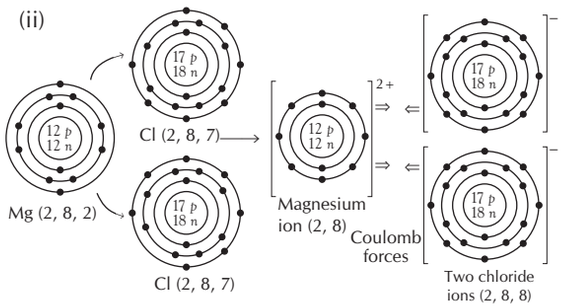
(iii) **Addition of zinc to sodium hydroxide solution**

$$\underset{\text{zinc}}{Zn} + \underset{\substack{\text{(Hot and conc.)}\\ \text{Sodium hydroxide}}}{2NaOH} \xrightarrow{\Delta} \underset{\substack{\text{Sodium zincate}\\ \text{(Colourless)}}}{Na_2ZnO_2} + H_2\uparrow$$

(C) (i) Magnesium chloride ($MgCl_2$)



(ii)



3. (A) (i) Industrial method used for the production of hydrogen gas is Bosch process.

(ii) Nickel (Ni) is used as a catalyst for the above process.

(iii) On passing super-heated steam over red coke or coal at 1000°C in the presence of Ni as a catalyst, a mixture of carbon monoxide (CO) and dihydrogen (H_2) is obtained.

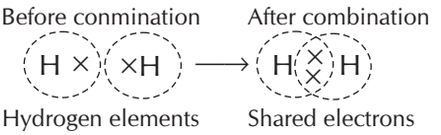
$$C(s) + H_2O(g) \xrightarrow{1000°C} \underbrace{CO(g) + H_2(g)}_{\text{Water gas}}$$

(B) (i) In Modern Periodic Table, there are 18 vertical columns, called the groups. These groups are numbered from 1 to 18 according to IUPAC.

(ii) The elements present in the same group contains same number of valence electrons and therefore exhibit same chemical behaviour.

(iii) Inert or noble gases are placed in zero group or group 18 of periodic the table.

(C) (i) Hydrogen element having electronic configuration $_1H = \overset{K}{1}$ needs one electron to attain nearest noble gas configuration. Thus, forms a duplet structure.



(ii) Lithium is the lightest alkali metal due to very low density.

(iii) Halogen of period 2 is Ne having atomic number 10 and electronic configuration $_{10}Ne = \overset{K}{2}, \overset{L}{8}$

(iv) Missing element is phosphorus (P): number = 15 and electronic configuration: $\overset{K}{2}, \overset{L}{8}, \overset{M}{5}$

4. (A) Given, $V_1 = 380$ L, $T_1 = 300$ K, $p_1 = 70$ cm,

$V_2 = ?$, $T_2 = 273$ K, $p_2 = 76$ cm

Applying ideal gas equation, $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$, we get

$$\frac{70 \times 380}{300} = \frac{76 \times V_2}{273} \Rightarrow V_2 = \frac{70 \times 380 \times 273}{300 \times 76}$$

$$V_2 = 318.5 \text{ L} \approx 319 \text{ L}$$

(B) Given, $V_1 = 70$ L, $T_1 = 27°$ C $\Rightarrow (27 + 273) = 300$ K

$V_2 = ?$, $T_2 = 273°$C $\Rightarrow (273 + 273) = 546$ K

Applying Charles' law,

at constant pressure, $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$$\therefore \quad \frac{70}{300} = \frac{V_2}{546} \Rightarrow V_2 = 127.4 \text{ L}$$

(C) Relative molecular mass of each of the following:

(i) Ammonium dichromate $[(NH_4)_2Cr_2O_7]$

= 2 × atomic mass of N + 8 × atomic mass of H + 2 × atomic mass of Cr + 7 × atomic mass of O.

= 2 × 14 + 8 × 1 + 2 × 52 + 7 × 16 = 252 u

(ii) Hydrated copper sulphate $[CuSO_4 \cdot 5H_2O]$

= 1× atomic mass of Cu + atomic mass of S × 1 + 4 × atomic mass of O + 5 × (2 × atomic mass of H + atomic mass of O)

= 64 + 32 + 4 × 16 + 5 (2 × 1 + 16) = 250 u

5. (A) (i) Isotopes are defined as the atoms of the same element, having the same atomic number (or number of protons) but different mass number (or number of neutrons).

(ii) Chemical properties of elements largerly depend on their electronic configuration or outermost electrons and as the isotopes of an element have same electronic configuration, therefore isotopes of an element have the same chemical properties.

(iii) Protium ($_1^1H$) an isotope of hydrogen does not have a neutron in it.

(B) The type of covalent bonding in the following molecules is as follows:

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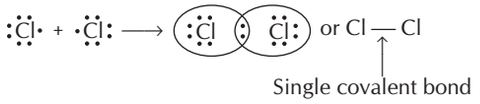
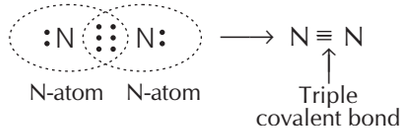
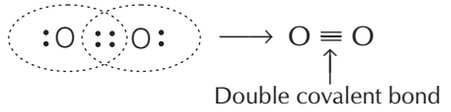
(i) Chlorine



(ii) Nitrogen



(iii) Oxygen



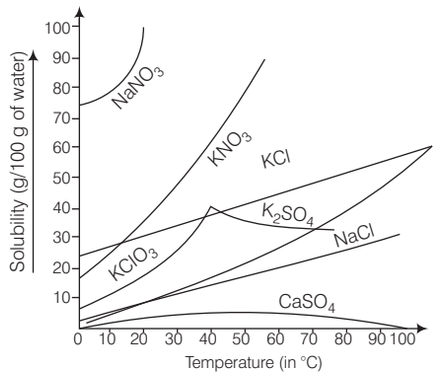
(C) (i) On performing flame test, sodium chloride produces yellow flame while potassium chloride produces light lilac coloured flame.

(ii) On dry heating, zinc carbonate forms zinc oxide and CO_2 gas is liberated while, lead carbonate forms lead oxide and CO_2 gas is produced.

$$ZnCO_3(s) \xrightarrow{\Delta} ZnO(s) + CO_2(g) \uparrow$$

$$PbCO_3(s) \xrightarrow{\Delta} PbO(s) + CO_2(g) \uparrow$$

6. (A) The change in solubility with temperature can be explained on the basis of solubility curve as shown below:



(i) Solubility of $CaSO_4$ increases with the rise in temperature and then decreases after attaining maximum value.

(ii) Solubility of potassium nitrate increases considerably with the increase in temperature.

(iii) Solubility of sodium chloride increases very little with increases in temperature.

(B) (i)

Temporary hard water	Permanent hard water
It is formed due to dissolved bicarbonate of calcium and magnesium $[Ca(HCO_3)_2$ and $Mg(HCO_3)_2]$	It is formed due to dissolved chlorides and sulphate of calcium and magnesium.

(ii) (a) Permanent hardness of water can be removed by adding washing soda.

$$MCl_2 + Na_2CO_3 \longrightarrow MCO_3 \downarrow + 2NaCl$$

$$MSO_4 + Na_2CO_3 \longrightarrow MCO_3 \downarrow + Na_2SO_4$$

M = Ca and Mg.

(b) Temporary hardness of water can be removed by boiling.

$$Mg(HCO_3)_2(aq) \xrightarrow{\Delta} Mg(OH)_2 \downarrow + 2CO_2 \downarrow$$

$$Ca(HCO_3)_2(aq) \xrightarrow{\Delta} CaCO_3 \downarrow + H_2O + CO_2 \downarrow$$

(C) (i) $2Al + Fe_2O_3 \longrightarrow Al_2O_3 + Fe$
Displacement reaction

(ii) $2KClO_3 \longrightarrow 2KCl + 3O_2$
Decomposition reaction

(iii) $BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaCl$
Double displacement reaction

(iv) $CaO + H_2O \longrightarrow Ca(OH)_2$
Combination reaction

7. (A)

Elements	Mass number	Atomic number	Number of electrons	Number of protons	Number of neutrons
Phosphorous	31	15	15	15	16
Potassium	39	19	19	19	20

∵ Atomic number = Number of protons or electrons

Mass number = Number of neutrons + Atomic number

(B) Electronic configuration of the following:

(i) $^{40}_{20}Ca$ = 2,8,8,2 (ii) $^{32}_{16}S$ = 2,8,6

(C) Valency of the element having

(i) 6 electrons in the valence shell is 2.

(ii) the electronic configuration of : 2,3 is 3.

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