



## ACADEMIC WINDOW

### CLASS XI



DELHI PRIVATE SCHOOL  
SHARJAH

## A NOTE FROM THE HOD

Chemistry has been called the science of what things are. Its intent is the exploration of the nature of the materials that fabricate our physical environment, why they hold the different properties that depict them, how their atomic structure may be fathomed, and how they may be manipulated and changed. Chemistry is the main incentive for our lives provided modern society with facilities that make our day to day lives easier.

Some students seem naturally enthusiastic about learning, but many need or expect their instructors to inspire, challenge, and stimulate them. There is no single magical formula for motivating students. Students learn by doing, making, writing, designing, creating, solving. So, we should ensure opportunities by assigning tasks that are neither too easy nor too difficult.

This academic window is planned as a skill-based questionnaire that emphasizes thinking skills, experimental skills, and application skills. It consists of the following units— Index, Exam wise syllabus, Glossary, Chapter names and, sample papers. **Glossary** explains all the short forms and symbols involved in each chapter; it strengthens the students understanding the type of questions. The synopsis given in the beginning of each chapter includes summary of the relevant chapter. To strengthen this, HOTS questions, Multi-disciplinary and Value based questions are included in it. The explanation of concepts is supported by photographs, diagrams and tables.

I take immense pleasure in bringing out this academic window which can play an instrumental role in developing my skills in chemistry.

Regards,

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1	Break of the chapters as per the CBSE guidelines, with weightage of marks	4-8
2	Some basic concepts in chemistry	9-16
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4	Classification of elements and periodicity in properties	24-30
5	Chemical bonding and molecular structure	31-40
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### CLASS-XI (THEORY) (2022-23)

Time:3Hours		Total Marks70	
S.NO	UNIT	PERIODS	MARKS
1	Some Basic Concepts of Chemistry	18	7
2	Structure of Atom	20	9
3	Classification of Elements and Periodicity in Properties	12	6
4	Chemical Bonding and Molecular Structure	20	7
5	Chemical Thermodynamics	23	9
6	Equilibrium	20	7
7	Redox Reactions	9	4
8	Organic Chemistry: Some basic Principles and Techniques	20	11
9	Hydrocarbons	18	10
<b>TOTAL</b>		<b>160</b>	<b>70</b>

#### **Unit I: Some Basic Concepts of Chemistry**

**18 Periods**

General Introduction: Importance and scope of Chemistry. Nature of matter, laws of chemical combination, Dalton's atomic theory: the concept of elements, atoms, and molecules. Atomic and molecular masses, mole concept and molar mass, percentage composition, empirical and molecular formula, chemical reactions, stoichiometry, and, calculations based on stoichiometry.

#### **Unit II: Structure of Atom**

**20 Periods**

Discovery of Electron, Proton and Neutron, atomic number, isotopes and isobars. Thomson's model and its limitations. Rutherford's model and its limitations, Bohr's model and its limitations, the concept of shells and subshells, dual nature of matter and light, de Broglie's relationship, Heisenberg uncertainty principle, concept of orbitals, quantum numbers, shapes of s, p and d orbitals, rules for filling electrons in orbitals - Aufbau principle, Pauli's exclusion principle and Hund's rule, electronic configuration of atoms, stability of half-filled and completely filled orbitals.

#### **Unit III: Classification of Elements and Periodicity in Properties**

**12 Periods**

Significance of classification, a brief history of the development of the periodic table, modern periodic law and the present form of the periodic table, periodic trends in properties of elements - atomic radii, ionic radii, inert gas radii, Ionization enthalpy, electron gain enthalpy, electronegativity, valency. Nomenclature of elements with atomic number greater than 100.

#### **Unit IV: Chemical Bonding and Molecular Structure**

**20 Periods**

Valence electrons, ionic bond, covalent bond, bond parameters, Lewis's structure, polar

character of covalent bond, covalent character of ionic bond, valence bond theory, resonance, geometry of covalent molecules, VSEPR theory, concept of hybridization, involving s, p and d orbitals and shapes of some simple molecules, molecular orbital theory of homonuclear diatomic molecules (qualitative idea only), Hydrogen bond.

**Unit VI: Chemical Thermodynamics****23 Periods**

Concepts of System and types of systems, surroundings, work, heat, energy, extensive and intensive properties, state functions. First law of thermodynamics -internal energy and enthalpy, heat capacity and specific heat, measurement of  $\Delta U$  and  $\Delta H$ , Hess's law of constant heat summation, enthalpy of bond dissociation, combustion, formation, atomization, sublimation, phase transition, ionization, solution and dilution. Second law of Thermodynamics (brief introduction) Introduction of entropy as a state function, Gibb's energy change for spontaneous and non-spontaneous processes, criteria for equilibrium. Third law of thermodynamics (brief introduction).

**Unit VII: Equilibrium****20 Periods**

Equilibrium in physical and chemical processes, dynamic nature of equilibrium, law of mass action, equilibrium constant, factors affecting equilibrium - Le Chatelier's principle, ionic equilibrium- ionization of acids and bases, strong and weak electrolytes, degree of ionization, ionization of poly basic acids, acid strength, concept of pH, hydrolysis of salts (elementary idea), buffer solution, Henderson Equation, solubility product, common ion effect (with illustrative examples).

**Unit VIII: Redox Reactions****09 Periods**

Concept of oxidation and reduction, redox reactions, oxidation number, balancing redox reactions, in terms of loss and gain of electrons and change in oxidation number, applications of redox reactions.

**Unit XII: Organic Chemistry -Some Basic Principles and Techniques****20 Periods**

General introduction, methods of purification, qualitative and quantitative analysis, classification and IUPAC nomenclature of organic compounds. Electronic displacements in a covalent bond: inductive effect, electromeric effect, resonance and hyper conjugation. Homolytic and heterolytic fission of a covalent bond: free radicals, carbocations, carbanions, electrophiles and nucleophiles, types of organic reactions.

**Unit XIII: Hydrocarbons****18 Periods**

Classification of Hydrocarbons Aliphatic Hydrocarbons: Alkanes - Nomenclature, isomerism, conformation (ethane only), physical properties, chemical reactions including free radical mechanism of halogenation, combustion and pyrolysis. Alkenes - Nomenclature, the structure of double bond (ethene), geometrical isomerism, physical properties, methods of preparation, chemical reactions: addition of hydrogen, halogen, water, hydrogen halides (Markovnikov's addition and peroxide effect), ozonolysis, oxidation, mechanism of electrophilic addition.

Alkynes - Nomenclature, the structure of triple bond (ethyne), physical properties, methods of preparation, chemical reactions: acidic character of alkynes, addition reaction of - hydrogen, halogens, hydrogen halides and water.

Aromatic Hydrocarbons: Introduction, IUPAC nomenclature, benzene: resonance, aromaticity, chemical properties: mechanism of electrophilic substitution. Nitration, sulphonation, halogenation, Friedel Craft's alkylation and acylation, directive influence of the functional group in monosubstituted benzene. Carcinogenicity and toxicity.

### PRACTICALS

3 HOURS/ 30 Marks

Evaluation Scheme for Examination	Marks
Volumetric Analysis	08
Salt Analysis	08
Content Based Experiment	06
Project Work	04
Class record and viva	04
<b>Total</b>	<b>30</b>

### PRACTICAL SYLLABUS

Total Periods: 60

#### Quantitative Estimation

1. Using a mechanical balance/electronic balance.
2. Preparation of standard solution of Oxalic acid.
3. Determination of strength of a given solution of Sodium hydroxide by titrating it against standard solution of Oxalic acid.
4. Preparation of standard solution of Sodium carbonate.
5. Determination of strength of a given solution of hydrochloric acid by titrating it against standard Sodium Carbonate solution.

#### Qualitative Analysis

1. Determination of one anion and one cation in a given salt

##### Cation:

$\text{Pb}^{2+}$ ,  $\text{Cu}^{2+}$ ,  $\text{As}^{3+}$ ,  $\text{Al}^{3+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{NH}_4^+$

##### Anions:

$(\text{CO}_3)^{2-}$ ,  $\text{S}^{2-}$ ,  $(\text{SO}_3)^{2-}$ ,  $(\text{NO}_2)^{-}$ ,  $(\text{SO}_4)^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$ ,  $(\text{PO}_4)^{3-}$ ,  $(\text{C}_2\text{O}_4)^{2-}$ ,  $\text{CH}_3\text{COO}^-$ ,  $\text{NO}_3^-$

(Note: Insoluble salts excluded)

**Note:** The above practical may be carried out in an experiential manner rather than recording observations.

**PRESCRIBED BOOKS:**

1. Chemistry Part – I, Class-XI, Published by NCERT.
2. Chemistry Part – II, Class-XI, Published by NCERT.
3. Laboratory Manual of Chemistry, Class XI Published by NCERT
4. Other related books and manuals of NCERT including multimedia and online sources

**Note:** The content indicated in NCERT textbooks as excluded for the year 2023-24 is not to be tested by schools.

S.	Typology of Questions	Very Short Answer (VSA) (1 mark)	Short Answer-I (SA-I) (2 marks)	Short Answer - II (SA-II) (3marks)	Long Answer (LA) (5 marks)	Total Marks	% Weightage
1.	Remembering- (Knowledge based Simple recall questions, to know specific facts, terms, concepts, principles, or theories, Identify, define,or recite, information)	2	1	1	-	7	10%
2	Understanding- Comprehension -to be familiar with meaning and to understand conceptually, interpret, compare, contrast, explain, paraphrase information)	-	2	4	1	21	30%
3	Application (Use abstract information in concrete situation, to apply knowledge to new situations, Use given content to interpret a situation, provide an example, or solve a problem)	-	2	4	1	21	30%
4	High Order Thinking Skills (Analysis & Synthesis- Classify, compare, contrast, or differentiate between different pieces of information, Organize and/or integrate unique pieces of information from a variety of sources)	2	-	1	1	10	14%
5	Evaluation- (Appraise, judge, and/or justify the value or worth of a decision or outcome, or to predict outcomes based on values)	1	2	2	-	11	16%
	<b>TOTAL</b>	<b>5X1=5</b>	<b>7x2=14</b>	<b>12x3=36</b>	<b>3x5=15</b>	<b>70(27)</b>	<b>100%</b>

### QUESTION WISE BREAK UP

Type of Question	Mark per Question	Total No. of Questions	Total Marks
VSA	1	5	05
SA-I	2	7	14
SA-II	3	12	36
LA	5	3	15
Total		27	70

1. Internal Choice: There is no overall choice in the paper. However, there is an internal choice in one question of 2 marks weightage, one question of 3 marks weightage and all the three questions of 5 marks weightage.
2. The above template is only a sample. Suitable internal variations may be made for generating similar templates keeping the overall weightage to different form of questions and typology of questions same

## SOME BASIC CONCEPTS IN CHEMISTRY

### UNIT-1

**Mole concept:** A mole is the amount of a substance that contains as many particles as there are in 12g of carbon –12 isotope.

**Avogadro's constant (N<sub>A</sub>):** The number of entities in 1 mole of the substance. (6.022x10<sup>23</sup> particles /mole)

**Dalton's atomic theory:**

- All matter is made of atoms, which are indivisible.
- All the atoms of a given element are identical and atoms of different elements have different properties and different masses.
- Atoms are neither created nor destroyed.
- Compounds are formed by the combination of different atoms in the ratio of small whole numbers.
- Chemical reactions involve only combination, separation, and rearrangement of atoms.

**Drawbacks of Dalton's theory:**

- An atom is divisible.
- All atoms of atom are not identical in mass.

**Relative atomic mass:** The number of times a given element is heavier than 1/12 <sup>th</sup> mass of C-12 atom.

**Atomic mass unit -a.m.u (u):** The quantity of mass equal to 1/12<sup>th</sup> of the mass of a C-12 atom.

**Relative Molecular mass:** It is the sum of the relative atomic masses of the constituting atoms.

**Molar mass:** The mass of 1 mol of any substance.

**Molar volume:** The volume of 1 mol of the substance. The molar volume of every gas at STP(Standard temperature and Pressure) is 22.4L

**Mass-Mole-Number relationship:**

$$\text{Number of moles} = \frac{\text{Mass in grams}}{\text{Molar mass in gmol}^{-1}}$$

$$\text{Number of moles} = \frac{\text{Number of atoms or molecules}}{\text{Avogadro's Number}}$$

$$\text{Mass percentage of an element in a compound} = \frac{\text{Total mass of element}}{\text{Molar mass}} \times 100 \%$$

$$\text{Mass of 1 atom} = \frac{\text{Gram atomic mass}}{6.022 \times 10^{23}}$$

**Empirical formula:**

The formula showing the relative number of atoms in the simplest ratio. The empirical formula of glucose ( $C_6H_{12}O_6$ ) is  $CH_2O$ .

**Molecular formula:**

The formula in which the exact number of atoms of different elements are presenting one molecule of a compound.  $C_6H_6$  is the molecular formula of benzene. **Molecular formula is an integral multiple of empirical formula.**

$$n = \frac{\text{Molecular formula weight}}{\text{Empirical formula weight}}$$

$$\text{Molecular weight} = 2 \times \text{vapour density}$$

**Limiting reagent:**

The reactant, which is entirely consumed when a reaction goes to completion.

**Molarity:**

Number of moles of solute dissolved per litre of the solution

$$\text{i) Molarity (M)} = \frac{\text{weight of solute} \times 1000}{\text{Molar mass of solute} \times \text{volume solution (ml)}}$$

$$\text{ii) Molarity (M)} = \frac{\% \text{ by mass} \times \text{density} \times 10}{\text{Molecular weight of the solute.}}$$

Unit: mol/L

$$\text{iii) Molality (m)} = \frac{\text{weight of solute} \times 1000}{\text{Molar mass of solute} \times \text{weight of solvent(g)}}$$

Unit: mol/Kg

$$\text{iv) Mass percent} = \text{Mass of solute per 100 g of solution}$$

$$= \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

$$\text{v) Mole fraction of A} = \frac{n_A}{n_A + n_B}$$

$n_B$  is the number of moles of solute = mass of the solute /Molar mass of the solute

$n_A$  is the number of moles of the solvent = mass of solvent /Molar mass of the solvent

$$\text{Mole fraction of B} = \frac{n_B}{n_A + n_B}$$

$$(\text{vi}) \text{ Parts per million (ppm)} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 10^6$$

**For dilution:**

$$M_1 V_1 = M_2 V_2$$

**UNIT -1 Basic concepts of Chemistry**  
**Question Details**

S No	Question Details	Marks
<b>Read the given passage and answer the questions 1 to 5 that follow:</b>		
Stoichiometry is the calculation of relative masses of reactants and products involved in chemical equations. Stoichiometric problems can be solved in just four simple steps:		
i) Balance the equation.		
ii) Convert into appropriate units (mass to moles or vice-versa).		
iii) Calculate mass/moles yielded.		
Limiting Reagent: The reagent that is completely consumed in a chemical reaction and limits the amount of product formed is called the limiting reagent.		
Excess Reagent: The reagent that is left behind in a chemical reaction is the excess reagent. It is always provided in excess amount.		
1.	Construct a balanced chemical equation for the combustion of ethene.	1
2.	What is the amount of oxygen required for the complete combustion of 2.8kg of ethene?	1
3.	In the following reaction: $4\text{NH}_3\text{(g)} + 5\text{O}_2\text{(g)} \rightarrow 4\text{NO}\text{(g)} + 6\text{H}_2\text{O}\text{(l)}$ When 1 mol of ammonia and 1 mol of O <sub>2</sub> are mixed, then the number of moles of NO formed will be: a) 0.8 b) 0.7 c) 0.6 d) 0.5	1
4.	10 g of marble(calcium carbonate) was added to 15 g of dilute hydrochloric acid, the product formed is calcium chloride, water, and carbon dioxide. Which of the following is true? a) Hydrochloric acid is the limiting reactant. b) Hydrochloric acid is the excess reactant. c) Calcium carbonate is the excess reactant. d) None of the above	1
5.	6 g of H <sub>2</sub> reacts with 14 g of N <sub>2</sub> to form NH <sub>3</sub> until the reaction consumes the limiting reagent completely. The amount of another reactant remaining in g is: a) 3g	1

- b) 4g
- c) 5g
- d) 6g

**Questions 6, 7, and 8 are multiple-choice questions:**

6. If the concentration of glucose ( $C_6H_{12}O_6$ ) in the blood is  $0.9\text{ g L}^{-1}$ , what will be the molarity of glucose in the blood? 1  
  - (i) 5 M
  - (ii) 50 M
  - (iii) 0.005 M
  - (iv) 0.5 M
7. What will be the molality of the solution containing 18.25 g of HCl gas in 500 g of water? 1  
  - (i) 0.1 m
  - (ii) 1 M
  - (iii) 0.5 m
  - (iv) 1 m
8. One mole of any substance contains  $6.022 \times 10^{23}$  atoms/molecules. Number of molecules of  $H_2SO_4$  present in 100 mL of 0.02M  $H_2SO_4$  solution is \_\_\_\_\_.  
  - (i)  $12.044 \times 10^{20}$  molecules
  - (ii)  $6.022 \times 10^{23}$  molecules
  - (iii)  $1 \times 10^{23}$  molecules
  - (iv)  $12.044 \times 10^{23}$  molecules

**Questions 9 and 10 are Assertion and Reason types:**

9. **Assertion:** In Haber's process starting with 5 moles of  $N_2$  and 2.5 mol of  $H_2$ , on complete reaction, only 1.66 moles of  $NH_3$  were produced. 1  
**Reason:**  $H_2$  acts as a limiting reagent in this reaction.  
  - (i) Both A and R are true and R is the correct explanation of A.
  - (ii) Both A and R are true but R is not the correct explanation of A.
  - (iii) A is true but R is false.
  - (iv) Both A and R are false.
10. Assertion: Combustion of 16g of methane gives 18g of water. 1  
Reason: In the combustion of methane, water is one of the products.  
  - (i) Both A and R are true and R is the correct explanation of A.
  - (ii) Both A and R are true but R is not the correct explanation of A.
  - (iii) A is true but R is false.
  - (iv) Both A and R are false.

11. Aspirin has the formula  $C_9H_8O_4$ . How many moles and molecules of aspirin are in a tablet weighing 500mg? 1
12. How many atoms are present in 52 u of He? [13] 1
13. Calculate the number of hydrogen atoms in 39.6g of ammonium sulfate. 1
14. Which sample contains the greatest number of atoms? Two moles of helium atoms or half mole of methane molecule  $CH_4$ . 1
15. Why molality is considered better for expressing the concentration as compared to molarity? 1
16. Vitamin C is known to contain  $1.29 \times 10^{24}$  hydrogen atoms. Calculate the number of moles of hydrogen atoms. 1
17. A solution is prepared by dissolving 18.25g of NaOH in distilled water to give 200cm<sup>3</sup> of solution. Calculate the molarity of the solution. 1
18. Copper wire reacts with  $AgNO_3$  solution to give Ag metal and a Copper (II) nitrate solution. How many grams of metallic silver are produced if 2.37g of Copper has reacted? [8.061g] 2
19. Boron occurs in nature in the form of two isotopes,  $_5B^{11}$  and  $_5B^{10}$ , having an average atomic mass of 10.81. Find the % abundance of the two isotopes. 2  

$$[_5B^{11} = 81\% ; _5B^{10} = 19\%]$$
20. A compound with molar mass 180g/mol contains C, H and O in the molar ratio 1:2:1. What are its empirical and molecular formulae? [C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>] 2
21. What volume of 0.250 M HCl is required to react completely with 22.6g of sodium carbonate according to the reaction? 2  

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2 \quad [1.7 \text{ L}]$$
22. (a) When 8 grams of NaOH is dissolved in distilled water to give 400ml of solution, calculate molarity of the solution. [0.5M] 2  
(b) if the solution is poured into a volumetric flask and made up to 1 L in volume, what would the molarity of the solution become? [0.2 M]
23. 0.5 mol each of  $H_2S$  and  $SO_2$  mixed in a reaction flask, react according to the equation:  

$$2H_2S + SO_2 \longrightarrow 2H_2O + 3S$$
  
Calculate the number of moles of S produced. [0.75 mols] 2
24. Which out of the two weighs more – 32 g of oxygen or 0.5 moles of iron? 2
25. Phosphorous and chlorine form two compounds. The first compound containing 22.54% by mass of phosphorous and 45.08% by mass of chlorine. In the second compound the percentages are 14.88 for phosphorous and 59.52 for chlorine. Show that this data is consistent with the law of multiple proportions. 2

26. a) What is a limiting reagent? 3  
 b) A mixture of 100g of H<sub>2</sub> and 100g of O<sub>2</sub> is ignited to form water. Identify the limiting reagent and calculate the amount of water formed. [ 112.5g]
27. 100g of CaCO<sub>3</sub> is treated with 500ml of M/2 solution of HCl. Find out the volume of CO<sub>2</sub> evolved at STP. Which substance is acting as the limiting reagent? [2.8L] 3
28. a) The compound adrenaline contains 56.79% C, 6.56% H, 28.37% O and 8.28% N by mass. What is the empirical formula for adrenaline? [C<sub>8</sub>H<sub>11</sub>O<sub>3</sub>N] 3  
 b) Calculate mass percent of Hydrogen in HCHO. [6.67%]
29. An alcohol contains elements carbon, hydrogen and oxygen. The weight percentages of each element was measured and found to be C=52.1%, H=13.1%, O= 34.7%. Determine the empirical formula. The molar mass of ethanol is found to be about 46.1g/mole. Determine its molecular formula. [C<sub>2</sub>H<sub>6</sub>O] 3
30. (a) How many moles of nitric acid are there in a 75mL sample of a 0.60M solution of nitric acid? [ 0.045 mols] 3  
 (b) If the sample is made up to 2L in volume, what would the molarity of the solution be? [0.0225M]
31. Commercially available sulphuric acid contains 93% by mass and has a density of 1.84g/cm<sup>3</sup> . Calculate (i)molarity of the solution(ii)volume of concentrated acid required to prepare 2.5L of 0.50 M H<sub>2</sub>SO<sub>4</sub> [17.46M; 0.0715 L] 3
32. Nitrogen gas is prepared by passing gaseous ammonia over solid Copper (II) oxide at high temperatures. If a sample containing 18.1g of ammonia is reacted with 90.4g of CuO, which is the limiting reagent? How many grams of Nitrogen will be formed?  

$$2\text{NH}_3 + 3\text{CuO} \rightarrow \text{N}_2 + 3\text{Cu} + 3\text{H}_2\text{O}$$
 [ 10.6g] 3
33. Certain non-metal X forms two oxides I and II. The mass percentage of oxygen in (X<sub>4</sub>O<sub>6</sub>) is 43.7 which is same as that of X in the 2<sup>nd</sup> oxide. Find the formula of 2<sup>nd</sup> oxide. [X<sub>2</sub>O<sub>5</sub>] 3
34. Calculate the molality and mole fraction of the solute in an aqueous solution containing 3.0 g of urea (NH<sub>2</sub>CONH<sub>2</sub>) per 250g of water. [m =0.2m; X<sub>urea</sub> = 0.0036] 3
35. (a) A compound contains 4% hydrogen, 24%carbon and 71.65% chlorine. Its molar mass is 98.9g, what are its empirical and molecular formulae? [CH<sub>2</sub>Cl;C<sub>2</sub>H<sub>4</sub>Cl<sub>2</sub>] 5  
 (b) Calculate the mass of carbon dioxide that will be produced on complete combustion of 64g of methane. [176g]

36. (a) Calculate the number of moles and the amount in gram, of 250 cc of a 0.1 M NaOH solution. [ 0.025 mole; 1 g] 5

(b) Mass of copper oxide obtained on treating 2.16 g of metallic copper with HNO<sub>3</sub> and subsequent ignition was 2.70 g. In another experiment 1.15 g of copper oxide on reduction yielded 0.92 g of copper. Show that these results illustrate the law of constant composition.

37. (a) How many atoms of oxygen are present in 300 g of CaCO<sub>3</sub>? [54.198 × 10<sup>23</sup>] 5

(b) How many grams of Cl<sub>2</sub> is produced from 15.8 g of KMnO<sub>4</sub> and 50 mL of 10 M HCl according to the reaction:

$$2\text{KMnO}_4 + 16\text{HCl} \longrightarrow 2\text{KCl} + 2\text{MnCl}_2 + 8\text{H}_2\text{O} + 5\text{Cl}_2$$

**HOTS**

38. (a) Are 0.5mole of NaOH and 0.5M of NaOH solution same? 3

(b) 1.24g white phosphorous P<sub>4</sub> was allowed to react with O<sub>2</sub> to produce P<sub>4</sub>O<sub>6</sub>, an acidic oxide. The solution of P<sub>4</sub>O<sub>6</sub> in water is acidic and is neutralized with NaOH. How many moles of NaOH are required to neutralize H<sub>3</sub>PO<sub>3</sub> generated in the above case?

39. (a) Two bottles of A and B contains 1M and 1m aqueous solutions (d=1g/ml) of sulphuric acid respectively. Which one is more concentrated and why? 5

(b) In the combustion of methane, why is methane regarded as the limiting reagent?

(c) Commercially available concentrated HCl contains 38% HCl by mass.

(i) What is the molarity of the solution if its density is 1.19gcm<sup>-3</sup>?

(ii) What volume of concentrated HCl is needed to make 1.0L of 0.2M HCl solution?

## STRUCTURE OF ATOM UNIT-2

### **Bohr's theory:**

An electron does not radiate energy if it stayed in one orbit.

The angular momentum of orbits in which electron revolves must be an integral multiple of  $\frac{h}{2\pi}$ .

The energy of orbit closest to the nucleus is lowest whereas energy of the orbit far away from the nucleus is highest.

When an electron moves from one orbit to another it either radiates or absorbs energy.  $\Delta E = E_2 - E_1 = h\nu$

### **Energy $E_n$ of an electron in orbit n**

$$E_n = \frac{(-2.18 \times 10^{-18} \text{ J})}{n^2} \text{ atom}^{-1} \quad n=1,2,3\dots$$

$$E_n = \frac{(-13.595 \text{ eV})}{n^2} \text{ atom}^{-1}$$

Radius of each circular orbit

$$r_n = 0.529 A^0 (n^2) \quad n=1,2,3\dots$$

### **Energy of hydrogen like systems.**

$$E_n = \frac{-(13.595 \text{ eV}) Z^2}{n^2} \text{ atom}^{-1} \quad \text{where } Z = \text{atomic number}$$

### **Radius of hydrogen like systems.**

$$r_n = \frac{0.529 A^0 (n^2)}{Z}$$

Quantum mechanical model of atom is based upon the wave particle, duality of matter and Heisenberg uncertainty principle.

Both these concepts though applicable to all matter in motion are significant only in the case of microscopic particles.

### **de-Broglie Relationship**

$\lambda = h/mv$  or  $\lambda = h/p$  or where  $p$  =momentum of the particle.

$h$  is Plank's constant= $6.626 \times 10^{-34} \text{ Js}$

### **Heisenberg's Uncertainty Principle**

It is impossible to determine simultaneously both the position and momentum of a microscopic particle with certainty.

Mathematically it can be expressed as

$$\Delta x \cdot \Delta p \geq h/4\pi \quad \text{or} \quad \Delta x \cdot \Delta v \geq h/4\pi m$$

$\Delta x$  = uncertainty in position;  $\Delta p$  = uncertainty in momentum  $h$  = Planks constant

### Aufbau Principle

In the ground state of an atom, the orbitals are filled in order of their increasing energies.

**Orbitals fill in the order of increasing value of  $(n+l)$**

**If the orbitals have same values of  $(n + l)$  the orbital with the lower value of  $n$  will be filled first.**

### Pauli Exclusion Principle

No two electrons in an atom can have the same set of four quantum numbers.

### **Hund's Rule of Maximum Multiplicity**

Pairing of electrons in the orbitals belonging to the same subshell (p, d or f) does not take place until each orbital belonging to that subshell has got one electron each, ie singly occupied

The quantum state of an electron is determined by its quantum numbers:

name	Symbol	orbital meaning	Range of values	Value example
Principal quantum number	n	Shell	$n=1,2,3,4\dots$	$n=1,2,3\dots$
azimuthal quantum number (angular momentum)	$\ell$	sub shell (s orbital is listed as 0, p orbital as 1, d orbital as 2 etc.)	$\ell=0,1\dots(n-1)$ $\ell \neq n$	for: $n=5$ , $\ell=0,1,2,3,4$ s,p,d,f,g
magnetic quantum number	$m_\ell$	orientation of the sub shell	$m_\ell=-\ell\dots 0\dots+\ell$	for: $\ell=2$ , $m_\ell=-2, -1, 0, +1, +2$
spin quantum number	$m_s$	spin of the electron (-1/2 = counter-clockwise, 1/2 = clockwise)	$+ \frac{1}{2}, - \frac{1}{2}$	for an electron, either: $\frac{1}{2}, - \frac{1}{2}$

## UNIT -2 Structure of atom

S No	Question Details	Marks
<b>Read the given passage and answer the questions 1 to 5 that follow:</b>		
The French physicist, de Broglie, in 1924 proposed that matter, like radiation, should also exhibit dual behavior i.e., both particle and wavelike properties. This means that just as the photon has momentum as well as wavelength, electrons should also have momentum as well as wavelength. de Broglie, from this analogy, gave the following relation between wavelength ( $\lambda$ ) and momentum (p) of a material particle,		
	$\lambda = \frac{h}{mv} = \frac{h}{p}$	
Werner Heisenberg a German physicist in 1927, stated the uncertainty principle which is the consequence of dual behavior of matter and radiation. It states that it is impossible to determine simultaneously, the exact position and exact momentum (or velocity) of an electron. Mathematically, it can be given as in the equation,		
	$\Delta x \times \Delta p_x \geq \frac{h}{4\pi}$	
1.	Quantum mechanics is a theoretical science that deals with the study of the motions of the ..... objects. (a) Macroscopic (b) Microscopic (c) Laparoscopic (d) All the above	1
2.	The probability density of the electron at a point is given by- (a) $2\Psi$ (b) $\Psi^2$ (c) $\Psi/2$ (d) $\Psi^3$	1
3.	The maximum number of electrons that may exist in the same orbital is- (a) One (b) Two (c) Three (d) Four	1
4.	For a given principal level $n = 4$ , the energy of its subshells is in the order (a) $s < p < d < f$ (b) $s > p > d > f$ (c) $s < p < f < d$ (d) $f < p < d < s$	1

5. Which of the following statements do not form a part of Bohr's model of hydrogen atom ? 1  
(a) Energy of the electrons in the orbits are quantized  
(b) The electron in the orbit nearest the nucleus has the lowest energy  
(c) Electrons revolve in different orbits around the nucleus  
(d) The position and velocity of the electrons in the orbit cannot be determined simultaneously.

**Questions 6, 7 and 8 are multiple choice questions:**

6. Which of the following statements in relation to the hydrogen atom is correct? 1  
(a) 3s orbital is lower in energy than 3p orbital  
(b) 3p orbital is lower in energy than 3d orbital  
(c) 3s and 3p orbitals are of lower energy than 3d orbital  
(d) 3s, 3p and 3d orbitals all have the same energy
7. If electron, hydrogen, helium and neon nuclei are all moving with the velocity of light, then the wavelength associated with these particles are in the order 1  
(a) Electron > hydrogen > helium > neon  
(b) Electron > helium > hydrogen > neon  
(c) Electron < hydrogen < helium < neon  
(d) Neon < hydrogen < helium < electron
8. Which of the following sets of quantum numbers represents the highest energy of an atom?  
(a)  $n = 3, l = 0, m = 0, s = +1/2$   
(b)  $n = 3, l = 1, m = 1, s = +1/2$   
(c)  $n = 3, l = 2, m = 1, s = +1/2$   
(d)  $n = 4, l = 0, m = 0, s = +1/2$

**Questions 9 and 10 are Assertion and Reason type:**

9. Assertion (A) : All isotopes of a given element show the same type of chemical behavior. 1  
Reason (R) : The chemical properties of an atom are controlled by the number of electrons in the atom.  
(i) Both A and R are true and R is the correct explanation of A.  
(ii) Both A and R are true but R is not the correct explanation of A.  
(iii) A is true but R is false.  
(iv) Both A and R are false.
10. Assertion: Isotopes are electrically neutral. 1  
Reason: Isotopes are species with same mass number but different atomic numbers.
11. Using s, p, d, f notations, designate the orbital with the following quantum numbers- 1  
a)  $n = 2, l = 1, m_l = -1$    b)  $n = 3, l = 2, m_l = 0, m_s = +1/2$
12. Arrange the following in increasing order of energy for hydrogen 1s, 3s, 2p, 3p, 2s. 1
13. Calculate the atomic number of an element having  $4s^2 4p^6$  configuration in its last orbit? 1

- 14.** An element has electronic configuration [Ar]3d<sup>4</sup> in its +3 oxidation state. What will be the electronic configuration of its atom? 1
- 15.** Which orbital experiences the lowest effective nuclear charge? 1
- a) 1s or 2s   b) 3p or 4p
- 16.** The arrangement of orbitals based on energy is based upon their (n+l) values. Lower the value of (n+l), lower is the energy. 2
- Based on the above information, arrange the following orbitals in increasing order of energy-
- a) 1s,2s,3s,3p  
 b) 4s,3s,3p,4d  
 c) 5p, 4d, 5d, 4f  
 d) 5f,6d, 7s, 7p
- 17.** Arrange the electrons represented by following set of quantum numbers in the decreasing order of energy for a multi electron atom- 2
- (a) n=4, l=0, m<sub>l</sub>=0, m<sub>s</sub>=+1/2   (b) n=3, l=1 , m<sub>l</sub>=1 ,m<sub>s</sub>= -1/2   (c) n=3, l=2, m<sub>l</sub>=0, m<sub>s</sub>=+1/2  
 (d) n=3, l=0, m<sub>l</sub>=0, m<sub>s</sub>=-1/2.
- 18.** Calculate the momentum of a particle, which has a de Broglie wavelength of 1A<sup>0</sup>(h=6.6×10<sup>-34</sup>Kgm<sup>2</sup>s<sup>-1</sup>). 2  
 [p = 6.6 ×10<sup>-24</sup>Kgms<sup>-1</sup>]
- 19.** What are the quantum numbers for? 2
- a) 2p electrons in Nitrogen  
 b) 19<sup>th</sup> electron of chromium  
 c) highest energy electron in sodium atom  
 d)unpaired electron in copper.
- 20.** Write the electronic configurations of the following? 2
- a) Cr   b) Mn<sup>+2</sup>
- 21.** The kinetic energy of an electron is 5×10<sup>-5</sup> eV. What is the wavelength of the de Broglie wave associated with it? (1eV = 1.602 x 10<sup>-19</sup>J) 3
- 22.** Show that the wavelength of a 150gm rubber ball travelling at the velocity of 50m/s is short enough to be observed. 3  
 [8.834x10<sup>-30</sup>m]
- 23.** According to Bohr's theory the electronic energy of hydrogen atom in the nth orbit is given by 3  

$$E_n = (-21.76 \times 10^{-19} \text{J}) / n^2$$
- Calculate the longest wavelength of light that will be needed to remove an electron from the third orbit of He<sup>+</sup> ion.

- 24.** a) Hydrogen atom has only one electron, so mutual repulsion between electrons is absent. However, in multielectron atoms, mutual repulsion between electrons is significant. How does this affect the energy of an electron in the orbitals of the same principal quantum number in multielectron atoms? Illustrate with an example. 3
- b) Which of the following orbitals are degenerate?
- $3d_{xy}, 4d_{xy}, 3d_{z^2}, 3d_{yz}, 4d_{yz}, 4d_{z^2}$
- 25.** Calculate the frequency and wavelength of the radiation in nanometers emitted when an electron in the hydrogen atom jumps from third orbit to the ground state. In which region of the electromagnetic spectrum will this line lie? 3
- 26.** (a) How many electrons in an atom have the following quantum numbers?  
 $n = 3, l = 1$   
(b) Out of 4s and 4d, which will experience more effective nuclear charge from the nucleus?  
(c) How many unpaired electrons are present in Kr ( $Z=36$ )? 3
- 27.** The electron energy in Hydrogen atom is given by 3
- $$E_n = \frac{-2.18 \times 10^{-18} \text{ J}}{n^2}$$
- Calculate the energy required to remove an electron completely from the  $n=2$  orbit. What is the longest wavelength of light in cm that can be used to cause this transition?
- 28.** Account for the following: 3
- (a) Cr has electronic configuration  $[\text{Ar}]3d^54s^1$  and not  $[\text{Ar}]3d^44s^2$   
(b) In building up of atoms, the filling up of 4s orbitals takes place before the 3d orbitals  
(c) The ground state configuration of Nitrogen is not written as  $1s^22s^22p_x^22p_y^12p_z^0$
- 29.** a) Calculate the accelerating potential that must be applied to a proton beam to give it an effective wavelength of 0.005 nm. 3  
b) Calculate ionization potential in volts of  $\text{Li}^{2+}$  ion. [122.4 eV]
- 30.** a) State Heisenberg's Uncertainty Principle.  
b) Which of the two, an electron or a neutron will show more accuracy in its position, if there is an equal uncertainty in their velocities?  
[ mass of electron =  $9.1 \times 10^{-31}$  Kg; mass of proton =  $1.67 \times 10^{-27}$  Kg] 5
- [Ans:  
neutron]  
c) Calculate the uncertainty in the velocity of wagon of mass 2000 kg whose position is known to an accuracy of  $\pm 10\text{m}$ . [ $2.64 \times 10^{-39}$  m/s]

### HOTS

- 31.** (a) Why are 2d and 3f orbitals not possible? 5  
(b) If the velocity of the electron in Bohr's first orbit is  $2 \times 10^6$ m/sec, calculate the de Broglie wavelength associated with it.  
(c) What is the significance of  $\psi^2$ ?
- 32.** Answer the following. 5
- (a) How many electrons can be filled in all the orbitals with  $n+l=5$ ? ( $5s, 3d, 4p = 18$  electrons)  
(b) Which of the two is paramagnetic, V(IV) or V(V) and why?  
(c) How many unpaired electrons are present in Pd( $Z=46$ )  
(d) What is the ground electronic configuration of oxygen in  $OF_2$ ?

## CLASSIFICATION OF ELEMENTS AND PERIODICITY IN PROPERTIES

### UNIT-3

#### **Modern periodic law**

The physical and chemical properties of the elements are the periodic functions of their atomic numbers.

#### **Periods**

- The horizontal rows in a periodic table.
- There are seven periods
- The number of elements in the subsequent periods are 2,8,8,18,18,32 and incomplete. The number of elements available in each period is twice the number of atomic orbital available in the main energy level that is being filled.

#### **Groups**

- The vertical columns in a periodic table are called groups.
- There are 18 groups in a periodic table.
- In a group the elements have the same valance electrons and similar chemical properties.

#### **s block elements**

The elements in which the last electron enters the s sublevel of their outermost energy level are called s block elements. [group 1and 2] The general electronic configuration is  $ns^{1-2}$ .

#### **p block elements.**

The elements belong from group 13-18. The general electronic configuration is  $ns^2np^{1-6}$ .

#### **d block elements.**

The elements in which the last electron enters the d orbital of the penultimate shell are called d block elements. [Group3-12]. The general electronic configuration

$(n-1)d^{1-10}ns^{1-2}$

#### **f block elements**

The elements in which the last electron enters the f sublevel of the anti-penultimate shell are called f block elements.

The general electronic configuration is  $(n-2)f^{1-14}(n-1)d^{0-1}ns^2$ .

**The two rows of elements at the bottom of the Periodic Table, called the Lanthanoids, Ce(Z = 58) – Lu(Z = 71) and Actinoids, Th(Z = 90) – Lr (Z = 103)**

**These two series of elements are called the Inner-Transition Elements (f-Block Elements).**

They are all metals. Actinoid elements are radioactive. Many of the actinoid elements have been made only in nanogram quantities or even less by nuclear reactions and their chemistry is not fully studied.

The elements after uranium are called **Transuranium Elements**.

#### **Periodicity in properties.**

The periodic repetition of properties with the increase in atomic number is called periodicity in properties. This is due to periodic repetition in electronic configuration.

## **Nature of elements**

**Metals** appear on the left-hand side. [Solids-high melting and boiling points-malleable and ductile-good conductors of heat and electricity]

**Non-metals** appear on the top right-hand side. [Solids or gases-low melting and boiling points-poor conductors of heat and electricity-nonmalleable and non-ductile]

**Metalloids** are the borderline elements placed diagonally across the periodic table and shows properties of both metals and non-metals. **Eg: Ge, Si, As, Te, Po etc**

- Metallic character increases from down a group.
- Non-metallic character increases from left to right in a periodic table.

## **Atomic Radius:**

The distance from the center of the nucleus to the valance shell in an atom.

### **Variation of atomic radius in a period:**

The atomic size decreases across a period because the nuclear charge increases progressively by one unit, but the additional electron goes to the same shell.

### **Variation of atomic radius in a group:**

In moving down the group the increase in the number of shells outweighs the increase in nuclear charge. So, the atomic size increases.

**Note** that the atomic radii of noble gases are not considered here. Being monoatomic, their (non-bonded radii) values are very large. In fact radii of noble gases should be compared not with the covalent radii but with the van der Waals radii of other elements.

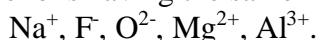
**Ionic Radii:** The effective distance from the nucleus of an ion to a point up to, which the nucleus has an influence in the ionic bond.

The size of an anion will be larger than that of the parent atom because the addition of one or more electrons would result in increased repulsion among the electrons and a decrease in effective nuclear charge.

A cation is smaller than its parent atom because it has fewer electrons while its nuclear charge remains the same

## **Isoelectronic species:**

The ions having the same number of electrons and different nuclear charges.



**Ionic Size increasing order:**  $\text{Al}^{3+} \text{ Mg}^{2+} \text{ Na}^+ \text{ F}^- \text{ O}^{2-}$

## **Ionization Enthalpy**

### **First ionization enthalpy:**

The energy required to remove the loosely bound electron from an isolated gaseous atom in its ground state is called ionization enthalpy.

### **Second ionization enthalpy:**

The energy required to remove the second electron from an isolated gaseous uni positive ion. Energy is always required to remove electrons from an atom and hence ionization enthalpies are always positive.

The ionization enthalpy is expressed in units of  $\text{kJ mol}^{-1}$ .

### **Variation of IE in a group.**

IE decreases in a group. [The increase in size and shielding effect outweighs the increase in nuclear charge]

### **Variation of IE in a period.**

IE increases from left to right in a period. [The nuclear charge increases and the size decreases]

### **Electron gain enthalpy:**

The energy given out when an electron is added to an isolated gaseous atom to form a monovalent gaseous anion.

The electron gain enthalpy is negative because energy is given out.

The group 17 elements (the halogens) have very high negative electron gain enthalpies because they can attain stable noble gas electronic configurations by picking up an electron.

The noble gases have large positive electron gain enthalpies because the electron has to enter the next higher principal quantum level leading to a very unstable electronic configuration.

The electron gain enthalpy of O or F is less negative than that of the succeeding element. This is because when an electron is added to O or F, the added electron goes to the smaller  $n = 2$  quantum level and suffers significant repulsion from the other electrons present in this level. For the  $n = 3$  quantum level (S or Cl), the added electron occupies a larger region of space and the electron-electron repulsion is much less.

### **Variation of electron gain enthalpy in a period:**

The electron gain enthalpy becomes more negative from left to right in a period as the nuclear charge increases and the atomic size decreases. So the nuclear force on the incoming electron increases, so electron gain enthalpy will become more negative.

### **Variation of electron gain enthalpy in a group:**

The electron gain enthalpy becomes less negative in a group because the increase in atomic size outweighs the increase in nuclear charge.

**Electronegativity** A qualitative measure of the ability of an atom in a chemical compound to attract shared electrons to itself is called electronegativity.

The electronegativity of any given element is not constant; it varies depending on the element to which it is bound.

Fluorine is the most electronegative element.

Electronegativity generally increases across a period from left to right (say from lithium to fluorine) and decrease down a group (say from fluorine to astatine) in the periodic table.

**Periodicity of Valence** The valence of representative elements is usually equal to the number of electrons in the outermost orbitals and / or equal to eight minus the number of outermost electrons

**Anomalous Properties of Second Period Elements** The anomalous behaviour

is attributed to their small size, large charge/ radius ratio and high electronegativity of the elements.

The first element of each of the groups 1 (lithium) and 2 (beryllium) and groups 13-17 (boron to fluorine) differs in many respects from the other members of their respective group. In fact the behaviour of lithium and beryllium is more similar with the second element of the following group

i.e., magnesium and aluminium, respectively. This sort of similarity is commonly referred to as **diagonal relationship** in the periodic properties.

The first member of group has only four valence orbitals ( $2s$  and  $2p$ ) available for bonding, whereas the second member of the groups have nine valence orbitals ( $3s$ ,  $3p$ ,  $3d$ ). As a consequence of this, the maximum covalency of the first member of each group is 4

The first member of  $p$ -block elements displays greater ability to form  $p\pi - p\pi$  multiple bonds to itself (e.g.,  $C = C$ ,  $N = N$ ) and to other second period elements (e.g.,  $C = O$ ,  $C = N$ ,  $N = O$ ) compared to subsequent members of the same group.

### **Periodic Trends and Chemical Reactivity**

The maximum chemical reactivity at the extreme left (among alkali metals) is exhibited by the loss of an electron leading to the formation of a cation and at the extreme right (among halogens) shown by the gain of an electron forming an anion.

The metallic character of an element, which is highest at the extremely left decreases and the non-metallic character increases while moving from left to right across the period.

The normal oxide formed by the element on extreme left is the most basic (e.g.,  $Na_2O$ ), whereas that formed by the element on extreme right is the most acidic (e.g.,  $Cl_2O_7$ ).

Oxides of elements in the centre are amphoteric (e.g.,  $Al_2O_3$ ,  $As_2O_3$ ) or neutral (e.g.,  $CO$ ,  $NO$ ,  $N_2O$ ). Amphoteric oxides behave as acidic with bases and as basic with acids, whereas neutral oxides have no acidic or basic properties.

## Classification of elements and periodicity in properties

### UNIT 3

S No	Question Details	Marks
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**Read the given passage and answer the questions 1 to 5 that follow:**

In the modern periodic table, elements are arranged in order of increasing atomic numbers which is related to the electronic configuration. Depending upon the type of orbitals receiving the last electron, the elements in the periodic table have been divided into four blocks, viz, s, p, d and f. The modern periodic table consists of 7 periods and 18 groups. Each period begins with the filling of a new energy shell. In accordance with the Aufbau principle, the seven periods (1 to 7) have 2, 8, 8, 18, 18, 32 and 32 elements respectively. The seventh period is still incomplete. To avoid the periodic table being too long, the two series of f-block elements, called lanthanoids and actinoids are placed at the bottom of the main body of the periodic table. Periodic trends are those which explain certain properties of elements that are present in the periodic table. The periodic trends are atomic radii, ionic radii, ionization energy, electron gain enthalpy, electronegativity, metallic character, etc.

For the same element.



In the 13th group, the first ionization energy of thallium is greater than that of gallium. This is due to the poor shielding of outer electrons by the inner d-electrons in thallium and the lanthanoid contraction in gallium. Also, noble gases have the highest ionization energy value in a given period. Cesium has the lowest ionization energy and is therefore used in photoelectric cells. Elements with half-filled and fully filled orbitals are more stable. Therefore, adding an electron to a stable electron configuration required more energy. Hence, electron gain enthalpy has a high positive value.

1. Arrange the following elements in order of increasing atomic radii. Justify your order. 1  
Cs, F, K, Cl
2. Arrange the following elements in the order of increasing electronegativity. B, Na, F, O. 1
3. Arrange the following in order of increasing radius and assign a common name for the species shown:  $Mg^{2+}$ ,  $Na^+$ ,  $Al^{3+}$  1
4. An element has electronic configuration  $1s^2 2s^2 2p^6 3s^2 3p^6$ , determine the location in the periodic table. 1
5. Addition of an electron to  $Na(g)$  is slightly exothermic process, whereas addition of an electron to  $Mg(g)$  is strongly endothermic. Explain. 1

**Questions 6, 7 and 8 are multiple choice questions:**

6. The outer electronic configuration of some elements is given below. The element that belongs to d-block has the configuration- 1
- $3s^2 3p^4$
  - $3d^{10} 4s^2$
  - $3s^2 3p^6 4s^2$
  - $6s^2 4f^3$
7. The  $IE_1$  and  $IE_2$  values (KJ/mole) of a few elements designated by A, B, C, D are shown below 1

	$IE_1$	$IE_2$
A	2372	5251
B	520	7300
C	900	1760
D	1680	3380

Which of the above element is likely to be,

- a reactive metal
  - a reactive nonmetal
  - a noble gas
  - a metal A that forms a stable binary halide of the formula  $AX_2$
8. Which of the following options' order of arrangement does not agree with the variation of the property indicated against it? 1
- $Al^{3+} < Mg^{2+} < Na^+ < F^-$  (increasing ionic size)
  - $B < C < N < O$  (increasing first ionization enthalpy)
  - $I < Br < Cl < F$  (increasing electron gain enthalpy)
  - $Li < Na < K < Rb$  (increasing metallic radius)

**Questions 9 and 10 are Assertion and Reason type:**

- A and R both are correct, and R is correct explanation of A.
  - A and R both are correct, but R is not the correct explanation of A.
  - A is true but R is false.
  - A and R both are false.
9. Assertion: Second ionization enthalpy will be higher than the first ionization enthalpy. 1  
 Reason: Ionization enthalpy is a quantitative measure of the tendency of an element to lose an electron.
10. Assertion: Electron gain enthalpy of noble gases is exothermic. 1  
 Reason: Electron gain enthalpy provides a measure of the ease with which an atom adds an electron to form anion.

11. Give reasons- 3
- In a period generally, the size of an atom decreases with an increase in atomic number, at the end of each period in noble gases the atomic size increases abruptly.
  - Halogens have the highest negative electron gain enthalpies in the respective periods.
  - Lanthanides and actinides are placed in separate rows at the bottom of the periodic table
12. Explain why  $IE_1$  of the elements given below show these trends. 3
- ${}_7N$  greater than  ${}_8O$ .
  - ${}_{12}Mg$  greater than both Al and Na .
  - Be greater than B.
13. i) A, B & C are three elements with atomic numbers Z-1, Z, Z+1 respectively. If B is an inert gas, answer the following questions- 3
- Which out of the three has positive electron gain enthalpy and why?
  - Which of the three has least value of ionization enthalpy?
- ii) Name the element with atomic number 111.
14. Arrange the following in the decreasing order of the property mentioned 3
- P, S, Cl, F (negative electron gain enthalpy)
  - $F^-$ ,  $Mg^{2+}$ ,  $O^{2-}$ ,  $Na^+$  (ionic radius)
  - Mg, B, Al, K (metallic character)
15. The electronic configuration of a few elements are given below 3
- A -  $1s^2 2s^2 2p^6 3s^2$   
B -  $1s^2 2s^2 2p^6$   
C -  $1s^2 2s^2 2p^3$   
D -  $1s^2 2s^2 2p^6 3s^1$   
E -  $1s^2 2s^2 2p^5$
- Name the elements A and B
  - Which of these has lowest ionization energy?
  - Which is a halogen?
16. (a) What is diagonal relationship? 3  
(b) Arrange the following in order of increasing radius and assign a common name for the species shown:  $Mg^{2+}$ ,  $Na^+$ ,  $Al^{3+}$
17. The outer electronic configuration of an element is  $3d^7 4s^2$ . Assign its position (period, group, and block) in the periodic table and state any two general properties of this block. 3

18. (a) Among 3d and 3p orbitals which orbital will experience the larger effective nuclear charge? 3  
 (b) Using s,p,d notations, describe the orbital with the following quantum numbers.  
 (i) n=1,l=0    (ii) n=4,l=3  
 (c) An atomic orbital has n=3. What is the maximum no. of electrons which can be accommodated in this orbit?
19. Answer the following giving reasons: 3  
 a) Out of F and Cl which has more negative electron gain enthalpy.  
 b) Which is the most reactive element in the alkali metals?  
 c) What is the general electronic configuration of group 15 elements?
20. Give a suitable explanation for the following. 3  
 a) Nitrogen has positive electron gain enthalpy while Oxygen has a negative value.  
 b) Noble gasses have positive electron gain enthalpies.  
 c) Ne and Na<sup>+</sup> ions are isoelectronic species. Do they have the same ionization enthalpies also?
21. Explain the following - 5  
 a) there are ten elements in each transition series.  
 b) the members of the oxygen family are in p-block.  
 c) the position of hydrogen in the periodic table is still not satisfactory.  
 d) elements in a group show similar chemical characteristics.  
 e) give the electronic configuration of the fifth element of the first transition series.

### HOTS

22. a) Predict the formula of stable binary compounds that would be formed by following pairs of elements. 5  
 i) silicon and oxygen ii) aluminium and bromine.  
 b) Argon (atomic mass =39.94) has been placed before potassium (39.10) in the periodic table why?  
 c) Arrange the following in increasing bond length: H<sub>2</sub>, N<sub>2</sub>, O<sub>2</sub>  
 d) The outer electronic configuration of an element is 3d<sup>7</sup>4s<sup>2</sup>. Assign its position in the periodic table and state any two general properties of this block.
23. (a) Although Fluorine is more electronegative than chlorine, the electron gain enthalpy of chlorine is more negative than fluorine. Why? 5  
 (b) Explain the following:  
 (i) Size of anion is larger than the parent atom.  
 (ii) Electron gain enthalpy of oxygen is more negative than that of O<sup>-</sup>.  
 (c) Answer the following questions about the elements with the electronic configurations below:  
 $A = [\text{Ar}]3\text{p}^64\text{s}^2$        $B = [\text{Ar}]4\text{s}^23\text{d}^{10}4\text{p}^5$   
 (i) Which element has higher ionization enthalpy?  
 (ii) Which element should be smaller of the two?

## **CHEMICAL BONDING AND MOLECULAR STRUCTURE UNIT-4**

### **Chemical bond:**

The attractive force, which holds various atoms and ions in different chemical species, is called chemical bond.

### **Kossel –Lewis approach to chemical bonding**

octet rule- Atoms of various elements enter chemical combination so as to attain 8 electrons in their valence shells. They attain octet configuration by sharing of electrons or transferring electrons.

### **Lewis dot symbol:**

The simple notation to denote the valance electrons in an atom.

### **Formal charge and its calculation.**

The difference between the number of valence electrons in a free atom and the number of electrons assigned to that atom in the Lewis structure.

Formal charge on an atom= Total number of valance electrons – [total number of lone pair electrons +½ (total number of bond pair electrons)]

### **The ionic bond:**

The electrostatic force of attraction holding the opposite charged ions. It is formed by the transference of electrons from a metal to a non-metal. The electrovalency is the number of unit charges on the ion.

### **Factors required for stable ionic bonding:**

- Low ionization energy of the cation.
- High electron gain enthalpy of the anion.
- Lattice energy should be high.

**Lattice enthalpy:** The amount of energy released when 1 mol of the ionic solid is formed from the constituent ions in the gaseous state.

Consequence of lattice enthalpy;

- Greater the lattice enthalpy more stable is the ionic compound.
- The lattice enthalpy is greater for ions of smaller size and higher charge.
- The lattice enthalpy affects the solubility of ionic compounds.

**Covalent bond:** The force, which binds the atoms of same or different elements by mutual sharing of electrons. Covalency is the number of electrons contributed for sharing.

### **Bond length:**

The internuclear distance between the bonded atoms in a molecule.

### **Bond enthalpy:**

The enthalpy required to break a bond in one mole of the gaseous molecule.

### **Bond order:**

The number of bonds between two atoms in a molecule.

### **Resonance:**

When a molecule can be represented by more than one Lewis formula none of it is able to explain all the observed properties of the compound, then the actual structure of the molecule is the intermediate of the various Lewis structures and is called a resonance hybrid, This phenomenon is called resonance.

- The Lewis structures are called resonating structures or canonical forms.
- The resonance between the canonical forms is represented by double-headed arrows.
- The difference in energy between the most stable resonance structures and the resonance hybrid is called resonance energy.

**Electronegativity:** The tendency of an atom to attract the bonded pair of electron towards itself in a molecule. It is just a number.

### **Electron gain enthalpy:**

The tendency of an atom for an additional electron. It is determined experimentally.

### **Polar covalent bonds:**

A covalent bond of 2 dissimilar atoms develops a partial ionic character as a result of the difference of electronegativities of the atoms forming the bond.

Greater the difference in electronegativity greater is the percentage ionic character.

### **Dipole moment:**

The product of the charge on any one of the atoms and the distance between them.

The percentage of ionicity in a polar covalent bond is expressed in terms of dipole moment.

The unit of dipole moment is Debye (D)

The dipole moment of the individual bond is called bond dipole.

It is represented by an arrow pointing from the positive end to the negative end of the dipole.

In polyatomic molecules the dipole moment depends on the structure and the orientation of the various bond dipoles.

### **Shapes of molecules: [VSEPR Theory (Valence shell electron pair repulsion theory)]**

1. The shape of the molecule is determined by the total number of electron pairs (bonding and lone pairs) around the central atom.
2. The electrons stay as far as possible to attain maximum stability and minimum energy.
3. The repulsive interactions follow the order lone pair-lone pair > lone pair –bond pair > bond –bond pair
4. A multiple bond is treated as a single electron pair

### **Types of covalent bonds.**

**Sigma bond:** The type of bond formed by the axial overlapping of half-filled atomic orbitals is called sigma bond. The strength of the sigma bond depends on the extent of overlap p-p > s-p > s-s (Increasing strength of sigma bond)

The bond is stronger because the overlapping takes place to a larger extent.

**Pi bond ( $\pi$ ):** The bond formed by the sideways overlap of the atomic orbitals. It is possible between p-orbitals. The bond formed is weaker because the overlapping occurs to a smaller extent.

**Hybridization:** The phenomenon of intermixing of atomic orbitals of slightly different energies of atom to form new set of orbitals of equivalent energies and identical shapes is called hybridization.

**sp hybridization:** The mixing of one s-orbital and one p orbital of the valence shell of an atom to form two sp hybrid orbitals of equivalent shape and energy is called sp hybridization. The sp hybrid orbitals are oriented at an angle of  $180^{\circ}$ . The sp orbital have equal s and p character (50%)

**sp<sup>2</sup> hybridization:** The mixing of one s-orbital and two p orbitals of the valence shell of an atom to form three sp<sup>2</sup> hybrid orbitals of equivalent shape and energy is called sp<sup>2</sup> hybridization.

**sp<sup>3</sup> hybridization:** The mixing of one s-orbital and three p orbitals of the valence shell of an

atom to form four  $sp^3$  hybrid orbitals of equivalent shape and energies is called  $sp^3$  hybridization.

	Hybridization	Shape	Type of bonds	
$PCl_5$	$sp^3d$	Trigonal bipyramidal	2 bonds (axial)	3 bonds (Equatorial)
			$90^\circ$	$120^\circ$
$SF_6$	$sp^3d^2$	Octahedral	All bonds – $90^\circ$	

**Molecular Orbital theory** uses a **linear combination of atomic orbitals** (LCAO) to form molecular orbitals which cover the whole molecule.

These are often divided into **bonding orbitals** and **anti-bonding orbitals**.

#### Formation of molecular orbitals

Bonding Molecular Orbital	Antibonding Molecular Orbital
<p>When the two electronic waves are in phase so that they add up the amplitude of the new wave is</p> $\Psi = \psi_A + \psi_B$ <p>Probability of finding electron increases</p> <p>The molecular orbital formed by additive effect is called <b>Bonding Molecular Orbital</b> (<math>\sigma 1s, \pi 2p_x</math>)</p> <p>Bonding molecular orbital has lower energy and greater stability</p> <p>The electron density increases in the region between the nuclei of bonded atom.</p>	<p>When the two electronic waves are out of phase so that the waves are subtracted from each other so that the amplitude of the new wave is</p> $\Psi = \psi_A - \psi_B$ <p>Probability of finding electron decreases</p> <p>The molecular orbital formed by subtractive effect is called <b>Antibonding Molecular Orbital</b> (<math>\sigma^* 1s, \pi^* 2p_x</math>)</p> <p>Antibonding molecular orbital has higher energy and lower stability</p> <p>The electron density decreases in the region between the nuclei of bonded atom</p>

In a hydrogen molecule, atomic orbitals combine to form two molecular orbitals, one bonding ( $\sigma$ ) and one antibonding ( $\sigma^*$ ) molecular orbital.

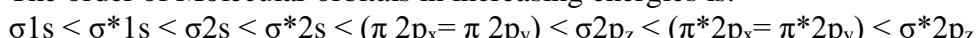
#### Conditions for the combination of atomic orbitals to form molecular orbitals:

The combining atomic orbitals should have comparable energies.

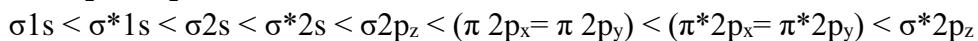
The combining atomic orbitals should have proper symmetry.

The extent of overlapping should be large.

The order of Molecular orbitals in increasing energies is:



For O<sub>2</sub> and F<sub>2</sub> the order is:



$$\text{Bond Order} = (N_b - N_a) / 2$$

N<sub>b</sub> = No of bonding electron N<sub>a</sub> = No of antibonding electron

N<sub>b</sub> > N<sub>a</sub>, the molecule is stable

N<sub>b</sub> = N<sub>a</sub> or N<sub>b</sub> < N<sub>a</sub>, the molecule is unstable

Greater the bond order, greater will be the stability.

Greater the bond order, greater will be the bond dissociation energy.

Greater the bond order, lesser will be the Bond length.

Greater the no of electrons in antibonding orbital, lesser will be the stability

**Electronic configuration of O<sub>2</sub>** =  $\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, (\pi 2p_x^2 = \pi 2p_y^2), (\pi^* 2p_x^1 = \pi^* 2p_y^1), \sigma^* 2p_z$

Bond Order of O<sub>2</sub> = (10-6)/2 = 2



O<sub>2</sub> molecule is paramagnetic (due to presence of unpaired electron).

### **Hydrogen Bond:**

The attractive force which binds hydrogen atom of one molecule with the electronegative atom (F,N or O) of another molecule.

Hydrogen bond is of two types:

Intermolecular eg H<sub>2</sub>O, NH<sub>3</sub>, HF

Intramolecular eg. o-Nitrophenol

## CHEMICAL BONDING AND MOLECULAR STRUCTURE UNIT-4

S No	Question Details	Marks
<b>Read the given passage and answer the questions 1 to 5 that follow:</b>		
The distribution of electrons among various molecular orbitals is called the electronic configuration of the molecule which provides us the following very important information about the molecule.		
	<ul style="list-style-type: none"> <li>• Stability of molecule: The molecule is stable if number of bonding molecular orbital electrons <math>N_b</math> is greater than the number of anti-bonding molecular orbital electrons <math>N_a</math>. Bond order: Bond order = <math>1/2(N_b - N_a)</math></li> <li>• A positive bond order means a stable molecule while a negative or zero bond order means an unstable molecule.</li> <li>• Nature of the bond: Bond order 1,2 and 3 correspond to single, double and triple bonds respectively.</li> <li>• Bond length: Bond length decreases as bond order increases.</li> <li>• Magnetic nature: If molecular orbitals in a molecule are doubly occupied, the substance is diamagnetic and if one or more molecular orbitals are singly occupied, it is paramagnetic.</li> </ul>	
1.	The following molecules/species have been arranged in the order of their increasing bond orders. Identify the correct order:  I. $O_2$ II. $O_2^-$ III. $O_2^{-2}$ IV. $O_2^+$  a). IV < III < II < I b). III < II < I < IV c). II < III < I < IV d). III < II < IV < I	1
2.	Which of the following statement is correct?  a). In $F_2$ molecule, the energy of $\sigma 2p_x$ is more than $\pi 2p_y$ and $\pi 2p_z$ b). $C_2$ , $O_2^-$ and $Li_2$ are diamagnetic c). $O_2^+$ molecule does not exist as the bonding and anti-bonding orbitals cancel each other d). Among $O_2^+$ , $O_2$ and $O_2^-$ the bond length decreases as $O_2^- > O_2 > O_2^+$	1
3.	$N_2$ has greater dissociation energy than $N_2^+$ , whereas $O_2^+$ has a higher dissociation energy than $O_2$ because –	1

- a). Bond order is increased when O<sub>2</sub> is ionized to O<sub>2</sub><sup>+</sup> and bond order is decreased when N<sub>2</sub> is ionized to N<sub>2</sub><sup>+</sup>
  - b). Bond order is decreased when O<sub>2</sub> is ionized to O<sub>2</sub><sup>+</sup> and bond order is increased when N<sub>2</sub> is ionized to N<sub>2</sub><sup>+</sup>
  - c). Bond order is decreased when O<sub>2</sub> is ionized to O<sub>2</sub><sup>+</sup> and bond order is decreased when N<sub>2</sub> is ionized to N<sub>2</sub><sup>+</sup>
  - d). Question does not provide enough data
4. Which of the following has maximum bond strength? 1
- a) O<sub>2</sub><sup>2+</sup>
  - b) O<sub>3</sub><sup>+</sup>
  - c) O<sub>2</sub><sup>+</sup>
  - d) O<sub>2</sub>
5. The bond order of N<sub>2</sub><sup>-</sup> anion is – 1
- a) 3
  - b) 2
  - c) 2.5
  - d) 1

**Questions 6, 7 and 8 are multiple choice questions:**

6. Which of the following have identical bond order? 1
- a) CN<sup>-</sup>
  - b) O<sub>2</sub><sup>-</sup>
  - c) NO<sup>+</sup>
  - d) CN<sup>+</sup>
7. Shape of NH<sub>3</sub> is very similar to- 1
- a) :CH<sub>3</sub>
  - b) CH<sub>4</sub>
  - c) CH<sub>3</sub><sup>+</sup>
  - d) BH<sub>3</sub>
8. Which of the following does not exist based on molecular orbital theory? 1
- a) He<sub>2</sub><sup>+</sup>
  - b) He<sub>2</sub>
  - c) H<sub>2</sub>
  - d) H<sub>2</sub><sup>+</sup>

**Questions 9 and 10 are Assertion and Reason type:**

9. **Assertion (A):** Though the central atom of both NH<sub>3</sub> and H<sub>2</sub>O molecules are sp<sup>3</sup> hybridized, yet H–N–H bond angle is greater than that of H–O–H. 1  
**Reason (R):** This is because nitrogen atom has one lone pair and oxygen atom has two lone pairs.  
(i) A and R both are correct, and R is the correct explanation of A.  
(ii) A and R both are correct, but R is not the correct explanation of A.  
(iii) A is true but R is false.

- (iv) A and R both are false.
- 10.** **Assertion (A):** Among the two O–H bonds in H<sub>2</sub>O molecule, the energy required to break the first O–H bond and the other O–H bond is the same. **Reason (R):** This is because the electronic environment around oxygen is the same even after breakage of one O–H bond.
- (i) A and R both are correct, and R is correct explanation of A.  
(ii) A and R both are correct, but R is not the correct explanation of A.  
(iii) A is true but R is false.  
(iv) A and R both are false.
- 11.** The three resonance structures of N<sub>2</sub>O are given below. Which structure out of the three is most stable and why? 1
- 1
2
3
- 12.** Why are the two O–O bond distances in ozone molecule equal? 1
- 13.** Why is a triple bond shorter and stronger than a double bond and single bond? 1
- 14.** Which of the following molecules have expanded octet configuration? 1  
CO<sub>2</sub>, ClF<sub>3</sub>, SO<sub>2</sub>, IF<sub>5</sub>
- 15.** Draw the Lewis structure and calculate the formal charge on all elements of CO<sub>3</sub><sup>2-</sup> ion 2
- 16.** Why NF<sub>3</sub> is pyramidal while BF<sub>3</sub> is triangular planar? 2  
Using the concept of hybridization explain the shapes of
- 17.** BeF<sub>2</sub>, BF<sub>3</sub>, CH<sub>4</sub> and NH<sub>3</sub> 2
- 18.** Arrange the following sets of molecules in the decreasing order of bond angle. 2  
a) SF<sub>6</sub>, CCl<sub>4</sub>, H<sub>2</sub>O, NH<sub>3</sub>, H<sub>2</sub>S  
b) NH<sub>3</sub>, NH<sub>4</sub><sup>+</sup>, NH<sub>2</sub><sup>-</sup>
- 19.** Which compound from each of the following pairs is more covalent and why? 2  
(a) CuO or CuS  
(b) PbCl<sub>2</sub> or PbCl<sub>4</sub>
- 20.** Which of the following species has greater polarizing power and why? 2  
(a) Fe<sup>3+</sup> or Fe<sup>2+</sup>  
(b) Cu<sup>2+</sup> or Na<sup>+</sup>
- 21.** Sketch the corresponding diagram leading to the bond formation of 2  
a) s-s overlap  
b) s-p overlap  
c) side way p-p overlap  
d) end to end p-p overlap

- 22.** a) Explain the hybridization and shape of  $\text{SF}_6$  3  
 b) In the following process, how is the bond order in  $\text{N}_2$  influenced?  

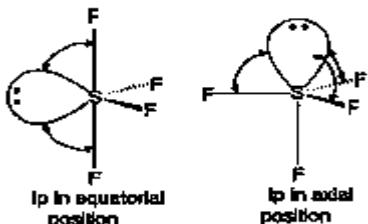
$$\text{N}_2 \rightarrow \text{N}_2^+ + \text{e}^-$$
- 23.** a) How would the bond lengths vary in di-carbon species  $\text{C}_2$ ,  $\text{C}_2^-$   $\text{C}_2^{2-}$  3  
 b) The bond angles in  $\text{PF}_5$  are  $90^\circ$  and  $120^\circ$  while all bond angles in  $\text{PF}_6^-$  are  $90^\circ$ . Explain based on VSEPR theory.
- 24.** a) Write the formal charges of the oxygen atoms in  $\text{H}_2\text{SO}_4$ . 3  
 b) Ortho- and para-nitrophenol are isomers of the same compound. It was observed that one of the isomers was more soluble and had higher B.Pt compared to the other one. Which of the two is predicted to have the abovementioned properties? State the basis of your conclusion by drawing the structures.
- 25.** Give reasons for the following: 3  
 (i) Covalent bonds are directional bonds while ionic bonds are nondirectional.  
 (ii) Water molecule has bent structure whereas carbon dioxide molecule is linear.  
 (iii) Ethyne molecule is linear.
- 26.** Assign reasons for the following: 3  
 (i)  $\text{B}_2$  is paramagnetic while  $\text{C}_2$  is diamagnetic.  
 (ii) The dipole moment of  $\text{CH}_3\text{F}$  is greater than that of  $\text{CH}_3\text{Cl}$ .  
 (iii)  $\text{H}_2$  and  $\text{F}_2$  are nonpolar whereas  $\text{HF}$  is polar
- 27.** On the basis of Molecular Orbital Theory, calculate the bond order of  $\text{N}_2^+$ . Compare the stability and bond length of this species with that of  $\text{N}_2$ . 3
- 28.** (a) Predict the shapes of the following molecules/ions using VSEPR Theory: 3  
 (i)  $\text{BrF}_5$   
 (ii)  $\text{XeF}_4$   
 (iii)  $\text{NH}_4^+$   
 (iv)  $\text{O}_3$   
 (b) Give two examples of odd electron molecules.
- 29.**  $\text{N}_2$  molecule has greater bond dissociation energy than  $\text{N}_2^+$  ion whereas  $\text{O}_2$  molecule has lower bond dissociation energy than  $\text{O}_2^+$  ion. Explain in terms of MO theory. 3
- 30.** (a) What do you understand by the term dipole moment? Give its SI units 3  
 (b) Out of  $\text{NaCl}$  and  $\text{MgO}$ , which has higher value of lattice energy and why?  
 (c) Why is water liquid whereas  $\text{H}_2\text{S}$  is a gas at room temperature?
- 31.** (a) Benzene ring has alternate single and double bonds, yet all the C-C bonds are of equal lengths. Why? 3  
 (b) What type of hybridization is involved in carbon atoms of benzene?  
 (c) Arrange the following bonds in the increasing order of polarity:  

$$\text{P-H, H-O, C-Cl}$$

- 32.** a) Give the difference between covalent and van der Waal's radius. 3  
 b) Which of the following pair is expected to have the same bond order and why?  
 (i)  $O_2, N_2$  (ii)  $O_2^+, N_2^-$  (iii)  $O_2^-, N_2$   
 c)  $NH_3$  has higher boiling point than  $PH_3$ . Give reason.

- 33.** Account for the following: 3  
 (a)  $LiCl$  is more covalent than  $NaCl$   
 (b)  $LiI$  is more covalent than  $LiF$ .  
 (c) The melting point of  $CaCl_2$  is less than  $NaCl$ .

- 34.** (a) Two arrangements of bond pairs and lone pairs in  $SF_4$  molecule are shown below. Explain based on VSEPR theory, why the lone pair in equatorial position is preferred? 5



- b) Why is there a difference in the bond enthalpy of O-H bond in ethanol and water?  
 c) Why is the carbonate ion more stable than  $H_2CO_3$ ?

- 35.** (a) Define hybridization.  
 (b) Explain hybridization in ethyne molecule. Draw its orbital diagram and mention the bond angle.  
 (c) Distinguish between bonding and antibonding molecular orbitals with respect to  
 (i) Energy  
 (ii) Electron density in internuclear region 5

- 36.** Account for the following: 5  
 a) Ethylene is a planar molecule while acetylene is linear.  
 b) In  $H_2O, H_2S, H_2Se, H_2Te$ , the bond angle decreases though all have the same bent shape.  
 c)  $O_2^-$  is paramagnetic while  $O_2^{2-}$  is diamagnetic.  
 d) Antibonding molecular orbitals destabilize the molecule.  
 e)  $N_2, CO$  and  $NO^+$  all have a bond order of three.

### HOTS

- 37.** Give reasons:  
 a) Ethyl alcohol dissolves in water  
 b) HF is polar though it possesses covalent bond.  
 c) Melting point of  $MgO$  is higher than that of  $BaO$ .  
 d) Solubility of  $MgCl_2$  is greater than that of  $MgF_2$   
 $AlF_3$  is a high melting solid whereas  $SiF_4$  is a gas

**38.** Answer the following:

**5**

- a) What is the total number of electrons in  $\text{NO}^{3-}$  and  $\text{NH}_4^+$
- b) Why are Carbon- Oxygen bond lengths in  $\text{Na}_2\text{CO}_3$  equal?
- c) How is molecular orbital different from atomic orbital?
- d) What are the two conditions for the formation of a Hydrogen bond?
- e) Why  $\text{KHF}_2$  exists but  $\text{KHCl}_2$  does not?

## THERMODYNAMICS

### UNIT-6

**Chemical energetics:** The branch of science that deals with the energy changes in chemical reactions.

**Thermodynamics:** The branch of science that deals with the quantitative relationship between heat and other forms of energy.

**System:** A specified part of the universe that is under investigation.

**Surroundings:** The part of the universe other than the system.

**Boundaries:** The imaginary boundary that separates the system and the surroundings.

**Types of system:**

**Open system:** The system that can exchange matter as well as energy with the surroundings.

**Closed system:** The system which cannot exchange matter, but can exchange energy, with the surroundings.

**Isolated system:** The system that cannot exchange matter and energy with the surroundings.

**Macroscopic system:** A system containing a large number of chemical species.

**Macroscopic properties:** The properties that arise from the bulk behavior of matter.

**Macroscopic Properties.** e.g. pressure, volume, temperature, viscosity, surface tension, density, refraction, index etc. It is of two types:

a) **Intensive Properties:** The properties of the system whose value is independent of the amount of substance present in the system are called Intensive Properties, e.g. Temperature, Pressure, Viscosity, Surface tension.

b) **Extensive Properties:** Whose value depends on the amount of substance present in system e.g. mass, volume, surface area, energy, enthalpy.

**State of the system:** The condition of existence of a system when the macroscopic properties have definite values is called the state of the system.

**State variables or state functions:** A thermodynamic property whose value depends on the initial and final states of the system and is independent of the manner by which the change is brought about.

**Thermodynamic processes:** The process, which brings about the changes in the state of the system.

**Isothermal process:** A process, which is carried out at constant temperature.

**Adiabatic process:** A process in which no heat exchange takes place between the system and the surroundings.

**Isobaric process:** A process, which is carried out at constant pressure.

**Isochoric process:** A process, which is carried out at constant volume.

**Reversible process:** when a process is carried out slowly so that the system and the surroundings are always at equilibrium the process is termed as reversible process.

**Irreversible process:** A process which takes place so rapidly that the system and the surroundings are not at equilibrium is termed as an irreversible process.

**Internal energy:** Every substance possesses a definite amount of energy which depends on the chemical nature of the substance and the state of existence.

**Enthalpy:** The sum of the internal energy and the sum of the pressure volume work of a system is called enthalpy of the system.

**First law of thermodynamics:** Energy can neither be created nor destroyed although it may be changed from one form to another.

Change in Internal Energy  $\Delta U = q + w$

Expression for pressure – Volume work

$$w = -P \Delta V$$

For isothermal ( $T = \text{constant}$ ) expansion of an ideal gas into vacuum,  $w=0$  since  $p_{ex}=0$ . Also, Joule determined experimentally that  $q = 0$ ; therefore,  $\Delta U = 0$

**Heat capacity**[C]: The amount of heat required to raise the temperature of the system by  $1^\circ\text{C}.$ ( $\text{JK}^{-1}$ )

$$q = C \Delta T$$

**Specific Heat Capacity**[c]: The quantity of heat required to raise the temperature of unit mass of the substance by  $1^\circ\text{C}.$  ( $\text{JK}^{-1}\text{mol}^{-1}$ )  $q = mc \Delta T$

**Molar heat capacity** [C<sub>m</sub>]: The quantity of heat required to raise the temperature of one mole of the substance by  $1^\circ\text{C}.$   $q = MC_m \Delta T$

**The relationship between Cp and Cv for an ideal gas:**  $C_p - C_v = R$

**Exothermic reactions:** The reactions which proceed with the evolution of heat energy are called exothermic reactions.

**Endothermic reactions:** The reactions which proceed with the absorption of heat energy are called endothermic reactions.

**Thermochemical equation:** A balanced chemical equation together with enthalpy change is called thermochemical equation.

**Some important aspects of thermochemical equations:**

The coefficients in a balanced chemical thermochemical equation refer to the number of moles of the reactants and products involved in the reaction.

When the chemical equation is reversed the value of  $\Delta H$  is reversed in sign.

Physical states of all the species should be specified in the equation.

Standard enthalpy change is expressed as enthalpy change per mole as shown in the equation.

**Standard enthalpy of reaction:**

The enthalpy change for a reaction when all the reacting substances are in the standard state. (Pure state of a substance at 298K and 1bar)

**Standard enthalpy of the combustion**[Δ<sub>c</sub>H<sup>0</sup>]: The enthalpy change accompanying the combustion of one mole of a substance.  $\Delta_c H^0$  is always negative.

**Enthalpy of formation:** The enthalpy change for the formation of one mole of a compound from the constituent elements in their standard state.

**As a convention the Δ<sub>f</sub>H<sup>0</sup>of every element is assumed to be zero.**

**Enthalpy of fusion:** The enthalpy change accompanying the conversion of 1mole of a solid substance into its liquid state at its melting point.

**Enthalpy of vaporization/Δ<sub>vap</sub>H<sup>0</sup>:** The enthalpy change accompanying the conversion of 1mole of liquid into its vapours at the boiling point.

**Enthalpy of sublimation/Δ<sub>sub</sub>H<sup>0</sup>:** The enthalpy change accompanying the conversion of 1 mole of solid into a liquid.

**Bond dissociation energy:** the enthalpy change involved in the breaking the bond between atoms in a gaseous homonuclear molecule.

**Bond enthalpy**[ $\Delta_{bond}H^0$ ]: The amount of energy required to break a bond in one mole of a covalent substance in the gaseous state.

$$\Delta H = \sum \Delta H_f^\circ (\text{product}) - \sum \Delta H_f^\circ (\text{reactants}).$$

$$\Delta H = \Delta U + \Delta n g RT \quad \Delta n_g = \text{No. of gaseous moles of products} - \text{No. of gaseous moles of reactants}$$

$$\Delta H = \Delta U + P \Delta V \quad R = 8.314 \text{ J/mol/K}$$

$$\Delta H = \text{Bond enthalpy of reactants} - \text{Bond enthalpy of products}$$

**Hess Law of Constant Heat Summation:** If the reaction occurs in several steps then its standard reaction enthalpy is the sum of the standard enthalpies of the intermediate reactions into which the overall reaction may be divided at the same temperature.

**Enthalpy of Solution** ( $\Delta_{sol}H^0$ ) Enthalpy of solution of a substance is the enthalpy change when one mole of it dissolves in a specified amount of solvent.

**Lattice Enthalpy:** The lattice enthalpy of an ionic compound is the enthalpy change which occurs when one mole of an ionic compound dissociates into its ions in gaseous state.

**Since it is impossible to determine lattice enthalpies directly by experiment, we use an indirect method where we construct an enthalpy diagram called a Born-Haber Cycle**

**Entropy(S):** Entropy may be defined as “The property of a system which measures the degree of disorder or randomness in the system”. It is a state function.

$$\Delta S = S_{(\text{final})} - S_{(\text{initial})} \quad \{S-\text{Entropy}; \Delta S-\text{Change in Entropy}\}$$

$$\Delta S = q_{\text{rev}}/T \quad \{q_{\text{rev}} \text{ represents the heat supplied at temperature } T\}$$

### **Second Law of Thermodynamics:**

In an isolated system the change in entropy is positive i.e  $\Delta S > 0$ . However, if the system is not isolated we have to take into account the entropy change of the system and surroundings.

$$\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$$

For a spontaneous process  $\Delta S_{\text{total}}$  must be positive i.e

$$\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}} > 0$$

### **The second law of thermodynamics states that:**

“The entropy of the universe always increases in the course of every spontaneous change.”

### **Free Energy or Gibb's energy (G) And Free Energy Change or Gibb's energy change( $\Delta G$ )**

$$G = H - TS$$

$$\Delta G = \Delta H - T\Delta S \quad (\text{Gibbs's eqn.})$$

### **Gibbs energy change for predicting feasibility of a reaction:**

We have seen that for a system which is not isolated from its surroundings, it is  $\Delta S_{\text{total}}$  which decides the spontaneity of a process.

$$\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surrounding}}$$

$$\Delta S_{\text{Total}} = \Delta S_{(\text{system})} + \Delta H_{(\text{surrounding})} / \{ \Delta S_{\text{surrounding}} = \Delta H_{(\text{surrounding})} / T \}$$

$$\Delta S_{\text{Total}} = \Delta S_{(\text{system})} - \Delta H_{(\text{system})} / T \quad \{ \Delta H_{(\text{surrounding})} = -\Delta H_{(\text{system})} \}$$

Multipplied by T

$$T\Delta S_{(\text{Total})} = T\Delta S_{(\text{system})} - \Delta H_{(\text{system})}$$

$$\Delta H_{(\text{system})} - T\Delta S_{(\text{system})} = -T\Delta S_{(\text{total})}$$

$$\boxed{\Delta G = -T\Delta S_{(\text{total})}}$$

$$\{ \text{since } \Delta G = \Delta H_{(\text{system})} - T\Delta S_{(\text{system})} \}$$

**Gibbs Free Energy:** It is defined as maximum amount of energy available to a system during the process that can be converted into useful work. It is the measure of capacity to do useful work.

**Standard Gibbs energy change  $\Delta G^\circ$ ,**

$\Delta G^\circ$  = Standard Gibbs energy change (at 298 K and 1 bar)

$\Delta G^\circ$  = {Sum of the standard Gibbs energies of product} – {sum of the standard Gibbs energies of reactants}

$$\Delta G^\circ = [\Sigma \Delta G^\circ (\text{Product})] - [\Sigma \Delta G^\circ (\text{Reactants})]$$

Sign of $\Delta H$	Sign of $\Delta S$	Value of T	Spontaneity
-	+	Any	Spontaneous
+	-	Any	Non-Spontaneous
-	-	Low	Spontaneous
-	-	High	Non-Spontaneous
+	+	Low	Non-Spontaneous
+	+	High	Spontaneous

At equilibrium  $\Delta S = 0$  so that if  $\Delta G = 0$  the system has attained equilibrium

If  $\Delta G$  = +ve, the process is non-spontaneous

If  $\Delta G$  = -ve, the process is spontaneous

If  $\Delta G$  = zero, the process is at equilibrium

Standard free energy change and equilibrium constant (K)

$$\Delta G^\circ = -2.303 RT \log K_c$$

## THERMODYNAMICS

### UNIT –6

S.No.	Question Details	Marks
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**Read the given passage and answer the questions 1 to 5 that follow:**

In a chemical reaction, reactants are converted into products and is represented by, Reactants → Products The enthalpy change accompanying a reaction is called the reaction enthalpy. The enthalpy change of a chemical reaction, is given by the symbol  $\Delta rH$ .

$\Delta rH = (\text{sum of enthalpies of products}) - (\text{sum of enthalpies of reactants})$

$$\begin{aligned} \text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) &\rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \\ \Delta_rH = \sum_i a_i H_{\text{Products}} - \sum_i b_i H_{\text{Reactants}} \\ &= [H_m(\text{CO}_2, \text{g}) + 2H_m(\text{H}_2\text{O}, \text{l})] - [H_m(\text{CH}_4, \text{g}) \\ &\quad + 2H_m(\text{O}_2, \text{g})] \end{aligned}$$

The standard enthalpy of reaction is the enthalpy change for a reaction when all the participating substances are in their standard states. The standard state of a substance at a specified temperature is its pure form at 1 bar.

Hess's Law: If a reaction takes place in several steps then its standard reaction enthalpy is the sum of the standard enthalpies of the intermediate reactions into which the overall reaction may be divided at the same temperature.

1. The enthalpy change of a chemical reaction is given by the symbol ... 1
  - $\Delta rH$
  - $\Delta rG$
  - $\Delta rF$
  - $\Delta rR$
  
2. For the phase change given below ..... remains constant- 1

$$\text{H}_2\text{O}(\text{s}) \rightarrow \text{H}_2\text{O}(\text{l}); \Delta_{\text{fus}}H^\theta = 6.00 \text{ kJ mol}^{-1}$$
  - Volume
  - Enthalpy
  - Entropy
  - Temperature
  
3. For the reaction given below, 1

$$\text{Na}(\text{s}) \rightarrow \text{Na}(\text{g}); \Delta_aH^\theta = 108.4 \text{ kJ mol}^{-1}$$
  - $\Delta_aH^\theta > \Delta_{\text{sub}}H^\theta$
  - $\Delta_aH^\theta < \Delta_{\text{sub}}H^\theta$

- c)  $\Delta_a H^\circ = \Delta_{\text{sub}} H^\circ$
- d) None of the above
4. For the reaction given below, the sign for enthalpy change is-
- $$2\text{Cl(g)} \rightarrow \text{Cl}_2\text{(g)}$$
- a) +ve
- b) -ve
- c) Zero
- d) Equal to entropy
5. A spontaneous process is a/an ... process.
- a) irreversible
- b) reversible
- c) partially irreversible
- d) partially reversible
- Questions 6, 7 and 8 are multiple choice questions:**
6. When a system is in equilibrium, the entropy is maximum, and the change in entropy,  $\Delta S \dots 0$ .
- a) <
- b) >
- c) =
- d) None of above
7. Which of the following does not discriminate between reversible and irreversible processes?
- a)  $\Delta H$
- b)  $\Delta S$
- c)  $\Delta G$
- d)  $\Delta U$

8. One mole of which of the following has the highest entropy?

- a) Liquid nitrogen
- b) Hydrogen gas
- c) Mercury
- d) Diamond

**Questions 9 and 10 are Assertion and Reason type:**

9. **Assertion:** Enthalpy of formation of graphite is zero but of diamond it is not zero.

**Reason:** Enthalpy of formation of the most stable allotrope is taken as zero.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

(b) Assertion and reason both are correct statements, but reason is not correct explanation for assertion.

(c) Assertion is a correct statement, but reason is wrong statement.

(d) Assertion is a wrong statement, but the reason is a correct statement.

10. Assertion: A decrease in free energy causes the spontaneous reaction.

Reason: Spontaneous reactions are invariable exothermic reactions.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

(b) Assertion and reason both are correct statements, but the reason is the not correct explanation for assertion.

(c) Assertion is a correct statement, but the reason is wrong statement.

(d) Assertion is a wrong statement, but the reason is correct statement.

11. What is the enthalpy of formation of the most stable form of an element in its standard state? 1

12.  $\Delta_f H^\ominus$  of  $Al_2O_3$  is  $-1670\text{ kJ/mol}$ . What is the enthalpy change for the reaction?



13. Why is enthalpy considered more useful than internal energy in chemical reactions? 1

14. What is the limitation of first law of thermodynamics? 1

15. Neither q nor W is a state function but  $q+W$  is a state function? 1

a) If  $\Delta_f H^\ominus$  of Freon,  $CCl_2F_2$  is  $-480\text{ KJmol}^{-1}$ . What is the thermo chemical equation for this change? 2

b) The enthalpy change for the reaction  $2H_2O \rightarrow 2H_2 + O_2$  is  $574\text{ kJ}$ . What is the heat of formation of water?  $[-287\text{ kJ/mol}]$

17. The enthalpy of dissociation of  $PH_3$  is  $954\text{ kJ/mol}$  and that of  $P_2H_4$  is  $1,485\text{ KJ mol}^{-1}$ . What is the bond enthalpy of the P-P bond? 2  
[ $213\text{ kJ/mol}$ ]

- 18.** Calculate standard heats of formation of carbon-di-sulphide.  
 Given the standard heat of combustion of C (s), S (s) and CS<sub>2</sub> (l) are: - 393.3, - 293.72 and - 1108.76 kJ mol<sup>-1</sup> respectively? [128.02kJ/mol]
- 19.** Explain the effect of temperature on spontaneity in the following cases 2  
 (a) when ΔH>0 and ΔS>0  
 (b)when ΔH<0 and ΔS<0
- 20.** One mole of ice is converted into water at 273 K. The entropies of H<sub>2</sub>O(s) and H<sub>2</sub>O(l) are 38.20 and 60.01 J mole<sup>-1</sup> K<sup>-1</sup> respectively. What is the enthalpy change for the conversion? 2  

$$\text{H}_2\text{O}(\text{s}) \rightarrow \text{H}_2\text{O}(\text{l})$$
- 21.** a) Calculate the entropy change when 36g of liquid water evaporates at 373 K 3  
 ( $\Delta_{\text{vap}} \text{H}=40.63 \text{ kJ mol}^{-1}$ ) [218J/Kmol]  
 b) It has been found that 221.4J of heat is needed to heat 30g of ethanol from 15°C to 18°C. Calculate the molar heat capacity.  
 [molar heat capacity = 110.4Jmol<sup>-1</sup> K<sup>-1</sup>]
- 22.** a) Propane (C<sub>3</sub>H<sub>8</sub>) is used for heating water for domestic supply. Assume that for 150 Kg of hot water supply per day must be heated from 10°C to 65°C. What moles of propane would be used for heating this amount of water. [ $\Delta_c \text{H}$  for C<sub>3</sub>H<sub>8</sub> = - 2050kJ/mol, c for water=  $4.184 \times 10^{-3}$  kJ/g] 3  
 [n = 0.01683]  
 b) H<sub>2</sub>(g) + Cl<sub>2</sub>(g) → 2HCl(g) + 185 kJ. State whether this reaction is exothermic or endothermic and why?
- 23.** a) Calculate difference of heat of reaction at constant pressure and that at constant volume for the combustion of 2 moles of liquid benzene at 25°C. 3  

$$2\text{C}_6\text{H}_{6(\text{l})} + 15\text{O}_{2(\text{g})} \rightarrow 12\text{CO}_{2(\text{g})} + 6\text{H}_2\text{O}(\text{l})$$
  
 [-7432.71kJ]  
 b) The internal energy change for the given reaction, is - 885 kJmol<sup>-1</sup> and 298K. What is Δ<sub>r</sub>H at 298K?  

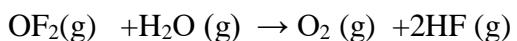
$$\text{CH}_{4(\text{g})} + 2\text{O}_{2(\text{g})} \rightarrow \text{CO}_{2(\text{g})} + 2\text{H}_2\text{O}(\text{l})$$
  
 [ΔH = - 889.955kJ/mol]
- 24.** a) Derive the relation between change in internal energy and change in enthalpy for a system in which the reactants and products are gases.  
 b) State a chemical reaction in which ΔH and ΔU are equal.
- 25.** Calculate the standard internal energy change for the reaction at 25°C. 3  

$$\text{C}_2\text{H}_{4(\text{g})} + 3\text{O}_{2(\text{g})} \rightarrow 2\text{CO}_{2(\text{g})} + 2\text{H}_2\text{O}(\text{g}),$$
  
 [Δ U = -1323kJ]  
 b) What are the ways in which the internal energy of a system can be changed?

- 26.** The enthalpy change for the reaction 3  
 $C_3H_8 + H_2(g) \rightarrow C_2H_6(g) + CH_4(g)$  at  $25^\circ C$  is  $-55.7\text{ kJ/mol}$ .  
 Calculate the heat of combustion of  $C_2H_6(g)$ . The heats of combustion of  $H_2$ ,  $CH_4$  &  $C$ (graphite) are  $-285.8$ ,  $-890.0$  &  $-393.5\text{ kJ/mol}$  respectively. Heat of combustion of propane is  $-2220\text{ kJ mol}^{-1}$ .  $[-1560\text{ kJmol}^{-1}]$
- 27.** When  $1.000\text{ mol } C_6H_{12}O_6$  (glucose) is oxidized to carbon dioxide and water at  $25^\circ C$  according to the equation  $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ , calorimetric measurements give  $\Delta U = -2808\text{ kJ mol}^{-1}$  and  $\Delta S = +182.4\text{ J K}^{-1}\text{ mol}^{-1}$  at  $25^\circ C$ . How much of this energy change can be extracted as (a) heat at constant pressure, (b) work? 3  
[a]  $54.355\text{ kJmol}^{-1}$  b)  $2753.645\text{ kJmol}^{-1}$ ]
- 28.** For the reaction  $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$  3  
 $\Delta H = -95.4\text{ kJ}$   $\Delta S = -198.3\text{ JK}^{-1}$   
 Calculate the temperature at which Gibb's energy change ( $\Delta G$ ) is equal to zero. Predict the nature of the reaction at this temperature and above it.  
[ $\Delta G = 481.09\text{ K}$ ; Non-spontaneous above this temperature]
- Calculate the enthalpy change of the following reaction 3  
**29.**  $2C_2H_2(g) + 5O_2 \rightarrow 4CO_2(g) + 2H_2O(g)$   
 given average bond enthalpies of various bonds,  
 $C-H$ ,  $C\equiv C$ ,  $O=O$ ,  $C=O$ ,  $O-H$  as  $414, 810, 499, 724$  and  $460\text{ kJmol}^{-1}$ .  
 $[\Delta rH = -1861\text{ kJmol}^{-1}]$
- 30.** The enthalpy of a reaction,  $HCN(g) + 2H_2(g) \rightarrow CH_3NH_2(g)$  is  $-150\text{ kJ}$ . Calculate the bond energy of  $C\equiv N$  bond. Given that the bond energies of  $C-H$ ,  $H-H$ ,  $N-H$ ,  $C-N$  as  $414$ ,  $435$ ,  $390$  and  $293\text{ kJmol}^{-1}$  respectively. 3
- 31.** a) What is free energy? 5  
 b) Discuss the criterion for the spontaneity of a process.  
 c) Calculate the standard Gibbs free energy change from the free energies of formation data for the following reaction:  
 $C_6H_6(l) + 15/2O_2(g) \rightarrow 6CO_2(g) + 3H_2O(l)$   
 Given that :  $\Delta_fG^\theta[C_6H_6(l)] = 172.8\text{ kJ/mol}$   $\Delta_fG^\theta[CO_2(g)] = -394.4\text{ kJ/mol}$   $\Delta_fG^\theta[H_2O(l)] = -228.6\text{ kJ/mol}$ . Predict the spontaneity of the reaction.  
[ $\Delta G = -3225\text{ kJmol}^{-1}$  ; Spontaneous]

### HOTS

- 32.** a) Define standard enthalpy of formation. Explain why the enthalpy changes for the reactions given below are not the enthalpies of formation of  $CaCO_3$  and  $HBr$ . 5  
 i)  $CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$  ;  $\Delta H = -178.3\text{ KJ/mol}$   
 ii)  $H_2(g) + Br_2(g) \rightarrow 2HBr(g)$  ;  $\Delta H = -72.8\text{ KJ/mol}$   
 b) Calculate the standard enthalpy change ( $\Delta H$ ) and standard internal energy change ( $\Delta U$ ) for the following reaction at  $300K$ .



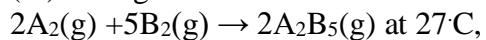
33. Standard enthalpies of formation of various species are given below: 5

$\Delta H_f/\text{kJ mol}^{-1}$  :  $\text{OF}_2(\text{g}) = 23.0$ ,  $\text{H}_2\text{O}(\text{g}) = -241.8$ ,  $\text{HF}(\text{g}) = -268.6$ , ( $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ )

(i) Define enthalpy of neutralization. The enthalpy of neutralization of strong acid and strong base is constant, why?

(ii) What is the basis of Hess's Law?

(iii) For a gaseous reaction



The heat change at constant pressure is found to be  $-50.16 \text{ kJ}$ .

Calculate the value of internal energy change ( $\Delta U$ ). (Given:  $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ )

34. a) Why standard entropy of an elementary substance is not zero whereas standard enthalpy of formation is taken as zero? 3

b) The equilibrium constant for a reaction is one or more if  $\Delta G^\circ$  for it is less than zero.

Explain.

c) Many thermodynamically feasible reactions do not occur under ordinary conditions. Why?

## EQUILIBRIUM UNIT-7

**Equilibrium:** The state at which the concentration of the reactants and products do not change with time. The state can be recognized by constancy of certain measurable properties such as pressure, colour, concentration etc.

**Dynamic Equilibrium:** A system is said to be dynamic in nature when the forward and backward reactions takes place at microscopic level and the concentration of each of the species becomes constant.

The rate of forward reaction = The rate of backward reaction

**Physical Equilibrium:** The equilibrium set up in physical processes is called physical equilibrium.

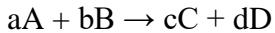
### **Chemical equilibrium**

The equilibrium set up in chemical process is called chemical equilibrium.

#### **Law of chemical equilibrium:**

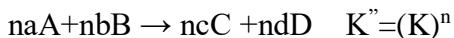
At a given temperature the product of the concentration of the products each raised to the respective stoichiometric coefficient in the balanced chemical equation divided by the product of the concentration of the reactants raised to their individual stoichiometric coefficient has a constant value known as equilibrium constant. ( $K_c$ )

For a general reversible reaction :



$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

The subscript c indicates that the concentration is expressed in mol L<sup>-1</sup>

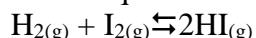


#### **Relation between $K_c$ and $K_p$**

$$K_p = K_c (RT)^{\Delta n}$$

#### **Homogeneous equilibrium**

In this equilibrium all the reactants and products are in the same phase.



#### **Heterogeneous equilibrium**

In this system all the reactants and products are having more than one phase



In heterogeneous equilibria the concentration of pure solid and liquid does not exist in the expression of equilibrium constant.

#### **Applications of equilibrium constants.**

##### **1. Predicting the extent of a reaction**

- $K_c > 10^3$ , products predominate over reactants.
- $K_c < 10^{-3}$ , reactants predominate over products.

c) If  $K_c$  is in the range  $10^{-3}$  to  $10^3$  appreciable quantities of reactants and products.

## 2. Predicting the direction of a reaction

### Reaction quotient ( $Q_c$ )

The equilibrium constant at any stage of the reaction.

If  $Q_c > K_c$  the reaction will proceed in the direction of the reactants. (Reverse reaction)

If  $Q_c < K_c$  the reaction will proceed in the direction of the products. (forward reaction)

$Q_c = K_c$  the reaction mixture is at equilibrium.

### Le Chatelier's principle.

Change in any of the factors that determine the equilibrium conditions of a system will shift the equilibrium in such a manner to reduce the effect of the change.

### Ionic Equilibrium

In weak electrolytes the equilibrium is established between the ions and the un-ionized molecules in aqueous solution is called ionic equilibrium.

### Arrhenius Concept of acids and bases.

Acids are substances that dissociate in water to give  $H^{+}_{(aq)}$  and bases are substances that produce  $OH^{-}_{(aq)}$

### Bronsted concept of acid and bases

Acid is substance that can donate a proton easily and base is a substance that can accept a proton easily

### Conjugate Acid of a base

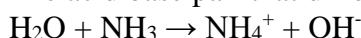
The acid formed by a base by accepting proton

### Conjugate base of an acid

The base formed by an acid by donating a proton

### Conjugate acid base pair

The acid base pair that differs by only one proton.



[ $OH^-$  is the conjugate base of  $H_2O$  and  $NH_4^+$  is the conjugate acid of  $NH_3$ ]

### Ionization constant of water(Ionic product)

$$K_w = [H^+] [OH^-]$$

$$K_w = 1 \times 10^{-14} M^2$$

$$pK_w = pH + pOH = 14$$

### The pH scale:

The pH of a solution is defined as the negative logarithm to the base 10 of hydrogen ion concentration.

$$pH = -\log [H^+]$$

Acidic solution has pH less than 7  
Basic solution has pH greater than 7  
Neutral solution has pH equal to 7

### **Ionization constant of weak acids**

$$K_a = [H^+] [X^-] / [HX]$$

$$K_a = c\alpha^2 / c(1-\alpha)$$

$$[H^+] = [X^-] = c\alpha$$

### **Ionization constant of weak bases**

$$K_b = [M^+][OH^-] / [MOH]$$

$$K_b = c\alpha^2 / c(1-\alpha)$$

$$[M^+] = [OH^-] = c\alpha$$

### **Relation between $K_a$ and $K_b$**

$$K_a \times K_b = K_w$$

$$pK_a + pK_b = pK_w = 14$$

### **Common Ion Effect**

The decrease in the concentration of one of the ions by adding other ion as common ion.

### **Buffer Solution**

It is the solution whose pH does not change by addition of small amount of strong acid or base.

### **Solubility Product**

It is defined as the product of the molar concentration of the ions raised to the power equal to the number of times each ion occurs in the equation for solubility equilibrium

## EQUILIBRIUM

### UNIT 7

S No	Question Details	Marks
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**Read the given passage and answer the questions 1 to 5 that follow:**

Acids, bases, and salts find widespread occurrence in nature. Hydrochloric acid present in the gastric juice is secreted by the lining of our stomach in a significant amount of 1.2-1.5 L/day and is essential for digestive processes. A common example of a base is washing soda used for washing purposes. When acids and bases are mixed in the right proportion, they react with each other to give salts.

According to Arrhenius theory, acids are substances that dissociate in water to give hydrogen ions  $H^+(aq)$  and bases are substances that produce hydroxyl ions  $OH^-(aq)$ .

The Danish chemist, Johannes Brönsted and the English chemist, Thomas M. Lowry gave a more general definition of acids and bases. According to Brönsted-Lowry theory, acid is a substance that can donate a hydrogen ion  $H^+$  and bases are substances capable of accepting a hydrogen ion,  $H^+$ . In short, acids are proton donors and bases are proton acceptors.

G.N. Lewis in 1923 defined an acid as a species that accepts an electron pair and a base which donates an electron pair.

- |   |   |
|---|---|
| 1. What is a conjugate acid-base pair?  | 1 |
| 2. What will be the conjugate bases for $H_2SO_4$ and $HCO_3^-$ ?   | 1 |
| 3. Some species can act both as Bronsted acids and bases. For $NH_3$ , give the corresponding conjugate acid and conjugate base.                      | 1 |
| 4. In the following reaction:<br>$BF_3 + :NH_3 \rightarrow BF_3:NH_3$<br>Identify the Lewis acid and Lewis base.                                      | 1 |
| 5. "As far as bases are concerned, there is not much difference between Brönsted-Lowry and Lewis concepts." Do you agree with the statement? Justify. | 1 |

**Questions 6, 7, and 8 are multiple- choice questions:**

- |   |   |
|---|---|
| 6. We know that the relationship between $K_c$ and $K_p$ is : $K_p = K_c (RT)^{\Delta n_g}$ | 1 |
|---|---|

What would be the value of  $\Delta n_g$  for the reaction  $NH_4Cl_{(s)} \rightleftharpoons NH_3_{(g)} + HCl_{(g)}$

- a) 1
- b) 0.5

- c) 1.5  
d) 2
7. For the reaction  $\text{H}_2\text{(g)} + \text{I}_2\text{(g)} \rightleftharpoons 2\text{HI(g)}$ , the standard free energy is  $\Delta G^\ominus > 0$ . The equilibrium constant (K) would be: 1  
a)  $K = 0$   
b)  $K > 1$   
c)  $K = 1$   
d)  $K < 1$
8. The ionization constant of an acid,  $K_a$ , is the measure of strength of an acid. The  $K_a$  values of acetic acid, hypochlorous acid and formic acid are  $1.74 \times 10^{-5}$ ,  $3.0 \times 10^{-8}$  and  $1.8 \times 10^{-4}$  respectively. Which of the following orders of pH of  $0.1 \text{ mol dm}^{-3}$  solutions of these acids is correct?  
(i) acetic acid > hypochlorous acid > formic acid  
(ii) hypochlorous acid > acetic acid > formic acid  
(iii) formic acid > hypochlorous acid > acetic acid  
(iv) formic acid > acetic acid > hypochlorous acid

**Questions 9 and 10 are Assertion and Reason type:**

9. **Assertion (A):** The ionization of hydrogen sulphide in water is low in the presence of hydrochloric acid. 1

**Reason (R):** Hydrogen sulphide is a weak acid.

- (i) Both A and R are true, and R is correct explanation of A.  
(ii) Both A and R are true, but R is not correct explanation of A.  
(iii) A is true but R is false  
(iv) Both A and R are false

10. **Assertion (A):** In the dissociation of  $\text{PCl}_5$  at constant pressure and temperature, addition of helium at equilibrium increases the dissociation of  $\text{PCl}_5$ . 1

**Reason (R):** Helium removes  $\text{Cl}_2$  from the field of action.

- (i) Both A and R are true, and R is correct explanation of A.  
(ii) Both A and R are true, but R is not correct explanation of A.  
(iii) A is true but R is false.

- (iv) Both A and R are false. 1
- 11.** Can equilibrium be achieved between water and its vapor in an open vessel? 1
- 12.** Write the expression  $K_p$  and  $K_c$  for the reaction, 1
- $$\text{CaCO}_3\text{(s)} \rightleftharpoons \text{CaO(s)} + \text{CO}_2\text{(g)}$$
- 13.** The values of  $K_a$  of pairs of some acids and bases are given below. Predict which is stronger in the pair. i) Benzoic acid=  $6.3 \times 10^{-5}$  ii) HCN=  $6.2 \times 10^{-10}$  1
- 14.** Acetic acid is highly soluble in water but still a weak electrolyte. Why? 1
- 15.** Which of the following can act both as Bronsted acid and Bronsted base?  
 $\text{H}_2\text{O}$ ,  $\text{HS}^-$ ,  $\text{O}_2^-$  1
- 16.** For the reaction  $\text{CO}_2\text{(g)} + \text{Cl}_2\text{(g)} \rightarrow \text{COCl}_2\text{(g)}$ ; find  $K_p/ K_c$ . 1
- 17.** What will be the decreasing order of basic strength of the following conjugate base.  
 $\text{OH}^-$ ,  $\text{RO}^-$ ,  $\text{CH}_3\text{COO}^-$ ,  $\text{Cl}^-$  1
- 18.** The value of  $K_c$  for the reaction  $2\text{HI(g)} \rightarrow \text{H}_2\text{(g)} + \text{I}_2\text{(g)}$  is  $1 \times 10^{-4}$  At a given time, the composition of reaction mixture is  $[\text{HI}] = 2 \times 10^{-5}$  mol,  $[\text{H}_2] = 1 \times 10^{-5}$  mol and  $[\text{I}_2] = 1 \times 10^{-5}$  mol In which direction will the reaction proceed? 2
- 19.**  $\text{BF}_3$  does not have a proton, but still acts as a an acid and reacts with  $\text{NH}_3$ . Why is it so? What type of bond is formed between the two? 2
- 20.** In the manufacture of ammonia as  $\text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightleftharpoons 2\text{NH}_3\text{(g)}$ .  $\Delta H = -93.8 \text{ kJ}$ , work out the conditions for maximum yield of ammonia. 2
- 21.** The value of  $K_w$  is  $9.55 \times 10^{-14}$  at a certain temperature. Calculate the pH of water at this temperature. 2
- 22.** Calculate the pH of 4.9g of sulphuric acid present in 500ml of the solution. 2
- 23.** Calculate the dissociation constant of conjugate acid of  $\text{CO}_3^{2-}$ ,  $K_b = 2.1 \times 10^{-4}$  2
- 24.** pH of a solution of a strong acid is 5.0. What will be the pH of the solution obtained after diluting the given solution 100 times? [6.6990] 3
- 25.** What is the pH of an aqueous solution with hydrogen ion concentration equal to  $3 \times 10^{-5}$  mol/L. What is the conc. of hydroxyl ions in the solution? Identify the nature of the solution.  
 $[\text{OH}^-] = 3.33 \times 10^{-10}$  mol/L [Acidic, since pH is < 7] 3
- 26.** Calculate the pH of 0.01M solution of  $\text{CH}_3\text{COOH}$  for which  $K_a = 1.8 \times 10^{-5}$  at  $25^\circ\text{C}$ . 3
- 27.** The reaction:  $\text{CO(g)} + 3\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_4\text{(g)} + \text{H}_2\text{O(l)}$  is at equilibrium at 1300K in a one litre flask. The gaseous equilibrium mixture contains 0.30mol of CO, 0.10mol of  $\text{H}_2$  and 0.20mol of water and an unknown amount of  $\text{CH}_4$  in the flask. Determine the concentration of  $\text{CH}_4$  in the mixture. The equilibrium constant  $K_c$  for the reaction at given temperature is 3.90. 3

28. The equilibrium constant at 278K for  $\text{Cu}_{(s)} + 2\text{Ag}^{+}_{(aq)} \rightleftharpoons \text{Cu}^{2+}_{(aq)} + 2\text{Ag}_{(s)}$  is  $2.0 \times 10^{15}$ . In a solution in which copper has displaced some silver ions from solution, the concentration of  $\text{Cu}^{2+}$  ions is  $1.8 \times 10^{-2} \text{ mol L}^{-1}$  and the concentration of  $\text{Ag}^{+}$  ions is  $3.0 \times 10^{-9} \text{ mol L}^{-1}$ . Is this system at equilibrium? 3
29. The equilibrium constant for the reaction  $\text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \rightleftharpoons \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}$  is 4. What will be the composition of the equilibrium mixture if 1 mole of acid is taken with 1 mole of alcohol? 3
30. Equal volumes of  $25\text{cm}^3$  of  $5 \times 10^{-2} \text{ M}$  barium nitrate  $2 \times 10^{-2} \text{ M}$  sodium fluoride solution are mixed. Predict whether the precipitate of barium fluoride will be formed or not. The solubility product of barium fluoride is  $1.7 \times 10^{-6}$  at 298K. 3
31. Solid Cadmium Arsenate,  $\text{Cd}_3(\text{AsO}_4)_2$ , is in equilibrium with its own saturated solution. The salt has a solubility product constant  $K_{sp} = 2.2 \times 10^{-32}$ . What are the concentrations of the two ionic species  $\text{Cd}^{+2}$  and  $\text{AsO}_4^{-3}$ ? 3
32. What is common ion effect? Explain its application in qualitative analysis of group II radicals. 3
33. The concentration of hydrogen ions in two samples of soft drinks A and B are  $4.0 \times 10^{-7}$  and  $3.2 \times 10^{-6}$  respectively. Which of these two soft drinks has higher pH? 3
34. At 700 K, the equilibrium constant  $K_p$ , for the reaction  

$$2\text{SO}_3(\text{g}) \rightleftharpoons 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g})$$
  
is  $1.8 \times 10^{-3} \text{ k Pa}$ . What is the numerical value of  $K_c$ , in moles per litre, for this reaction at the same temperature? 3
35. For the exothermic formation of  $\text{SO}_3$  from  $\text{SO}_2$  and  $\text{O}_2$  in the gaseous phase,  

$$2\text{SO}_2(\text{g}) + \text{O}_2 \rightarrow 2\text{SO}_3(\text{g})$$
  
 $K_p = 40.5 \text{ Atm}^{-1}$  at 900K and  $\Delta H = -198 \text{ KJ/mol}$  5
- Write the expression for the equilibrium constant for the reaction
  - At room temp (300K) will  $K_p$  be greater than, less than or equal to  $K_p$  at 900K
  - How will the equilibrium be affected if the vessel containing the 3 gases are reduced, keeping the temp constant?
  - What is the effect of adding 1 mol of He (g) to a flask containing  $\text{SO}_2$ ,  $\text{O}_2$  and  $\text{SO}_3$  at equilibrium at constant temperature?
36. Consider the reaction:  $2\text{SO}_{2(g)} + \text{O}_{2(g)} \rightleftharpoons 2\text{SO}_{3(g)} + 189.4 \text{ kJ}$ . Indicate the direction in which the equilibrium will shift when 5
- temperature is increased
  - Volume is increased
  - A catalyst is added
  - pressure is increased
  - The concentration of  $\text{SO}_2$  is increased

37. a) The solubility product of  $\text{Al(OH)}_3$  is  $2.7 \times 10^{-11}$ . Calculate its solubility in  $\text{gL}^{-1}$  and find out pH of this solution. (Atomic mass of Al = 27 u).

[Ans: Solubility of  $\text{Al(OH)}_3$  =  $7.8 \times 10^{-2}$  g L<sup>-1</sup>; pH of the solution=11.4771]

- b) pH of 0.08 mol dm<sup>-3</sup> HOCl solution is 2.85. Calculate its ionization constant.

$$[\text{K}_a = 2.4957 \times 10^{-5}]$$

**HOTS**

38. At 298 K, a 0.1 M solution of acetic acid is 1.34% ionized. What is the ionization constant  $\text{K}_a$  of acetic acid?

3

39. An equilibrium mixture at 300K contains  $\text{N}_2\text{O}_4$  and  $\text{NO}_2$  at 0.28 and 1.1 atm pressure respectively. If the volume of the container is doubled, calculate the new equilibrium pressure of the two gases.  
[p  $\text{N}_2\text{O}_4$ = 0.095 atm, p  $\text{NO}_2$  = 0.64 atm]

3

## REDOX REACTIONS

### UNIT-8

**Redox reactions:** Reactions in which the oxidation and reduction takes place simultaneously.

**Reduction:** Reduction is removal of oxygen/electronegative element from a substance or addition of hydrogen/ electropositive element to a substance.

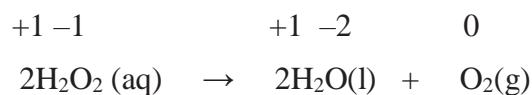
**Oxidation:** Oxidation is defined as the addition of oxygen/electronegative element to a substance or removal of hydrogen/electropositive element from a substance.

**Reducing agent (reductant):** A substance that helps in the reduction of other substance in a chemical reaction or itself undergoing oxidation.

**Oxidizing agent (oxidants):** A substance that helps in the oxidation of other species in a reaction or itself undergoing reduction.

**Oxidation number:** The charge which an atom appears to have when all the other atoms are removed from it as ions.

**Disproportionation reaction** -In a disproportionation reaction an element in one oxidation state is simultaneously oxidised and reduced.



**Rules for calculating oxidation number (Refer text book)**

**Stock notation.** According to this, the oxidation number of an element is expressed by putting a Roman numeral representing the oxidation number in parenthesis after the symbol of the metal in the molecular formula.

**A redox couple** is defined as having together the oxidized and reduced forms of a substance taking part in an oxidation or reduction half reaction.

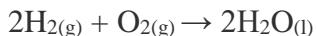
## UNIT-8

### REDOX REACTIONS

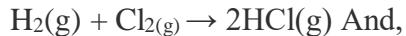
S No	Question Details	Marks
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**Read the given passage and answer the questions 1 to 5 that follow:**

A less obvious example of electron transfer is realized when hydrogen combines with oxygen to form water by the reaction:



Though not simple in its approach, we can visualize the H atom as going from a neutral (zero) state in  $\text{H}_2$  to a positive state in  $\text{H}_2\text{O}$ , the O atom goes from a zero state in  $\text{O}_2$  To a binegative state in  $\text{H}_2\text{O}$ . It is assumed that There is an electron transfer from H to O and consequently  $\text{H}_2$  is oxidized and  $\text{O}_2$  is reduced. However, the charge transfer is only partial and is perhaps better Described as an electron shift rather than a complete loss of electron by H and gain by O. Two examples of this class of the reactions are:



A set of rules has been formulated to determine the oxidation number of an Element in a compound/ion.

1. **H atom goes from a ... state in  $\text{H}_2$  to a positive state in  $\text{H}_2\text{O}$  in water formation**      1  
$$2\text{H}_{2(\text{g})} + \text{O}_{2(\text{g})} \rightarrow 2\text{H}_2\text{O}_{(\text{l})}$$
- a) Neutral
  - b) Positive
  - c) Negative
  - d) All the above
2. **In  $\text{Na}_2\text{O}_2$  each oxygen atom is assigned an oxidation number of ...**      1
- a) +1
  - b) -2
  - c) +2
  - d) -1
3. **The algebraic sum of the oxidation number of all the atoms in a compound must be...**      1
- a) 0

- b) 1  
c) 2  
d) -2
- 4.** In .... an element in one oxidation state is simultaneously oxidized and reduced. 1
- a) displacement reaction
  - b) decomposition reaction
  - c) disproportionation reaction
  - d) combination reaction
- 5.** Reactions which involve change in oxidation number of the interacting species... 1
- a) Exothermic reaction
  - b) Endothermic reaction
  - c) Neutralization reaction
  - d) Redox reaction
- Questions 6, 7 and 8 are multiple choice questions:**
- 6.** Identify disproportionation reaction 1
- (i)  $\text{CH}_4 + 2\text{O}_2 \longrightarrow \text{CO}_2 + 2\text{H}_2\text{O}$
  - (ii)  $\text{CH}_4 + 4\text{Cl}_2 \longrightarrow \text{CCl}_4 + 4\text{HCl}$
  - (iii)  $2\text{F}_2 + 2\text{OH}^- \longrightarrow 2\text{F}^- + \text{OF}_2 + \text{H}_2\text{O}$
  - (iv)  $2\text{NO}_2 + 2\text{OH}^- \longrightarrow \text{NO}_2^- + \text{NO}_3^- + \text{H}_2\text{O}$
- 7.** The largest oxidation number exhibited by an element depends on its outer electronic configuration. With which of the following outer electronic configurations the element will exhibit largest oxidation number? 1
- (i)  $3d^1 4s^2$
  - (ii)  $3d^3 4s^2$
  - (iii)  $3d^5 4s^1$
  - (iv)  $3d^6 4s^2$
- 8.** The oxidation half reaction for following reaction is  
 $\text{Fe}^{2+}(\text{aq}) + \text{Cr}_2\text{O}_7^{2-}(\text{aq}) \rightarrow \text{Fe}^{3+}(\text{aq}) + \text{Cr}^{3+}(\text{aq})$

- a)  $\text{Fe}^{3+}_{(\text{aq})} \rightarrow \text{Fe}^{2+}$
- b)  $\text{Cr}_2\text{O}_7^{2-}_{(\text{aq})} \rightarrow \text{Cr}^{3+}$
- c)  $\text{Cr}^{3+}_{(\text{aq})} \rightarrow \text{Cr}_2\text{O}_7^{2-}_{(\text{aq})}$
- d)  $\text{Fe}^{2+}_{(\text{aq})} \rightarrow \text{Fe}^{3+}$

**Questions 9 and 10 are Assertion and Reason type:**

- |     |   |   |
|-----|---|---|
| 9.  | <b>Assertion (A) :</b> Among halogens fluorine is the best oxidant.   | 1 |
|     | <b>Reason (R) :</b> Fluorine is the most electronegative atom.  |   |
|     | (i) Both A and R are true and R is the correct explanation of A.  |   |
|     | (ii) Both A and R are true but R is not the correct explanation of A.   |   |
|     | (iii) A is true but R is false.   |   |
|     | (iv) Both A and R are false.  |   |
| 10. | <b>Assertion (A):</b> In the reaction between potassium permanganate and potassium iodide, permanganate ions act as oxidising agent.  | 1 |
|     | <b>Reason (R) :</b> Oxidation state of manganese changes from +2 to +7 during the reaction.   |   |
|     | (i) Both A and R are true and R is the correct explanation of A.  |   |
|     | (ii) Both A and R are true but R is not the correct explanation of A.   |   |
|     | (iii) A is true but R is false.   |   |
|     | (iv) Both A and R are false.  |   |
| 11. | Give an example of disproportionation reaction.   | 1 |
| 13. | Oxidation and reduction go side by side in a redox reaction. Justify it.  | 1 |
| 14. | Which of the following is not an example of redox reaction?   | 1 |
|     | (i) $\text{CuO} + \text{H}_2 \rightarrow \text{Cu} + \text{H}_2\text{O}$  |   |
|     | (ii) $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$   |   |
|     | (iii) $2\text{K} + \text{F}_2 \rightarrow 2\text{KF}$   |   |
|     | (iv) $\text{BaCl}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{BaSO}_4 + 2\text{HCl}$  |   |
| 15. | Nitric acid is an oxidizing agent and reacts with PbO but it does not react with $\text{PbO}_2$ . Explain why?  | 2 |
| 16. | a) Justify that the reaction: $2\text{Na(s)} + \text{H}_2\text{(g)} \rightarrow 2\text{NaH(s)}$ is a redox reaction.<br>b) Calculate the oxidation number of Mn in $\text{K}_2\text{MnO}_4$ | 2 |
| 17. | HNO <sub>3</sub> acts as an oxidizing agent while HNO <sub>2</sub> can act both as a reducing agent as well as an oxidizing agent. Explain.   | 2 |

18. Using Stock notation, represent the following compounds: 2  
 $\text{FeCl}_3$ ,  $\text{KMnO}_4$ ,  $\text{K}_2\text{Cr}_2\text{O}_7$  and  $\text{Na}_2\text{CrO}_4$ .
19. Arrange the following molecules in the decreasing order of the oxidation state of nitrogen: 2  
 $\text{NO}_2$ ,  $\text{NH}_3$ ,  $\text{NO}_2^-$ ,  $\text{N}_2\text{H}_4$ .
20. Using half-reactions, write the balanced equation for the reaction of sulfuric acid with iodide ion to form free iodine and hydrogen sulfide gas. 3
21. Use the half-reaction method to determine the correct stoichiometry for this reaction. 3  
a)  $\text{MnO}_4^-(aq) + \text{H}_2\text{O}_2(aq) \xrightarrow{\text{H}^+} \text{Mn}^{2+}(aq) + \text{O}_2(g)$   
b)  $\text{Cr}_2\text{O}_7^{2-}(aq) + \text{HNO}_2(aq) \rightarrow \text{Cr}^{3+}(aq) + \text{NO}_3^-(aq)$
22. Justify each of the following as oxidation-reduction reactions. Note that mercury usually exists in one of three oxidation states: mercury metal,  $\text{Hg}_2^{2+}$  ions, or  $\text{Hg}^{2+}$  ions. 3  
(a)  $\text{Hg}_2^{2+}(aq) + \text{Sn}^{2+}(aq) \rightarrow 2 \text{Hg}(l) + \text{Sn}^{4+}(aq)$   
(b)  $\text{Hg}_2^{2+}(aq) + \text{H}_2\text{S}(aq) \rightarrow \text{Hg}(l) + \text{HgS}(s) + 2 \text{H}^+(aq)$
24. What are the oxidation number of the underlined elements in each of the following and how do you rationalize your results? 3  
C<sub>3</sub>O<sub>2</sub>, H<sub>2</sub>S<sub>4</sub>O<sub>6</sub> and Br<sub>3</sub>O<sub>8</sub>
25. Balance the following equation by half reaction method. 3  
a)  $\text{Fe(OH)}_2 + \text{H}_2\text{O}_2 \rightarrow \text{Fe(OH)}_3 + \text{H}_2\text{O}$  [Basic medium]  
b)  $\text{MnO}_4^- + \text{Br}^- \rightarrow \text{Mn}^{2+} + \text{Br}_2$  [Acidic medium]
26. a) Would you use an oxidizing agent or reducing agent for the following reactions to occur? 3  
i)  $\text{ClO}_3^- \rightarrow \text{ClO}_2$   
ii)  $\text{SO}_4^{2-} \rightarrow \text{S}^{2-}$   
iii)  $\text{Mn}^{2+} \rightarrow \text{MnO}_2$   
b) Write a balanced equation for the disproportionation of bromine in the presence of a strong base.
27. Balance the following equations in basic medium by ion –electron method: 3  
a)  $\text{MnO}_4^- + \text{C}_2\text{H}_5\text{OH} \rightarrow \text{Mn}^{2+} + \text{CH}_3\text{COOH}$   
b)  $\text{Cl}_2\text{O}_7 + \text{H}_2\text{O}_2 \rightarrow \text{ClO}_2^- + \text{O}_2$
28. i) Balance the following redox reaction in acidic medium: 5  
 $\text{I}^-(\text{aq}) + \text{ClO}^-(\text{aq}) \rightarrow \text{I}_3^-(\text{aq}) + \text{Cl}^-(\text{aq})$   
ii) Balance the following reaction in basic medium:  
 $\text{Al(s)} + \text{MnO}_4^-(\text{aq}) \longrightarrow \text{MnO}_2(\text{s}) + \text{Al(OH)}_4^-(\text{aq})$   
iii) Why  $\text{ClO}_4^-$  does not show disproportionation reaction whereas  $\text{ClO}^-$ ,  $\text{ClO}_2^-$  and  $\text{ClO}_3^-$  shows?

## BASIC PRINCIPLES AND TECHNIQUES IN ORGANIC CHEMISTRY

### UNITS 12

- The **functional group** may be defined as an atom or group of atoms joined in a specific manner which is responsible for the characteristic chemical properties of the organic compounds.
- A group or a series of organic compounds each containing a characteristic functional group forms a homologous series and the members of the series are called *homologues*.
- A systematic method of naming has been developed and is known as the **IUPAC International Union of Pure and Applied Chemistry**) system of nomenclature.
  - The longest chain of carbon atoms containing the functional group is numbered in such a way that the functional group is attached at the carbon atom possessing lowest possible number in the chain.
  - The choice of principal functional group is made based on order of preference. **The order of decreasing priority for some functional groups is:** -COOH, -SO<sub>3</sub>H, -COOR (R=alkyl group), COCl, -CONH<sub>2</sub>, -CN, -HC=O, >C=O, -OH, -NH<sub>2</sub>, >C=C<, -C≡C-
- **Isomerism:** Two or more compounds having the same chemical formula, but different physical and chemical properties are called isomers and the phenomenon is known as isomerism.
  - I) **Structural isomerism.** Compounds having the same molecular formula but different arrangement of atoms or groups within the molecule.
    - a) Chain isomerism: When two or more compounds have the same molecular formula but different arrangement of carbon chains within the molecule.
    - b) Position isomerism: When two or more compounds have the same molecular formula but differ in the positions of atoms, functional groups and multiple bonds.
    - c) Functional type isomerism: Two or more compounds having the same molecular formula but different functional groups in the molecule.
    - d) Metamerism: The compounds having the same molecular formula but different number of carbon atoms on either side of the functional group.
  - II) **Stereoisomerism:** The compounds that have the same constitution and sequence of covalent bonds but differ in relative positions of their atoms or groups in space are called stereoisomers. This special type of isomerism is called as stereoisomerism it is of two types: *geometrical* and *optical isomerism*.
- **Fission of a Covalent Bond**
  - **Heterolytic cleavage:** the bond breaks in such a fashion that the shared pair of electrons remains with one of the fragments.

- **Homolytic cleavage:** one of the electrons of the shared pair in a covalent bond goes with each of the bonded atoms. Thus in homolytic cleavage, the movement of a single electron takes place instead of an electron pair.
- **Inductive effect:** Polarization of sigma bond caused by the polarization of adjacent sigma bond is called inductive effect.
  - **Electromeric effect:** The complete transfer of shared pair of pi electrons to one of the atoms joined by a multiple bond on the demand of an attacking reagent.
  - **Hyperconjugation:** The delocalization of sigma electrons of C-H bond of an alkyl group directly attached to an atom of the unsaturated system or to an atom with an unshared p orbital
  - **Resonance Effect:** The resonance effect is defined as ‘the polarity produced in the molecule by the interaction of two  $\pi$ -bonds or between a  $\pi$ -bond and lone pair of electrons present on an adjacent atom’. The effect is transmitted through the chain.

### Isomerism

**Stereoisomerism:** Compounds having the same molecular formula and sequence of covalent bonds but differ in their relative position of atoms or groups in space are stereo isomers and the phenomenon is called stereoisomerism.

**Conformation:** Due to the free rotation around sigma bond in alkanes two spatial isomers are called conformers and this phenomenon is called conformation.

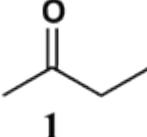
**Geometrical isomerism:** The restricted rotation about the double bond gives cis-trans isomerism. Cis means similar groups on the same side and trans means similar groups on opposite side.

## ORGANIC CHEMISTRY: SOME BASIC PRINCIPLES AND TECHNIQUES

### UNIT-12

	<b>Question Details</b>	<b>Marks</b>
	<p><b>Read the given passage and answer the questions 1 to 5 that follow:</b></p> <p>For the nomenclature of branched chain alkanes, the longest carbon chain in the molecule is identified. The numbering is done in such a way that the branched carbon atoms get the lowest possible numbers. The lower number is given to the one coming first in the alphabetical listing. The carbon atom of the branch that attach to the root alkane, in alphabetical order, the prefixes iso- and neo- are the part of the fundamental name of the alkyl group. The prefixes sec- and tert- are not considered to be the part of the fundamental name.</p> <p><b>Cyclic Compounds:</b> A saturated monocyclic compound is named by prefixing ‘cyclo’ to the corresponding straight-chain alkane. If side chains are present, then the rules given above are applied.</p>	
1.	<p>For the nomenclature of branched chain alkanes, the numbering is done in such a way that the branched carbon atoms get the ... possible numbers.</p> <ul style="list-style-type: none"> <li>a) biggest</li> <li>b) Lower</li> <li>c) Highest</li> <li>d) lowest</li> </ul>	
2.	<p>The structure of 4-Methylpent-2-en-1-ol is:</p> <ul style="list-style-type: none"> <li>a) <math>\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{OH}</math></li> <li>b) <math>(\text{CH}_3)_2\text{C}=\text{CHCH}_2\text{CH}_2\text{OH}</math></li> <li>c) <math>(\text{CH}_3)_2\text{CHCH}=\text{CHCH}_2\text{OH}</math></li> <li>d) <math>\text{CH}_3\text{CH}(\text{OH})\text{CH}-\text{CH}=\text{C}(\text{CH}_3)_2</math></li> </ul>	
3.	<p> <math display="block">\begin{array}{ccccc} \text{H} &amp; &amp; \text{H} &amp; &amp; \text{H} \\   &amp; &amp;   &amp; &amp;   \\ \text{H} - \text{C} &amp; - &amp; \text{C} &amp; - &amp; \text{C} - \text{H} \\   &amp; &amp;   &amp; &amp;   \\ \text{C} &amp; &amp; \text{C} &amp; &amp; \text{C} \\     &amp; &amp;     &amp; &amp;     \\ \text{N} &amp; &amp; \text{N} &amp; &amp; \text{N} \end{array}</math> </p> <p>The IUPAC name of the above-mentioned compound is-</p> <ul style="list-style-type: none"> <li>a) 1,2,3-Tricyanopropane</li> </ul>	

	b) Propane-1,2,3-tricarbonitrile c) 1,2,3-Tricyanopropane d) Propane tricarbonylamine	
	<b>Questions 6, 7 and 8 are multiple choice questions:</b>	
6.	The correct structure of 3,3-Dimethylbutyne is-  a) $\text{CH}_3\text{CH}_2-\text{C}\equiv\text{C}-\text{CH}_2\text{CH}_3$ b) $(\text{CH}_3)_2\text{C}-\text{C}\equiv\text{CH}$ c) $\text{CH}_3-\text{C}\equiv\text{C}(\text{CH}_3)_2-\text{CH}_3$  d)	$\begin{array}{c} \text{CH}_3 - \text{C} = \text{C} - \text{CH}_3 \\   \qquad   \\ \text{CH}_3 \quad \text{CH}_3 \end{array}$
7.	The compound that has an isopropyl group is-  a) 2- Methylpentane b) 2, 2, 3- Trimethylpentane c) 2, 2 - Dimethylpentane d) 2, 2, 3, 3 - Tetramethylpentane	
8.	A tertiary butyl carbocation is more stable than a secondary butyl carbocation because-  a) + R effect of $-\text{CH}_3$ groups b) - R effect of $-\text{CH}_3$ groups c) Hyperconjugation d) -I effect of $-\text{CH}_3$ group	
	<b>Questions 9 and 10 are Assertion and Reason type:</b>	
9.	(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion. (b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion (c) Assertion is correct, reason is incorrect (d) Assertion is incorrect, reason is correct.	

	<b>Assertion:</b> Energy of resonance hybrid is equal to the average of energies of all canonical forms.  <b>Reason:</b> Resonance hybrid cannot be presented by a single structure.	
10.	<b>Assertion:</b> Aniline is a better nucleophile than the anilium ion.  <b>Reason:</b> Anilium ion has a +ve charge.	
11.	Write the bond line formula for-  OH  $\text{N} \equiv \text{C} - \text{CH} - \text{C} = \text{N}$ .	1
12.	Which compound is different from compound 1?    a) $\text{CH}_3\text{COCH}_2\text{CH}_3$ <input type="radio"/> b) $\text{CH}_3\text{CH}_2\overset{\text{O}}{=} \text{CCH}_2\text{CH}_3$ <input type="radio"/> c) $\text{CH}_3\text{CH}_2\text{COCH}_3$ <input checked="" type="radio"/> d) $\text{CH}_3\text{CH}_2\overset{\text{O}}{=} \text{CCH}_3$ <input type="radio"/>	1
13.	Identify the type of organic reaction mechanism in each case: a. $\text{R-X} + \text{OH}^- \rightarrow \text{R-OH} + \text{X}^-$ b. Bromoethane to ethene	1
14.	How many primary carbons are there in the following hydrocarbon?  $\text{CH}_3 - \text{CH}(\text{CH}_3) - \text{C}(\text{CH}_3)_2$	1
15.	Write structural formula of the compound Pentan 2,4-dione.	1
16.	How many sigma and pi bonds are present in each of the following;	

	a) $\text{CH}_3\text{CN}$ b) $(\text{CH}_3)_2\text{CO}$	
17.	Write bond line formula for Tert-butyl cyclopentane.	1
18.	Explain the following. a. $(\text{CH}_3)_3\text{C}^+$ is more stable than $\text{CH}_3\text{CH}_2^+$ and $\text{CH}_3^+$ b. Chloroethanoic acid is stronger than ethanoic acid.	2
19.	Write the bond line structural formulae and the condensed formulae for the following: a) $\text{C}_4\text{H}_8\text{O}_2$ b) $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CO-CH}_2\text{Br}$	2
20.	a) Name the chain isomer of $\text{C}_5\text{H}_{12}$ which has a tertiary carbon atom. b) Why is the carbon with sp hybrid orbital more electronegative than $\text{sp}^2$ or $\text{sp}^3$ hybridized orbitals?	2
21.	Write two points of differences between homolytic and heterolytic fission.	2
22.	Write the resonance structures of- (a) $\text{CH}_3\text{NO}_2$ (b) $\text{CH}_3\text{COO}^-$	2
23.	Draw the orbital diagram showing hyperconjugation in ethyl cation.	3
24.	Write structural formulae of the following compounds a. 3 – Hexenoic acid b. 4 – Nitropent - 1 – yne c. 2 – Formylbut – 3 - enenitrile	3
25.	Write the IUPAC names of the following: a. $(\text{CH}_3)_2\text{CHCOOH}$ b. $\text{Ph-CH=CH-CHO}$ c. $\text{HOOC -(CH}_2)_2\text{-COOH}$	3
26.	Write the structural formula for each of the following compounds: a. 1, 4-Dicyclopropylhexane b. 1, 1-Dichlorocyclopentane c. Neopentyl alcohol	3
27.	What is resonance? Draw the resonating structures for the following molecules showing electron shift using curved arrow notation. a) Phenol b) Benzyl carbocation.	3
28.	Identify the type of isomerism exhibited by the following compounds. a)Butane   b) Pentene   c) $\text{C}_3\text{H}_6\text{O}$	3

29.	<p>Draw resonance structures for <math>\text{NO}_2^+</math> and find the structure with lowest energy? What are the different types of reaction intermediates formed by homolytic and heterolytic fission of a covalent bond? Explain with examples.</p>	<b>3</b>
<b>High Order Thinking Skills</b>		
30.	<p>Draw the resonance structures of the following compounds:</p> <p>(i) <math>\text{CH}_2 = \text{CH} - \ddot{\text{Cl}}</math>:</p> <p>(ii) <math>\text{CH}_2 = \text{CH} - \text{CH} = \text{CH}_2</math></p> <p>(iii) <math>\text{CH}_2 = \text{CH} - \begin{matrix} \text{C} = \text{O} \\   \\ \text{H} \end{matrix}</math></p>	<b>3</b>
31.	<p>Identify the most stable species in the following set of ions giving reasons:</p> <p>(i) <math>\overset{+}{\text{CH}_3}</math>, <math>\overset{+}{\text{CH}_2\text{Br}}</math>, <math>\overset{+}{\text{CHBr}_2}</math>, <math>\overset{+}{\text{CBr}_3}</math></p> <p>(ii) <math>\overset{\bullet}{\text{CH}_3}</math>, <math>\overset{\bullet}{\text{CH}_2\text{Cl}}</math>, <math>\overset{\bullet}{\text{CHCl}_2}</math>, <math>\overset{\bullet}{\text{CCl}_3}</math></p>	<b>2</b>

## Unit-13 HYDROCARBONS

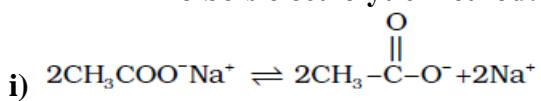
- **Name Reactions**

- **Wurtz reaction:** Alkyl halides on treatment with sodium metal in dry ethereal solution gives higher alkanes.
- **Decarboxylation reaction:** The process of elimination of carbon dioxide from carboxylic acid.
- **Substitution reaction:** When one or more hydrogen atoms of alkanes can be replaced by other atoms or group of atoms.
- **Isomerization reaction:** n- alkanes on heating in the presence of anhydrous aluminum chloride and hydrogen chloride gas isomerize to branched chain alkanes.
- **Aromatization reaction/ Reforming:** n-alkanes having six or more carbon atoms on heating to 773K at 10-20 atmospheric pressure in the presence of vanadium pentoxide supported on alumina get dehydrogenated and cyclized to benzene and its homologues.
- **Pyrolysis:** Higher alkanes on heating decompose into lower alkanes and alkenes.
- **$\beta$ -elimination reaction:** Alkyl halides on heating with alcoholic KOH eliminate one molecule of halogen acid to form alkenes.
- **Markovnikov's rule:** When a reactant is added to the unsymmetrical alkene the negative addendum goes to the carbon with lesser number of hydrogen atoms.
- **Anti Markovnikov's rule:** When a HBr is added to the unsymmetrical alkene in the presence of peroxides the negative addendum goes to the carbon with greater number of hydrogen atoms.
- **Ozonolysis:** Addition of ozone to an alkene to form an ozonide followed by the reaction of Zn and H<sub>2</sub>O to either aldehydes or ketones. It is used to detect the structure of the unsaturated
- **Polymerization reaction:** The reaction in which a large number of monomers combine to form a polymer at very high temperature and pressure.
- **Delocalisation:** The equal movement of all the pi electrons on all the carbon atoms present in the molecule.
- **Aromaticity:** The compounds which show aromaticity should be planar, planar and should follow Huckel's rule.
- **Friedel Craft's alkylation reaction:** When benzene is treated with alkyl halide in the presence of anhydrous aluminium chloride alkyl benzene is formed.

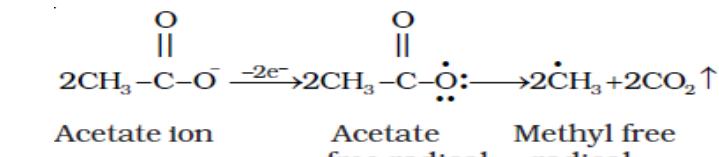
- **Friedel Craft's acylation reaction:** When benzene is treated with acyl halide or acetic anhydride in the presence of anhydrous aluminium chloride alkyl benzene is formed.
- **Addition reaction:** When benzene is treated with excess of chlorine in the presence of sunlight it forms gammaxene.  
*But when benzene is treated with excess of chlorine in the dark and cold medium in the presence of anhydrous aluminium chloride, it forms gammaxene.*

- **Mechanisms**

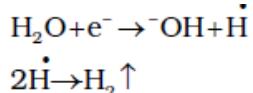
- **Kolbe's electrolytic method:**



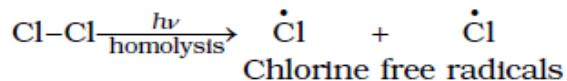
ii) At anode:



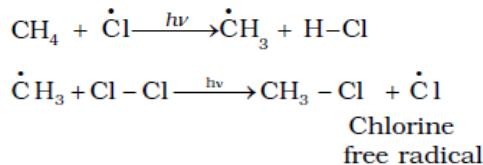
iv) At cathode:



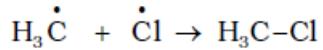
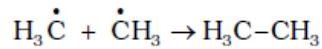
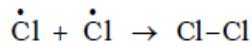
- **Halogenation:** Initiation:



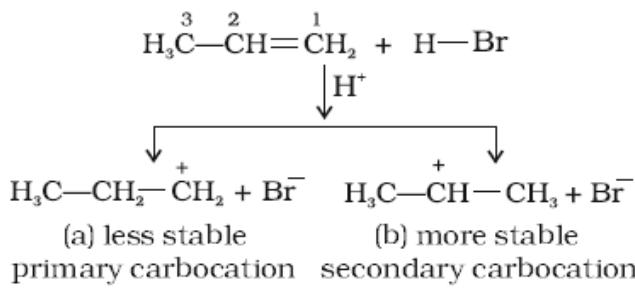
Propagation:



Termination:

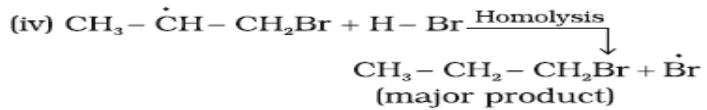
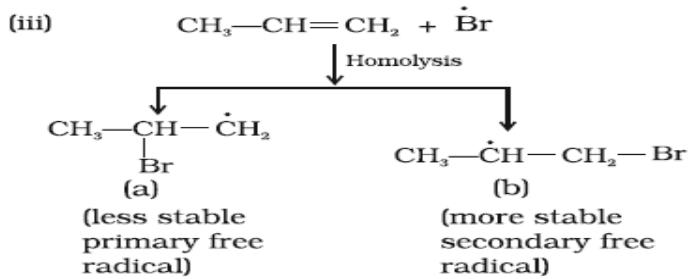
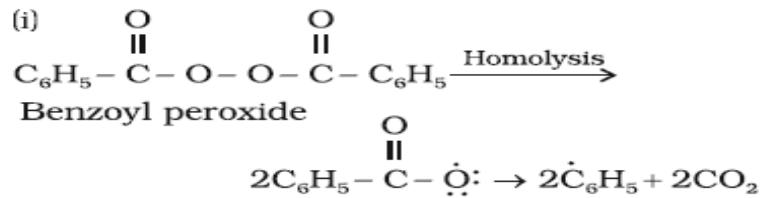


## ➤ MARKONIKOV'S ADDITION



## ➤ ANTI-MARKONIKOV'S ADDITION

**Mechanism :** Peroxide effect proceeds via free radical chain mechanism as given below:

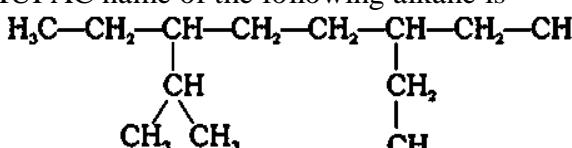


## **REASONING QUESTIONS**

- 1. Boiling point of alkenes is higher than alkanes because electrons of alkenes can be easily polarised.**
- 2. Boiling point of alkanes increases with branching because** as branching increases, the molecule attains the shape of a sphere; so less surface area; less van der waals forces hence lesser boiling point.
- 3. cis alkene has greater dipole moment than trans isomer because** in trans the bond dipoles cancel each other as similar groups are in opposite direction.
- 4. Melting point of trans isomer is greater than cis because** trans fits better into the crystal lattice due to high symmetry.

## UNIT-13

### HYDROCARBONS

S No	Question Details	Marks
<b>Read the given passage and answer the questions 1 to 5 that follow:</b>		
Alkanes generally have low boiling points. The boiling points of straight-chain alkanes goes on increasing with the increase in carbon atoms and decreases with branching. Hydrocarbons are soluble in nonpolar solvents and insoluble in polar solvents. The dipole moment and boiling points of alkenes depend on the position of group attached to double bonded carbon atom. Depending on hybridization of carbon atoms, acidic nature also varies.		
1.	Why does cis-but-2ene have a higher boiling point than its trans isomer?	1
2.	Arrange alkene, alkane and alkyne in increasing order of acidic nature. Give reason for your answer.	1
3.	Arrange isomers of pentane in the decreasing order of boiling points. Give reason.	1
4.	Hydrocarbons are insoluble in polar solvents. Why?	1
5.	Give a chemical test to distinguish between ethyne & ethene.	1
<b>Questions 6, 7, and 8 are multiple-choice questions:</b>		
6.	In an electrophilic substitution reaction of nitrobenzene, the presence of nitro group: a) Deactivate the ring by inductive effect b) Activate the ring by inductive effect. c) Decrease the charge density at the ortho and para position of the ring relative to the meta position by resonance. d) Increase the charge density at the meta position of the ring relative to the ortho and para position by resonance.	1
7.	IUPAC name of the following alkane is-  a) 3,6-Diethyl-2-methyloctane b) 5-Isopropyl-3-ethyloctane c) 3-Ethyl-5-isopropyloctane d) 3-Isopropyl-6-ethyloctane	1

8. Electrophile that participates in sulphonation of benzene is

- a)  $\text{SO}_3\text{H}$
- b)  $\text{SO}_3$
- c)  $\text{SO}_2$
- d)  $\text{SO}_3^-$

**Questions 9 and 10 are Assertion and Reason type:**

9. Assertion (A): The compound cyclooctatetraene has the following structural formula: 1



It is cyclic and has conjugated  $8\pi$ -electron system, but it is not an aromatic compound.

Reason (R):  $(4n + 2)\pi$  electrons rule does not hold good..

- a) Both A and R are correct, and R is the correct explanation of A.
- b) Both A and R are correct, but R is not the correct explanation of A.
- c) Both A and R are not correct.
- d) A is correct but R is incorrect.

10. Assertion (A): Among isomeric pentanes, 2, 2-dimethylpropane has highest boiling point. 1

Reason (R): Branching does not affect the boiling point.

- a) Both A and R are correct, and R is the correct explanation of A.
- b) Both A and R are correct, but R is not the correct explanation of A.
- c) Both A and R are not correct
- d) A is correct but R is incorrect.

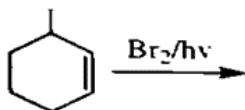
11. Give the IUPAC name of the lowest molecular weight alkane that contains a quaternary carbon.

12. Why is peroxide effect seen only in case of HBr and not in case of HCl or HI?

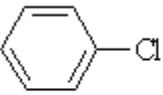
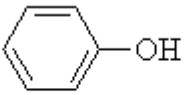
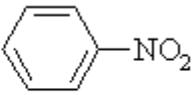
13. Why is iodination of  $\text{CH}_4$  done in the presence of periodic acid?

14. Draw the Newman's projection formula of the staggered form of 1,2-dichloro ethane.

15. What is the major product of the following reaction?



16.	<p>What is the best reagent to make the following product?</p> <p><math>\text{H}_3\text{C}-\text{C}\equiv\text{C}-\text{CH}_3 \longrightarrow</math></p> <p style="text-align: center;"><b>cis-2-butene</b></p>	2
17.	<p>(a) Butanone is formed when an alkyne is passed through a dil. solution of <math>\text{H}_2\text{SO}_4</math> at 330K in the presence of mercuric sulphate. Write the possible structure of the alkyne.</p> <p>(b) What is the product of the following reaction?</p> <p><math>\text{CH}_3\text{CH}_2\text{C}\equiv\text{CH} + \text{NaNH}_2 \longrightarrow</math></p> <p>1-butyne      sodium amide</p>	2
18.	<p>a) Alkynes on reduction with sodium in liquid ammonia form trans alkenes. Will the butene thus formed on reduction of the 2-butyne show the geometrical isomerism?      b) Rotation around the carbon-carbon single bond of ethane is not completely free. Justify the statement.</p>	2
19.	<p>Write the mechanism for the reaction:</p> <p><math>\text{CH}_3\text{CH}=\text{CH}_2 + \text{HBr} \xrightarrow{\text{peroxide}} \text{CH}_3\text{CH}_2\text{CH}_2\text{Br}</math></p>	2
20.	<p>Why is Wurtz reaction not preferred for the preparation of alkanes containing odd number of carbon atoms? Illustrate your answer by taking one example.</p>	2
21.	<p>How will you bring out the following conversions:</p> <p>a) Benzene to gamma-xylene.      b) Ethyne to benzene.      c) Butyne to cis-butene.</p>	3
22.	<p>A hydrocarbon 'A' adds one mole of hydrogen in the presence of Pt as catalyst to form n-hexane. 'A' is oxidized vigorously with <math>\text{KMnO}_4</math>, a single carboxylic acid containing three carbon atoms is isolated. Give the structure and name of 'A' and explain the reactions.</p>	3
23.	<p>(a) When benzene is alkylated with butyl bromide, sec-butyl benzene is the major product. Why?      (b) Give the structures of the major organic products from 3-Ethylpent-2-ene under each of the following reaction conditions.      (i) <math>\text{HBr}</math> in the presence of peroxide      (ii) <math>\text{O}_3</math> followed by <math>\text{Zn}/\text{H}_2\text{O}</math></p>	3
24.	<p>Complete the following reactions:</p> <p><math>\text{CH}_3\text{CHBr}-\text{CH}_2\text{Br}+\text{Zn} \longrightarrow</math></p> <p><math>\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-\text{Na}^+ + \text{NaOH} \xrightarrow{\text{CaO}}</math></p>	3

	$\text{CH}_3 - \text{C} \equiv \text{C} - \text{H} + \text{Na}^+ \text{NH}_2^- \rightarrow$	
25.	Complete and name the following reaction: a.  + CH <sub>3</sub> Cl $\xrightarrow[\text{Dry ether}]{\text{Anhyd. AlCl}_3}$ b. CH <sub>3</sub> Br + Na + CH <sub>3</sub> Br $\longrightarrow$	3
26.	What happens when - a) 1-Bromopropane is treated with alcoholic potassium hydroxide b) Sodium acetate solution is electrolyzed c) Benzene is treated with conc. Nitric and conc. Sulphuric acid	3
27.	(a) Give the structure of alkene (C <sub>4</sub> H <sub>8</sub> ), which adds on HBr in the presence and in absence of peroxide to give the same product, C <sub>4</sub> H <sub>9</sub> Br.  (b) Use Markonikov's rule to predict the product of the reaction i) HBr with CH <sub>3</sub> CCl=CH <sub>2</sub> ii) HBr with CH <sub>3</sub> CH=C(CH <sub>3</sub> ) <sub>2</sub>	3
28.	(a) Arrange the following in order according to their relative rate of reaction with bromine / FeBr <sub>3</sub> . Justify the order.   (i)  (ii)  (iii)	3
29.	(a) How do you account for the acidic nature of alkynes as compared to alkenes? Give a reaction in which acetylene behaves as an acid. b) How would you distinguish between but-1-yne and but-2-yne?	3
30.	(a) A gas decolorizes bromine water and gives CH <sub>2</sub> =CH Br and CH <sub>3</sub> CHBr <sub>2</sub> on treatment with one or two moles of HBr, respectively. Identify the gas and explain the reaction. (b) Do the following conversions: (i) But-2-ene into ethanal (ii) Benzoic acid to benzene	3
31.	Which of the following are aromatic compounds? Explain your answer. a). 2-ethylcyclopentene b). anthracene c). 3-methyl-1-hexyne	3

32	An unknown alkene ‘A’ on reductive ozonolysis gives two isomeric carbonyl compounds ‘B’ and ‘C’ with molecular formula C <sub>3</sub> H <sub>6</sub> O. Write the complete equation and draw the structures of A, B and C.	3
33	(a) When benzene is alkylated with butyl bromide, sec-butyl benzene is the major product. Why? (b) Give the structures of the major organic products from 3-Ethylpent-2-ene under each of the following reaction conditions. (i) HBr in the presence of peroxide (ii) O <sub>3</sub> followed by Zn/H <sub>2</sub> O	3
34.	(i) Explain whether the following systems are aromatic or non- aromatic (a)  (b)  (ii) Which of the following has the highest boiling point? Why? a) 2-Methyl pentane b) 2,3-Dimethyl butane c) 2,2 - Dimethyl butane (iii) Draw the conformers of propane (Sawhorse). (iv) 1-Hexene gives no reaction with AgNO <sub>3</sub> in ammonia, while 1-hexyne gives a white precipitate. Why? (v) 2-Butene + Br <sub>2</sub> ---CCl <sub>4</sub> ---> X X + NaNH <sub>2</sub> -----> Y (Identify X and Y)	5
35	a) An alkane C <sub>8</sub> H <sub>18</sub> is obtained as the only product on subjecting a primary alkyl halide to Wurtz reaction. On monobromination the alkane yields a single isomer of a tertiary bromide. Write the structure of alkane and the tertiary bromide. b) Despite their – I effect, halogens are o- and p-directing in haloarenes. Why? c) Nucleophiles and electrophiles are reaction intermediates having electron rich and electron deficient centers respectively. Hence, they tend to attack electron deficient and electron rich centers respectively. Classify the following species as electrophiles and nucleophiles. (i) H <sub>3</sub> CO <sup>-</sup> (ii) CH <sub>3</sub> COO <sup>-</sup> (iii) SO <sub>3</sub> (iv) H <sub>2</sub> O   (v) Cl <sup>+</sup> (vi) NH <sub>3</sub>	5

### **High Order Thinking Skills**

<p><b>36.</b> (i) Complete the following:</p> <p>a) Isopropyl bromide      <math>\xrightarrow[\text{Heat}]{\text{alc. KOH}}</math> A      <math>\xrightarrow[\text{Peroxide}]{\text{HBr}}</math> B</p> <p>b) 1,1,2,2-tetra chloroethane      <math>\xrightarrow[\text{Heat}]{\text{Zn, alcohol}}</math> A      <math>\xrightarrow[\text{675K}]{\text{Iron tube}}</math> B</p> <p>(ii) An unsaturated hydrocarbon A adds two molecules of H<sub>2</sub> and on reductive ozonolysis gives butan-1,4-dial, ethanal and propanone, Give the structure of A, write its IUPAC name and explain the reactions.</p>	<b>5</b>
<p><b>37.</b> (a) In the presence of conc. H<sub>2</sub>SO<sub>4</sub>, does conc. HNO<sub>3</sub> act as an acid or base during nitration of benzene?</p> <p>(b) Draw all the possible structural isomers with the molecular formula C<sub>5</sub>H<sub>10</sub> and name them.</p> <p>(c) A compound is formed by the substitution of two chlorine atoms by two hydrogen atoms in propane. What is the number of structural isomers possible?</p>	<b>5</b>



# مدرسۃ دلھی الخاصۃ ذ.م.م. DELHI PRIVATE SCHOOL L.L.C.

Affiliated to C.B.S.E., DELHI

(Approved & Recognized By Ministry of Education - United Arab Emirates)

## PERIODIC TEST 1 (2022-2023)

**Subject:** Chemistry

**Max. Marks: 35**

**Grade:** XI

**Time: 1Hr 15min**

**Name:**

**Section:**

**Roll No:**

### **General Instructions:**

Read the following instructions carefully.

1. There are 16 questions in this question paper.
2. SECTION A - Q. No. 1 to 5 are mcq questions carrying 1marks each.
3. SECTION B - Q. No. 6 to 10 are short answer questions carrying 2 marks each.
4. SECTION C- Q. No. 11 to 15 are short answer questions carrying 3 marks each.
5. SECTION C- Q. No. 16 is a long answer question carrying 5 mark.
6. All questions are compulsory.
7. Use of calculators is not allowed

### **SECTION A**

1. One mole of any substance contains  $6.022 \times 10^{23}$  atoms/molecules. What will be number of molecules of  $\text{H}_2\text{SO}_4$  present in 100 mL of 0.02 M  $\text{H}_2\text{SO}_4$  solution? 1  
(a)  $12.044 \times 10^{20}$  molecules  
(b)  $6.022 \times 10^{23}$  molecules  
(c)  $1 \times 10^{23}$  molecules  
(d)  $12.044 \times 10^{23}$  molecules
2. 8 g of NaOH is dissolved in 18 g of  $\text{H}_2\text{O}$ . Mole fraction of NaOH in solution and molality (in  $\text{mol kg}^{-1}$ ) of the solution respectively are 1  
(a) 0.2, 11.11  
(b) 0.167, 22.20  
(c) 0.2, 22.20  
(d) 0.167, 11.11
3. Which of the following series of transitions in the spectrum of hydrogen atom fall in visible region? 1

	(a) Balmer series (b) Paschen series (c) Brackett series (d) Lyman series	
4	Which transition in the hydrogen atomic spectrum will have the same wavelength as the Balmer transition (i.e. n = 4 to n = 2) of He + spectrum?	1
	(a) n = 4 to n = 3 (b) n = 3 to n = 2 (c) n = 4 to n = 2 (d) n = 2 to n = 1	
5	A molar solution is one that contains one mole of solute in:	1
	(a) 1000 g of solvent (b) 1.0 L of solvent (c) 1.0 L of solution (d) 22.4 L of solution	
	<b>SECTION B</b>	
6	a) How many oxygen atoms are present in 16 g of ozone ( $O_3$ )? b) A substance has molecular formula $C_6H_{12}O_6$ . What is its empirical formula	2
7	Write short note on: a) Continuous and discontinuous spectrum. b) Absorption and emission spectrum.	2
8	a) Why is molality preferred over molarity of a solution? b) In three moles of ethane ( $C_2H_6$ ), calculate the following: (i) Number of moles of carbon atom, (ii) Number of moles of hydrogen atoms	2
9	a) What does the negative electronic energy ( $E_n$ ) for hydrogen atom mean? b) Calculate the radius of Bohr's third orbit for hydrogen atom	2
10	The Molarity of a solution of sulphuric acid is 1.35 M. Calculate its molality. (The density of acid solution is $1.02 \text{ g cm}^{-3}$ ).	2
	<b>SECTION C</b>	
11	A photon of wavelength $4 \times 10^{-7} \text{ m}$ strikes on metal surface, the work function of the metal being 2.13 eV. Calculate (i) the energy of the photon (eV), (ii) the kinetic energy of the emission, (iii) velocity of the photoelectron ( $1 \text{ eV} = 1.6020 \times 10^{-19} \text{ J}$ ).	3
12	Define: a) Limiting reagent b) Law of multiple proportion c) Mole fraction	3
13	Mention 3 applications of line emission spectrum.	3

14	3.0 g of H <sub>2</sub> react with 29.0 g of O <sub>2</sub> yield H <sub>2</sub> O. (i) Which is the limiting reagent. (ii) Calculate the maximum amount of H <sub>2</sub> O that can be formed (iii) Calculate the amount of reactant left unreacted	3
15	State the observation when during photoelectric effect – a) Intensity of the light striking the metal surface is increased. b) Frequency of light striking the metal surface is increased. c) Frequency less than the threshold frequency strikes the metal surface.	3
	<b>SECTION D</b>	
16	a) State Gay-Lussac's law. b) Define atomic mass unit. Mention its (i) earlier abbreviation (ii) latest abbreviation according to IUPAC. c) Calculate the number of atoms in each of the following (i) 52 moles of Ar (ii) 52 u of He	5



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**DELHI PRIVATE SCHOOL L.L.C.**

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(Approved & Recognized By Ministry of Education - United Arab Emirates)

**PT 1 – SUBJECTIVE PAPER (2022-2023)**

**Subject: Chemistry**

**Max. Marks: 35**

**Grade: XI**

**Time:**

**Name:**

**Section:**

**Roll No:**

- |    |   |   |
|----|---|---|
| 1. | (a) $12.044 \times 10^{20}$ molecules   | 1 |
| 2  | (d) 0.167, 11.11  | 1 |
| 3  | (a) Balmer series   | 1 |
| 4  | (d) n = 2 to n = 1  | 1 |
| 5  | (c) 1.0 L of solution   | 1 |
| 6  | c) Number of oxygen atoms = $16 \times 6.022 \times 10^{23} / 48 = 2.007 \times 10^{23}$<br>d) CH <sub>2</sub> O.   | 2 |
| 7  | Write short note on :<br><br>a) Continuous spectrum is a spectrum (as of light emitted by a white-hot lamp filament) having no apparent breaks or gaps throughout its wavelength range<br>Discontinuous spectrum is a spectrum between a range of wave lengths that contains breaks or gaps in terms of wavelengths<br><br>b) Absorbtion spectrum: It is defined as a spectrum of electromagnetic radiation transmitted through a substance, showing dark lines or bands due to absorption at specific wavelengths.<br>Emission spectrum: It is defined as a spectrum of radiation emitted by a substance that has absorbed energy. | 2 |
| 8  | c) It is because molality does not change with temperature as it involves mass of solvent.<br>d)<br>(i) 6 moles of carbon atom, (ii) 18 moles of hydrogen atoms   | 2 |

9

- c) This negative sign means that the energy of the electron in the atom is lower than the energy of a free electron at rest. A free electron at rest means that is infinitely far away from the nucleus and has the negligible attraction towards the nucleus. Thus it is assigned the energy value of zero.

2

d)

$$r = 0.529 \times n^2 A^0$$

For  $n = 3$

e)  $r = 4.761 A^0$

10

$\therefore$  Number of moles of  $H_2SO_4 = 1.35$

2

Wt. of solution =  $1000 \times 1.02 = 1020\text{g}$

Wt. of sulphuric acid =  $1.35 \times 98 = 132.3\text{g}$

Wt. of water =  $1020 - 132.3 = 887.7\text{g}$

$$\text{Molality of } H_2SO_4 = \frac{1.35}{887.7} \times 1000 = 1.52\text{m}$$

11

i)

$$E = hv = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{4 \times 10^{-7}} = 4.97 \times 10^{-19}\text{J}$$

$$= \frac{4.97 \times 10^{-19}}{1.6 \times 10^{-19}} = 3.1\text{eV}$$

ii)

kinetic energy of emission,

$$= hv - hv_0 = 3.1 - 2.13 = 0.97\text{eV}$$

iii)

$$\frac{1}{2}mv^2 = 0.97\text{eV} = 0.97 \times 1.6 \times 10^{-19}$$

$$\frac{1}{2}(9.11 \times 10^{-31}) \times v^2 = 0.97 \times 1.6 \times 10^{-19}$$

$$v^2 = 34.1 \times 10^{10}$$

$$v = 5.84 \times 10^5 \text{ms}^{-1}$$

3

12

Define:

3

- d) Limiting reagent: a reactant present to a lesser extent and therefore gets consumed completely .
- e) Law of multiple proportion : when two elements combine with each other to form more than one compound, the weights of one element that combine with a fixed weight of the other are in a ratio of small whole numbers.
- f) Mole fraction: it is the ratio of number of moles of a component to the total number of moles of all the components in a mixture

- 13 i) used in chemical analysis to identify unknown atoms  
 ii) Elements like rubidium (Rb), caesium (Cs) thallium (Tl), indium (In), gallium (Ga) and scandium (Sc) were discovered when their minerals were analysed by spectroscopic methods.  
 iii) The element helium (He) was discovered in the sun by spectroscopic method.

14 3 g of hydrogen will be the limiting reagent.



From the above equation, it is clear that 2 mole H<sub>2</sub> reacts with 1 mole O<sub>2</sub>

The molar mass of H<sub>2</sub> = 2 g

The molar mass of O<sub>2</sub> = 32 g

4 g H<sub>2</sub> react with 32 g O<sub>2</sub>

3 g H<sub>2</sub> reacts with =  $(32/4) \times 3$  g of O<sub>2</sub> gas= 24 g

As the given amount of O<sub>2</sub> is more than required therefore O<sub>2</sub> is the excess reagent and H<sub>2</sub> is the limiting reagent.

2 mole of hydrogen gas reacts to form 2 mole of the water molecule, therefore,

4 g of H<sub>2</sub> produces = 36 g of water

So the amount of H<sub>2</sub>O produced by 3 g H<sub>2</sub> =  $(36/4) \times 3 = 27$  g

Hence, 27 g of water will be produced during the reaction

As 24 g of oxygen has been utilized during the reaction and 29 g of oxygen was supplied

therefore the amount of oxygen gas left is  $(29-24) = 5$  g

- 15 State the observation when during photoelectric effect –

- d) Number of photoelectrons increase
- e) Kinetic energy of photoelectrons increase
- f) No photoelectric effect occurs

16 d) State Gay-Lussac's law states that the pressure of a given mass of gas varies directly with the absolute temperature of the gas when the volume is kept constant 5

e) It is a physical constant equal to one-twelfth of the mass of an unbound atom of carbon-12 (i) amu (ii)u.

f) (i) 1 mole of Ar =  $6.022 \times 10^{23}$  atoms of Ar  
52 moles of Ar =  $52 \times 6.022 \times 10^{23}$

$$\therefore 52 \text{ moles of Ar} = 3.13144 \times 10^{25} \text{ atoms of Ar}$$

(ii) The atomic mass of He is 4 amu.

**52 u of He will contain  $52/4 = 13$  atoms**



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### HALF YEARLY EXAM (2022-23)

**Subject: CHEMISTRY**

**Max. Marks:70**

**Grade: XI**

**Time: 3Hrs**

**Name:**

**Section:**

**Roll  
No:**

**General Instructions:**

- GENERAL INSTRUCTIONS: Read the following instructions carefully.
  - There are 37 questions in this question paper.
  - SECTION A - Q. No. 1 to 10 are multiple choice questions carrying 1mark each.
  - SECTION B - Q. No. 11 to 20 are very short answer questions carrying 1 mark each.
  - SECTION C - Q. No. 21 to 27 are short answer questions carrying 2 marks each.
  - SECTION D- Q. No. 28 to 34 are short answer questions carrying 3 marks each.
  - SECTION E- Q. No. 35 to 37 are long answer question carrying 5 marks.
  - All questions are compulsory.
  - Use of calculators is not allowed

#### SECTION A

1	If the concentration of glucose ( $C_6H_{12}O_6$ ) in blood is $0.9\text{ g L}^{-1}$ , what will be the molarity of glucose in blood? (a) 5 M (b) 50 M (c) 0.005 M (d) 0.5 M	1
2	Correct set of four quantum numbers for the valence electron of rubidium ( $Z = 37$ ) is : (a) 5, 0, 0, +1/2 (b) 5,1, 0, +1/2 (c) 5, 1, 1, +1/2	1

	(d) 6, 0, 0, + ½	
3	Which of the following molecules has maximum bond angle : (a) NH <sub>3</sub> (b) CH <sub>4</sub> (c) H <sub>2</sub> O (d) CO <sub>2</sub>	1
4	$6.02 \times 10^{20}$ molecules of urea are present in 100 mL of its solution. The concentration of the solution is : (a) 0.02 M (b) 0.01 M (c) 0.001 M (d) 0.1 M	1
5	In the reaction $6\text{ClO}_2^- \longrightarrow 4\text{ClO}_3^- + 2\text{Cl}^-$ , Cl <sup>-</sup> ion is (a) Oxidised and Reduced (b) Reduced (c) Oxidized (d) Neither Oxidised nor reduced	1
6	Which one undergoes disproportionation reaction? (a) HNO <sub>3</sub> (b) H <sub>2</sub> O (c) ClO <sub>4</sub> <sup>-</sup> (d) ClO <sub>2</sub> <sup>-</sup>	1
7	Which of the following is dependent of temperature ? (a) Molarity (b) Molality (c) Mole fraction (d) Mass percentage	1
8	Identify the molecule having sideways overlapping of atomic orbitals: (a) CH <sub>4</sub> (b) CO <sub>2</sub> (c) NH <sub>3</sub> (d) H <sub>2</sub> O	1
9	The oxidation state of Fe in Fe <sub>3</sub> O <sub>4</sub> is : (a) +2 (b) + 3 (c) 8/ 3	1

	(d) + 2, + 3	
10	The shape of XeF <sub>4</sub> molecule according to VSEPR theory is: (a) Square planar (b) Square pyramid (c) Tetrahedral (d) Pyramidal	1
<b>SECTION B</b>		
11	At what concentration of Cu <sup>2+</sup> (aq.) will electrode potential become equal to its standard electrode potential ?	1
12	Explain why BeH <sub>2</sub> molecule has zero dipole moment although the Be–H bonds are polar?	1
13	Write the maximum number of electron in a subshell with l = 3 and n = 4.	1
14	Which one is having higher energy? n = 4, l = 3 or n = 5, l = 2.	1
15	Using Stock notation, represent HAuCl <sub>4</sub> .	1
16	Boiling point of p-nitrophenol is more than O-nitrophenol why?	1
17	1L of a gas at STP weighs 1.97g. What is molecular mass ?	1
18	The displacement reactions of halogens using fluorine are not generally carried out in aqueous solution. Why?	1
19	Give one example each of a molecule in which empirical formula and molecular formula is (i) Same (ii) Different.	1
20	HNO <sub>3</sub> acts as oxidizing agent while HNO <sub>2</sub> can act both as reducing and oxidizing agent. Why?	1
<b>SECTION C</b>		
21	A compound with molar mass 180g/mol contains C, H and O in the molar ratio 1:2:1. What are its empirical and molecular formulae?	2
22	What are the quantum numbers for? a) 2p electrons in Nitrogen b) 19th electron of chromium	2
23	Draw the Lewis structure and calculate the formal charge on all elements of CO <sub>3</sub> <sup>2-</sup> ion.	2
24	Assign reasons for the following: (a) B <sub>2</sub> is paramagnetic while C <sub>2</sub> is diamagnetic. (b) H <sub>2</sub> and F <sub>2</sub> are nonpolar whereas HF is polar	2
25	a) Arrange the following in increasing order of energy for hydrogen 1s, 3s, 2p, 3p, 2s. b) Calculate the atomic number of an element having 4s <sup>2</sup> 4p <sup>6</sup> configuration in its last orbit?	2
26	a) What do you understand by the term dipole moment? Give its SI units  b) Why is water liquid whereas H <sub>2</sub> S is a gas at room temperature?	2

27	Calculate the momentum of a particle, which has a de Broglie wavelength of $1\text{A}^0$	2
<b>SECTION D</b>		
28	$\text{N}_2$ molecule has greater bond dissociation energy than $\text{N}_2^+$ ion whereas $\text{O}_2$ molecule has lower bond dissociation energy than $\text{O}_2^+$ ion. Explain in terms of MO theory.	3
29	Account for the following: (a) Cr has electronic configuration [Ar]3d5 4s1 and not [Ar]3d4 4s2 (b) In building up of atoms, the filling up of 4s orbitals takes place before the 3d orbitals. (c) The ground state configuration of Nitrogen is not written as $1\text{s}^2 2\text{s}^2 2\text{p}x^2 2\text{p}y^1 2\text{p}z^0$	3
30	Predict the shapes of the following molecules/ions using VSEPR Theory: (a) $\text{BrF}_5$ (b) $\text{XeF}_4$ (c) $\text{NH}_4^+$	3
31	(a) State Heisenberg's Uncertainty Principle. (b) Which of the two, an electron or a neutron will show more accuracy in its position, if there is an equal uncertainty in their velocities? [ mass of electron = $9.1 \times 10^{-31}$ Kg; mass of proton = $1.67 \times 10^{-27}$ Kg]	3
32	Commercially available sulphuric acid contains 93% by mass and has a density of 1.84g/cm <sup>3</sup> . Calculate : (i)molarity of the solution (ii)volume of concentrated acid required to prepare 2.5L of 0.50 M $\text{H}_2\text{SO}_4$	3
33	Balance the following reaction in basic medium: $\text{Al(s)} + \text{MnO}_4^-(\text{aq}) \longrightarrow \text{MnO}_2(\text{s}) + \text{Al(OH)}_4^-(\text{aq})$	3
34	Phosphorous and chlorine form two compounds. The first compound containing 22.54% by mass of phosphorous and 45.08% by mass of chlorine. In the second compound the percentages are 14.88 for phosphorous and 59.52 for chlorine. Show that this data is consistent with the law of multiple proportions.	3
<b>SECTION E</b>		
35	a) Why are 2d and 3f orbitals not possible? b) What is the significance of $\psi^2$ ? c) Calculate the uncertainty in the velocity of wagon of mass 2000 kg whose position is known to an accuracy of + 10m.	5
	<b>OR</b>	
	a) Which orbital experiences the lowest effective nuclear charge? i) 1s or 2s ii) 3p or 4p b) Calculate the frequency and wavelength of the radiation in nanometers emitted when an electron in the hydrogen atom jumps from third orbit to the ground state. In which region of the electromagnetic spectrum will this line lie?	

36	<p>a) What is a limiting reagent?      b) Which out of the two weighs more – 32 g of oxygen or 0.5 moles of iron?      c) Boron occurs in nature in the form of two isotopes, <math>^{11}\text{B}</math> and <math>^{10}\text{B}</math>, having an average atomic mass of 10.81. Find the % abundance of the two isotopes.</p> <p style="text-align: center;"><b>OR</b></p> <p>a) How many atoms are present in 52 u of He?      b) State the law of multiple proportion.      c) A mixture of 100g of <math>\text{H}_2</math> and 100g of <math>\text{O}_2</math> is ignited to form water. Identify the limiting reagent and calculate the amount of water formed.</p>	
37	<p>a) Out of NaCl and MgO, which has higher value of lattice energy and why?      b) Explain the hybridization and shape of ethyne.</p> <p style="text-align: center;"><b>OR</b></p> <p>a) The bond angles in <math>\text{PF}_5</math> are <math>90^\circ</math> and <math>120^\circ</math> while all bond angles in <math>\text{PF}_6^-</math> are <math>90^\circ</math>. Explain based on VSEPR theory.      b) Explain why <math>\text{NH}_3</math> is pyramidal whereas <math>\text{CH}_4</math> is tetrahedral although both nitrogen and carbon in <math>\text{NH}_3</math> and <math>\text{CH}_4</math> are <math>\text{sp}^3</math> hybridized?</p>	



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**HALF YEARLY EXAM (2022-23)**

<b>Subject:</b> <b>CHEMIST</b> <b>RY</b> <b>Grade: XI</b>	<b>Max. Marks:70</b> <b>Time: 3Hrs</b>
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**Name:** \_\_\_\_\_ **Section:** \_\_\_\_\_ **Roll No:** \_\_\_\_\_

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- SECTION E - Q. No. 35 to 37 are long answer question carrying 5 marks.
- All questions are compulsory.
- Use of calculators is not allowed

**SECTION A**

1	(d)0.5 M	1
2	e) 5, 0, 0, + 1/2	1
3	(d)CO <sub>2</sub>	1
4	(b)0.01 M	1
5	(d)Neither Oxidised nor reduced	1
6	(d)ClO <sub>2</sub> <sup>-</sup>	1
7	(e) Molarity	1
8	(b)CO <sub>2</sub>	1
9	(d)+ 2, + 3	1

10	(e) Square planar	1
<b>SECTION B</b>		
11	1M	1
12	Dipole moments of each H–Be bond are equal and are in opposite directions. Therefore, they nullify each other	1
13	14	1
14	$n = 5, l = 2$ .	1
15	$\text{HAu(III)}\text{Cl}_4$ .	1
16	p-nitrophenol is held by strong intermolecular H-bonding while O-nitrophenol has weak forces between them due to intramolecular H-bonding.	1
17	44.128 g	1
18	Fluorine is so highly reactive that it displaces oxygen from water	1
19	Give one example each of a molecule in which empirical formula and molecular formula is (i) $\text{H}_2\text{O}$ or any other (ii) $\text{C}_6\text{H}_{12}\text{O}_6$	1
20	In $\text{HNO}_3$ , N is in its highest OS hence it acts as oxidizing agent while in $\text{HNO}_2$ it is in its intermediate OS and can act both as reducing and oxidizing agent.	1
<b>SECTION C</b>		
21	Empirical formula = $\text{CH}_2\text{O}$ and molecular formula= $\text{C}_6\text{H}_{12}\text{O}_6$	2
22	What are the quantum numbers for? a) 2p electrons in Nitrogen : $n=2$ ; $l=1$ ; $m_l = -1, 0, 1$ b) 19th electron of chromium : $n=4$ ; $l=0$ ; $m_l = 0$	2
23	$O(a)=6-6=0$ $O(b)=6-7=-1$ $O(c)=6-7=-1$ $C=4-4=0$	2
24	Assign reasons for the following: (c) $\text{B}_2 : [\sigma 1s]2[\sigma^*1s]2[\sigma 2s]2[\sigma^*2s]2[\pi 2px]1[\pi 2py]1$ $\text{C}_2 : [\sigma 1s]2[\sigma^*1s]2[\sigma 2s]2[\sigma^*2s]2[\pi 2px]2[\pi 2py]$ Since, $\text{B}_2$ has two unpaired electrons, therefore, $\text{B}_2$ is paramagnetic $\text{C}_2$ has no unpaired electron, therefore, $\text{C}_2$ is diamagnetic	2

	(d) H <sub>2</sub> and F <sub>2</sub> both atoms in the molecule have the same electronegativity and so they share the electrons between them equally. The two atoms in HF have differing electronegativities, and so they do not share the bonding pair of electrons equally.			
25	c) 1s < 2s = 2p < 3s = 3p. d) 36	2		
26	c) Dipole moment is the product of magnitude of charge and the distance of separation between them. SI unit is Cm  d) Water has strong intermolecular H-bond hence a liquid whereas H <sub>2</sub> S has weak dipole-dipole forces hence is a gas at room temperature.	2		
27	$\lambda = \frac{h}{p}$ where p = momentum  $p = \frac{h}{\lambda} = \frac{6.625 \times 10^{-34}}{10^{-10}} = 6.625 \times 10^{-24} \text{ kg m/s}$	2		
	<b>SECTION D</b>			
28	$\therefore$ Bond order of N <sub>2</sub> = $\frac{1}{2}[8 - 2] = \frac{1}{2} \times 6 = 3$ Bond order of N <sub>2</sub> <sup>-</sup> = $\frac{1}{2}[8 - 3] = \frac{5}{2} = 2.5$ Bond order of O <sub>2</sub> = [8 - 4] = $\frac{4}{2} = 2$ Bond order of O <sub>2</sub> <sup>+</sup> = $\frac{1}{2}[8 - 3] = \frac{5}{2} = 2.5$	3		
29	Account for the following: (d) This is so because <b>half filled d orbitals have extra stability</b> <b>According to Aufbau principle, electrons first occupy the lowest-energy orbital available to them and enter into higher energy orbitals only after the lower energy orbitals are filled.</b>  <table style="width: 100%; text-align: center;"> <tr> <td style="width: 50%;"><b>4s orbital</b> <math>n = 4</math> <math>l = 0</math> <hr/><math>(e) \quad \underline{\underline{n + l = 4}}</math></td> <td style="width: 50%;"><b>3d orbital</b> <math>n = 3</math> <math>l = 2</math> <hr/><math>\underline{\underline{n + l = 5}}</math></td> </tr> </table> (f) According to Hund's rule, the electrons occupy the degenerate orbitals singly first	<b>4s orbital</b> $n = 4$ $l = 0$ <hr/> $(e) \quad \underline{\underline{n + l = 4}}$	<b>3d orbital</b> $n = 3$ $l = 2$ <hr/> $\underline{\underline{n + l = 5}}$	3
<b>4s orbital</b> $n = 4$ $l = 0$ <hr/> $(e) \quad \underline{\underline{n + l = 4}}$	<b>3d orbital</b> $n = 3$ $l = 2$ <hr/> $\underline{\underline{n + l = 5}}$			
30	(d) BrF <sub>5</sub> : square pyramidal (e) XeF <sub>4</sub> : square planar (f) NH <sub>4</sub> <sup>+</sup> : tetrahedral	3		
31	(c) It is impossible to determine the velocity and exact position of an electron simultaneously.	3		

	<p>(d) As per the Heisenberg's uncertainty principle,</p> $\Delta x \Delta V \geq \frac{h}{4\pi m}$ <p>As uncertainty in velocities is same, the one with more mass will have less uncertainty in position. i.e. more accuracy in position.</p> <p>So, neutron has more accuracy in position</p>	
32	<p>3% <math>\text{H}_2\text{SO}_4</math> by mass means that 93 g of <math>\text{H}_2\text{SO}_4</math> is present in 100 g of solution.</p> <p>Vol. of 100 g of solution = Mass/Density = <math>100/1.84 = 54.3</math> mL</p> <p>Moles of <math>\text{H}_2\text{SO}_4 = 93.98/98 = 0.95</math> mol</p> <p>Molarity = <math>0.95 \times 100/54.3 = 17.5</math> M</p> <p>(ii) Applying molarity equation.</p> $M_1V_1 = M_2V_2$ $17.5V_1 = 0.5 \times 2.5 \times 17.5$ $V_1 = 0.5 \times 2.5 / 17.5 = 0.5 \times 2.5 / 17.5$ $= 0.071 \text{ L} = 71 \text{ mL}$	3
33	$\text{Al} + 4\text{H}_2\text{O} \rightarrow \text{Al(OH)}_4^- + 4\text{H}^+ + 4e^- \quad ] \times 3$ $\text{MnO}_4^- + 4\text{H}^+ + 3e^- \rightarrow \text{MnO}_2 + 2\text{H}_2\text{O} \quad ] \times 4$ $3\text{Al(s)} + 4\text{MnO}_4^- (\text{aq}) + 4\text{H}^+ + 4\text{H}_2\text{O} \rightarrow 4\text{MnO}_2(\text{s}) + 3\text{Al(OH)}_4^- (\text{aq})$	3
34	<p>In compound 1, 1g of Cl combines with <math>\frac{22.54}{77.46} = 0.29</math> g of P.</p> <p>In compound 2, 1g of Cl combines with <math>\frac{14.88}{85.12} = 0.174</math> g of P.</p> <p>The ratio of total reacts with 1g of Cl is <math>0.29 : 0.174 \equiv 5 : 3</math></p> <p>Hence, data illustrate the law of multiple proportions.</p>	3
	<b>SECTION E</b>	
35	<p>d) For <math>n = 2</math>, the permitted values of <math>l</math> are 0 and 1. This means that the second shell has only s- and p-orbitals and no d-orbitals are present. Similar for <math>n = 3</math>, the permissible values of <math>l</math> are 0, 1, 2. Thus, only s, p and d orbitals are permitted and no f-orbital is present.</p>	5

- e)  $[\psi]^2$  is known as probability density and **determines the probability of finding an electron at a point within the atom.**

f)

$$\Delta u \cdot \Delta x = \frac{h}{4\pi m}$$

(Given  $\Delta x = 10\text{m}$ ;  $m = 2000\text{ kg}$ )

$$\therefore \Delta u \times 10 = \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 2000}$$

$$\therefore \Delta u = 2.64 \times 10^{-39}\text{ms}^{-1}$$

**OR**

c) i) 2s ii) 4p

d)

$$\bar{v} = R_H \left[ \frac{1}{n_1^2} - \frac{1}{n_2^2} \right], R_H = 109677\text{cm}^{-1}, n_1 = 1, n_2 = 3$$

$$\bar{v} = 109677 \left[ \frac{1}{1^2} - \frac{1}{3^2} \right] \text{cm}^{-1} = 109677 \times \frac{8}{9} \text{cm}^{-1} = 97480.7\text{cm}^{-1}.$$

$$\text{Wave length } (\lambda) = \frac{1}{\bar{v}} = \frac{1}{97490.7} \text{cm} = 1.03 \times 10^{-5} \text{cm} = 1.03 \times 10^{-7} \text{m} = 103 \times 10^{-9} \text{m} = 103\text{nm}.$$

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d) A reactant which is present to a lesser extent and hence gets consumed completely during the chemical reaction.

e) 32 g of oxygen

f)

Let the percentage abundance of first isotope be  ${}^10_B = x$

Hence the percentage abundance of second isotope is  ${}^11_B = 100 - x$ .

$$\text{Avg atomic mass} = \frac{x \times 10 + (100 - x) \times 11}{100}$$

$$1080 = 10x + 1100 - 11x$$

$$\text{or, } x = 20.$$

Hence the %abundance of the two isotopes are 20 & 80 %.

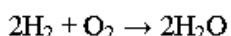
**OR**

a) The atomic mass of He is 4 amu.

52 gm of He will contain  $52/4 = 13$  atoms

b) if two elements form more than one compound, then the ratios of the masses of the second element which combine with a fixed mass of the first element will always be ratios of small whole numbers.

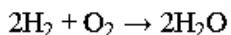
c)



$$100 \text{ gm H}_2 = \frac{100}{2} = 50 \text{ mole}$$

$$100 \text{ gm O}_2 = \frac{100}{32} = \frac{25}{8} \text{ mole}$$

According to stoichiometry



Since oxygen is limiting agent

$$\text{H}_2\text{O mole of H}_2\text{O} = \frac{25}{4}$$

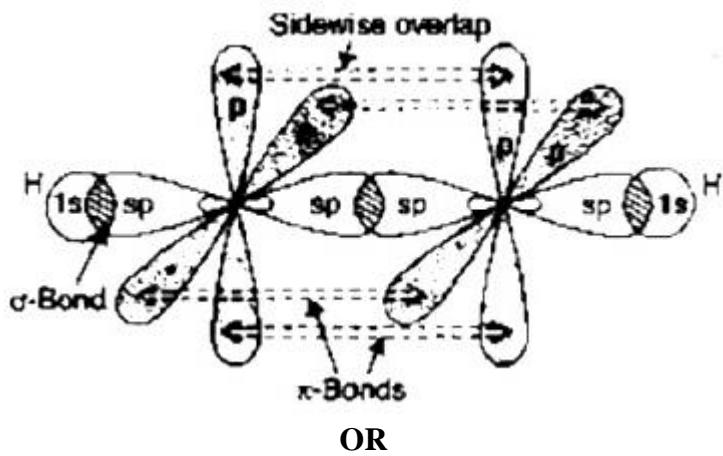
$$\text{Weight of H}_2\text{O} = \frac{25}{4} \times 18 = 112.5 \text{ gm}$$

37

c) MgO has higher lattice energy because each ion carries two-unit charge whereas in NaCl each ion carries one-unit charge.

d)

In the formation of ethyne ( $\text{C}_2\text{H}_2$ ), both the carbon atoms undergo sp hybridisation having two unhybridised orbitals ( $2\text{p}_x$  and  $2\text{p}_y$ ). One sp hybrid orbital of one carbon atom overlaps axially with sp hybrid orbital of the other carbon atom to form C-C sigma bond, while the other hybridised orbital of each carbon atom overlaps axially with the half filled s orbital of hydrogen atoms forming o bonds. Each of the two unhybridised p orbitals of both the carbon atoms overlaps sidewise to form two K bonds between the carbon atoms. Thus, ethyne has a linear geometry with  $\pi$  bond angle of  $180^\circ$ .



**OR**

- c) PF<sub>5</sub> is AB<sub>5</sub> type of molecule which has trigonal bipyramidal geometry hence the bond angle are 90° and 120° while all bond angles in PF<sub>6</sub><sup>-</sup> are 90° since it has octahedral geometry.

d)

The hybridisation in both CH<sub>4</sub> and NH<sub>3</sub> is sp<sup>3</sup>, yet CH<sub>4</sub> is tetrahedral and NH<sub>3</sub> is of pyramidal shape because (a) it contains three single bonds and no lone pair (b) it contains three single bonds and one lone pair (c) the number of surrounding atoms is three.



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<b>PERIODIC TEST 2 (2022-23)</b>		
<b>Subject: CHEMISTRY</b>	<b>Max. Marks:35</b>	
<b>Grade: XI</b>		<b>Time:1Hr15mts</b>
<b>Name:</b>	<b>Section:</b>	<b>Roll No:</b>
<b><u>General Instructions:</u></b>		
<ul style="list-style-type: none"> <li>• GENERAL INSTRUCTIONS: Read the following instructions carefully.</li> </ul> <ol style="list-style-type: none"> <li>1. There are 16 questions in this question paper .</li> <li>2. SECTION A - Q. No. 1 to 5 are multiple choice questions carrying 1marks each.</li> <li>3. SECTION B - Q. No. 6 to 10 are short answer questions carrying 2 marks each.</li> <li>4. SECTION C- Q. No. 11 to 15 are short answer questions carrying 3 marks each.</li> <li>5. SECTION C- Q. No. 16 is a long answer question carrying 5 mark.</li> <li>6. All questions are compulsory.</li> <li>7. Use of calculators is not allowed</li> </ol>		
<b>SECTION A</b>		
1	In which of the following resonance is possible (a) CH <sub>3</sub> -CH <sub>2</sub> -CH <sub>2</sub> -CHO (b) CH <sub>2</sub> =CH-CH=O (c) CH <sub>3</sub> COCH <sub>3</sub> (d) CH <sub>3</sub> -CH=CH-CH <sub>2</sub> -CHO	1
2	The alkane that gives only one monochloro product on chlorination with Cl <sub>2</sub> in presence of diffused sunlight is (a) 2,2-dimethylbutane (b) neopentane (c) n-pentane (d) isopentane	1
3	Reactivity of hydrogen atoms attached to different carbon atoms in alkanes has the order (a) tertiary > primary > secondary (b) primary > secondary > tertiary (c) both (a) and (b) (d) tertiary > secondary > primary	1
4	<b>Assertion (A) :</b> Among isomeric pentanes, 2, 2-dimethylpentane has lowest boiling point. <b>Reason (R) :</b> Branching does not affect the boiling point. Select the most appropriate answer from the options given below: a) Both A and R are true, and R is the correct explanation of A b) Both A and R are true, but R is not the correct explanation of A.	1

	c) A is true but R is false. d) A is false but R is true.	
5	<b>Assertion (A):</b> Pent- 1- ene and pent- 2- ene are position isomers. <b>Reason (R):</b> Position isomers differ in the position of functional group or a substituent Select the most appropriate answer from the options given below: a) Both A and R are true, and R is the correct explanation of A b) Both A and R are true, but R is not the correct explanation of A. c) A is true but R is false. d) A is false but R is true.	1
	<b>SECTION B</b>	
6	(i) Give the preparation of 2,3-Dimethyl hexane with the help of Wurtz reaction. (ii) Explain the limitation of Wurtz reaction.	2
7	Give reason for the following- (i) $(CH_3)_3C^+$ is more stable than $CH_3CH_2^+$ and $CH_3^+$ is the least stable cation. (ii) $O_2NCH_2CH_2O^-$ is expected to be more stable than $CH_3CH_2O^-$ . Explain?	2
8	(i) Give all the product which we are getting on pyrolysis of dodecane. (ii) Give the preparation of toluene though aromatization process.	2
9	Draw all possible alcohol isomer's of the given molecular formula of compound : $C_5H_{12}O$	2
10	(i) Why methane cannot be prepared by Kolbe's electrolytic method. (ii) Arrange the following compounds according to rate of reaction of alkanes with halogens $I_2$ , $Br_2$ , $F_2$ , $Cl_2$	2
	<b>SECTION C</b>	
1	Explain Kolbe's reaction with the help of its mechanism .	3
1	<b>Or</b>	
	How do you account for the formation of ethane during chlorination of methane?	
1	(a) Draw the resonating structures of Nitrobenzene .	3
2	(b) Arrange the following compound according to their acidic strength? <b>(i)</b> $NO_2CH_2COOH$ , $Cl_3C-COOH$ <b>(ii)</b> $F-CH_2CH_2CH_2COOH$ , $CH_3CHFCH_2COOH$ , $CH_3CH_2CHFCOOH$	
1	(i) Why iodination is carried out in the presence of oxidizing agents like $HIO_3$ or $HNO_3$ .	3
3	(ii) Give the two possible sodium salt of fatty acid which can form n-Butane through decarboxylation process?	
1	(i) Draw all the possible metamers of given compound(ether) $C_4H_{10}O$ ?	3
4	(ii) Out of given compound which can act as an electrophile : $SO_3$ , $PH_3$ , $H_2O$ , $NH_3$ (iii) Why geometrical isomerism not possible with Prop-1-ene?	

1	Convert the following –	1
5	(i) Ethane to ethanoic acid (ii) Propane to Propanal (iii) 2-Methyl butane to 2-Methyl butan-2-ol	2
	<b>SECTION D</b>	
1	Reaction of aldehyde and ketone with HCN to cyanohydrin follow which negative or positive effect.	
6	(b) Give the IUPAC name of the following: (i)	4
	$\text{OHC-CH}_2\text{-CH}(\text{OCH}_3)\text{-CH}_2\text{-CH-COOC}_2\text{H}_5$  $\text{HOOC-CH}_2\text{-CH}(\text{COOH})\text{-CH}_2\text{-COOH}$	
	(c) Write structural formulae of the following compounds (i) 3 – Hexenoic acid (ii) 2 – Formylbut – 3 - enenitrile	



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## Answer key PT 2 (2022-23)

**Subject: CHEMISTRY**

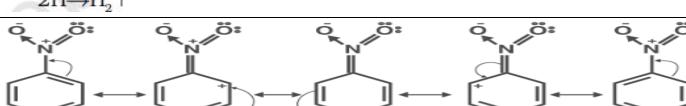
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**Grade: XI**

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<b>SECTION A</b>		
1	(b)	1
2	(b)	1
3	(d)	1
4	(b)	1
5	(a)	1
<b>SECTION B</b>		
6	i)1-Halo-2-methyl propane	2
7	i)Hyperconjugation interaction in $(\text{CH}_3)_3\text{C}^+$ is greater than in $\text{CH}_3\text{CH}_2^+$ as the $(\text{CH}_3)_3\text{C}^+$ has nine C-H bonds. In $\text{CH}_3^+$ , vacant p orbital is perpendicular to the plane in which C-H bonds lie; hence cannot overlap with it. Thus, $\text{CH}_3^+$ lacks hyper conjugative stability. ii) $\text{NO}_2$ group is an electron-withdrawing group and shows $-I$ effect. By withdrawing the electrons toward it, the $\text{NO}_2$ group decreases the negative charge on the compound, thereby stabilizing it. On the other hand, ethyl group is an electron-releasing group and shows $+I$ effect. This increases the negative charge on the compound, thereby destabilizing it.	2
8	$\text{C}_{12}\text{H}_{26} \xrightarrow[973\text{K}]{\text{Pt/Pd/Ni}} \text{C}_7\text{H}_{16} + \text{C}_5\text{H}_{10} + \text{other products}$ Dodecane      Heptane    Pentene	2
9	Alcohols: 1-pentanol 2-pentanol 3-pentanol 2-methylbutan-1-ol 2-methylbutan-2-ol 3-methylbutan-2-ol 3-methylbutan-1-ol 2,2-dimethylpropanol	2

10	i) Kolbe's electrolysis method is suitable for the preparation of symmetrical alkanes, that is alkanes containing even number of carbon atoms . <b>Methane has only one carbon</b> , hence it cannot be prepared by Kolbe' electrolytic method ii) F2>Cl2>Br2>I2	2
<b>SECTION C</b>		
11	i) $2\text{CH}_3\text{COO}^-\text{Na}^+ \rightleftharpoons 2\text{CH}_3-\overset{\text{O}}{\underset{\parallel}{\text{C}}}-\text{O}^- + 2\text{Na}^+$ ii) <b>At anode:</b> $2\text{CH}_3-\overset{\text{O}}{\underset{\parallel}{\text{C}}}-\text{O}^- \xrightarrow{-2e^-} 2\text{CH}_3-\overset{\text{O}}{\underset{\parallel}{\text{C}}}-\dot{\text{O}} \longrightarrow 2\text{CH}_3 + 2\text{CO}_2 \uparrow$ <p style="text-align: center;">Acetate ion      Acetate      Methyl free                         free radical      radical</p> iii) $\text{H}_3\dot{\text{C}} + \dot{\text{CH}}_3 \longrightarrow \text{H}_3\text{C}-\text{CH}_3 \uparrow$ iv) <b>At cathode :</b> $\text{H}_2\text{O} + e^- \rightarrow \text{OH} + \dot{\text{H}}$ $2\dot{\text{H}} \rightarrow \text{H}_2 \uparrow$	3
12	 (i) $\text{NO}_2\text{CH}_2\text{COOH} < \text{Cl}_3\text{C-COOH}$ (ii) $\text{F-CH}_2\text{CH}_2\text{CH}_2\text{COOH} < \text{CH}_3\text{CHFCH}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{CHFCOOH}$	3
13	(a) Iodination is very slow and a reversible reaction due to formation of strong reducing agent HI. So that's why carried out in the presence of oxidizing agents like $\text{HIO}_3$ or $\text{HNO}_3$ . (b) (i) Sodium pentanoate (ii) Sodium 2- methyl butanoate	3
14	(i) Three metamers are possible (ii) $\text{SO}_3$ (iii) propene does not show geometrical isomerism as it has same substituent (H atom) across double bonded carbon.	3
15	(ii) $\text{CH}_4 + \text{O}_2 \xrightarrow[\Delta]{\text{Mo}_2\text{O}_3} \text{HCHO} + \text{H}_2\text{O}$ Methanal (13.22) (iii) $2\text{CH}_3\text{CH}_3 + 3\text{O}_2 \xrightarrow[\Delta]{(\text{CH}_3\text{COO})_2\text{Mn}} 2\text{CH}_3\text{COOH}$ Ethanoic acid + $2\text{H}_2\text{O}$ (13.23) (iv) Ordinarily alkanes resist oxidation but alkanes having tertiary H atom can be oxidized to corresponding alcohols by potassium permanganate. $(\text{CH}_3)_3\text{CH} \xrightarrow[\text{Oxidation}]{\text{KMnO}_4} (\text{CH}_3)_3\text{COH}$ 2-Methylpropane                    2-Methylpropan-2-ol	1 2

SECTION D		
16	(a) Negative Electromeric acid (b) IUPAC names	1 4

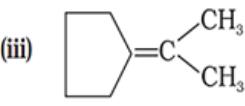


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<b>SECTION A</b>		
1	For an electrophilic substitution reaction, the presence of a halogen atom in the benzene ring _____.  a) activates the ring by inductive effect b) deactivates the ring by resonance c) increases the charge density at ortho and para position relative to meta position by resonance d) directs the incoming electrophile to meta position by increasing the charge density relative to ortho and para position.	1
2	The enthalpies of elements in their standard states are taken as zero. The enthalpy of formation of a compound  a) is always negative b) is always positive c) may be positive or negative d) is never negative	1
3	Which of the following alkenes on ozonolysis give a mixture of ketones only?  (i) $\text{CH}_3-\text{CH}=\text{CH}-\text{CH}_3$	1

	<p>(ii) <math>\begin{array}{c} \text{CH}_3-\text{C}-\text{CH}=\text{CH}_2 \\   \\ \text{CH}_3 \end{array}</math></p> <p>(iii) </p> <p>iv) <math>\text{CH}_3\text{CH}=\text{CH}_2</math></p>	
4	<p><b>Assertion (A):</b> The compound cyclooctane has the following structural formula:</p>  <p>It is cyclic and has conjugated <math>8\pi</math>-electron system but it is not an aromatic compound.</p> <p><b>Reason (R):</b> <math>(4n + 2)\pi</math> electrons rule does not hold good and ring is not planar.</p> <p>a) Both A and R are correct and R is the correct explanation of A.  b) Both A and R are correct but R is not the correct explanation of A.  c) Both A and R are not correct.  d) A is not correct but Incorrect.</p>	1
5	<p><b>Assertion (A):</b> Combustion of all organic compounds is an exothermic reaction.</p> <p><b>Reason (R):</b> The enthalpies of all elements in their standard state are zero.</p> <p>a) Both A and R are true and R is the correct explanation of A.  b) Both A and R are true but R is not the correct explanation of A.  c) A is true but R is false.  d) A is false but R is true.</p>	1
	<b>SECTION B</b>	
6	An alkene 'A' on ozonolysis gives a mixture of ethanal and 2 – methylpentan – 3 – one. Write the structure and IUPAC name of 'A'	2
7	<p>a) 18.0 g of water completely vapourises at <math>100^{\circ}\text{C}</math> and 1 bar pressure and the enthalpy change in the process is <math>40.79 \text{ kJ mol}^{-1}</math>. What will be the enthalpy change for vapourising two moles of water under the same conditions? What is the standard enthalphy of vapourisation for water?</p>	2

	b) What kind of system is the coffee held in a cup?	
8	How will you convert the following: a) 2-methyl propene to 2-methyl propan-2-ol b) Phenol to benzene	2
9	a) Change in internal energy is a state function while work is not, why? b) In a certain process, 6000 J of heat is added to a system while the system does work equivalent to 9000 J by expanding against the surrounding atmosphere. What is the change in internal energy for the system?	2
10	Explain with examples what are the necessary conditions for any system to be aromatic?	2
<b>SECTION C</b>		
11	a) The enthalpy of vapourisation of $\text{CCl}_4$ is $30.5 \text{ kJ mol}^{-1}$ . Calculate the heat required for the vapourisation of 284 g of $\text{CCl}_4$ at constant pressure. Ans. Given that enthalpy of vaporization of 1 mole of $\text{CCl}_4$ = $30.5 \text{ kJ/mol}$ . b) Derive the relationship between $C_p$ and $C_v$ .	3
12	a) Give the mechanism of addition of HBr to propene. b) What is Lindlar's catalyst?	3
13	a) The standard heat of formation of $\text{Fe}_2\text{O}_3$ (s) is $824.2 \text{ kJ mol}^{-1}$ Calculate heat change for the reaction. $4\text{Fe(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Fe}_2\text{O}_3\text{(s)}$ b) Write the statement of Hess's law.	3
14	a) How will you distinguish between 2-methyl propene and but-2-ene? b) Identify <b>A</b> and <b>B</b> in the given reactions: $\begin{array}{ccc} \text{1,2-dibromo ethane} & \xrightarrow{\text{(i) alcoholic KOH}} & \text{A} \\ & \xrightarrow{\hspace{1cm}} & \xrightarrow{\text{(ii) NaNH}_2} \text{B} \\ & & \xrightarrow{873\text{K}} \end{array}$	3
15	Calculate the standard enthalpy of formation of $\text{CH}_3\text{OH(l)}$ from the following data:  $\text{CH}_3\text{OH(l)} + \text{O}_{2(g)} \rightarrow \text{CO}_{2(g)} + 2\text{H}_2\text{O(l)} ; \Delta_f H^\theta = -726 \text{ kJ mol}^{-1}$  $\text{C(g)} + \text{O}_{2(g)} \rightarrow \text{CO}_{2(g)} ; \Delta_c H^\theta = -393 \text{ kJ mol}^{-1}$  $\text{H}_{2(g)} + \frac{1}{2}\text{O}_{2(g)} \rightarrow \text{H}_2\text{O(l)} ; \Delta_f H^\theta = -286 \text{ kJ mol}^{-1}$	3

<b>SECTION D</b>	
16	<p>a) How will you distinguish between a) propane and propene using a chemical test? Give equation also.</p> <p>b) Give a method of preparation of propene from i) an alkyne ii) from an alkyl halide.</p> <p>c) Draw the cis and trans structures of hex-2-ene. Which isomer will have higher boiling point and why?</p>

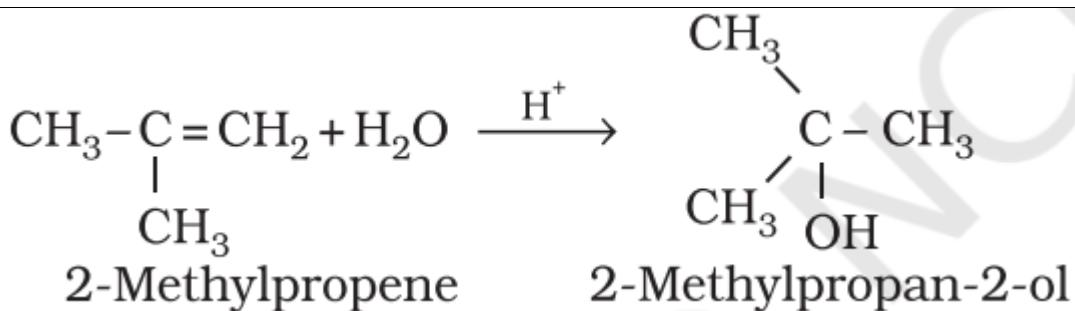


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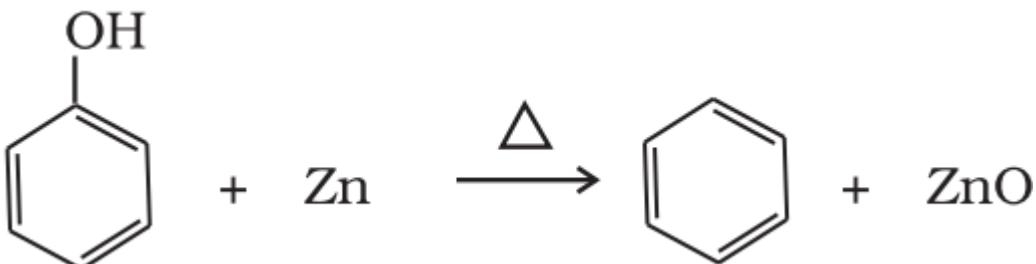
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<b>SECTION A</b>		
1	c	1
2	c	1
3	c	1
4	a	1
5	b	1
<b>SECTION B</b>		
6	The alkene A is 3-Ethyl-4-methylpent-2-ene. On ozoloysis, it gives a mixture of ethanal and 2 – methylpentan – 3 – one. Equation required	2
7	c) Enthalpy change for vaporizing 18g of water means 1 mol water. Given that the enthalpy change for 1 mole of water = 40.79 kJ/mol. Therefore, enthalpy change for 2 moles of water $= 2 \times 40.79 = +81.58 \text{ kJ}$ , $\Delta_{\text{vap}} H = +40.79 \text{ kJ mol}^{-1}$ . d) Coffee held in a cup is an open system because it can exchange matter (water vapors) and energy (heat) with the surroundings.	2
8	c) In the presence of a few drops of concentrated sulphuric acid alkenes react with water to form alcohols, in accordance with the Markovnikov rule.	2



- d) Phenol is reduced to benzene by passing its vapours over heated zinc dust



- 9 c) The change in internal energy during a process depends only upon the initial and final state of the system. Therefore it is a state function. But the work is related to the path followed. Therefore, it is not a state function rather it is a path function

$$\Delta U = UB - UA = q - w$$

$$\Delta U = 6000 \text{ J} - 9000 \text{ J} = -3000 \text{ J}$$

Hence, the change in internal energy for the system is equal to  $-3000 \text{ J}$

- 10 A compound is said to be aromatic if it satisfies the following three conditions:

(i) It should have a planar structure.

(ii) The  $\pi$  - electrons of the compound are completely delocalized in the ring.

(iii) The total number of  $\pi$  - electrons present in the ring should be equal to  $(4n + 2)$ , where  $n = 0, 1, 2 \dots$  etc. This is known as Huckel's rule.

e.g. benzene, naphthalene.

### SECTION C

- 11 a) It means 1 mole of  $\text{CCl}_4 = 154 \text{ g}$ .

$154 \text{ g}$  requires heat of vaporization  $= 30.5 \text{ kJ/mol}$ .

$\therefore$  Heat required for vapourisation of  $284 \text{ g}$  of  $\text{CCl}_4$

$$= \frac{284\text{g}}{154\text{g mol}^{-1}} \times 30.5 \text{ kJ/mol}^{-1}$$

$$= 56.2 \text{ KJ}$$

b)

At constant volume, the heat capacity, C is denoted by  $C_v$  and at constant pressure, this is denoted by  $C_p$ . Let us find the relationship between the two.

We can write equation for heat, q

at constant volume as  $q_v = C_v \Delta T = \Delta U$

at constant pressure as  $q_p = C_p \Delta T = \Delta H$

The difference between  $C_p$  and  $C_v$  can be derived for an ideal gas as:

For a mole of an ideal gas,  $\Delta H = \Delta U + \Delta(pV)$

$$= \Delta U + \Delta(RT)$$

$$= \Delta U + R\Delta T$$

$$\therefore \Delta H = \Delta U + R\Delta T \quad (6.12)$$

On putting the values of  $\Delta H$  and  $\Delta U$ , we have

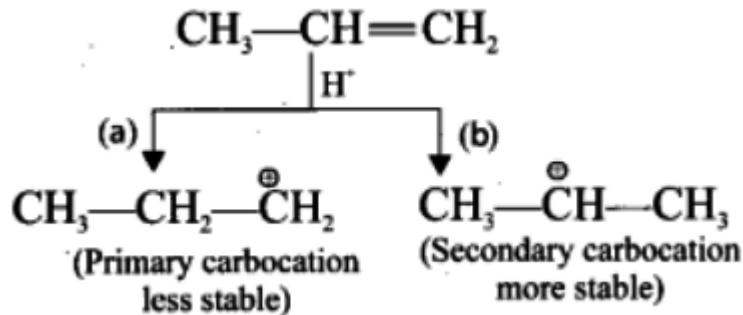
$$C_p \Delta T = C_v \Delta T$$

$$C_p = C_v + R$$

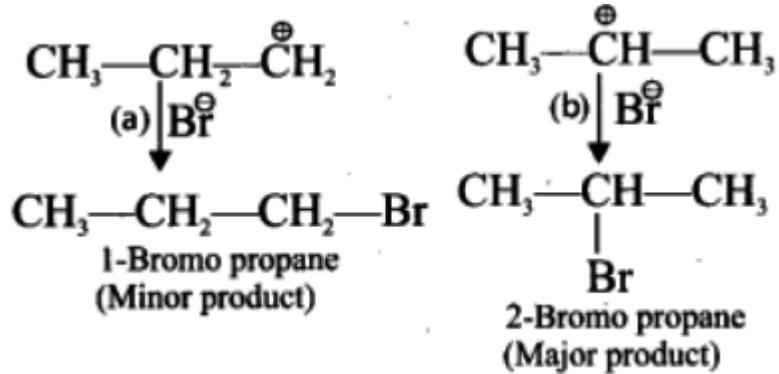
$$C_p - C_v = R \quad (6.13)$$

2

- 12 c) Step 1: Formation of electrophile: In HBr, Br is more electronegative than H. When bonded electron move towards Br, polarity is developed and it creates electrophile H<sup>+</sup> which attacks to the double bond to form a carbocation.



Step 2 : Secondary carbonation is more stable than primary carbonation and it predominates over the primary carbonation. Step 3 : The Br-1 ion attack the 2°- carbocation to form 2- Bromo propane as the major product.



- d) Lindlar catalyst is a heterogeneous catalyst that consists of palladium deposited on calcium carbonate or barium sulphate which is then poisoned with various forms of lead or sulphur like lead acetate or quinoline.

It is used for the reduction of alkyne to cis-alkenes.

1

13      a) 
$$\Delta H^\circ = \sum \Delta H_f^\circ (\text{products}) - \sum \Delta H_f^\circ (\text{reactants})$$

$$= [2 \times \Delta H_f^\circ \text{Fe}_2\text{O}_3(\text{s})] - [4 \Delta H_f^\circ \text{Fe}(\text{s}) + 3 \Delta H_f^\circ \text{O}_2(\text{g})]$$

$$= 2(-824.2 \text{ kJ}) - [4 \times 0 + 3 \times 0]$$

$$= \underline{\underline{-1648.4 \text{ kJ}}}$$

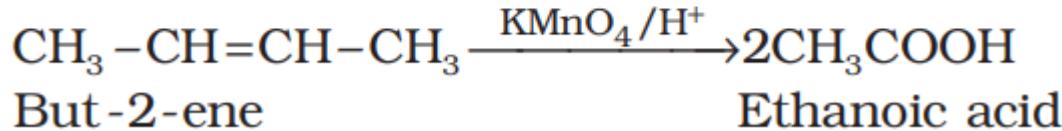
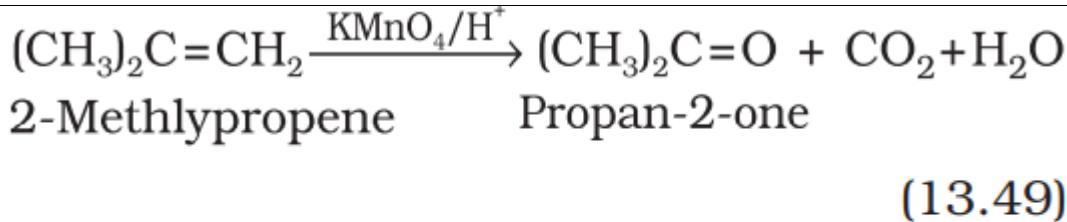
2

- b) Hess law: It states that the total amount of heat evolved or absorbed in a reaction is the same whether the reaction takes place in one step or in several steps.

1

- 14      c) Acidic potassium permanganate or acidic potassium dichromate oxidises alkenes to ketones and/or acids depending upon the nature of the alkene and the experimental conditions

2



1

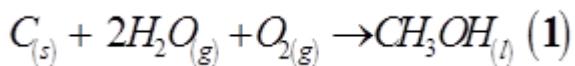
d) Identify A and B in the given reactions:

A-Ethyne

B-Benzene

15

The reaction that takes place during the formation of  $\text{CH}_3\text{OH}$  (*l*) can be written as:



The reaction (1) can be obtained from the given reactions by following the algebraic calculations as:

Equation (ii) + 2 × equation (iii) - equation (i)

$$\begin{aligned}
 \Delta_f H^\circ [\text{CH}_3\text{OH}_{(l)}] &= \Delta_c H^\circ + 2\Delta_f H^\circ [\text{H}_2\text{O}_{(l)}] - \Delta_r H^\circ \\
 &= (-393 \text{ kJ mol}^{-1}) + 2(-286 \text{ kJ mol}^{-1}) - (-726 \text{ kJ mol}^{-1}) = (-393 - 572 + 726) \text{ kJ mol}^{-1} \\
 \therefore \Delta_f H^\circ [\text{CH}_3\text{OH}_{(l)}] &= -239 \text{ kJ mol}^{-1}
 \end{aligned}$$

#### SECTION D

16

d) Halogens like Br and Cl add up to propene to form vicinal dihalides. The reddish orange colour of the bromine solution in  $\text{CCl}_4$  is discharged  
Equations



e) i)

3

1

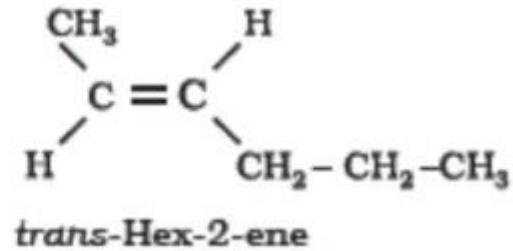
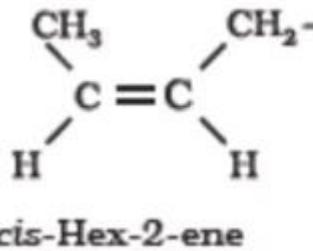
2



ii)

- f) The cis form will have higher boiling point due to more polar nature leading to stronger intermolecular dipole-dipole interaction, thus requiring more heat energy to separate them.

2





**EEE CONSORTIUM  
FINAL EXAMINATION (2022-23 )**

**Subject: CHEMISTRY**

**Max. Marks: 70**

**Grade: 11**

**Time: 3 hrs**

**Name:**

**Section:**

**Roll No:**

**General Instructions:**

**Read the following instructions carefully.**

- a) There are 35 questions in this question paper with internal choice.
- b) SECTION A consists of 18 multiple-choice questions carrying 1 mark each.
- c) SECTION B consists of 7 very short answer questions carrying 2 marks each.
- d) SECTION C consists of 5 short answer questions carrying 3 marks each.
- e) SECTION D consists of 2 case- based questions carrying 4 marks each.
- f) SECTION E consists of 3 long answer questions carrying 5 marks each.
- g) All questions are compulsory.
- h) Use of log tables and calculators is not allowed

**SECTION A**

The following questions are multiple-choice questions with one correct answer. Each question carries 1 mark. There is no internal choice in this section.

- |    |   |   |
|----|---|---|
| Q1 | Find the molecule with the maximum dipole moment.   | 1 |
|    | (a) CH <sub>4</sub> (b) NH <sub>3</sub> (c) CO <sub>2</sub> (d) NF <sub>3</sub>                       |   |
| Q2 | How many ml of water must be added to 200 ml of 0.65 M HCl to further dilute the solution to 0.20 M ? | 1 |
|    | (a) 450 ml      (b) 750 ml      (c) 550 ml      (d) 500 ml  |   |
| Q3 | The element with atomic number 35 belongs to:   | 1 |
|    | (a) d – Block      (b) f – Block      (c) p – Block      (d) s – Block                                |   |

- Q4 The I.U.P.A.C. name of the following compound is: 1
- CC(C)C(Br)C(=O)O
- (a) 2-Bromo-3-methylbutanoic acid  
 (b) 3-Bromo-2-methylbutanoic acid  
 (c) 2-Bromo-2-methylbutanoic acid  
 (d) 3-Bromo-3-methylbutanoic acid
- Q5 During change of  $O_2$  to  $O_2^{2-}$  ion, the electron adds on which of the following orbitals ? 1
- (a)  $\sigma^*$  orbital      (b)  $\pi$  orbital      (c)  $\sigma$  orbital      (d)  $\pi^*$  orbital
- Q6 Which of the following pairs of gases contains the same number of molecules? 1
- (a) 16 g of  $O_2$  and 14 g of  $N_2$       (b) 6 g of  $O_2$  and 22 g of  $CO_2$   
 (c) 28 g of  $N_2$  and 22 g of  $CO_2$       (d) 32 g of  $CO_2$  and 32g of  $N_2$
- Q7 Oxidation number of P in  $PO_4^{3-}$ , of S in  $SO_4^{2-}$  and that of Cr in  $Cr_2O_7^{2-}$  are respectively: 1
- (a) +3, +6 and +5      (b) +5, +3 and +6  
 (c) +3, +6 and +6      (d) +5, +6 and +6
- Q8 Isopropyl bromide on Wurtz reaction gives: 1
- (a) Hexane      (b) Propane  
 (c) 2, 3 – Dimethylbutane      (d) Neo hexane
- Q9 Find the pair with  $sp^2$  hybridisation of the central atom: 1
- (a)  $NH_3$  and  $NO_2^-$       (b)  $BF_3$  and  $NH_2^-$   
 (c)  $BF_3$  and  $NO_2^-$       (d)  $NH_2^-$  and  $H_2O$
- Q10 In a process, 701 J of heat is absorbed by a system and 394 J of work is done by the system. What is the change in internal energy for the process? 1
- (a) 307 J      (b) 209 J      (c) 394 J      (d) 500 J
- Q11 In a reversible chemical reaction at equilibrium, if the concentration of any one of the reactants is doubled, then the equilibrium constant will: 1
- (a) Also be Doubled      (b) Be Halved  
 (c) Remain the Same      (d) Become One-Fourth
- Q12 Arrange the following in order of increasing oxidation number of Mn: 1
- (a)  $MnCl_2$ ,  $MnO_2$ ,  $Mn(OH)_3$       (b)  $MnCl_2$ ,  $Mn(OH)_3$ ,  $MnO_2$   
 (c)  $Mn(OH)_3$ ,  $MnCl_2$ ,  $MnO_2$       (d)  $MnO_2$ ,  $Mn(OH)_3$ ,  $MnCl_2$
- Q13 Benzene reacts with  $CH_3Cl$  in the presence of anhydrous  $AlCl_3$  to form: 1
- (a) Chlorobenzene      (b) Benzyl chloride      (c) xylene      (d) toluene
- Q14 The ion which is iso-electronic with CO is \_\_\_\_\_ 1

- |     |  |                    |                    |                    |   |   |
|-----|--|--------------------|--------------------|--------------------|---|---|
|     | (a) $\text{CN}^-$  | (b) $\text{O}_2^-$ | (c) $\text{N}_2^+$ | (d) $\text{O}_2^+$ |   |   |
| Q15 | In the following questions from Q15 to Q18 a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.                  |                    |                    |                    | 1 |   |
|     | (a) Both assertion and reason are wrong.   |                    |                    |                    |   |   |
|     | (b) Both assertion and reason are correct statements but reason is not correct explanation of assertion.   |                    |                    |                    |   |   |
|     | (c) Assertion is correct statement but reason is wrong statement.  |                    |                    |                    |   |   |
|     | (d) Both assertion and reason are correct statements and reason is correct explanation of assertion.   |                    |                    |                    |   |   |
|     | (e) Assertion is wrong statement but reason is correct statement.  |                    |                    |                    |   |   |
|     | <b>Assertion (A):</b> The empirical mass of ethene is half of its molecular mass.  |                    |                    |                    |   |   |
|     | <b>Reason (R):</b> The empirical formula represents the simplest whole number ratio of various atoms present in a compound.  |                    |                    |                    |   |   |
| Q16 | <b>Assertion (A):</b> Boron has a smaller first ionisation enthalpy than beryllium.  |                    |                    |                    |   | 1 |
|     | <b>Reason (R):</b> The penetration of a 2s electron to the nucleus is more than the 2p electron hence 2p electron is more shielded by the inner core of electrons than the 2s electrons. |                    |                    |                    |   |   |
| Q17 | <b>Assertion (A):</b> A liquid crystallises into a solid and is accompanied by decrease in entropy.  |                    |                    |                    |   | 1 |
|     | <b>Reason (R):</b> In crystals, molecules organise in an ordered manner.   |                    |                    |                    |   |   |
| Q18 | <b>Assertion (A):</b> For any chemical reaction at a particular temperature, the equilibrium constant is fixed and is a characteristic property.   |                    |                    |                    |   | 1 |
|     | <b>Reason (R):</b> Equilibrium constant is independent of temperature.   |                    |                    |                    |   |   |

### SECTION B

This section contains 7 questions with internal choice in two questions. The following questions are very short answer type and carry 2 marks each.

- |     |  |  |  |  |  |   |
|-----|--|--|--|--|--|---|
| Q19 | Two elements C and D have atomic numbers 36 and 58 respectively. On the basis of electronic configuration predict the group, and period to which each element belongs. |  |  |  |  | 2 |
| Q20 | Give reason for the following:   |  |  |  |  | 2 |
|     | (i) Neither q nor w is a state function but $q + w$ is a state function.   |  |  |  |  |   |
|     | (ii) A real crystal has more entropy than an ideal crystal.  |  |  |  |  |   |

OR

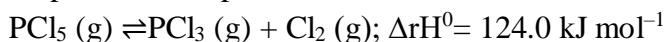
Discuss the effect of temperature on the spontaneity of an exothermic reaction.

- |     |  |  |  |  |  |   |
|-----|--|--|--|--|--|---|
| Q21 | A reaction between ammonia and boron trifluoride is given below: |  |  |  |  | 2 |
|     | $\text{:NH}_3 + \text{BF}_3 \rightarrow \text{H}_3\text{N:BF}_3$ |  |  |  |  |   |

Identify the acid and base in this reaction. Which theory explains it?

OR

If decomposition is depicted as,



What would be the effect on Kc if?

- (i) pressure is increased.
- (ii) the temperature is increased.

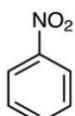
Q22 For each of the following pairs, predict which one has lower first ionization enthalpy? 2

- (i) N or O
- (ii) Na or Na<sup>+</sup>

Q23 Balance the following redox reaction: 2



Q24 Draw the resonance structures for C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>. 2



Q25 Derive the relationship Cp – Cv = R. 2

### SECTION C

This section contains 5 questions with internal choice in two questions. The following questions are short answer type and carry 3 marks each.

Q26 Use the molecular orbital theory to show that N<sub>2</sub> would be expected to have a triple bond, F<sub>2</sub> a single bond and Ne<sub>2</sub> no bond. 3

Q27 Yellow light emitted from a sodium lamp has a wavelength ( $\lambda$ ) of 580 nm. Calculate the frequency ( $\nu$ ) and wave number of the yellow light. 3

OR

Find energy of each of the photons which:

- (i) corresponds to light of frequency  $3 \times 10^{15} \text{ Hz}$ .
- (ii) have wavelength of  $0.50 \text{ \AA}^\circ$ .

Q28 (i) Why is benzene extra-ordinarily stable though it contains three double bonds? 3  
(ii) Arrange benzene, n-hexane and ethyne in decreasing order of acidic behaviour. Also give reason for this behaviour.

OR

How will you convert the following compounds into benzene?

- (i) Ethyne
- (ii) Ethene
- (iii) Hexane.

Q29 A hydrocarbon 'A' adds one mole of hydrogen in the presence of Pt as catalyst to form n-hexane. 'A' is oxidized vigorously with KMnO<sub>4</sub>, a single carboxylic acid containing three carbon atoms is isolated. Give the structure and name of 'A', explain and name the reactions. 3

- Q30 The enthalpy of combustion of methane, graphite and dihydrogen at 298 K are -890.3 KJ mol<sup>-1</sup>, - 393.5 KJmol<sup>-1</sup> and – 285.8 KJ mol-respectively. Calculate enthalpy of formation of CH<sub>4</sub> (g)? 3

#### SECTION D

The following questions are case-based questions. Each question has an internal choice and carries 4 (1+1+2) marks each. Read the passage carefully and answer the questions that follow.

- Q31 The identity of a substance is defined not only by the types of atoms or ions it contains, but by the quantity of each type of atom or ion. The experimental approach required the introduction of a new unit for amount of substances, the mole, which remains indispensable in modern chemical science. The mole is an amount unit similar to familiar units like pair, dozen, gross, etc. It provides a specific measure of the number of atoms or molecules in a bulk sample of matter. A mole is defined as the amount of substance containing the same number of discrete entities (atoms, molecules, ions, etc.) as the number of atoms in a sample of pure 12C weighing exactly 12g. One Latin connotation for the word “mole” is “large mass” or “bulk,” which is consistent with its use as the name for this unit. The mole provides a link between an easily measured macroscopic property, bulk mass, and an extremely important fundamental property, number of atoms, molecules and so forth. The number of entities composing a mole has been experimentally determined to be  $6.02214179 \times 10^{23}$ . 4

$6.02214179 \times 10^{23}$ , a fundamental constant named Avogadro’s number ( $N_A$ ) or the Avogadro constant in honour of Italian scientist Amedeo Avogadro. This constant is properly reported with an explicit unit of “per mole,” a conveniently rounded version being  $6.022 \times 10^{23}/\text{mol}$ . Consistent with its definition as an amount unit, 1 mole of any element contains the same number of atoms as 1 mole of any other element. The masses of 1 mole of different elements, however, are different, since the masses of the individual atoms are drastically different. The molar mass of an element (or compound) is the mass in grams of 1 mole of that substance, a property expressed in units of grams per mole (g/mol).

(i) A sample of copper sulphate pentahydrate contains 8.64 g of oxygen. How many grams of Cu is present in the sample?

- (a) 0.952g (b) 3.816g (c) 3.782g (d) 8.64g

(ii) The mass of oxygen gas which occupies 5.6 litres at STP could be

- (a) gram atomic mass of oxygen  
(b) one fourth of the gram atomic mass of oxygen

- (c) double the gram atomic mass of oxygen  
 (d) half of the gram atomic mass of oxygen  
 (iii) Find the number of moles and number of atoms of H and S in 10 mole of  $\text{H}_2\text{S}$ .

OR

Calculate the number of atoms of each element in 245 g of  $\text{KClO}_3$ .

- Q32 Orbitals are regions or spaces where there is a maximum probability of finding electrons. Qualitatively, these orbitals can be distinguished by their size, shape, and orientation. An orbital of small size means there is more chance of finding the electron near the nucleus. Shape and orientation mean the direction in which the probability of finding the electron is maximum. Atomic orbitals can be distinguished by quantum numbers. Each orbital is designated by three quantum numbers n, l, and ml (magnetic quantum number) which define energy, shape, and orientation but these are not sufficient to explain spectra of multi-electrons atoms. Spin quantum number ( $m_s$ ) determines the spin of electrons. Spin angular momentum of the electron has two orientations relative to the chosen axis which are distinguished by spin quantum numbers  $m_s$  which can take values +1/2 and -1/2.

(i) How many orbitals are associated with  $n = 3$ ?

- (a) 3                    (b) 9                    (c) 18                    (d) 32

(ii) How many maximum electrons are possible in an orbital of 3d?

- (a) 0                    (b) 2                    (c) 10                    (d) 6

(iii) What is the shape of 's' and 'p' orbitals?

OR

Name two d-orbitals that are on-axis.

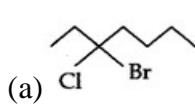
### SECTION E

The following questions are long answer type and carry 5 marks each. Two questions have an internal choice.

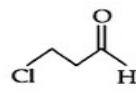
- Q33 (i) Complete the following: 5
- (a) Isopropyl bromide      alc. KOH      A      HBr      B  
                                 Heat                          Peroxide
- (b) 1,1,2,2-tetra chloroethane      Zn, alcohol      A      Iron tube      B  
                                 Heat                                  675K
- (ii) An unsaturated hydrocarbon A adds two molecules of  $\text{H}_2$  and on reductive ozonolysis gives butan-1,4-dial, ethanal and propanone. Give the structure of A, write its IUPAC name and explain the reactions.

- Q34 (i) Write bond-line formulas for: tertiary butylalcohol, 2,3-Dimethylbutanol 5

(ii) Give the TUPAC names of the following compounds:



(b)



OR

- (i) Write two points of differences between homolytic fission and heterolytic fission  
(ii) Arrange the following carbocations in increasing order of their stability:  $(\text{CH}_3)_3\text{C}^+$ ,  $\text{CH}_3\text{CH}_2^+$ ,  $(\text{CH}_3)_2\text{CH}^+$

Justify your answer.

Q35 (i) Describe the effect of:

5

- (a) Addition of  $\text{H}_2$       (b) Addition of  $\text{CH}_3\text{OH}$   
(c) Removal of CO      (d) Removal of  $\text{CH}_3\text{OH}$

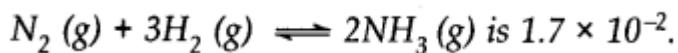
on the equilibrium of the reaction:  $2\text{H}_2(\text{g}) + \text{CO}(\text{g}) \leftrightarrow \text{CH}_3\text{OH}$

(ii) 13.8 g of  $\text{N}_2\text{O}_4$  was placed in a 1 L reaction vessel at 400 K and allowed to attain equilibrium:  $\text{N}_2\text{O}_4(\text{g}) \leftrightarrow 2\text{NO}_2(\text{g})$ ; The total pressure at equilibrium was found to be 9.15 bar. Calculate  $K_c$ ,  $K_p$  and partial pressure at equilibrium.

OR

(i) State Le-Chatelier principle and mention the factors affecting equilibrium.

(ii) A mixture of 1.57 mol of  $\text{N}_2$ , 1.92 mol of  $\text{H}_2$  and 8.13 mol of  $\text{NH}_3$  is introduced into a 20 L reaction vessel at 500 K. At this temperature, the equilibrium constant  $K_c$  for the reaction.



Is this reaction at equilibrium? If not, what is the direction of net reaction?

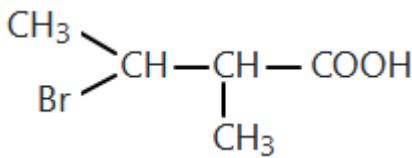
**EEE CONSORTIUM**  
**FINAL EXAMINATION (2022-23)**

**Class: 11**

**Subject: CHEMISTRY(ANSWER KEY)**

**MM:70**

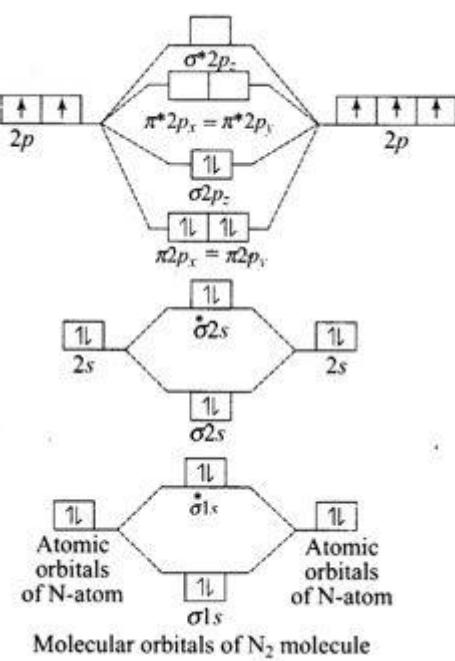
**Time: 3 hours**

<b>SECTION A</b>			
	The following questions are multiple-choice questions with one correct answer. Each question carries 1 mark. There is no internal choice in this section.		
<b>Q1</b>	<b>Find the molecule with the maximum dipole moment</b>	(a) CH <sub>4</sub> , (b) NH <sub>3</sub> (c) CO <sub>2</sub> (d) NF <sub>3</sub>	1
	<b>Answer: (b)</b>		
<b>Q2</b>	How many ml of water must be added to 200 ml of 0.65 M HCl to further dilute the solution to 0.20 M? (a) 450 ml (b) 750 ml (c) 550 ml (d) 500 ml <b>Answer: (a)</b>		1
<b>Q3</b>	c		1
<b>Q4</b>	The I.U.P.A.C. name of the following compound is  (a) 2-Bromo-3-methylbutanoic acid (b) 3-Bromo-2-methylbutanoic acid (c) 2-Bromo-2-methylbutanoic acid (d) 3-Bromo-3-methylbutanoic acid <b>Ans : (b) 3-Bromo-2-methylbutanoic acid</b>		1
<b>Q5</b>	During change of O <sub>2</sub> to O <sub>2</sub> <sup>2-</sup> ion, the electron adds on which of the following orbitals? (a) σ* orbital (b) π orbital (c) σ orbital (d) π* orbital <b>Ans: (d) π* orbital</b>		1
<b>Q6</b>	Which of the following pairs of gases contains the same number of molecules? (a) 16 g of O <sub>2</sub> and 14 g of N <sub>2</sub> (b) 6 g of O <sub>2</sub> and 22 g of CO <sub>2</sub> (c) 28 g of N <sub>2</sub> and 22 g of CO <sub>2</sub> (d) 32 g of CO <sub>2</sub> and 32g of N <sub>2</sub> <b>Answer : (a) 16 g of O<sub>2</sub> and 14 g of N<sub>2</sub></b>		1
<b>Q7</b>	Oxidation number of P in PO <sub>4</sub> <sup>3-</sup> , of S in SO <sub>4</sub> <sup>2-</sup> and that of Cr in Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup> are respectively:		1



	This section contains 7 questions with internal choice in two questions. The following questions are very short answer type and carry 2 marks each.	
Q19	<p>Two elements C and D have atomic numbers 36 and 58 respectively. On the basis of electronic configuration predict the following:</p> <p>(i) The group, period, and block to which each element belongs,</p> <p>Answer: The electronic configuration of elements C and D are: C (At. no 36) = <math>1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^6</math>. D (At. no. 58) = <math>1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^6, 5s^2 4d^{10} 5p^6, 6s^2 5d^1 4f^1</math>. The element C belongs to the 18th group, lies in the 4th period, and belongs to the p-block of elements. The element D belongs to lanthanides, lies in the 6th period, and belongs to f-block of elements.</p>	2
Q20	<p>Give reason for the following:</p> <p>(i) Neither q nor w is a state function but <math>q + w</math> is a state function. (ii) A real crystal has more entropy than an ideal crystal.</p> <p>Answer: (i) <math>q + w = \Delta u</math> As <math>\Delta u</math> is a state function hence, <math>q + w</math> is a state function. (ii) A real crystal has some disorder due to the presence of defects in its structural arrangement whereas ideal crystal does not have any disorder. Hence, a real crystal has more entropy than an ideal crystal.</p> <p style="text-align: center;">OR</p> <p>Discuss the effect of temperature on the spontaneity of an exothermic reaction. If the temperature is so high that <math>T\Delta S &gt; \Delta H</math> in magnitude, <math>\Delta G</math> will be positive and the process will be non-spontaneous. If the temperature is made low so that <math>T\Delta S &lt; \Delta H</math> in magnitude, <math>\Delta G</math> will be negative and the process will be spontaneous.</p>	2
Q21	<p>NH<sub>3</sub> is Lewis base while BF<sub>3</sub> is Lewis acid. Lewis electronic theory of acids and bases explains it.</p> <p style="text-align: center;">OR</p> <p>i) equilibrium will shift to the reactant side. ii) equilibrium will shift to the product side.</p>	2
Q22	<p>For each of the following pairs, predict which one has lower first ionization enthalpy?</p> <p>(i) N or O Answer: O (ii) Na or Na<sup>+</sup> Answer: Na</p>	2

Q23	<p>Balance the following redox reaction:</p> $\text{Cr}_2\text{O}_7^{2-} + \text{SO}_2 \rightarrow \text{Cr}^{+3} + \text{SO}_4^{2-}$ (acidic medium)	2
Q24		2
Q25	<p>From the equation <math>q = n C \Delta T</math>, we can say:          At constant pressure P, we have  <math>q_P = n C_P \Delta T</math>          This value is equal to the change in enthalpy, that is,  <math>q_P = n C_P \Delta T = \Delta H</math>          Similarly, at constant volume V, we have  <math>q_V = n C_V \Delta T</math>          This value is equal to the change in internal energy, that is,  <math>q_V = n C_V \Delta T = \Delta U</math>          We know that for one mole (n=1) of an ideal gas,  <math>\Delta H = \Delta U + \Delta(pV) = \Delta U + \Delta(RT) = \Delta U + R \Delta T</math>          Therefore, <math>\Delta H = \Delta U + R \Delta T</math>          Substituting the values of <math>\Delta H</math> and <math>\Delta U</math> from above in the former equation,  <math>C_P \Delta T = C_V \Delta T + R \Delta T</math>  <math>C_P = C_V + R</math>  <math>C_P - C_V = R</math></p>	2
	<b>SECTION C</b> <p>This section contains 5 questions with internal choice in two questions. The following questions are short answer type and carry 3 marks each.</p>	
Q26	<p>Use the molecular orbital theory to show that <math>\text{N}_2</math> would be expected to have a triple bond, <math>\text{F}_2</math>, a single bond and <math>\text{Ne}_2</math>, no bond.</p> <p><b>Answer.</b>          Formation of <math>\text{N}_2</math> molecule:          Electronic configuration is- <math>\sigma 1s^2</math>, <math>\sigma*1s^2</math>, <math>\sigma 2s^2</math>, <math>\sigma*2s^2</math>, <math>\pi 2p_x^2 = \pi 2p_y^2</math>, <math>\sigma 2p_z^2</math></p>	3



Molecular orbitals of  $N_2$  molecule

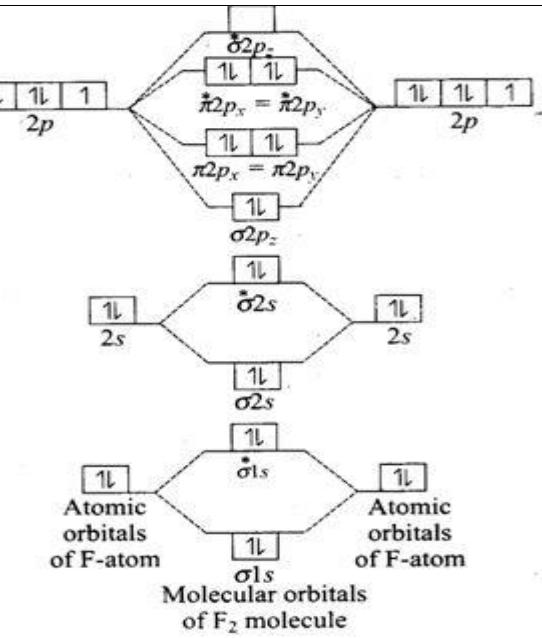
Here,  $N_b = 10$ ,  $N_a = 4$

Hence, Bond Order =  $\frac{1}{2} (N_b - N_a) = \frac{1}{2} (10 - 4) = 3$

Bond order indicates the number of bonds in diatomic molecule is 3. Hence, the molecule has TripleBond.

Formation of  $F_2$  molecule:

Electronic configuration is-  $\sigma 1s^2$ ,  $\sigma^* 1s^2$ ,  $\sigma 2s^2$ ,  $\sigma^* 2s^2$ ,  $\sigma 2p_z^2$ ,  $\pi 2p_x^2 = \pi 2p_y^2$ ,  $\pi^* 2p_x^2 = \pi^* 2p_y^2$



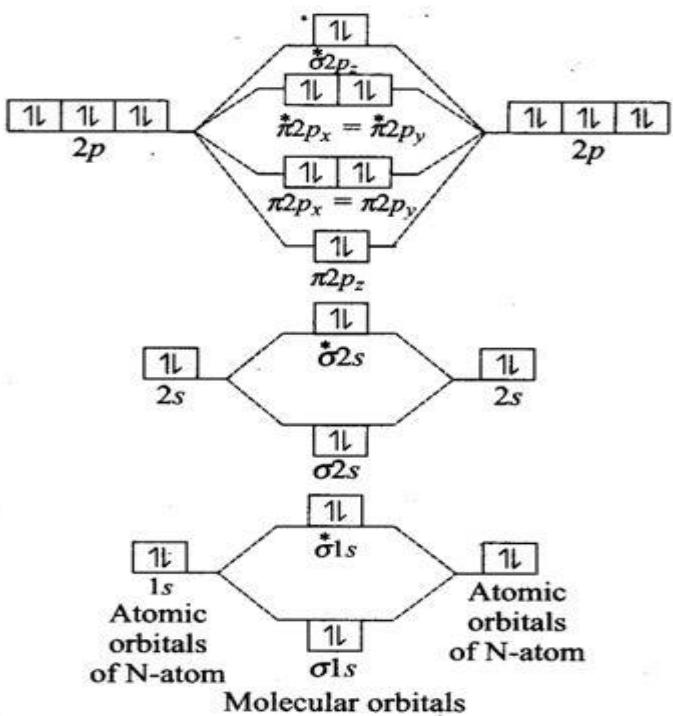
Here,  $N_b = 10$ ,  $N_a = 8$

Hence, Bond Order =  $\frac{1}{2} (N_b - N_a) = \frac{1}{2} (10 - 8) = 1$

Bond order indicates the number of bonds in diatomic molecule is 1. Hence, the molecule has a Single Bond.

Formation of  $Ne_2$  molecule:

Electronic configuration is-  $\sigma 1s^2$ ,  $\sigma*1s^2$ ,  $\sigma 2s^2$ ,  $\sigma*2s^2$ ,  $\sigma 2p_z^2$ ,  $\pi 2p_x^2 = \pi 2p_y^2$ ,  $\pi*2p_x^2 = \pi*2p_y^2$ ,  $\sigma*2p_z^2$



Here,  $N_b = 10$ ,  $N_a = 10$

Hence, Bond Order =  $\frac{1}{2} (N_b - N_a) = \frac{1}{2} (10 - 10) = 0$

Bond order indicates the number of bonds in diatomic molecule is 0. Hence, the molecule has no bond.

- Q27 Yellow light emitted from a sodium lamp has a wavelength ( $\lambda$ ) of 580 nm. Calculate the frequency ( $v$ ) and wavenumber of the yellow light. 3

$$\begin{aligned}\text{Wavelength of yellow light} &= 580 \text{ nm} \\ &= 580 \times 10^{-9} \text{ m} \quad [\because 1 \text{ nm} = 10^{-9} \text{ m}]\end{aligned}$$

$$\text{Frequency } (v) = \frac{c}{\lambda},$$

where  $c$  = velocity of light =  $3.0 \times 10^8 \text{ m s}^{-1}$ ,  
 $\lambda$  = wavelength of sodium lamp

$$v = \frac{3.0 \times 10^8}{580 \times 10^{-9}} = 5.17 \times 10^{14} \text{ s}^{-1}$$

$$\begin{aligned}\text{Again, wavenumber } (\bar{v}) &= \frac{1}{\lambda} = \frac{1}{580 \times 10^{-9} \text{ m}} \\ &= 1.724 \times 10^6 \text{ m}^{-1}\end{aligned}$$

Therefore, frequency =  $5.17 \times 10^{14} \text{ s}^{-1}$  and  
wavenumber =  $1.724 \times 10^6 \text{ m}^{-1}$ .

OR

Find energy of each of the photons which

- (i) corresponds to light of frequency  $3 \times 10^{15} \text{ Hz}$ .  
(ii) have wavelength of  $0.50 \text{ \AA}$ .

(i) We know that,  $E = h\nu$

where  $E$  = energy of photons,  $h$  = Planck's constant,  $\nu$  = frequency of light  
 $\therefore E = h\nu = 6.626 \times 10^{-34} \times 3 \times 10^{15}$   
 $= 1.99 \times 10^{-18} \text{ J}$

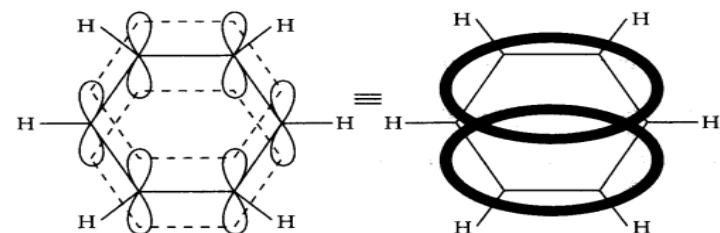
$$(ii) E = \frac{hc}{\lambda}$$

where  $c$  = velocity of light,  $h$  = Planck's constant,  $\lambda$  = wavelength

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{0.50 \times 10^{-10}} = 3.98 \times 10^{-15} \text{ J}$$

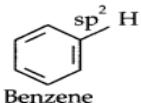
Q28

- a. The six electrons of the p-orbitals cover all the six carbon atoms, and are said to be delocalized. As a result of delocalization there formed a stronger n-bond and a more stable molecule.

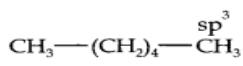


b.

The hybridization state of carbon in these three compounds is:



Type of orbital:  $sp^2$   
s-Character: 33.3%



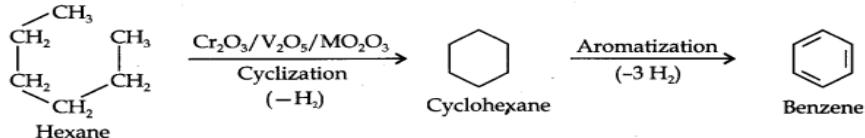
Hexane  
Type of orbital:  $sp^3$   
s-Character: 25%



Ethyne  
Type of orbital:  $sp$   
s-Character: 50%

Since s-electrons are closer to the nucleus, therefore, as the s-character of the orbital making the C—H bond increases, the electrons of C—H bond lie closer and closer to the carbon atom. In other words, the partial +ve charge on the H-atom and hence the acidic character increases as the s-character of the orbital increases. Thus, the acidic character decreases in the order: Ethyne > Benzene > Hexane.

OR

	<p>(i) <math>3 \text{HC}\equiv\text{CH}</math> Ethyne <math>\xrightarrow[873 \text{ K}]{\text{Red hot Fe tube}}</math>  Benzene</p> <p>(ii) Ethene is first converted into ethyne and then to benzene as shown above.</p> $\text{CH}_2=\text{CH}_2 \xrightarrow{\text{Br}_2/\text{CCl}_4} \text{Br}-\text{CH}_2-\text{CH}_2-\text{Br} \xrightarrow[\text{(Dehydrobromination)}]{\text{KOH (alc), } \Delta} \text{CH}_2=\text{CHBr}$ <p style="text-align: center;">1,2-Dibromoethane</p> $\xrightarrow[196 \text{ K}]{\text{(Dehydrobromination)}} \text{HC}\equiv\text{CH} \xrightarrow[873 \text{ K}]{\text{Red hot Fe tube}} \text{Benzene}$ <p>(iii) When vapours of hexane are passed over heated catalyst consisting of <math>\text{Cr}_2\text{O}_3</math>, <math>\text{MO}_2\text{O}_3</math> and <math>\text{V}_2\text{O}_5</math> at 773 K under 10-20 atm pressure, cyclization and aromatization occurs simultaneously to afford benzene</p> 	
Q29	$\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}_3 \xrightarrow[\text{n - Hexane}]{\text{Pt}, \text{H}_2}$ <p style="text-align: center;">(A)</p> <p style="text-align: center;"><math>\downarrow \text{KMnO}_4</math></p> $2\text{CH}_3\text{CH}_2\text{COOH}$ <p><math>\therefore</math> A is Hex-3-ene.</p>	3
Q30	<p>The enthalpy of combustion of methane, graphite and dihydrogen at 298 K are <math>-890.3 \text{ KJ mol}^{-1}</math>, <math>-393.5 \text{ KJ mol}^{-1}</math> and <math>-285.8 \text{ KJ mol}^{-1}</math> respectively. Calculate enthalpy of formation of <math>\text{CH}_4(\text{g})</math>?</p> <p>(i) <math>\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})</math>; <math>\Delta_f\text{H}^\ominus = -890.3 \text{ kJ mol}^{-1}</math></p> <p>(ii) <math>\text{C}(\text{s}) + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})</math>; <math>\Delta_f\text{H}^\ominus = -393.5 \text{ kJ mol}^{-1}</math></p> <p>(iii) <math>\text{H}_2(\text{g}) + 1/2\text{O}_2(\text{g}) \longrightarrow \text{H}_2\text{O}(\text{l})</math>; <math>\Delta_f\text{H}^\ominus = -285.8 \text{ kJ mol}^{-1}</math></p> <p>The equation we aim at:</p> $\text{C}(\text{s}) + 2\text{H}_2(\text{g}) \longrightarrow \text{CH}_4(\text{g}); \Delta_f\text{H}^\ominus = ?$ <p>Eqn. (ii) + <math>2 \times</math> Eqn. (iii) – Eqn. (i) and the correct <math>\Delta_f\text{H}^\ominus</math> value is:  <math>= (-393.5) + 2 \times (-285.8) - (-890.3) = -74.8 \text{ kJ mol}^{-1}</math></p> <p><math>\therefore</math> (i) is the correct answer.</p>	3
	<b>SECTION D</b>	
	<p>The following questions are case-based questions. Each question has an internal choice and carries 4 (1+1+2) marks each. Read the passage carefully and answer the questions that follow.</p>	
Q31	(i)b (ii)d	4

	<p>(iii) 1 mole of <math>\text{H}_2\text{S}</math> contains 2 mole of H, 1 mole of S      Therefore      10 mole of <math>\text{H}_2\text{S}</math> contains  <math>20 \text{ mole of H} = 20 \times 6.022 \times 10^{23} = 12.044 \times 10^{24}</math>  <math>20 \times 6.022 \times 10^{23} = 12.044 \times 10^{24}</math> H atoms  <math>10 \text{ mole of S} = 10 \times 6.022 \times 10^{23} = 6.022 \times 10^{24}</math>  <math>10 \times 6.022 \times 10^{23} = 6.022 \times 10^{24}</math> S atoms</p> <p style="text-align: center;">OR</p> <p>Molecular mass of <math>\text{KClO}_3 = 39 + 35.5 + 3 \times 16 = 122.5</math>  <math>39 + 35.5 + 3 \times 16 = 122.5</math>      No. of mole of <math>\text{KClO}_3 = 245 \text{ g}/122.5 \text{ g} = 2 \text{ mole}</math>      2 mole of <math>\text{KClO}_3</math> contains  <math>2 \text{ mole of K} = 2 \times 6.022 \times 10^{23} = 12.044 \times 10^{23}</math>  <math>2 \times 6.022 \times 10^{23} = 12.044 \times 10^{23}</math> K atoms  <math>2 \text{ mole of Cl} = 2 \times 6.022 \times 10^{23} = 12.044 \times 10^{23}</math>  <math>2 \times 6.022 \times 10^{23} = 12.044 \times 10^{23}</math> Cl atoms  <math>6 \text{ mole of O} = 6 \times 6.022 \times 10^{23} = 1.806 \times 10^{24}</math>  <math>6 \times 6.022 \times 10^{23} = 1.806 \times 10^{24}</math> O atoms.</p>	
Q32	<p>(i) Number of orbitals = <math>n^2 = 3^2 = 9</math> orbitals, <math>3s</math>, <math>3p_x</math>, <math>3p_y</math>, <math>3p_z</math>, <math>3d_{x^2-y^2}</math>, <math>3d_{z^2}</math>, <math>3d_{xy}</math>, <math>3d_{yz}</math> and <math>3d_{zx}</math>.</p> <p>(ii) b</p> <p>(iii) 's' orbitals are spherical and 'p' orbitals have dumb-bell shaped.</p> <p style="text-align: center;">OR</p> <p><math>d_{x^2-y^2}</math>, <math>d_{z^2}</math></p>	4
	<p style="text-align: center;"><b>SECTION E</b></p> <p>The following questions are long answer type and carry 5 marks each. Two questions have an internal choice.</p>	
Q33	<p>i) a) A- propene B - 1-bromopropane</p> <p>ii) A- Ethyne              B- Benzene</p> <div style="background-color: #e0f2e0; padding: 10px; margin-top: 10px;"> <math display="block">\begin{array}{ccccccc}  &amp; \text{H} &amp; &amp; \text{H} &amp; &amp; \text{H} &amp; \\  &amp;   &amp; &amp;   &amp; &amp;   &amp; \\  \text{CH}_3 &amp; \text{C} = \text{O} + \text{O} = \text{C} - &amp; \text{CH}_2 - &amp; \text{CH}_2 - &amp; \text{C} = \text{O} + \text{O} = &amp; \text{C} - \text{CH}_3 \rightarrow \\  &amp; (\text{Ethan}) &amp; &amp; (\text{Butane-1, 4-dial}) &amp; &amp; (\text{Propanone}) &amp;  \end{array}</math> <math display="block">\text{CH}_3\overset{8}{\underset{7}{\text{CH}}}=\overset{6}{\text{CH}}-\overset{5}{\text{CH}_2}-\overset{4}{\text{CH}_2}-\overset{3}{\text{CH}}=\overset{2 }{\text{C}}-\overset{\text{CH}_3}{\text{CH}_3}</math> <p>b) (A) 2-methylocta-2, 6-diene</p> </div>	5

Q34	<p>(ii) Give the TUPAC names of the following compounds:</p> <p style="text-align: center;"></p> <p style="text-align: center;">(e) </p> <p style="text-align: center;">(f) <math>\text{Cl}_2\text{CHCH}_2\text{OH}</math></p>	5
	<p><b>Answer:</b> (a) 3-Bromo- 3-chloroheptane (b) 3-Chloropropanal (c) 2, 2-Dichloroethanol OR</p> <p>(i) Write two points of differences between homolytic fission and heterolytic fission</p> <p>Answer: Homolytic cleavage gives rise to the formation of free radicals, that is, neutral species that carry an unpaired electron. Heterolytic cleavage gives rise to the formation of ions, that is, species that carry a positive or a negative charge.</p> <p>(ii) Explain why <math>(\text{CH}_3)_3\text{C}^+</math> is more stable than <math>\text{CH}_3\text{CH}_2^+</math>.</p> <p>Answer: <math>(\text{CH}_3)_3\text{C}^+</math> has nine alpha hydrogens and has nine hyperconjugation structures while <math>\text{CH}_3\text{C}^+\text{H}_2</math> has three alpha hydrogens and has three hyperconjugation structures, therefore <math>(\text{CH}_3)_3\text{C}^+</math> is more stable than <math>\text{CH}_3\text{CH}_2^+</math>.</p>	
Q35	<p><b>(a)</b> According to Le Chatelier's principle, on addition of <math>\text{H}_2</math>, the equilibrium of the given reaction will shift in the forward direction.</p> <p><b>(b)</b> On addition of <math>\text{CH}_3\text{OH}</math>, the equilibrium will shift in the backward direction.</p> <p><b>(c)</b> On removing <math>\text{CO}</math>, the equilibrium will shift in the backward direction.</p> <p><b>(d)</b> On removing <math>\text{CH}_3\text{OH}</math>, the equilibrium will shift in the forward direction.</p>	5

**Solution**

We know  $pV = nRT$   
 Total volume ( $V$ ) = 1 L  
 Molecular mass of  $\text{N}_2\text{O}_4$  = 92 g  
 Number of moles =  $13.8\text{g}/92\text{ g} = 0.15$  of the gas ( $n$ )  
 Gas constant ( $R$ ) =  $0.083 \text{ bar L mol}^{-1}\text{K}^{-1}$   
 Temperature ( $T$ ) = 400 K

$$pV = nRT$$

$$p \times 1\text{L} = 0.15 \text{ mol} \times 0.083 \text{ bar L mol}^{-1}\text{K}^{-1} \times 400 \text{ K}$$

$$p = 4.98 \text{ bar}$$

$$\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$$

Initial pressure: 4.98 bar      0  
 At equilibrium:  $(4.98 - x)$  bar       $2x$  bar  
 Hence,

$$p_{\text{total}} \text{ at equilibrium} = p_{\text{N}_2\text{O}_4} + p_{\text{NO}_2}$$

$$9.15 = (4.98 - x) + 2x$$

$$9.15 = 4.98 + x$$

$$x = 9.15 - 4.98 = 4.17 \text{ bar}$$

Partial pressures at equilibrium are,

$$p_{\text{N}_2\text{O}_4} = 4.98 - 4.17 = 0.81 \text{ bar}$$

$$p_{\text{NO}_2} = 2x = 2 \times 4.17 = 8.34 \text{ bar}$$

(b)

$$K_p = (p_{\text{NO}_2})^2 / p_{\text{N}_2\text{O}_4}$$

$$= (8.34)^2 / 0.81 = 85.87$$

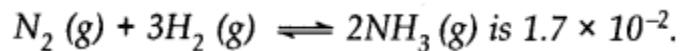
$$K_p = K_c (RT)^{\Delta n}$$

$$85.87 = K_c (0.083 \times 400)^1$$

$$K_c = 2.586 = 2.6$$

OR

- (a) Le Chatelier's principle can be stated as follows: A change in one of the variables that describe a system at equilibrium produces a shift in the position of the equilibrium that counteracts the effect of this change.
- (b) A mixture of 1.57 mol of N<sub>2</sub>, 1.92 mol of H<sub>2</sub> and 8.13 mol of NH<sub>3</sub> is introduced into a 20 L reaction vessel at 500 K. At this temperature, the equilibrium constant K<sub>c</sub> for the reaction.



Is this reaction at equilibrium? If not, what is the direction of net reaction?

**(b)Ans**

The reaction is: N<sub>2</sub>(g) + 3 H<sub>2</sub>(g)  $\rightleftharpoons$  2NH<sub>3</sub>(g)

$$\begin{aligned} \text{Concentration quotient } (Q_c) &= \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(8.13/20 \text{ mol L}^{-1})^2}{(1.57 / 20 \text{ mol L}^{-1}) \times (1.92 / 20 \text{ mol L}^{-1})^3} \\ &= 2.38 \times 10^3 \end{aligned}$$

The equilibrium constant (K<sub>c</sub>) for the reaction =  $1.7 \times 10^{-2}$

As Q<sub>c</sub> ≠ K<sub>c</sub>; this means that the reaction is not in a state of equilibrium.

# Chemistry Practicals

## EXPERIMENT 1

### ACID BASE TITRATION – I

**AIM:** To prepare 100ml of M/20 sodium carbonate solution and with its help determine the molarity and strength of the given HCl solution.

**APPARATUS:** Chemical balance, 100ml measuring flask, wash bottle, glass funnel, burette, pipette and weighing bottle.

**CHEMICALS :** High purity sodium carbonate, HCl, methyl orange and distilled water.

**THEORY :** (A) Being a primary standard sodium carbonate can be prepared by directly weighing crystalline sodium carbonate ( $\text{Na}_2\text{CO}_3$ , its molecular Wt. is 106). To prepare 100ml of M/20, sodium carbonate required will be:

$$\text{Molarity} = \frac{\text{mass of solute} \times 1000}{\text{Molar mass} \times \text{volume of the solution in ml}}$$
$$\frac{M}{20} = \frac{x \times 1000}{106 \times 100}$$

$$x = \frac{1 \times 106 \times 100}{1000 \times 20} = 0.53\text{g}$$

(B) This is a neutralization reaction involving a weak base and a strong acid.



**INDICATOR:** Methyl orange

**END POINT:** yellow to pink.

#### **PROCEDURE:**

##### **(A) PREPARATION OF STANDARD SOLUTION:**

Take a filter paper and weigh it. Tare its weight. Now put sodium carbonate crystals to the filter paper and weigh it till the weight of sodium carbonate is about 0.53 g. Record this value. Transfer the weighed oxalic acid to a glass funnel placed above a 100 ml-measuring flask. Give a fine spray of distilled water from the wash bottle to the funnel so that everything comes down to the measuring flask. Dissolve the salt in minimum amount of water and make up the solution to 100 ml. Shake the solution well to get a concentrated solution.

##### **(B) TITRATION:**

Rinse the burette with distilled water and HCl solution and fill it with the same solution. Remove all the air bubbles from burette. Rinse the pipette with distilled water sodium carbonate and solution. Pipette out 10 ml of M/20 sodium carbonate solution to a clean conical flask. Add one or two drops of methyl orange and titrate it against HCl solution in the burette. Allow the HCl solution to run into the flask with constant shaking till a pink colour is reached. Read the lower meniscus of the burette and record it as final reading. Repeat the titration till concordant values are obtained.

### **OBSERVATIONS:**

Molarity of sodium carbonate solution = 0.05M

S.No	VOLUME OF SODIUM CARBONATE USED (mL)	INITIAL BURETTE READING (mL)	FINAL BURETTE READING (mL)	VOL.OF HYDROCHLORIC ACID (mL)	CONCORDANT READING (mL)

Volume of HCl used = mL

### **CALCULATIONS:**

#### **MOLARITY OF HCl solution**

$$\frac{M_{HCl} \times V_{HCl}}{M_{Na_2CO_3} \times V_{Na_2CO_3}} = \frac{2}{1}$$

$$M_{HCl} = \frac{M_{Na_2CO_3} \times V_{Na_2CO_3} \times 2}{V_{HCl} \times 1}$$

$$M_{HCl} = \frac{0.05 \times 10 \times 2}{V_{HCl}} = M$$

$$\begin{aligned} \text{Strength of HCl solution} &= \text{Molarity of HCl} \times \text{Molecular mass} \\ &= \times 36.5 \\ &= \text{g/L} \end{aligned}$$

**RESULT :** (a) Molarity of the given HCl solution = M  
 (b) The strength of the given HCl solution = g/L

## EXPERIMENT - 2

### ACID BASE TITRATION – 2

**AIM:** To prepare 100ml of M/20 oxalic acid solution and with its help determine the molarity and strength of the given NaOH solution.

**APPARATUS :** Chemical balance, 100 ml measuring flask, wash bottle, glass funnel, glass rod, burette, pipette, burette stand and weighing bottle.

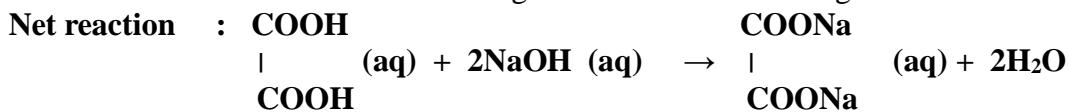
**CHEMICALS :** Oxalic acid crystals, NaOH, phenolphthalein and distilled water.

**THEORY :** (A) Being a primary standard oxalic acid can be prepared by directly weighing crystalline oxalic acid ( $C_2H_2O_4$ ; its molecular Wt. is 126). To prepare 100 ml of M/20 oxalic acid , oxalic acid required will be:

$$\text{Molarity} = \frac{\text{mass of solute} \times 1000}{\text{Molar mass} \times \text{volume of the solution in ml}}$$
$$\frac{M}{20} = \frac{x \times 1000}{126 \times 100}$$

$$x = \frac{1 \times 126 \times 100}{1000 \times 20} = 0.63\text{g}$$

(B) This is a neutralization reaction involving a weak acid and a strong base.



**INDICATOR:** Phenolphthalein

**END POINT:** pink to colourless.

#### **PROCEDURE:**

##### **(A) PREPARATION OF STANDARD SOLUTION:**

Take a filter paper and weigh it. Tare its weight. Now put oxalic acid crystals to the filter paper and weigh it till the weight of oxalic acid is about 0.63 g. Record this value. Transfer the weighed oxalic acid to a glass funnel placed above a 100ml-measuring flask. Give a fine spray of distilled water from the wash bottle to the funnel so that everything comes down to the measuring flask. Dissolve the salt in minimum amount of water and make up the solution to 100ml. Shake the solution well to get a concentrated solution.

##### **(B) TITRATION:**

Rinse the burette with distilled water and oxalic acid solution and fill it with the same solution. Remove all the air bubbles from burette. Rinse the pipette with distilled water and sodium hydroxide solution. Pipette out 10 ml of sodium hydroxide solution to a clean conical flask. Add one or two drops of phenolphthalein and titrate it against oxalic acid solution in the burette. Allow the oxalic acid solution to run into the flask with constant shaking till pink colour just disappears. Read the upper meniscus of the burette and record it as final reading. Repeat the titration till concordant values are obtained.

### **OBSERVATIONS:**

Molarity of oxalic acid solution = 0.05M

S.No	VOLUME OF SODIUM HYDROXIDE (mL)	INITIAL BURETTE READING (mL)	FINAL BURETTE READING (mL)	VOLUME OF OXALIC ACID (mL)	CONCORDANT READING (mL)

Volume of oxalic used = ml

### **CALCULATIONS:**

#### **MOLARITY OF OXALIC ACID SOLUTION**

$$\frac{M_{H_2C_2O_4} \times V_{H_2C_2O_4}}{M_{NaOH} \times V_{NaOH}} = \frac{1}{2}$$

Where  $M_{H_2C_2O_4}$  : Molarity of oxalic acid  
 $V_{H_2C_2O_4}$  : Volume of oxalic acid  
 $M_{NaOH}$  : Molarity of sodium hydroxide  
 $V_{NaOH}$  : Volume of sodium hydroxide

$$M_{NaOH} = \frac{M_{H_2C_2O_4} \times V_{H_2C_2O_4} \times 2}{V_{NaOH}}$$

$$M_{NaOH} = \frac{0.05 \times V_{H_2C_2O_4} \times 2}{V_{NaOH}} = M$$

Strength of NaOH solution = Molarity of NaOH  $\times$  Molecular mass of NaOH  
 $=$   
 $=$  g/L

RESULT : (a) Molarity of the given NaOH solution = M

(b) The strength of the given NaOH solution = g/L

## VIVA QUESTIONS

### VOLUMETRIC ANALYSIS

#### **1. What is volumetric analysis?**

In volumetric analysis, the concentration of a solution is determined by allowing a known volume of this to react quantitatively with another solution of known concentration.

#### **2. What is titration?**

The process of adding one solution from the burette to another in the titration flask in order to complete the chemical reaction involved, is known as titration.

#### **3. What is titrand?**

The solution whose strength or concentration is to be determined is called titrand.

#### **4. What is titrant?**

The solution of known strength is called titrant.

#### **5. What is indicator?**

Indicator is a chemical substance which changes colour at the end point.

#### **6. What is end point?**

The stage during titration at which the reaction is just complete is known as the end point of the titration.

#### **7. What is molarity?**

Molarity is defined as number of moles of solute dissolved per litre of solution.

#### **8. Why a titration flask should not be rinsed?**

This is because during rinsing, some liquid will remain sticking to the titration flask therefore the pipetted volume taken in the titration flask will increase.

#### **9. What are primary and secondary standard substances?**

A substance is known as primary standard if it is available in high degree of purity, if it is stable and unaffected by air, if it does not lose or gain moisture in air, if it is readily soluble and its solution in water remains as such for long time.

On the other hand, a substance which does not possess the above characteristics is called a secondary standard substance. Primary standards are crystalline oxalic acid, anhydrous  $\text{Na}_2\text{CO}_3$ , Mohr's salt etc.

#### **10. Burette and pipette must be rinsed with the solution with which they are filled, why?**

They are rinsed in order to remove any substances sticking to their sides, which otherwise would decrease the volume of the liquids to be taken in them.

#### **11. It is customary to read the lower meniscus in case of colourless and transparent solutions and upper meniscus in case of highly coloured solutions, why?**

Because it is easy to read the lower meniscus in case of colourless solutions, while the upper meniscus in case of coloured solutions.

#### **12. Why the last drop of pipette must not be blown out of a pipette?**

Since the drop left in the jet end is extra of the volume measured by the pipette.

#### **13. Why pipette should not be held from its bulb?**

The heat of our body may expand the glass bulb and introduce an error in the measurement of the volume.

#### **14. Why is temperature mentioned on pipette?**

Volume of pipette is most accurate at that temperature.

**15. What is meant by concordant reading?**

Volume of acid used remaining same, i.e difference in final and initial reading should be same.

**16. What is strength of a solution?**

Strength of a solution is defined as amount of solute dissolved per litre of solution.

Strength = Molarity  $\times$  Molecular weight

**17. What is basicity of an acid?**

It is the number of replaceable hydrogen atoms in a molecule of the acid.

**18. What is the relation between equivalent mass of acid and molecular mass?**

$$\text{Equivalent mass of acid} = \frac{\text{Molecular mass}}{\text{Basicity}}$$

**19. What is standard solution?**

The solution whose concentration i.e. is known is called standard solution.

## EXPERIMENT#

### SYSTEMATIC QUALITATIVE ANALYSIS

#### **THEORY OF PRECIPITATION OF DIFFERENT GROUPS**

The classification of cations into different groups is based on **solubility product**(K<sub>sp</sub>)of the salts of basic radicals. Common ion plays an important role for precipitating of radicals of a particular group and not the other group.

**COMMON ION EFFECT:** The decrease in concentration of the ions by adding a common ion is called common ion effect.

Weak electrolytes do not ionize completely in aqueous solution and there exists an equilibrium between ions and unionized molecules. The degree of ionization can be further decreased by adding a strong electrolyte having a common ion so that radicals of that group ( whose K<sub>sp</sub> is low )get precipitated and other group radicals do not get precipitated, e.g..degree of dissociation of H<sub>2</sub>S (weak acid) is suppressed by adding HCl (strong acid ) so that only group II radicals get precipitated because the K<sub>sp</sub> of their sulphides is low whereas group IV radicals do not get precipitated because K<sub>sp</sub> of their sulphides is higher.

Similarly in group III,NH<sub>4</sub>Cl (strong electrolyte) solid is added along with group reagent ,ammonium hydroxide (NH<sub>4</sub>OH) which is a weak electrolyte. NH<sub>4</sub><sup>+</sup> ion being common ion, concentration of OH<sup>-</sup> is decreased so that only group III radicals get precipitated.

Group IV radicals( Ni<sup>2+</sup>,Co<sup>2+</sup>,Mn<sup>2+</sup>,Zn<sup>2+</sup>) are also precipitated as sulphides in basic medium in group IV. The solubility product of group IV sulphides is quite high, therefore higher concentration of sulphide ion is required. In basic medium, OH<sup>-</sup> take up H<sup>+</sup> and dissociation of H<sub>2</sub>S increases, S<sup>2-</sup> concentration increases which is needed to precipitate group IV radicals.

Group V radicals (Ba<sup>2+</sup>, Sr<sup>2+</sup>, Ca<sup>2+</sup>) are precipitated as their carbonates by adding ammonium carbonate solution in presence of NH<sub>4</sub>Cl and NH<sub>4</sub>OH so as to decrease CO<sub>3</sub><sup>2-</sup> concentration so that only group V radicals are precipitated( K<sub>sp</sub> is low) and Mg<sup>2+</sup> does not precipitate.

## **TEST FOR ANIONS:**

### **Preliminary Test:**

1. **Action of dilute H<sub>2</sub>SO<sub>4</sub>:** Anions that can be identified by the action of dil. H<sub>2</sub>SO<sub>4</sub> are CO<sub>3</sub><sup>-2</sup>, S<sup>-2</sup>, SO<sub>3</sub><sup>-2</sup> and NO<sub>2</sub><sup>-1</sup>

EXPERIMENT	OBSERVATION	INFERENCE
Take a small amount of the substance in a test tube and add 2-3 ml of dil. H <sub>2</sub> SO <sub>4</sub> to it.	a) Brisk effervescence of colourless gas which turns limewater milky.	May be CO <sub>3</sub> <sup>-2</sup>

2. **Action of conc. H<sub>2</sub>SO<sub>4</sub>:** Anions that can be identified by the action of conc. H<sub>2</sub>SO<sub>4</sub> are Cl<sup>-1</sup>, Br<sup>-1</sup>, I<sup>-1</sup>, CH<sub>3</sub>COO<sup>-1</sup> and NO<sub>3</sub><sup>-1</sup>

EXPERIMENT	OBSERVATION	INFERENCE
Heat little of the given substance with 2-3 drops of Conc. H <sub>2</sub> SO <sub>4</sub> .	a) Colourless gas pungent smell and gives dense white fumes with a glass rod dipped in NH <sub>4</sub> OH.	May be Cl <sup>-</sup>
	b) Colourless gas with smell of vinegar.	May be CH <sub>3</sub> COO <sup>-</sup>
	c) brown fumes  Heat and add Cu turnings to the above solution - Dense brown fumes and the solution turn blue.	May be NO <sub>3</sub> <sup>-</sup>

3. **If the test with dil. and conc. H<sub>2</sub>SO<sub>4</sub> is negative then test for SO<sub>4</sub><sup>2-</sup> directly.**

## **Confirmatory Test of Anions:**

### Preparation of the test solution:

Take a small amount of the salt in a test tube and add water. The substance dissolves completely, this solution is referred to as the test solution or water extract.

EXPERIMENT	OBSERVATION	INFERENCE
$\text{CO}_3^{2-}$		
1. To water extract add $\text{BaCl}_2$ . 2. To the water extract add $\text{MgSO}_4$ solution.	White precipitate soluble in dil. $\text{HCl}$ and dil. $\text{HNO}_3$ White precipitate.	$\text{CO}_3^{2-}$ confirmed
$\text{Cl}^-$		
1. <b>Silver Nitrate Test:</b> To the water extract add $\text{AgNO}_3$ soln.  2. <b>Chromyl Chloride test:</b> Heat the mixture or salt with $\text{K}_2\text{Cr}_2\text{O}_7$ (solid) and conc. $\text{H}_2\text{SO}_4$ Pass the red vapours through $\text{NaOH}$ solution. Add lead acetate to the yellow solution.	Curdy white precipitate which is soluble in $\text{NH}_4\text{OH}$ .  Red vapours  Yellow solution  Yellow ppt.	$\text{Cl}^-$ confirmed   $\text{Cl}^-$ confirmed
$\text{NO}_3^-$ <b>Ring test:</b>	Brown ring at the junction of the two liquids.	$\text{NO}_3^-$ confirmed

<b>CH<sub>3</sub>COO<sup>-</sup></b> 1. To 1ml of the water extract add few drops of FeCl <sub>3</sub> solution. Dilute red colour solution with little water and boil the solution.  2. Rub a pinch of the salt with oxalic acid and water between the fingers and smell.	Red colour appears  Reddish brown precipitate  Smell of Vinegar	CH <sub>3</sub> COO <sup>-</sup> confirmed  CH <sub>3</sub> COO <sup>-</sup> confirmed
<b>SO<sub>4</sub><sup>2-</sup></b> 1. To the water extract add BaCl <sub>2</sub> solution.  2. To the water extract add lead acetate solution.	White ppt. which is insoluble in conc. HNO <sub>3</sub> and conc. HCl.  White ppt. which is insoluble in dil. HCl but soluble in ammonium acetate solution.	SO <sub>4</sub> <sup>2-</sup> confirmed  SO <sub>4</sub> <sup>2-</sup> confirmed

## **TEST FOR CATIONS:**

Preliminary Tests:

<b>EXPERIMENT</b>	<b>OBSERVATION</b>	<b>INFERENCE</b>
1. Colour of the substance	Blue	$\text{Cu}^{+2}$ suspected
	Brown or yellowish brown	$\text{Fe}^{+3}$ suspected
	Green	$\text{Fe}^{+2}$ salts
	Pink or Flesh colour	$\text{Mn}^{+2}$ suspected
2. <b>Flame test:</b> Make a paste of the salt or mixture with conc. HCl in a watch glass. Dip the platinum wire/glass rod in the paste and introduce into the non-luminous flame.	Apple green	Presence of $\text{Ba}^{+2}$
	Brick red	Presence of $\text{Ca}^{+2}$
3. <b>Ash test:</b> To a little of the salt in a watch glass, add cobalt nitrate and concentrated nitric acid, dip a filter paper in this solution and burn it, note the colour of the ash.	Green ash	Presence of $\text{Zn}^{+2}$
	Blue Ash	Presence of $\text{Al}^{+3}$
	Light Pink coloured ash	Presence of $\text{Mg}^{+2}$

## **Confirmatory Test of Cations:**

<b>EXPERIMENT</b>	<b>OBSERVATION</b>	<b>INFERENCE</b>
<b>Zero group</b> Heat a pinch of the salt with NaOH solution.	Smell of $\text{NH}_3$ gas which gives dense white fumes with a glass rod dipped in conc. HCl.	$\text{NH}_4^+$ present

1. Bring moist red litmus paper near the mouth of test tube.  2. To the water extract add Nessler's reagent followed by the addition of excess of NaOH.	Red litmus turns to blue.  Reddish brown precipitate	$\text{NH}_4^+$ confirmed.  $\text{NH}_4^+$ confirmed.
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Preparation of Original Solution:

Take a small amount of the salt in a test tube and add water. The substance dissolves completely, this solution is referred to as Original Solution.

## ❖ INTERGROUP SEPARATION

<b>EXPERIMENT</b>	<b>OBSERVATION</b>	<b>INFERENCE</b>
1. Add dil. HCl to the Original solution.	White precipitate.	1 <sup>st</sup> group ( $Pb^{2+}$ )
2. Add dil. HCl and $H_2S$ to the Original solution.	Black precipitate.	2 <sup>nd</sup> group( $Cu^{2+}$ )
3. To the Original solution, add solid $NH_4Cl$ and add $NH_4OH$ in excess.	White gelatinous precipitate.	3 <sup>rd</sup> group( $Al^{3+}$ )
4. To the Original solution, add solid $NH_4Cl$ add $NH_4OH$ and $H_2S$ .	Dirty white precipitate.	$Zn^{2+}$ (4 <sup>th</sup> group)
	Buff or flesh precipitate.	$Mn^{2+}$ (4 <sup>th</sup> group)
5 .To the Original solution. add solid $NH_4Cl$ add $NH_4OH$ and ammonium carbonate solution	White precipitate.	5 <sup>th</sup> group ( $Ba^{2+}, Sr^{2+}, Ca^{2+}$ )
6. To the Original solution. add $NH_4Cl$ boil, add $NH_4OH$ and then add $Na_2HPO_4$ (sodium hydrogen phosphate) solution	White precipitate.	6 <sup>th</sup> group. ( $Mg^{2+}$ )

Confirmatory tests from Group I to Group VI:

<b>EXPERIMENT</b>	<b>OBSERVATION</b>	<b>INFERENCE</b>
<b>Group I</b> <b>If white precipitate</b> Dissolve the white precipitate. in hot water and divide the hot solution in 2 parts. 1. To 1 <sup>st</sup> part, add $K_2CrO_4$ .	Yellow precipitate.	$Pb^{2+}$ confirmed
	Yellow precipitate.	$Pb^{2+}$ confirmed

2. To 2 <sup>nd</sup> part, add KI solution.		
<b>Group II</b> If black precipitate. Dissolve the black precipitate in 50% HNO <sub>3</sub>		
1. To 1 <sup>st</sup> part add NH <sub>4</sub> OH drop by drop and then in excess.	Light blue precipitate which dissolves in excess of NH <sub>4</sub> OH and gives deep blue colour.	Cu <sup>2+</sup> confirmed.
2. To 2 <sup>nd</sup> add acetic acid and [K <sub>4</sub> Fe(CN) <sub>6</sub> ] potassium ferrocyanide.	Chocolate brown precipitate.	Cu <sup>2+</sup> confirmed.
<b>Group III</b> Brown ppt. Dissolve brown ppt in dil. HCl and divide the solution in 2 parts.		
1. To 1 <sup>st</sup> part add potassium ferrocyanide K <sub>4</sub> Fe(CN) <sub>6</sub> .	Prussian blue colour or precipitate.	Fe <sup>3+</sup> confirmed
2. To 2 <sup>nd</sup> part add ammonium thiocyanate. (NH <sub>4</sub> CNS)	Blood red colour	Fe <sup>3+</sup> confirmed
White ppt.[for Al <sup>3+</sup> ] 1. Dissolve the white precipitate in dil. HCl and add two drops of litmus solution .To this add NH <sub>4</sub> OH dropwise till blue colour develops.	Blue precipitate floating in the colourless solution.	Al <sup>3+</sup> confirmed
2. Ash test - To a little of the precipitate in a watch glass, add cobalt nitrate and	Blue ash	Al <sup>3+</sup> confirmed

concentrated nitric acid, dip a filter paper in this solution and burn it, note the colour of the ash.		
<b>Group IV</b> White precipitate.[for Zinc] Dissolve white precipitate in dil HCl and divide the solution in 2 parts. 1. 1st part, add NaOH.	White precipitate which is soluble in excess of NaOH.	Zn <sup>2+</sup> confirmed
2. To 2 <sup>nd</sup> part add potassium ferrocyanide K <sub>4</sub> Fe(CN) <sub>6</sub> solution.  <b>Buff ppt.[for Mn <sup>2+</sup> ]</b> 1.Dissolve buff precipitate in dil. HCl and add NaOH. 2. Boil the 4 <sup>th</sup> group precipitate with conc. HNO <sub>3</sub> and PbO <sub>2</sub> .	White precipitate  White precipitate turns brown  Purple colour	Zn <sup>2+</sup> confirmed.  Mn <sup>2+</sup> confirmed  Mn <sup>2+</sup> confirmed
<b>Group V</b> Dissolve white precipitate in dilute acetic acid .  <b>For Ba<sup>2+</sup></b> 1.To the above solution add K <sub>2</sub> CrO <sub>4</sub> . [potassium chromate] 2.Flame test - Make a paste of the precipitate with conc. HCl in a watch glass. Dip the platinum wire/ glass rod in the	Yellow precipitate  Apple green colour	Ba <sup>2+</sup> confirmed  Ba <sup>2+</sup> confirmed

paste and introduce into the non-luminous flame		
<b><u>For Ca<sup>2+</sup></u></b>		
1. Add ammonium oxalate to the groupV precipitate dissolved in acetic acid.  2.Flame test- Make a paste of the precipitate with conc. HCl in a watch glass. Dip the platinum wire/ glass rod in the paste and introduce into the non-luminous flame	White precipitate  Brick red colour	Ca <sup>2+</sup> confirmed.  Ca <sup>2+</sup> confirmed
<b><u>Group VI</u></b>		
White precipitate To the white precipitate, add cobalt nitrate solution.  Ash test- To a little of the precipitate in a watch glass, add cobalt nitrate and concentrated nitric acid, dip a filter paper in this solution and burn it, note the colour of the ash.	Violet or purple precipitate  Pink ash	Mg <sup>2+</sup> confirmed  Mg <sup>2+</sup> confirmed

## SPECIMEN RECORD OF ANALYSIS OF A SALT

### SALT NO:1

#### AIM

To analyse the anion and cation present in the given salt.

EXPERIMENT	OBSERVATION	INFERENCE
<u>PRELIMINARY TEST FOR ANION</u> <b>Action of dilute H<sub>2</sub>SO<sub>4</sub>:</b> Take a small amount of the substance in a test tube and add 2-3 ml of dil. H <sub>2</sub> SO <sub>4</sub> to it. <u>Confirmatory test for CO<sub>3</sub><sup>-2</sup></u> To water extract add BaCl <sub>2</sub>	Brisk effervescence of colourless gas which turns limewater milky.  White ppt. soluble in dil. HCl and dil. HNO <sub>3</sub>	May be CO <sub>3</sub> <sup>-2</sup>  CO <sub>3</sub> <sup>-2</sup> confirmed

<u>TEST FOR CATION:</u>		
<b>Preliminary Tests:</b> Colour of the substance	Colourless	Cu <sup>2+</sup> ,Fe <sup>+3</sup> and Mn <sup>2+</sup> absent.
<b>Flame test:</b> Make a paste of the salt or mixture with conc. HCl in a watch glass. Dip the platinum wire/ glass rod in the paste and introduce into the non-luminous flame.	No Characteristic Color	Ba <sup>2+</sup> ,Ca <sup>+2</sup> Absent.
<b>Ash test:</b> To a little of the salt in a watch glass, add cobalt nitrate and concentrated nitric acid, dip a filter paper in this solution and burn it, note the colour of the ash.	No Characteristic coloured ash.	Al <sup>3+</sup> ,Zn <sup>2+</sup> and Mg <sup>2+</sup> are absent .

<b>Test for zero group</b>		
1..Heat a pinch of the salt with NaOH solution.	Smell of NH <sub>3</sub> gas which gives dense white fumes with a glass rod dipped in conc. HCl.	NH <sub>4</sub> <sup>+</sup> present
2..Bring moist red litmus paper near the mouth of test tube.	Red litmus turns to blue.	NH <sub>4</sub> <sup>+</sup> confirmed.
3.To the water extract add Nessler's reagent followed by the addition of excess of NaOH.	Reddish brown ppt.	NH <sub>4</sub> <sup>+</sup> confirmed.

## **RESULT**

The given salt contains  $\text{NH}_4^+$  as cation and  $\text{CO}_3^{2-}$  as anion. The salt is  $(\text{NH}_4)_2\text{CO}_3$

## SALT NO:2

### AIM

To analyse the anion and cation present in the given salt.

EXPERIMENT	OBSERVATION	INFERENCE
<b>PRELIMINARY TEST FOR ANION</b> <b>Action of dil. H<sub>2</sub>SO<sub>4</sub>:</b> Take a small amount of the substance in a test tube and add 2-3 ml of dil. H <sub>2</sub> SO <sub>4</sub> to it.	No Brisk effervescence .	CO <sub>3</sub> <sup>-2</sup> absent
<b>Action of conc. H<sub>2</sub>SO<sub>4</sub>:</b> Heat little of the given substance with 2-3 drops of Conc. H <sub>2</sub> SO <sub>4</sub> .	Brown fumes Heat and add Cu turnings to the above solution - Dense brown fumes and the solution turn blue.	May be NO <sub>3</sub> <sup>-</sup>

Confirmatory test for NO <sub>3</sub> <sup>-</sup>  <b>Ring test:</b> Acidify the water extract with dil. H <sub>2</sub> SO <sub>4</sub> and add equal volume of freshly prepared FeSO <sub>4</sub> and add few drops of conc. H <sub>2</sub> SO <sub>4</sub> by the sides of the test tube.	Brown ring at the junction of the two liquids.	NO <sub>3</sub> <sup>-</sup> confirmed
<b>TEST FOR CATION</b>  <b>Preliminary Tests:</b> Colour of the substance	Colourless	Cu <sup>2+</sup> , Fe <sup>+3</sup> and Mn <sup>2+</sup> absent.

<b>Flame test:</b> Make a paste of the salt or mixture with conc. HCl in a watch glass. Dip the platinum wire/ glass rod in the paste and introduce into the non-luminous flame.	Apple Green Color	Ba <sup>2+</sup> present.
<b>Ash test:</b> To a little of the salt in a watch glass, add cobalt nitrate and concentrated nitric acid, dip a filter paper in this solution and burn it, note the colour of the ash.	No Characteristic coloured ash.	Al <sup>3+</sup> , Zn <sup>2+</sup> and Mg <sup>2+</sup> are absent .
<b>Inter group separation:</b> Heat a pinch of the salt with NaOH solution.	No smell of ammonia	NH <sub>4</sub> <sup>+</sup> absent
1.Add dil. HCl to the original solution.	No White precipitate.	1 <sup>st</sup> group (Pb <sup>2+</sup> ) absent .
2. Add dil. HCl and H <sub>2</sub> S to the original solution.	No Black precipitate.	2 <sup>nd</sup> group(Cu <sup>2+</sup> ) absent.
3.To the original solution,add solid NH <sub>4</sub> Cl and add NH <sub>4</sub> OH in excess.	No White gelatinous precipitate.	3 <sup>rd</sup> group(Al <sup>3+</sup> ) absent.
4. To the original solution,add solid NH <sub>4</sub> Cl add NH <sub>4</sub> OH and H <sub>2</sub> S.	No Dirty white/Buff precipitate.	Zn <sup>2+</sup> , Mn <sup>2+</sup> (4 <sup>th</sup> group) absent.
5.To the original solution. add solid NH <sub>4</sub> Cl add NH <sub>4</sub> OH and ammonium carbonate solution	White precipitate .	5 <sup>th</sup> group (Ba <sup>2+</sup> ) present.

<p>Confirmatory Test For <b>Ba<sup>2+</sup></b>  Dissolve white ppt in dilute acetic acid .</p> <p>1.To the above solution, add K<sub>2</sub>CrO<sub>4</sub>. [potassium chromate]  2..Flame test: Make a paste of the precipitate with conc. HCl in a watch glass. Dip the platinum wire/glass rod in the paste and introduce into the non-luminous flame.</p>	<p>Yellow precipitate  Apple green colour</p>	<p>Ba<sup>2+</sup> confirmed</p>
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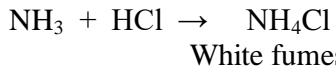
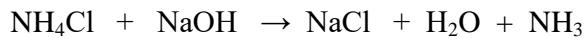
### **RESULT**

The given salt contains **Ba<sup>2+</sup>** as cation and **NO<sub>3</sub><sup>-</sup>** as anion. The salt is Ba(NO<sub>3</sub>)<sub>2</sub>

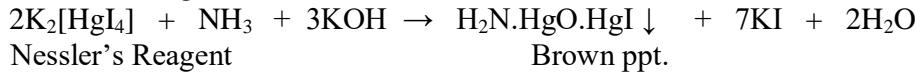
**CHEMICAL REACTIONS INVOLVED IN THE DETECTION OF BASIC RADICALS (CATIONS):**

GROUP	GROUP REAGENT	CATIONS	FORM IN WHICH CATIONS PRECIPITATED
1 <sup>st</sup> group	Dilute HCl	(Pb <sup>2+</sup> )	Chlorides
2 <sup>nd</sup> group	Dilute HCl and H <sub>2</sub> S	(Cu <sup>2+</sup> )	Sulphides
3 <sup>rd</sup> group	Solid NH <sub>4</sub> Cl and NH <sub>4</sub> OH in excess.	(Fe <sup>3+</sup> )	Hydroxides
4 <sup>th</sup> group	Solid NH <sub>4</sub> Cl, NH <sub>4</sub> OH and H <sub>2</sub> S.	Zn <sup>2+</sup> Mn <sup>2+</sup> Ni <sup>2+</sup>	Sulphides
5 <sup>th</sup> group	Solid NH <sub>4</sub> Cl, NH <sub>4</sub> OH and ammonium carbonate solution.	Ba <sup>2+</sup> Sr <sup>2+</sup> Ca <sup>2+</sup>	Carbonates
6 <sup>th</sup> group	NH <sub>4</sub> Cl, NH <sub>4</sub> OH and Na <sub>2</sub> HPO <sub>4</sub> (disodium hydrogen phosphate) solution	(Mg <sup>2+</sup> )	-----

**Zero Group (NH<sub>4</sub><sup>+</sup>)**

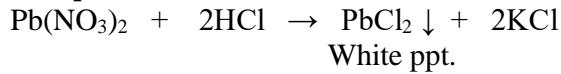


**Nessler's Reagent Test**



**Group I (Pb<sup>2+</sup>)**

**Group Test:**



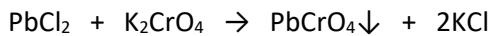
***Confirmatory tests:***

1. On cooling , precipitates settle down as  $\text{PbCl}_2$  is less soluble in cold water.
2. Potassium Iodide Test:



Yellow ppt.

3. Potassium Chromate Test:



Yellow ppt

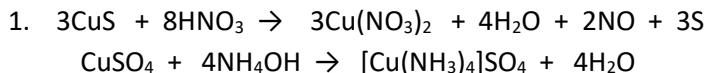
**Group II ( $\text{Cu}^{2+}$ )**

***Group Test:***

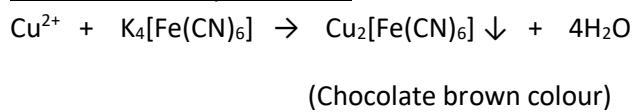


***Confirmatory tests:***

Black ppt. of CuS dissolves in 50% nitric acid and a blue solution is obtained on addition of excess of  $\text{NH}_4\text{OH}$

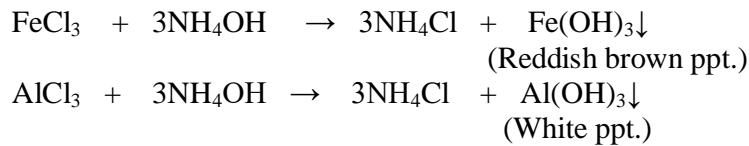


2. Potassium ferrocyanide test:



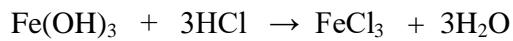
**Group III ( $\text{Fe}^{3+}/\text{Al}^{3+}$ )**

***Group Test***

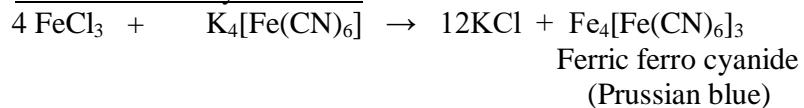


***Confirmatory tests: $\text{Fe}^{3+}$***

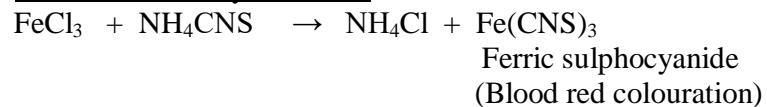
The reddish brown ppt. of  $\text{Fe(OH)}_3$  is dissolved in HCl.



1. Potassium ferrocyanide test:

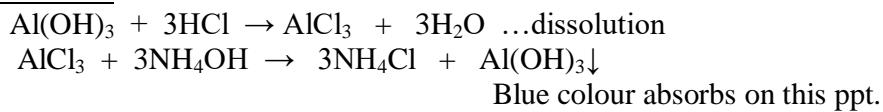


2. Ammonium thiocyanate test:



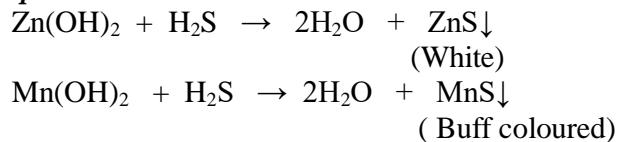
**Al<sup>3+</sup>**

Lake test:



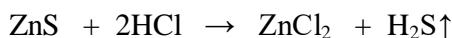
**Group III ( Zn<sup>2+</sup>/Mn<sup>2+</sup>)**

***Group Test:***

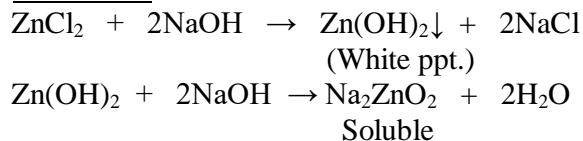


***Confirmatory tests:***

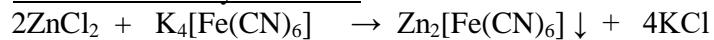
**Zn<sup>2+</sup>**



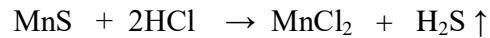
1. NaOH test:



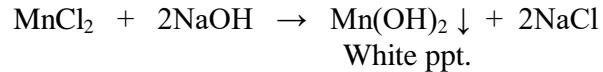
2. Potassium ferrocyanide test:



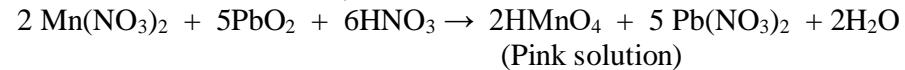
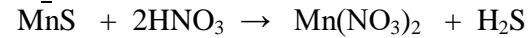
**Mn<sup>2+</sup>**

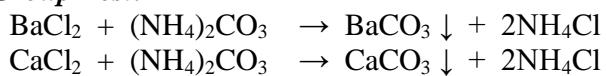
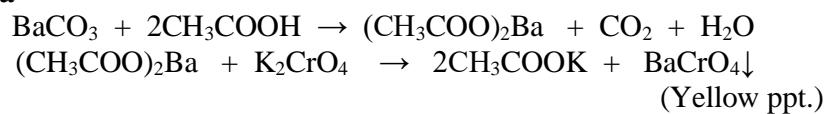
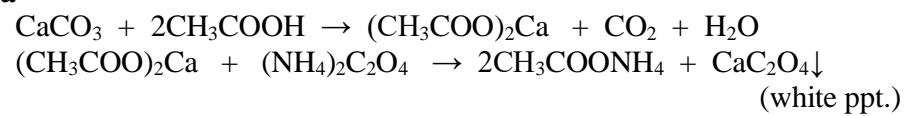
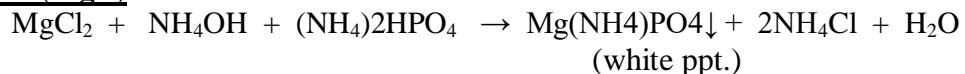


1. NaOH test:



2. PbO<sub>2</sub> test:



**Group V ( Ba<sup>2+</sup>/Ca<sup>2+</sup>)*****Group Test:******Confirmatory tests:*****Ba<sup>2+</sup>****Ca<sup>2+</sup>****Group VI (Mg<sup>2+</sup>)**

## VIVA QUESTIONS

### QUALITATIVE ANALYSIS

**1. What is qualitative analysis?**

The type of analysis that deals with the methods which are used to determine the constituents of a compound.

**2. What is the chemistry of flame test?**

In flame test, the valence electron of the atom gets excited and jumps to the higher level. When the electron jumps back to the ground state, the radiation is emitted whose frequency falls in the visible region.

**3. Why do we use conc. HCl in preparing a paste of the salt for flame test?**

In order to convert metal salts into metal chlorides which are more volatile than other salts.

**4. Why can't we use glass rod instead of platinum wire for performing flame test?**

This is because glass contains sodium silicate which imparts its own golden yellow color to the flame.

**5. Why is platinum metal preferred to other metals for flame test?**

Because it does not react with acids and does not itself impart any characteristic color to the flame.

**6. Why do barium salts not impart color to the flame immediately?**

Because barium chloride is less volatile, it imparts color to the flame after some time.

**7. What is Nessler's reagent?**

It is a solution of mercuric iodide in potassium iodide. Its formula is  $K_2HgI_4$ .

**8. Why dil.  $H_2SO_4$  is preferred while testing acid radicals over dil. HCl?**

When the salt is treated with HCl, during reaction HCl gas is also given out along with the gas evolved by the salt. So the actual gas cannot be identified whereas with dil.  $H_2SO_4$ , no such problem arises.

**9. Why the hot reaction mixture in case of conc.  $H_2SO_4$  test is not thrown into the sink?**

In order to avoid spouting, due to which  $H_2SO_4$  may fly and spoil clothes and may result into serious injuries.

**10. Why a dark brown ring is formed at the junction of two layers in ring test for nitrate ion?**

$H_2SO_4$  being heavier forms the lower layer and reacts only with a small amount of nitrate and  $FeSO_4$  at its surface, therefore, a brown ring appears only at the junction of the two layers.

**11. What is chromyl chloride test?**

When the salt is heated with conc.  $H_2SO_4$  and solid  $K_2Cr_2O_7$  in a dry test tube, deep brownish red vapours of chromyl chloride are formed. When these vapours are passed through NaOH solution, a yellow color is obtained due to the formation of sodium chromate( $Na_2CrO_4$ ). When lead acetate is added to it, a yellow ppt. is obtained due to formation of lead chromate( $PbCrO_4$ )

**12. Name the group reagents for different groups.**

Group I- Dil. HCl

Group II- H<sub>2</sub>S in the presence of dil. HCl

Group III – NH<sub>4</sub>OH in the presence of NH<sub>4</sub>Cl

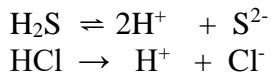
Group IV- H<sub>2</sub>S in the presence of

Group V-(NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub> in presence of

Group VI- No specific group reagent

**13. Why is it essential to add dil.HCl before proceeding to the test for the basic radicals of group II?**

In the precipitation of group II radicals as their sulphides,H<sub>2</sub>S is used in the presence of HCl. H<sub>2</sub>S itself is a weak acid and dissociates as follows:



HCl being a strong acid is largely ionized to H<sup>+</sup>. Thus, hydrogen ion concentration is increased and consequently the concentration of sulphide ions produced by the ionization of H<sub>2</sub>S is sufficiently decreased due to common ion effect as a result of which the sulphide ion concentration is sufficient only to exceed the solubility product of the sulphides of group II cations.

Since the solubility products (K<sub>sp</sub>) for the sulphides of group III and IV cations are very high,those cations are not precipitated out under the above conditions.

**14. Why is NH<sub>4</sub>Cl added along with NH<sub>4</sub>OH in III group?**

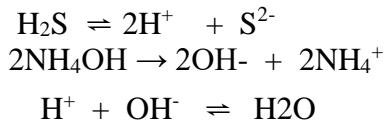
It is done in order to decrease the concentration of OH<sup>-</sup> ions by suppressing the ionization of NH<sub>4</sub>OH by common ion effect. If NH<sub>4</sub>OH alone is used in that case, the concentration of OH<sup>-</sup> is enough to precipitate the hydroxides of IV, V and VI groups.

**15. What is blue lake?**

It is blue particles, blue litmus adsorbed on white ppt. of Al(OH)<sub>3</sub>, floating in colourless solution.

**16. H<sub>2</sub>S is passed in presence of NH<sub>4</sub>OH in group IV. Explain, why?**

When H<sub>2</sub>S is passed in alkaline medium or NH<sub>4</sub>OH, the H<sup>+</sup> ions from the dissociation of H<sub>2</sub>S gas combine with the hydroxyl ions(OH<sup>-</sup>) from the dissociation of NH<sub>4</sub>OH to form nearly unionized water. and thereby they are not precipitated in V group.



**17. Presence os NH<sub>4</sub>Cl is quite essential before the addition of (NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub> in group V.**

**Explain why?**

Ammonium chloride suppresses the ionization of NH<sub>4</sub>OH and due to common ion effect which results in the decrease in the concentration of OH<sup>-</sup> and CO<sub>3</sub><sup>2-</sup> ions. So the ionic product does not exceed the solubility product of Mg(OH)<sub>2</sub> or MgCO<sub>3</sub>

**18. What is salt? What are its two parts?**

Salt is the neutralized product of acid and base. The two essential parts are acidic radical (Anion) and Basic radical (cation).

**19. What is meant by “ion”?**

Ion is an atom with positive or negative charge or charges.

**20. What is meant by radical?**

Charged atom or group of atoms. Which exists as a single unit in crystal or in solution form is known as a radical.

**21. What is Acid radical?**

The radical which is contributed by an acid during salt formation and having a negative charge is called acid radical (Anion).

**22. What is Basic radical?**

The radical which is contributed by a base during salt formation and having a positive charge is called basic radical (cation).

**23. Why positive radical is called cation?**

On passing the current through a solution it moves towards cathode.

**24. Why negative radical is called Anion?**

Negative ions moves towards anode during electrolysis hence they are called Anion.

**25. What is meant by group reagent?**

It is the reagent or chemical, used to find out a particular group of cations or Anions.

**26. How many groups are there for Anion?**

There are three main groups for Anions.

**27. How many groups are there for cation?**

There are six groups for cations.

**28. What are the group reagents for I, II & III group of cation?**

The group reagent for I group is HCl, HCl + H<sub>2</sub>S for II group and NH<sub>4</sub>Cl + NH<sub>4</sub>OH are the group reagent for III group.

**29. What are the group reagents for I, II and III of Anion?**

For I group H<sub>2</sub>SO<sub>4</sub> or HCl (dilute) is a group reagent for II groups H<sub>2</sub>SO<sub>4</sub> while III group gives precipitation by BaCl<sub>2</sub> or Ammonium molybdate (NH<sub>4</sub>)<sub>2</sub> MoO<sub>4</sub>.

**30. How the cations of group VI are precipitated?**

There is no any specific reagent to precipitate all the cations of the group at once, hence they are analysed individually e.g. BaCl<sub>2</sub> for SO<sub>4</sub><sup>2-</sup>.

**31. What is the group reagent for cation in group II?**

Hydrogen Sulphate (H<sub>2</sub>S) in presence of Hydrochloric acid (HCl)

**32. What is Nessler's reagent and what for its used?**

It is alkaline solution of potassium mercuric iodide  $K_2HgI_4$ . It gives brown precipitation with ammonium salts.

**33. What is chromyl chloride test?**

When solid chloride is heated with potassium dichromate and Conc. Sulphate acid it gives red vapours of chromyl chloride  $CrO_2Cl_2$ .

**34. Why water and HCl are preferred for the preparation of the original solution (O.S) in the detection of basic radical?**

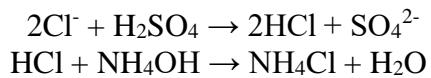
Because no interference is caused by  $H_2O$  and  $HCl$  while other acids like  $HNO_3$  and  $H_2SO_4$  interfere e.g. Cation like  $Pb^{2+}$ ,  $Ca^{2+}$ ,  $Sr^{2+}$  and  $Ba^{2+}$  form in soluble sulphates with  $H_2SO_4$  and  $HNO_3$  being oxidizing agent interferes in the second groups by oxidizing  $H_2S$  to S.

**35. What do you mean by qualitative analysis?**

It is the process by which the components of a substance or a mixture can be detected.

**36. Why is testing  $Cl^-$  radical, when a rod dipped in  $NH_4OH$  is held over the mouth of test tube, a dense white fumes are produced?**

Because chloride with conc.  $H_2SO_4$  produces  $HCl$  gas which forms white fumes of  $NH_4Cl$  with  $NH_4OH$ .



**37. During testing of 2nd group of acidic radicals a brown gas may evolve, which may be due to  $Br^-$  radical or due to  $NO_3^-$  radical, how will you distinguish them?**

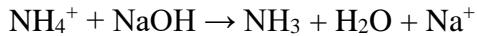
If evolved gas becomes denser on adding  $MnO_2$  then it is  $Br_2$  gas if it increased by adding copper turnings then it is  $NO_2$  gas.

**38. Why it is necessary to prepare the original solution (O.S) of the salt for the detection of basic radicals except  $NH_4^+$  radical?**

All the basic radicals are metallic ions except  $NH_4^+$  therefore they cannot form a volatile substance which can be detected by evolution of a gas by a particular smell. Hence they are detected only by precipitation method from their solution.

**39. Why  $NH_4^+$  radical can be detected, directly from its salt?**

On testing with an alkali, like  $NaOH$  it evolves  $NH_3$  gas the smell of which confirms the  $NH_4$  radical.



**40. Why the basic radicals are divided into six groups?**

Actually they are divided on the basis of solubility product of their corresponding compounds.

**41. If original solution is prepared in  $HCl$ , Why it is concluded that 1st group of basic radicals is absent?**

The first group radicals from in soluble chlorides with HCl, Hence if the solution is clear in HCl it means that 1st group radicals are absent.

**42. What is brisk effervescence?**

Brisk effervescence is due to the evolution of  $\text{CO}_2$  gas.

**43. Why the ppt. of  $\text{AgCl}$  is soluble in  $\text{NH}_4\text{OH}$ ?**

Because  $\text{AgCl}$  is insoluble in water but in the presence of  $\text{NH}_4\text{OH}$ , it forms a complex diamine compound which can be dissolved easily in water.

**44. How does lime water turn milky on passing  $\text{CO}_2$  gas through it?**

Lime water turns milky due to the formation of in soluble  $\text{CaCO}_3$ .

**45. What is lime water?**

It is a solution of  $\text{Ca}(\text{OH})_2$ .

**46. What is red gas?**

Chromyl chloride is called red gas  $\text{CrO}_2\text{Cl}_2$ .

**47. Mention some cations with their characteristics flames?**

Cations Colour of the flame:

$\text{Ca}^{2+}$  Brick red

$\text{Sr}^{2+}$  Deep red

$\text{Ba}^{2+}$  Grassy green

$\text{Cu}^{2+}$  Bluish green.

**48. If the salt is coloured what cations may be present?**

If the salt is coloured the following cations may be present e.g.  $\text{Cu}^{2+}$ ,  $\text{CO}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Mn}^{2+}$  and  $\text{Fe}^{3+}$  etc.

**49. Give the name of a non-metallic basic radical?**

The non-metallic basic radical is Ammonium  $\text{NH}_4^+$  radical.

**50. In the preparation of original solution for cation, why  $\text{H}_2\text{SO}_4$  is never used?**

Because it is oxidizing agent and precipitate various cations in different groups e.g.  $\text{Ba}^{2+}$ ,  $\text{Sr}^{2+}$  and  $\text{Pb}^{2+}$  are precipitate as sulphate in group II. In this way the whole scheme of cation will disturb.

**51. Lead may be precipitated in group I as well in group II of cation why?**

In first group  $\text{PbCl}_2$  is sparingly soluble and hence not all the lead ions  $\text{Pb}^{2+}$  are precipitated. Thus the remaining  $\text{Pb}^{2+}$  ions are separated out in group II as  $\text{PbS}$ .

PERIOD NUMBER	GROUP NUMBER		Representative elements							Noble gases								
	1	2	IA	IIA	d-Transition elements							13	14	15	16	17	18	
1	Li 2s <sup>1</sup>	Be 2s <sup>2</sup>	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	Sc 3d <sup>1</sup> 4s <sup>2</sup>	Ti 3d <sup>2</sup> 4s <sup>2</sup>	Cr 3d <sup>3</sup> 4s <sup>1</sup>	Mn 3d <sup>4</sup> 4s <sup>1</sup>	Fe 3d <sup>5</sup> 4s <sup>1</sup>	Co 3d <sup>6</sup> 4s <sup>1</sup>	Ni 3d <sup>7</sup> 4s <sup>1</sup>	Cu 3d <sup>8</sup> 4s <sup>1</sup>	Zn 3d <sup>10</sup> 4s <sup>2</sup>	Ga 3d <sup>10</sup> 4s <sup>2</sup>	Ge 4s <sup>2</sup> 4p <sup>2</sup>	As 4s <sup>2</sup> 4p <sup>3</sup>	Se 4s <sup>2</sup> 4p <sup>4</sup>	Br 4s <sup>2</sup> 4p <sup>5</sup>	Ne 1s <sup>2</sup>	H <sub>e</sub> 1s <sup>2</sup>	He 1s <sup>2</sup>	
3	K 4s <sup>1</sup>	Ca 3d <sup>1</sup> 4s <sup>2</sup>	Sc 3d <sup>2</sup> 4s <sup>2</sup>	Ti 3d <sup>3</sup> 4s <sup>1</sup>	V 3d <sup>4</sup> 4s <sup>1</sup>	Cr 3d <sup>5</sup> 4s <sup>1</sup>	Mn 3d <sup>6</sup> 4s <sup>1</sup>	Fe 3d <sup>7</sup> 4s <sup>1</sup>	Co 3d <sup>8</sup> 4s <sup>1</sup>	Ni 3d <sup>9</sup> 4s <sup>1</sup>	Cu 3d <sup>10</sup> 4s <sup>1</sup>	Zn 3d <sup>10</sup> 4s <sup>2</sup>	Ga 3d <sup>10</sup> 4s <sup>2</sup>	Ge 4s <sup>2</sup> 4p <sup>2</sup>	As 4s <sup>2</sup> 4p <sup>3</sup>	Se 4s <sup>2</sup> 4p <sup>4</sup>	Br 4s <sup>2</sup> 4p <sup>5</sup>	Kr 4s <sup>2</sup> 4p <sup>6</sup>
4	Rb 5s <sup>1</sup>	Na 3s <sup>1</sup>	Mg 3s <sup>2</sup>	Al 3s <sup>2</sup>	Si 3s <sup>2</sup>	P 3s <sup>2</sup>	S 3s <sup>2</sup>	Cl 3s <sup>2</sup>	Ar 3s <sup>2</sup>	Kr 3s <sup>2</sup>	Xe 3s <sup>2</sup>	Rn 3s <sup>2</sup>	Br 3s <sup>2</sup>	Kr 3s <sup>2</sup>	Xe 3s <sup>2</sup>	Xe 3s <sup>2</sup>	Xe 3s <sup>2</sup>	
5	Cs 6s <sup>1</sup>	Fr 7s <sup>1</sup>	Fr 7s <sup>1</sup>	Fr 7s <sup>1</sup>	Fr 7s <sup>1</sup>	Fr 7s <sup>1</sup>	Fr 7s <sup>1</sup>	Fr 7s <sup>1</sup>										
6	La 5d <sup>1</sup> 6s <sup>2</sup>	Ce 4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Pr 4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Nd 4f <sup>2</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Sm 4f <sup>3</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Eu 4f <sup>4</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Gd 4f <sup>5</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Tb 4f <sup>6</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Dy 4f <sup>7</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Ho 4f <sup>8</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Er 4f <sup>9</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Tm 4f <sup>10</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Yb 4f <sup>11</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Lu 4f <sup>12</sup> 5d <sup>1</sup> 6s <sup>2</sup>				
7	Th 5f <sup>1</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Pa 5f <sup>2</sup> 6d <sup>1</sup> 7s <sup>2</sup>	U 5f <sup>3</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Np 5f <sup>4</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Pu 5f <sup>5</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Am 5f <sup>6</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Cm 5f <sup>7</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Bk 5f <sup>8</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Cf 5f <sup>9</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Es 5f <sup>10</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Fm 5f <sup>11</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Md 5f <sup>12</sup> 6d <sup>1</sup> 7s <sup>2</sup>	No 5f <sup>13</sup> 6d <sup>1</sup> 7s <sup>2</sup>	Lr 5f <sup>14</sup> 6d <sup>1</sup> 7s <sup>2</sup>				

f - Inner transition elements

58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Ce 4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Pr 4f <sup>2</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Nd 4f <sup>3</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Pm 4f <sup>4</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Sm 4f <sup>5</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Eu 4f <sup>6</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Gd 4f <sup>7</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Tb 4f <sup>8</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Dy 4f <sup>9</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Ho 4f <sup>10</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Er 4f <sup>11</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Tm 4f <sup>12</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Yb 4f <sup>13</sup> 5d <sup>1</sup> 6s <sup>2</sup>	Lu 4f <sup>14</sup> 5d <sup>1</sup> 6s <sup>2</sup>			
90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106

Lanthanoids  
 $4f^n 5d^1 6s^2$

Actinoids  
 $5f^6 6d^{1-2} 7s^2$

# LOGARITHMS

**TABLE I**

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170		0212	0253	0294	0334	0374	5	9	13	17	21	26	30	34 38
11	0414	0453	0492	0531	0569		0607	0645	0682	0719	0755	4	8	12	16	20	24	28	32 36
12	0792	0828	0864	0899	0934		0969	1004	1038	1072	1106	3	7	11	14	18	21	25	28 32
13	1139	1173	1206	1239	1271		1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26 29
14	1461	1492	1523	1553	1584		1614	1644	1673	1703	1732	3	6	9	12	15	19	22	25 28
15	1761	1790	1818	1847	1875		1903	1931	1959	1987	2014	3	6	9	11	14	17	20	23 26
16	2041	2068	2095	2122	2148		2175	2201	2227	2253	2279	3	6	8	11	14	16	19	22 24
17	2304	2330	2355	2380	2405		2430	2455	2480	2504	2529	3	5	8	10	13	15	18	20 23
18	2553	2577	2601	2625	2648		2672	2695	2718	2742	2765	2	5	7	9	12	14	17	19 21
19	2788	2810	2833	2856	2878		2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18 20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17 19	
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16 18	
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15 17	
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15 17	
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14 16	
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14 15	
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13 15	
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13 14	
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12 14	
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12 13	
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11 13	
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11 12	
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11 12	
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10 12	
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10 11	
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10 11	
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10 11	
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9 10	
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9 10	
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9 10	
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9 10	
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8 9	
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8 9	
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8 9	
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8 9	
45	6532	6542	6551	6561	6471	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8 9	
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7 8	
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7 8	
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7 8	
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7 8	

# LOGARITHMS

**TABLE 1 (Continued)**

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7768	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

## ANTILOGARITHMS

**TABLE II**

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
.03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	2	3
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	3	3
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	3	3
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	3	3	3
.20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	2	3	3	3
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	2	3	3	3
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	2	3	3	3
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	2	3	3	4
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	2	3	3	4
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	2	3	3	4
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	3	4
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	3	3	3	4
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	3	3	4	4
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2	3	3	4	4
.30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	3	3	4	4
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2	3	3	4	4
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
.34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3	4	4	5	5
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
.47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	3	4	5	6	6
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	3	4	5	6	6

## ANTILOGARITHMS

**TABLE II (Continued)**

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20