PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "SOME BASIC CONCEPTS"

1. Which of the following contains the maximum number of molecules?
   a) 1g N_2 b) 1g CO_2 c) 1g H_2 d) 1g NH_3 (1)

   Ans: c) 1g H_2 (1)

2. Calculate the mass of SO_3 (g) produced, if 500 g SO_2 (g) reacts with 200 g O_2 (g) according to the equation: $2SO_2(g) + O_2(g) \rightarrow 2SO_3(S)$. Identify the limiting reagent. (3) [July 2019]

   Ans: $2SO_2(g) + O_2(g) \rightarrow 2SO_3(S)$

   128 g 32g 160g

   128g SO_2 requires 32g Oxygen for the complete reaction.

   So 500g SO_2 requires 32x500/128 = 125g O_2

   Here there is 200g O_2. So SO_2 is completely used up and hence it is the limiting reagent. (3)

3. Round off 0.0525 to a number with two significant figures. (1)

   Ans: 0.052

4. A reaction mixture for the production of NH_3 gas contains 250 g of N_2 gas and 50 g of H_2 gas under suitable conditions. Identify the limiting reactant if any and calculate the mass of NH_3 gas produced. (3) [March 2019]

   Ans: Nitrogen reacts with Hydrogen to form ammonia according to the equation,

   $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

   28g 6g 34g

   i.e. 28g N_2 requires 6g H_2 for the complete reaction.

   So 250g N_2 requires, 6x 250/28 = 53.57g H_2.

   But here there is only 50g H_2.

   So we have to consider the reverse case.

   i.e. 6g H_2 requires 28g N_2.

   So 50g H_2 requires 28 x 50/6 = 233.33g N_2

   Here H_2 is completely consumed. So it is the limiting reagent.

   *Amount of ammonia formed = 50+ 233.33 = **283.33 g***

5. Which among the following measurements contains the highest number of significant figures?
   a) 1.123×10^{-3} kg b) 1.2×10^{-3} kg c) 0.123×10^{3} kg d) 2×10^{5} kg (1)

   Ans: a) 1.123×10^{-3} kg

6. State and illustrate the law of multiple proportions. (2)

   Ans: It states that if two elements combine to form more than one compound, the different masses of one of the elements that combine with a fixed mass of the other element, are in small whole number ratio.

   Illustration: Hydrogen combines with oxygen to form two compounds – water and hydrogen peroxide.

   Hydrogen + Oxygen → Water
   2g 16g 18g

   Hydrogen + Oxygen → Hydrogen Peroxide
   2g 32g 34g

   Here, the masses of oxygen (i.e. 16 g and 32 g) which combine with a fixed mass of hydrogen (2g) bear a simple ratio, i.e. 16:32 or 1: 2.

7. Calculate the amount of CO_2(g) produced by the reaction of 32g of CH_4 (g) and 32g of O_2 (g). (3) [August 2018]

   Ans: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

16g 64g 44g 36g

64g O_2 requires 16g CH_4 for the complete reaction.

So, 32g O_2 requires 8g CH_4.

16g CH_4 combines with 64g O_2 to form 44g CO_2.

Therefore, 8g CH_4 combines with 32g Oxygen to form 22g CO_2.

8. The number of oxygen atoms present in 5 moles of glucose ($C_6H_{12}O_6$) is ..... (1)

Ans: 30 x 6.022 x 10^{23} atoms

9. Find the molecular formula of the compound with molar mass 78 g mol^{-1} and empirical formula CH. (2)

Ans: Molar mass = 78 g/mol

Empirical Formula mass = 12+1 = 13

Molecular formula = Empirical formula x n

n = Molar mass = 78/13 = 6

~~Empirical formula mass~~

So, Molecular formula = (CH) x 6 = C_6H_6

10. Calculate the mass of oxalic acid dihydrate ($H_2C_2O_4.2H_2O$) required to prepare 0.1M, 250 ml of its aqueous solution. (3) [March 2018]

Ans: Molarmass of Oxalic acid dihydrate = 126

Molarity = 0.1M

Volume of the solution = 250 mL

$$\text{Molarity} = \frac{\text{Mass of the solute} \times 1000}{\text{Molar mass of the solute} \times \text{volume of solution in mL}}$$

So Mass of the solute = (Molarity x Molar mass of the solute x volume of solution in mL)/1000

= (0.1 x 126 x 250/1000 = 3.15 g

11. a) NO and NO_2 are two oxides of nitrogen.

i) Which law of chemical combination is illustrated by these compounds? (1)

ii) State the law. (1)

b) Calculate the mass of a magnesium atom in grams. (1)

c) What is molality? (1) [July 2017]

Ans: a) i) Law of multiple proportions

ii) It states that if two elements combine to form more than one compound, the different masses of one of the elements that combine with a fixed mass of the other element, are in small whole number ratio.

b) Atomic mass of magnesium = 24g

i.e. Mass of 6.022 x 10^{23} atoms of Magnesium = 24g

So, Mass of one magnesium atom = 24/(6.022x10^{23}) = 3.98x10^{-23} g

c) Molarity is the no. of moles of solute present per litre of the solution.

12. a) Determine the number of moles present in 0.55 mg of electrons.

i) 1 mole ii) 2 moles iii) 1.5 moles iv) 0.5 mole (1)

b) Give the empirical formula of the following.

$C_6H_{12}O_6$, C_6H_6, CH_3COOH, $C_6H_6Cl_6$ (2)

c) Two elements, carbon and hydrogen combine to form C_2H_6, C_2H_4 and C_2H_2. Identify the law illustrated here. (1) [March 2017]

Ans: (a) (i) 1 mol (Score 1)

[Explanation: Mass of one electron = 9.1 x 10^{-28} g = 9.1 x 10^{-25} mg.

Mass of 1 mol of electron = 9.1 x 10^{-25} x 6.022 x 10^{23} mg = 0.55 mg.

So, 0.55 mg of electron ≡ 1 mol of electron.]

(b) Empirical formulae are: CH_2O, CH, CH_2O, CHCl. *(Score 2)*

(c) Law of multiple proportions *(Score 1)*

13. Empirical formula represents the simplest whole number ratio of various atoms present in a compound.
    a) Give the relation between empirical formula and molecular formula. (1)
    b) An organic compound has the following percentage composition C = 12.36%, H = 2.13%, Br = 85%. Its vapour density is 94. Find its molecular formula. (2)
    c) What is mole fraction? (1) [September 2016]

Ans: a) Molecular formula = Empirical formula x n *(1)*

b)

Element	*Percentage*	*Atomic mass*	*Percentage/ Atomic mass*	*Simple ratio*	*Simplest whole no. ratio*
C	*12.36*	*12*	*12.36/12 = 1.03*	*1.03/1.03 = 1*	*1*
H	*2.13*	*1*	*2.13/1 = 2.13*	*2.13/1.03 = 2*	*2*
Br	*85*	*80*	*85/80 = 1.06*	*1.06/1.03 = 1*	*1*

Empirical Formula = CH_2Br

Empirical Formula Mass (EFM) = 12+2+80 = 94

Molar mass (MM) = 2 x vapour density = 2 x 94 = 188

n = MM/EFM = 188/94 = 2

Molecular formula = Empirical formula x n

= (CH_2Br) x 2 = $C_2H_4Br_2$ *(2)*

c) Mole fraction is the ratio of the number of moles of a particular component to the total number of moles of solution. (1)

14. a) When nitrogen and hydrogen combines to form ammonia, the ratio between the volumes of gaseous reactants and products is 1: 3: 2. Name the law of chemical combination illustrated here. (1)
    b) A compound is made up of two elements A and B, has A = 70% and B = 30%. The relative number of moles of A and B in the compound are 1.25 and 1.88 respectively. If the molar mass of the compound is 160, find the molecular formula of the compound. (3) [March 2016]

Ans: a) Gay – Lussac's law of Gaseous volumes *(1)*

b) The relative number of moles means %/atomic mass.

Elements	*%*	*Relative no. of moles*	*Simple ratio*	*Simplest whole no. ratio*
A	*70*	*1.25*	*1.25/1.25 = 1*	*2*
B	*30*	*1.88*	*1.88/1.25 = 1.5*	*3*

Empirical formula is A_2B_3

(Here at. Mass is not given. But it can be find out from % composition and the no. of moles as follows)

Atomic mass of A = %/no. of moles = 70/1.25 = 56

Atomic mass of B = %/no. of moles = 30/1.88 = 15.96

So, emp. Formula mass = 56 x 2 + 15.96 x 3 = 159.88 = 160

n = Mol.mass/Emp. Formula Mass = 160/160 = 1

Molecular formula = (emp. Formula) x n = (A_2B_3)x 1 = A_2B_3 *(3)*

15. 12 g of ^{12}C contains Avogadro's number of carbon atoms.

a) Give the Avogadro's number. (1)

b) The mass of 2 moles of ammonia gas is .....

(i) 2 g (ii) 1.2 x 10^{22}g (iii) 17 g (iv) 34g (1)

c) Calculate the volume of ammonia gas produced at STP when 140 g of nitrogen gas reacts with 30 g of hydrogen gas. (Atomic mass: N = 14u, H = 1 u) (2) [October 2015]

Ans: a) 6022 x 10^{23} (1)

b) (iv) 34g (1)

c) No. of moles of N_2 = Mass in gram/ molar mass = 140/28 = 5 mol

No. of moles of H_2 = Mass in gram/ molar mass = 30/2 = 15 mol

N_2 combines with H_2 to form NH_3 according to the equation: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

From the equation, it is clear that 1 mol nitrogen reacts with 3 mol H_2 to form 20mol NH_3.

So, 5 mol N_2 reacts with 15 mol H_2 to form 10 mol NH_3.

Volume of 1 mol of ammonia at STP = 22.4 L

So volume of 10 mol of ammonia at STP = 224 L (2)

16. 'A given compound always contains exactly the same proportion of elements by weight.'

a) (i) Name the above law. (1)

(ii) Write the name of the Scientist who proposed this law. (1)

b) Calculate the number of molecules in each of the following:

i) 1 g N_2 ii) 1 g CO_2 (Given that N_A is 6.022 x 10^{23}, molecular mass of N_2 = 28 and CO_2 = 44) (2)

[March 2015]

Ans: a) (i) Law of definite (constant) proportions (1)

(ii) Joseph Proust (1)

b) No of molecules = Given mass in gram x NA / Molar mass

(i) (1 x 6.022 x 10^{23})/28 = 0.0357 x 10^{23} molecules (1)

(ii) (1 x 6.022x10^{23})/44 = 0.0227 x 10^{23} molecules (1)

17. a) How many moles of dioxygen are present in 64g of dioxygen? (Molar mass of dioxygen is 32). (1)

b) The following data were obtained when dinitrogen (N_2) and dioxygen (O_2) react together to form different compounds.

Mass of N_2	Mass of O_2
14 g	16 g
14 g	32 g
28 g	32 g
28 g	80 g

Name the law of chemical combination obeyed by the above experimental data. (1)

c) Define empirical formula. How is it related to the molecular formula of a compound? (2)

[March 2014]

Ans: a) No. of moles = Mass in gram / Molar mass = 64/32 = 2 moles (1)

b) Law of multiple proportion (1)

c) Empirical formula is the simplest formula which gives only the ratio of different elements present in the compound. It is related to molecular formula as Molecular formula = Empirical formula x n (2)

18. Hydrogen combines with oxygen to form two different compounds, namely water (H_2O) and hydrogen peroxide (H_2O_2).
    a) Which law is obeyed by this combination? (1)
    b) State the law. (2)
    c) How many significant figures are present in the following?
    i) 0.0025 ii) 285 (1) [August 2014]

Ans: a) Law of Multiple proportions (1)
b) It states that if two elements combine to form more than one compound, the different masses of one of the elements that combine with a fixed mass of the other element, are in small whole number ratio.
c) i) 2 ii) 3 (1)

19. a) Atoms have very small mass and so usually the mass of atoms are given relative to a standard called atomic mass unit. What is atomic mass unit (amu)? (1)
    b) In a reaction $A + B_2 \rightarrow AB_2$, identify the limiting reagent in the reaction mixture containing 5mol A and 2.5 mol B. (1)
    c) Calculate the mass of NaOH required to make 500 ml of 0.5M aqueous solution. (Molar mass of NaOH = 40) (2) [October 2013]

Ans: a) 1/12th the mass of a C^{12} atom is called atomic mass unit. (1)
b) B (1)
c) Molarity = Mass of the solute x 1000 / Molar mass of the solute x volume of solution in mL
So, Mass of the solute = (Molarity x Molar mass of the solute x volume of solution in mL)/1000
= (0.5 x 40 x 500)/1000 = 10 g (2)

20. The mole concept helps in handling a large number of atoms and molecules in stoichiometric calculations.
    a) Define 1 mol. (1)
    b) What is the number of hydrogen atoms in 1 mole of methane (CH_4)? (1)
    c) Calculate the amount of carbon dioxide formed by the complete combustion of 80g of methane as per the reaction:
    $CH_4\ (g) + 2O_2\ (g) \longrightarrow CO_2\ (g) + 2\ H_2O\ (g)$
    (Atomic mass of C = 12.01u, H = 1.008u, O = 16u) (2) [March 2013]

Ans: a) 1 mol is the amount of substance that contains as many particles as there are atoms in exactly 12g C^{12} isotope. (1)
b) 1 mol CH_4 contains 4 mol hydrogen = 4 x 6.022 x 10^{23} H atoms. (1)
c) $CH_4\ (g) + 2O_2\ (g) \longrightarrow CO_2\ (g) + 2\ H_2O\ (g)$
According to the equation, 16 g CH_4 gives 44 g CO_2
So 80 g CH_4 gives 44 x 80/16 = 220 g CO_2 (2)

21. a) Mole is a very large number to indicate the number of atoms, molecules etc. Write another name for one mole. (1)
    b) i) How the molecular formula is different from that of empirical formula? (1)
    ii) An organic compound on analysis gave the following composition. Carbon = 40%, Hydrogen = 6.66% and oxygen = 53.34%. Calculate its molecular formula if its molecular mass is 90. (2) [September 2012]

Ans: a) Avogadro's Number or Avogadro's constant (1)
b) (i) Empirical formula is the simplest formula which gives only the ratio of different elements present in the compound. But molecular formula is the actual formula that gives the exact number of different elements present in the compound. (1)
(ii)

Element	Percentage	Atomic mass	Percentage/ Atomic mass	Simple ratio	Simplest whole no. ratio
C	40	12	40/12 = 3.33	3.33/3.33 = 1	1
H	6.66	1	6.66/1 = 6.66	6.66/3.33 = 2	2
O	53.34	16	53.34/16 = 3.33	3.33/3.33 = 1	1

Empirical Formula = CH_2O

Empirical Formula Mass (EFM) = 12+2+16 = 30

Molar mass (MM) = 90

n = MM/EFM = 90/30 = 3

Molecular formula = Empirical formula x n

= (CH_2O) x 3 = $C_3H_6O_3$ *(2)*

22. The combination of elements to form compounds is governed by the laws of chemical combination.
    a. Hydrogen combines with oxygen to form compounds, namely water and hydrogen peroxide. State and illustrate the related law of chemical combination. (2)
    b. What is mean by limiting reagent in a chemical reaction? (1)
    c. 28 g of nitrogen is mixed with 12 g of hydrogen to form ammonia as per the reaction, $N_2 + 3\ H_2 \longrightarrow 2NH_3$. Which is the limiting reagent in this reaction? (1) [March 2012]

Ans: a) Law of multiple proportions (Answer of Qn. No. 6) *(2)*

b) A reagent that is completely consumed in a reaction. *(1)*

c) No. of mol of N_2 = 28/28 = 1 mol

No. of mol of H_2 = 12/2 = 6 mol.

Here N_2 is completely used up. So it is the limiting reagent. *(1)*

23. The laws of chemical combination govern the formation of compounds from elements.
    a) State the law of conservation of mass. Who put forward this law? (1½)
    b) The following data are obtained when dinitrogen and dioxygen react together to form different compounds.

Sl. No.	Mass of dinitrogen (in g)	Mass of dioxygen (in g)
1	14	16
2	14	32
3	28	48
4	28	80

Which law of chemical combination is illustrated by the above experimental data? Explain? (2½)
[October 2011]

Ans: a) It states that matter can neither be created nor destroyed. Or, in a chemical reaction, the total mass of reactants = the total mass of products. This law was put forward by Antoine Lavoisier.

b) Law of Multiple proportion (See the answer of Qn. No. 6)

24. The laws of chemical combination are the basis of the atomic theory.
    a) Name the law of chemical combination illustrated by the pair of compounds, CO and CO_2. (1)
    b) State and explain the law of conservation of mass. (1½)
    c) Calculate the molarity of a solution containing 8 g of NaOH in 500 mL of water. (1½) [March 2011]

Ans: a) Law of multiple proportions

b) It states that matter can neither be created nor destroyed. Or, in a chemical reaction, the total mass of reactants = the total mass of products.

Consider the reaction $2H_2 + O_2 \rightarrow 2H_2O$

Here 4 g of H_2 combines with 32 g of O_2 to form 36 g of water.

Total mass of reactants = 4 + 32 = 36g

Total mass of products = 36 g

c) *Molarity = Mass of the solute x 1000 / Molar mass of the solute x volume of solution in mL*

= (8 x 1000)/40x500 = 0.4 M

25. One mole is the amount of substance that contains as many particles as 12 g of C^{12} isotope of carbon.
    a) What do you mean by molar mass of a compound? (1)
    b) Calculate the number of moles in 1 L of water (Density of water 1 g/mL). Also calculate the number of water molecules in 1 L water. (3) [September 2010]

Ans: a) It is the mass of 1 mol of any substance. (1)

b) Since density of water = 1 g/mL, 1 L H_2O = 1 kg H_2O = 1000g H_2O (mass = density x volume)

No. of moles = Mass in gram / Molar mass = 1000/18 = 55.55 mol

No of molecules = no. of moles x N_A = 55.55 x 6.022 x 10^{23} molecules. (3)

26. If the mass percent of various elements of a compound is known, its empirical formula can be calculated.
    a) What is mass percent? (1)
    b) A compound contains 4.07% hydrogen, 24.27% carbon and 71.65% chlorine. Its molecular mass is 98.96. What are the empirical and molecular formulae? (3) [March 2010]

Ans: a) Mass % = Mass of solute × 100 / Mass of solution

OR, Mass percent = Mass of that element in the compound x 100 / Molar mass of the compound (1)

b)

Element	*Percentage*	*Atomic mass*	*Percentage/ Atomic mass*	*Simple ratio*	*Simplest whole no. ratio*
C	*24.27*	*12*	*24.27/12 = 2.02*	*2.02/2.02 = 1*	*1*
H	*4.07*	*1*	*4.07/1 = 4.07*	*4.07/2.02 = 2*	*2*
Cl	*71.65*	*35.5*	*71.65/35.5 = 2.02*	*2.02/2.02 = 1*	*1*

Empirical Formula = CH_2Cl

Empirical Formula Mass (EFM) = 12+2+35.5 = 49.5

Molar mass (MM) = 98.96

n = MM/EFM = 98.96/49.5 = 2

Molecular formula = Empirical formula x n

= (CH_2Cl) x 2 = $C_2H_4Cl_2$ (3)

27. Calculate the number of moles of oxygen required to produce 240 g of MgO by burning Mg metal. (Atomic mass Mg = 24, O = 16) (4) [March 2009]

Ans: No. of moles of MgO = 240/24 = 10 mol

2 Mg + O_2 ⟶ 2 MgO

2 mol MgO requires 1 mol O_2

So, 10 mol MgO requires 5 mol O_2. (4)

28. One gram atom of an element contains 6.02 x 10^{23} atoms.
    a) Find the number of oxygen atoms in 4 g of O_2. (1)
    b) Which is heavier, one oxygen atom or 10 hydrogen atoms? (1) [February 2008]

Ans: a) No. of moles of O_2 = 4/32 = 0.125 mol

1 mol O_2 contains 2 x 6.022 x 10^{23} Oxygen atoms.

So, 0.125 mol O_2 contains 0.125 x 2 x 6.022 x 10^{23} Oxygen atoms (1)

b) Mass of one oxygen atom = 16u

Mass of 10 hydrogen atoms = 10u

So one oxygen atom is heavier. *(1)*

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PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "STRUCTURE OF ATOM"

1. Represent the orbital with quantum numbers n = 5 and l = 3. (1)
   Ans: 5f
2. The threshold frequency for a metal is 7.0 x 10^{14} s^{-1}. Calculate the kinetic energy of an emitted electron when radiation of frequency (v) 1.0 x 10^{15} s^{-1} hits the metal. (2)
   Ans: Here threshold frequency (v_0) = 7.0 x 10^{14} s^{-1} and frequency of radiation (v) = 1.0 x 10^{15} s^{-1}
   K.E of emitted electron = $hv - hv_0 = h(v - v_0)$ = 6.626 x 10^{-34} (1.0 x 10^{15} - 7.0 x 10^{14}) = 19.878 x 10^{-20} J
3. What are the important observations and conclusions made by Rutherford from his alpha ray scattering experiment? Give any two limitations of Rutherford's nuclear model of atom. (4) [July 2019]
   Ans: The important observations made by Rutherford are:
   (i) Most of the α– particles passed through the gold foil without any deviation.
   (ii) A small fraction of the α–particles was deflected by small angles.
   (iii) A very few α– particles bounced back (that is, deflected by nearly 180°).
   Conclusions:
   (i) Most space in the atom is empty.
   (ii) The positive charge of the atom is concentrated in a very small volume at the centre called nucleus.
   (iii) The volume occupied by the nucleus is negligibly small as compared to the total volume of the atom.
   Limitations: (i) Rutherford's model cannot explain the stability of the atom.
   (ii) He cannot explain the electronic structure of atom.
4. The minimum value for the product of uncertainties in position and momentum of a moving microscopic particle is equal to ..... (1)
   Ans: h/4π
5. Mention two observations which could not be explained by wave nature of electromagnetic radiations. (2)
   Ans: Black body radiation, photoelectric effect (variation of heat capacity of solids with temperature, line spectra of atoms etc.)
6. Explain quantum numbers. Give the importance of quantum numbers in Pauli's Exclusion Principle. (4)

   Ans: Quantum Numbers are certain numbers used to explain the size, shape and orientation of orbitals. Or, Quantum numbers are the address of an electron. There are four quantum numbers - Principal Quantum number (n), Azimuthal Quantum number (l), Magnetic Quantum number (m) and Spin Quantum number (s)
   ***1. Principal Quantum Number (n)**: It gives the size the orbit, the energy of electron in an orbit, the shell in which the electron is found and the average distance between the electron and the nucleus.*
   The possible values are 1, 2, 3, 4, 5 etc.
   ***2. Azimuthal Quantum Number (l)**: It gives the shape of the orbital, the sub shell in which the electron is located and the orbital angular momentum of the electron.*
   The possible values of l are : l = 0, 1, 2, ... (n-1).
   3. Magnetic Quantum Number (m or m_l)
   It gives the orientation of orbitals in space. For a given 'l' value, there are 2l+1 possible values for m and these values are – l to 0 to + l
   4. Spin Quantum Number (s or m_s)
   It is the only experimental Quantum number and it gives the spin orientation of electrons. The values for s may be +½ or -½. +½ represents clock-wise spin and-½ represents anticlock-wise spin.
   *According to **Pauli's exclusion principle**, no two electrons in an atom can have the same set of four quantum numbers. i.e. an orbital can accommodate a maximum of only 2 electrons with opposite spin.*

7. Name the quantum number which gives the spatial orientation of an orbital with respect to standard set of co-ordinate axes. (1)

   Ans: Magnetic Quantum number

8. Write two important results observed during photoelectric effect. (2)

   Ans: (i) The electrons are ejected from the metal surface as soon as the beam of light strikes the surface.
   (ii) The number of electrons ejected is proportional to the intensity or brightness of light.
   (iii) For each metal, there is a minimum frequency called threshold frequency below which photoelectric effect is not observed.
   (iv) The kinetic energy of the ejected electrons is directly proportional to the frequency of the incident light. [Any 2 required]

9. Explain how, the different series of lines are formed in the hydrogen spectrum. Derive an equation to find the wave number of a line in the hydrogen spectrum. (4) [August 2018]

   Ans: According to Bohr atom model, line spectrum is formed by the excitation (de-excitation) of electron from one energy level to another.

   Consider two energy levels E_1 and E_2 in Hydrogen atom. The energy gap between the two orbits is given by equation: $\Delta E = E_2 - E_1$

   But $E_1 = \frac{-R_H}{n_1^2}$ and $E_2 = \frac{-R_H}{n_2^2}$

   Therefore, $\Delta E = R_H [1/n_1^2 - 1/n_2^2]$

   $= 2.18 \times 10^{-18} [1/n_1^2 - 1/n_2^2]$

   The frequency associated with the absorption and emission of the photon can be given as

   $$\nu = \frac{\Delta E}{h} = \frac{R_H}{h}\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$$

   $$= \frac{2.18 \times 10^{-18}}{6.626 \times 10^{-34}}\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$$

   $$= 3.29 \times 10^{15} [1/n_1^2 - 1/n_2^2]$$

   The wave number ($\bar{\upsilon}$) = $$1/\lambda = \frac{\nu}{c} = \frac{R_H}{hc}\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$$

   $$= \frac{3.29 \times 10^{15}}{3 \times 10^{8}}\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$$

   $$= 1.09677 \times 10^{7}\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\} m^{-1} \qquad = 109677\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\} cm^{-1}$$

10. How many angular nodes are present in a 5f-orbital? (1)

    Ans: For f orbitals, no. of angular nodes = 3

11. Give the postulates of Bohr model of hydrogen atom. Also write two merits and two limitations of this model. (4)

    Ans: The important postulates of Bohr model of hydrogen atom are:

(i) The electron in the hydrogen atom can move around the nucleus in circular paths of fixed radius and energy. These paths are called orbits or stationary states or allowed energy states.

(ii) The energy of an electron in an orbit does not change with time. However, when an electron absorbs energy, it will move away from the nucleus.

(iii) The radius of orbits can be given by the equation: $r_n = a_0 n^2$ where $a_0 = 52.9$ pm.

(iv) The energy of electron in an orbit is given by the expression: $E_n = -R_H (1/n^2)$, where n = 1,2,3..... and R_H is a constant called Rydberg constant. Its value is 2.18×10^{-18} J.

(v) The frequency of radiation absorbed or emitted when transition occurs between two stationary states that differ in energy by ΔE, is given by:

$$v = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h}$$

(vi) The angular momentum of an electron is an integral multiple of h/2π. i.e. $m_e vr = \frac{nh}{2\pi}$

Merits: (i) It could explain the stability of atom

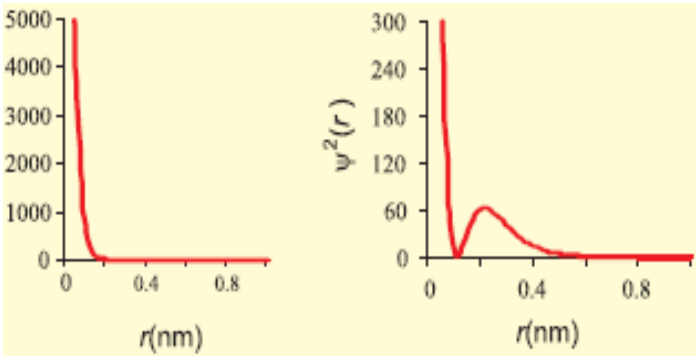
(ii) It could explain the line spectra of hydrogen atom and hydrogen like ions.

Demerits: (i) It could not explain the fine spectrum of hydrogen atom.

(ii) It could not explain the spectrum of atoms other than hydrogen.

12. Represent graphically, the variation of probability density ($\psi^2_{(r)}$) as a function of distance (r) of the electron from the nucleus for 1s and 2s orbitals. (2) [March 2018]

Ans:



1s 2s

13. a) Cathode rays are rays moving from cathode to anode. Give any two properties of cathode rays. (2)

b) Write the electronic configuration of Cr. (1)

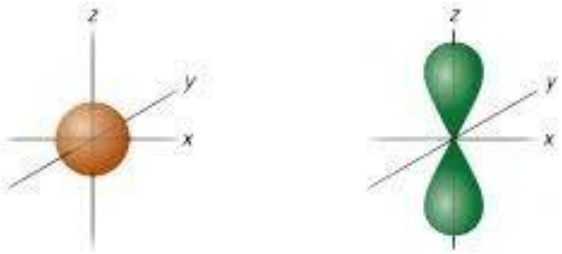
c) Draw the shapes of s and p orbitals. (2) [July 2017]

Ans: a) (i) Cathode rays start from cathode and move towards the anode.

(ii) They are invisible, but their behaviour can be observed with the help of fluorescent or phosphorescent materials. (2)

b) $_{24}Cr$: [Ar] $3d^5 4s^1$ OR $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$ (1)

c)



s orbital *p orbital* *(2)*

14. a) i) Write the electronic configuration of chromium (z = 24) (1)

ii) Find the number of electrons in the subshell with azimuthal quantum number l =2. (1)

iii) Represent the orbital with quantum numbers n = 1 and l = 0 (1)

b) Give the mathematical representation of Heisenberg's uncertainty principle and its one important significance. (2) [March 2017]

Ans: a) (i) $_{24}Cr$: [Ar] $3d^5 4s^1$ OR $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$ (1)

(ii) l = 2 denotes d subshell, which can accommodate a maximum of 10 electrons. (1)

(iii) 4s (1)

b) $\Delta x.\ \Delta p \geq h/4\pi$. This principle rules out the existance of definite paths or orbits for electrons. (2)

15. Bohr was the first to explain the structure of hydrogen atom and spectrum.
    a) Give the main postulates of Bohr model of atom. (2)
    b) Calculate the wavelength of the first line in Lyman series of the hydrogen spectrum (R = 109677 cm^{-1}). (3)

    Ans: a) Refer the answer of Qn. No. 11

    b) For the first line in Lyman series, $n_1 = 1$ and $n_2 = 2$

    Wave number, $\bar{\upsilon} = 1/\lambda = 109677\ (1/n_1^2 - 1/n_2^2) = 109677\ (1/1^2 - 1/2^2) = 109677 \times ¾ = 82257.75\ cm^{-1}$

    Wave length (λ) = $1/\bar{\upsilon} = 1/82257.75 = 1.21 \times 10\text{-}5\ cm = 121\ nm$ (3)

16. a) There are some rules governing the filling of electron in orbitals. State and explain Hund's rule of maximum multiplicity. (2)
    b) Quantum number gives the address of electrons. Explain the quantum number which determines:
        i) Distance of electron from nucleus.
        ii) The orbital angular momentum of electron. (3) [September 2016]

    Ans: a) It states that electron pairing takes place only after partially filling all the degenerate orbitals. For example the electronic configuration of N is $1s^2\ 2s^2\ 2px^1 py^1 pz^1$ and not $1s^2\ 2s^2\ 2px^2 py^1$.

    b) (i) Principal Quantum number

    (ii) Azimuthal or subsidiary Quantum number

17. Atomic orbitals are precisely distinguished by what are known as Quantum numbers.
    a) Name the four quantum numbers. (2)
    b) Represent the orbitals given below:
        i) n = 1, l = 0 ii) n = 2, l = 1 (2)
    c) The number of unpaired electrons present in Ni is ……. (Atomic number of Ni = 28)
        i) 2 ii) 0 iii) 1 iv) 3 (1) [March 2016]

    Ans: a) Principal Quantum number (n), Azimuthal Quantum number (l), Magnetic Quantum number (m) and Spin Quantum number (s)

    b) (i) 1s (ii) 2p

    c) 2

18. The quantum numbers provide / valuable information regarding electrons in an atom.
    a) Which one of the following statements is CORRECT about quantum numbers?
        i) The principal quantum number can have fractional values.
        ii) The azimuthal quantum number defines the three dimensional shape of the orbital.
        iii) The magnetic quantum number determines the size of the orbital.
        iv) Spin quantum number gives information about the spatial orientation of the orbital with respect to standard set coordinate axes. (2)

b) A photon has a wavelength of 3.5 A^0. Calculate its mass (Given h = 6.626 x 10^{-34} Js. Velocity of light = 3 x 10^8 m/s) (2)

Ans: a) (ii) The azimuthal quantum number defines the three dimensional shape of the orbital.

b) From the de Broglie's equation, λ = h/mv

m = h/ λv = 6.626x10^{-34}/(3.5x10^{-10}x3x10^8) = ***6.31x 10^{-33}kg***

19. The uncertainty principle contributed significantly in the formulation of the quantum mechanical model of atom.

a) Which one of the following statements is CORRECT about the uncertainty principle?

i) The exact position and the exact momentum of an electron in an atom can be determined simultaneously.

ii) It is a consequence of the dual behavior of matter and radiation.

iii) It is significant only for motion of microscopic objects and is negligible for that of macroscopic objects.

iv) It supports the existence of definite paths or trajectories of electrons and other similar particles. (1)

b) An electron is moving with a velocity of 2.5 x 10^6 m/s. If the uncertainty in its velocity is 0.1%. Calculate the uncertainty in its position. (Planck's constant, h = 6.626 x 10^{-34} Js. Mass of the electron = 9.1 x 10^{-31} kg). (2) [October 2015]

Ans: a) It is significant only for motion of microscopic objects and is negligible for that of macroscopic objects.

c) Here v = 2.5x10^6. Uncertainty in velocity (Δv) = 0.1% of 2.5x10^6 = 2.5x10^3, h = 6.626 x 10^{-34} Js, m = 9.1 x 10^{-31} kg.

We know that Δx.m.Δv = h/4π

So, Δx = $\frac{h}{4\pi.m.\Delta v} = \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 2.5 \times 10^3}$ = ***$\underline{0.023 \times 10^{-6}\ m}$***

20. a) The number of protons, electrons and neutrons in a species are equal to 17, 18 and 18 respectively. Which of the following will be the proper symbol of this species?

i) $_{17}{}^{35}Cl$ ii) $_{17}{}^{35}Cl^-$ iii)$_{17}{}^{36}Cl$ iv) $_{17}{}^{36}Cl^-$ (1)

b) i) Give any 2 postulates of Rutherford's nuclear model of an atom. (2)

ii) Write the two main drawbacks of Rutherford's atomic model. (2)

Ans: a) $_{17}{}^{35}Cl^-$

b) i) The important postulates of Rutherford's nuclear model of an atom are:

- *All the positive charge and most of the mass of the atom are concentrated in an extremely small region called nucleus.*
- *Electrons are revolving round the nucleus with a very high speed in circular paths called orbits.*
- *Electrons and the nucleus are held together by electrostatic forces of attraction. [Any 2]*

ii) Drawbacks: (i) Rutherford's model cannot explain the stability of the atom.

(ii) He cannot explain the electronic structure of atom.

21. a) Representation of the orbital with quantum numbers n = 3, l = 1 is ……

i) 3s ii) 3d iii) 3p iv) 1s (1)

b) i) Which of the following sets of quantum numbers are NOT possible?

1) n = 2, l = 2, m_l = 0, m_s = + ½

2) n=1, l = 0, m_l = 0, m_s = - ½

3) n = 3, l = 2, m_l = -3, m_s = + ½

4)n = 2, l = 1, m_l = 1, m_s = + ½ (2)

ii) Justify your answer. (2) [March 2015]

Ans: a) 3p

b) i) n = 2, l = 2, m_l = 0, m_s = + ½

n = 3, l = 2, m_l = -3, m_s = + ½

ii) When n =2, the values of l are 0 and 1. i.e. l cannot be 2

When l = 2, the values of m_l are -2, -1, 0, +1 and +2. i.e. ml cannot be -3.

22. a) Write the subshell-wise electronic configurations of the following elements:

i) Cu (Z = 29), ii) Cr (Z = 24) give reason for the extra stability of these atoms. (2)

b) Canal rays were discovered by discharge tube experiments conducted in a modified cathode ray tube. Give any two characteristics of canal rays. (1)

c) A microscope with suitable photons is employed to locate an electron in an atom within a distance of 0.4 A^0. What is the uncertainty involved in the measurement of its velocity? (2) [August 2014]

Ans: a) i) $_{29}Cu$: [Ar] $3d^{10}4s^1$ OR, $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$

ii) $_{24}Cr$: [Ar] $3d^5 4s^1$ OR, $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

This is because half-filled and completely filled electronic configurations have extra stability.

b) The nature of canal rays depends on the nature of gas present in the cathode ray tube. These are positively charged gaseous ions. They are invisible and can be observed with the help of fluorescent or phosphorescent materials.

c) Here $\Delta x = 0.4\ A^0 = 0.4 \times 10^{-10}$ m, $h = 6.626 \times 10^{-34}$ Js, $m = 9.1 \times 10^{-31}$ kg, Δv = ?

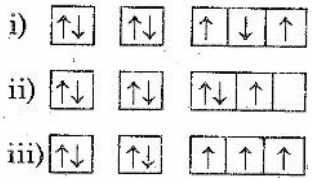
We know that $\Delta x.m.\Delta v = h/4\pi$

*So, $\Delta v = \frac{h}{4\pi.m.\Delta x} = \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 0.4 \times 10^{-10}} =$ **0.145×10^7 m/s***

23. a) The number of electrons, protons and neutrons in a species are equal to 18, 16 and 16 respectively. Assign the proper symbol to the species. (1)

b) Write any two drawbacks of the Rutherford model of atom. (2)

c) Among the following electronic configurations, which one is correct? Substantiate your answer.



(2) [March 2014]

Ans: a) $^{32}_{16}X^{2-}$

b) Refer question no. 22(b).

c) iii) is correct. This is because according to Hund's rule, the electron pairing occurs only after partially filling all the degenerate orbitals.

24. a) A large number of orbitals are possible in an atom. Using s, p, d or f notations describe the orbital with the following quantum numbers. i) n = 4, l = 0 ii) n = 3, l = 2 (1)

b) The Balmer series of lines in the hydrogen spectrum appear in the visible region of the electromagnetic spectrum. Calculate the wave number of the second line in the Balmer series. (Rydberg constant for Hydrogen is 109677 cm^{-1}) (2)

c) Bohr model of hydrogen atom contradicts dual behaviour of matter and Heisenberg's uncertainty principle. Justify. (2) [September 2013]

Ans: a) i) 4s ii) 3d

b) For the second line in Balmer series, $n_1 = 2$ and $n_2 = 4$

Wave number, $\bar{\upsilon} = 1/\lambda = 109677\ (1/n_1^2 - 1/n_2^2) = 109677\ (1/2^2 - 1/4^2) = 109677 \times 3/16 = 20564.4\ cm^{-1}$

c) Bohr model did not consider the wave character of the electron. Also, the concept of orbit is against Heisenberg uncertainty principle since both the position and the velocity of the electron in an orbit can be determined simultaneously.

25. Photoelectric effect was first observed by Hertz.
    a) The number of electrons ejected in the photoelectric effect is proportional to …… of light used. (frequency, intensity) (1)
    b) Select the correct statement related to the photoelectric effect:
        i) Threshold frequency is the maximum frequency required to photoelectric emission from a particular metal.
        ii) The kinetic energy of the photoelectrons is directly proportional to the frequency of incident light.
        iii) Work function is same for all metals. (1) [March 2013]

    Ans:intensity

    b) ii) The kinetic energy of the photoelectrons is directly proportional to the frequency of incident light.

26. The general features of the structure of a hydrogen atom and hydrogen like species were quantitatively explained by Niels Bohr.
    a) Write any postulate of the Bohr's model of hydrogen atom. (1)
    b) Calculate the radius of the second orbit of Li^{2+}. (Express answer in nm). (2) [March 2013]

    Ans: a) Refer question number 11.

    b) Radius, $r_n = a_0 n^2/z$

    Here $a_0 = 52.9$ pm, n=2 and z = 3 (for Li)

    So $r_n = 52.9 \times 2^2/3 =$ 70.53 pm

27. The dual behaviour of matter was proposed by French physicist de Broglie.
    a) State the dual behaviour of matter. (1)
    b) A moving electron has a de Broglie wave length of 7×10^{-7} m. Calculate its kinetic energy. (Planck's constant = 6.626×10^{-34} Js, mass of an electron = 9.1×10^{-31} kg) (2) [March 2013]

    Ans: a) Matter has both particle nature and wave nature. This is known as dual behaviour of matter.

    b) From the de Broglie's equation, $\lambda = h/mv$

    $v = h/\lambda.m = 6.626 \times 10^{-34}/(7 \times 10^{-7} \times 9.1 \times 10^{-31}) = 0.104 \times 10^4$ m/s

    K.E = ½ mv^2 = ½ $\times$ 9.1 $\times 10^{-31} \times (0.104 \times 10^4)^2 = 0.049 \times 10^{-23}$ kJ/mol

28. a) In order to specify the size, energy, shape and orientation of orbitals and spin of the electrons, we need 4 quantum numbers.
        i) Write the 4 quantum numbers. (1)
        ii) Represent the orbital with the following quantum numbers, n = 4 and l = 0. (1)
    b) State the rules behind the electronic configuration in an atom. (3) [September 2012]

    Ans: a) i) Ref. qn. No. 17(a)

ii) 4s

*b) 1. **Aufbau principle:** It states that **the orbitals are filled in the increasing order of their energies**.*

*2. **Pauli's Exclusion Principle:** It states that **no two electrons in an atom can have the same set of four quantum numbers**.*

*3. **Hund's rule:** It states that **electron pairing takes place only after partially filling all the degenerate orbitals**.*

29. The photon has a momentum as well as a wavelength.
    a) Which property of matter is revealed in the above statement? (1)
    b) A photon has a mass of 8.6 x10^{-30} kg. Calculate its wavelength. (Planck's constant = 6.626 x 10^{-34} Js (2) [March 2012]

    Ans: a) Dual behaviour of matter

    b) For photon, velocity (v) = 3 x 10^8 m/s

    From the de Broglie's equation, λ = h/mv

    = 6.626 x 10^{-34}/(8.6x10^{-30} x 3x10^8) = 0.257 x 10^{-12} m = 0.257 pm

30. Heisenberg's uncertainty principle rules out the existance of definite paths for electrons and other similar particles.
    a) State Heisenberg's uncertainty principle. (1)
    b) Calculate the uncertainty in the velocity of a cricket ball of mass 130 g, if the uncertainty in its position is of the order of 1.2 A^0. (2) [March 2012]

    Ans: a) It states that "it is impossible to determine simultaneously, the exact position and exact momentum (or velocity) of a moving microscopic particle like electron".

    b) We know that Δx.m.Δv = h/4π. Here m = 130g = 130 x 10^{-3} kg

    *So, Δx = $\frac{h}{4\pi.m.\Delta v} = \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 130 \times 10^{-3} \times 1.2 \times 10^{-10}}$ = **0.145 x 10^{-21} m***

31. The electrons in an atom are designated by a set of quantum numbers labeled as n, l, m and s.
    a) Give the values of n, l, m and s for the valence electron of sodium atom (Atomic number = 11) (2)
    b) Which of the following set of quantum numbers are not allowed?
        i) n = 3, l = 3, m = -3, s = +½
        ii) n = 2, l = 1, m = 0, s = -½
        iii) n = 1, l = 0, m = 0, s = +½
        iv) n = 0, l = 0, m = 0, s = +½ (2)
    c) State Pauli's exclusion principle. (1) [October 2011]

    Ans: a) The electronic configuration of sodium is 11Na – $1s^2$ $2s^2$ $2p^6$ $3s^1$.

    Here the last electron is at 3s subshell.

    The values of different quantum numbers for 3s subshell are n = 3, l = 0, m = 0 and s = + ½ or – ½.

    b) i) n = 3, l = 3, m = -3, s = +½ and iv) n = 0, l = 0, m = 0, s = +½

    c) Ref. qn. No. 28 (b)

32. Based on his α-ray scattering experiment, Rutherford proposed the nuclear model of an atom.
    a) Give the main postulates of Rutherford's atom model. (2)
    b) Write the important demerits of Rutherford model. (1)
    c) The threshold frequency, ν_0 for a metal is 6.2 x 10^4 s^{-1}. Calculate the K.E of an ejected electron when the radiation of frequency, ν = 8.7 x $10^4 s^{-1}$ strikes the metal. (2) [March 2011]

Ans: a) and b) Ref. qn. No. 20 (b)

c) K.E of emitted electron = hν - $hν_0$ = h(ν - $ν_0$) = 6.626 x 10^{-34} (8.7 x 10^4 – 6.2 x 10^4)= 16.565 x 10^{-30} J

33. During Rutherford's α-ray scattering experiment, it was observed that most of the α-particles passed through the Gold-foil without any deflection, a small fraction deflected by small angles and very few bounced back.
    a) What are the main conclusions made by Rutherford? (1½)
    b) Give the atom model proposed by him. (1½)
    c) What are the main drawbacks of this model and how Niels Bohr overcame these defects in his model? (2) [September 2010]

    Ans: Ref. qn. No. 3 & 20 (b.

    Bohr overcame these defects by assigning fixed circular paths for electrons.

34. Niels Bohr was the first to explain quantitatively the general features of hydrogen atom structure and its spectrum.
    a) Give the main postulates of Bohr's model of atom. (2)
    b) Find the maximum number of emission lines, when the excited electron of hydrogen atom in n =6, drops to the ground state (n = 1). (1½)
    c) Calculate the wave number of radiation due to transition of an electron from 4^{th} orbit to 2^{nd} orbit (R_H = 109677 cm^{-1}) (1½) [March 2010]

    Ans: a) Ref. qn. No. 11

    b) The maximum no. of emission lines = n(n-1)/2 = 6(6-1)/2 = 15.

    c) Ref. qn. No. 24(b)

35. Dual nature of matter was proposed by Louis-de-Broglie.
    a) Calculate the de Broglie wave length associated with an electron with velocity 1.6 x 10^6 m/s (3)
    b) State Pauli's exclusion principle and Hund's rule of maximum multiplicity. (2) [March 2009]

    Ans: a) From the de Broglie's equation, λ = h/mv

    = 6.626 x 10^{-34}/(9.1 x10^{-31} x 1.6 x 10^6) =0.455 x 10^{-9}m= 0.455 nm

    b) *Ref. qn. No. 28 (b)*

36. Quantum numbers give the address of an electron. Explain all the four quantum numbers. (4) [March 2008]

    Ans: Ref. qn. No. 6

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PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "CLASSIFICATION OF ELEMENTS AND PERIODICITY IN PROPERTIES"

1. (a) Give the IUPAC name of the element with Atomic number 117. (1)
   (b) In the modern periodic table elements in a given group have similar chemical properties. Give reason. (1)
   Ans: (a) Ununseptium (Uus)
   (b) Elements in a given group have same no. of valence electrons. So they have similar chemical properties.
2. Account for the following :
   (a) The ionic radius of fluoride ion (F^-) is 136 pm, while the atomic radius of fluorine (F) is only 64 pm. (1)
   (b) The second ionization enthalpy of an element is always greater than that of the first ionization enthalpy. (1)
   [July 2019]
   Ans: (a) This is due to greater electronic repulsion and lesser effective nuclear charge in F^-.
   (b) This is because it is more difficult to remove an electron from a positively charged ion than from a neutral atom.
3. 'Chlorine has the most negative electron gain enthalpy'. Justify the statement. (2)
   Ans: This is because, when an electron is added to F, it enters into the smaller 2nd shell. Due to the smaller size, the electron suffers more repulsion from the other electrons. But for Cl, the incoming electron goes to the larger 3rd shell. So the electronic repulsion is low and hence Cl adds electron more easily than F.

4. Identify the positions of Al (z=13) and S (z=16) in the periodic table with the help of their electronic configurations. Predict the formula of the compound formed between them. (2) [March 2019]
   Ans: $_{13}Al$ – [Ne] $3s^2\ 3p^1$, Period – 3, Group - 13
   $_{16}S$ – [Ne] $3s^2\ 3p^4$, Period – 3, Group - 16
   The formula of the compound formed between Al and S is Al_2S_3.
5. Among N^{3-}, O^{2-}, F^-, Na^+ and Al^{3+}, which one has the smallest size? (1)
   Ans: Al^{3+}
6. Give reasons for the following :
   a) 'O' has lower ionization enthalpy than N and F.
   b) Cl has higher negative electron gain enthalpy than F. (3) [August 2018]
   Ans: a) The electronic configuration of O is $1s^2\ 2s^2\ 2p^4$. After the removal of one electron, O gets the stable half filled electronic configuration. So it has lower ionisation enthalpy.
   b) Due to larger size and less electron-electron repulsion in chlorine.
7. Which is the acidic oxide among the following?
   a) Cl_2O_7 b) Na_2O c) Al_2O_3 d) CO (1)
   Ans: a) Cl_2O_7
8. Justify the following :
   a) Ne has positive value for electron gain enthalpy.
   b) The electron gain enthalpy of F is lower than that of Cl.
   c) The size of Al^{3+} is lower than that of F. (3) [March 2018]
   Ans: a) Due to stable octet configuration of Ne.
   b) Due to small size and greater electronic repulsion in fluorine.
   c) Due to greater effective nuclear charge in Al^{3+}.
9. a) Account for the following:
   i) Transition elements are d-block elements.
   ii) Chlorine has high electron gain enthalpy. (2)
   b) Select isoelectronic species from the following:
   O^-, F^-, Na^+, Mg^+ (2) [July 2017]
   Ans: a) i) Because in transition elements, the last electron enters in the penultimate d-subshell.
   ii) Refer qn. No. 6 (b).
   b) F^- and Na^+

10. Electron gain enthalpy is one of the important periodic properties.
    a) Define electron gain enthalpy. (1)
    b) Explain any two factors affecting electron gain enthalpy. (2)
    c) Write the oxidation state and covalency of Al in $[AlF_6]^{3-}$ (1) [March 2017]

    Ans: a) It is the heat change (enthalpy change) when an electron is added to the outer most shell of an isolated gaseous atom.

    b) Electron gain enthalpy depends on atomic size, nuclear charge, shielding effect etc.

    c) Oxidation state = +3, Covalency = 6.

11. a) In the periodic table, elements are classified into four blocks. Explain any two blocks. (2)
    b) Account for the following:
    i) First ionisation enthalpy of Boron is less than that of carbon.
    ii) First member of a group differs from the rest of the members of the same group. (2) [September 2016]

    Ans: a) s block elements: These are elements in which the last electron enters in the outer most s-sub shell. They include elements of the groups 1 and 2. Their general outer electronic configuration is ns^1 or ns^2.

    p block elements: *These are elements in which the last electron enters in the outer most p sub shell. They include elements of the groups 13 to 18. Their general outer electronic configuration is $ns^2\ np^{1\ to\ 6}$.*

    *b) **i)** $_5B - 1s^2\ 2s^2\ 2p^1$. After the removal of one electron, B gets the stable fully filled electronic configuration. So its first ionisation enthalpy is low.*

    ***ii)** Due to their smaller size, high electronegativity, large charge to radius ratio and absence of vacant d-orbitals.*

12. a) Account for the following:
    i) Ionisation enthalpy of Nitrogen is greater than that of oxygen.
    ii) 2nd period elements show anomalous behaviour. (3)
    b) A group of ions are given below. Find one pair which is not Isoelectronic.
    Na^+, Al^{3+}, Ca^{2+}, Br^-, F^- (1) [March 2016]

    Ans: a) i) Due to the stable half filled electronic configuration of Nitrogen.

    ii) *Due to their smaller size, high electronegativity, large charge to radius ratio and absence of vacant d-orbitals.*

    b) Ca^{2+} and Br^-

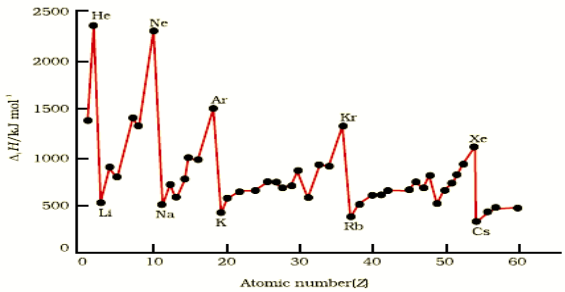
13. Names of elements with atomic numbers greater than 100 are given by IUPAC.
    a) The atomic number of element with IUPAC name 'Ununbium' is ……
    i) 112 ii) 110 iii) 111 iv) 114 (1)
    b) Why is potassium considered as an s-block element? (1)
    c) The first ionisation enthalpy of second period elements generally increase from left to right along the period. Give reason for this general trend. (2) [March 2015]

    Ans: a) 111

    b) $_{19}K - [Ar]\ 4s^1$. Its last electron enters in the valence s-subshell. So it is considered as an s-block element.

    c) This is because of the decrease in atomic size and increase in nuclear charge from left to right along the period.

14. Ionization enthalpy and atomic radius are closely related properties.
    a) Analyze the following graph :



What conclusion can you derive from the graph regarding the first ionization enthalpies of alkali metals and noble gases? Justify your answer. (2)

b) Aluminium forms $[AlF_6]^{3-}$ whereas boron cannot form $[BF_6]^{3-}$ but forms $[BF_4]^-$ even though both belong to the same group. Explain. (2) [October 2015]

Ans: a) In a period, the alkali metals have the least ionisation enthalpy and the noble gases have the most. This is because after the removal of only one electron from the valence shell, alkali metals get the stable completely filled electronic configuration. So they have low ionisation enthalpy. Noble gases have stable octet configuration. So they have high ionisation enthalpy.

b) Due to the presence of vacant d orbitals in Al, Al can extend its covalency beyond 4. So it can form $[AlF_6]^{3-}$. But in B, there is no vacant d-orbitals. So its maximum covalency is 4.

15. a) Transition elements were placed in groups 3 and group 12 of the periodic table. Give any two characteristics of transition elements. (2)

b) Does the ionization enthalpy decrease along a group? Give reason. (2) [August 2014]

Ans: a) Transition metals are all metals. They form coloured compounds or ions. They show variable oxidation states and valencies. Most of them are paramagnetic and show catalytic properties.

b) Yes, the ionization enthalpy decreases due to increase in atomic size, decrease in nuclear charge and increase in shielding effect along a group.

16. a) The first member of a group of elements in the s and p block differs from the rest of the family in chemical behaviour. Write any one reason for this. (1)

b) Write the general electronic configuration of d-block elements. (1)

c) The first ionization enthalpy sodium is lower than that of magnesium but its second ionization enthalpy is higher than that of magnesium. Explain. (2) [March 2014]

Ans: a) Due to their smaller size.

b) $(n-1)d^{1\text{ to }10}\ ns^{0\text{ to }2}$

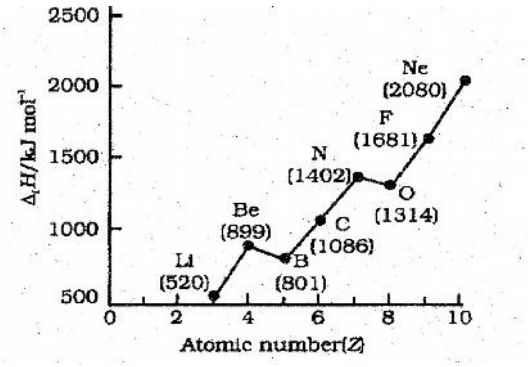
c) The electronic configuration of sodium is: $_{11}Na$ – [Ne] $3s^1$

After the removal of one electron, Na gets the stable noble gas configuration. So it has lower first ionisation enthalpy and higher second ionisation enthalpy.

17. The reactivity of an element is very much related to its ionisation enthalpy.

a) In general, ionisation enthalpy increases from left to right across a period. Give reason. (1)

b) Observe the following graph in which the first ionisation enthalpies (Δ_iH) of elements of the second period are plotted against their atomic numbers (Z):



Identify the anomalous values and justify. (3) [March 2013]

Ans: a) Due to decrease in atomic size and increase in nuclear charge across a period.

b) B and O have lower ionisation enthalpy than expected. This is because after the removal of one electron, B gets the stable fully filled configuration and O gets the stable half filled configuration.

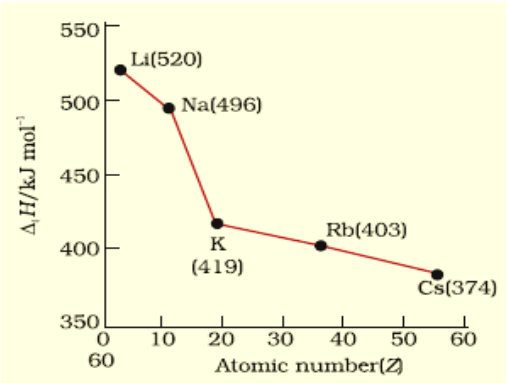
18. a) The IUPAC has made some recommendations to name elements with atomic numbers above 100. What would be the name for the element with atomic number 104? (1)
    b) Electro negativity is the ability of an element to attract shared pair of electrons. Name a numerical scale of electro negativity of elements. (1)
    c) Give reason for the following:
    i) Phosphorus forms PCl_5 while nitrogen cannot form NCl_5. Why? (1)
    ii) The first ionization enthalpy of oxygen is smaller compared to nitrogen. (1) [September 2013]
    Ans: a) Unnilquadium (Unq)
    b) *Pauling's electronegativity scale*
    c) *i) Due to the absence of vacant d-orbitals in N*
    ii) *Ref. qn. No. 6 (a)*
19. a) Electron gain enthalpy is the amount of energy released when an isolated gaseous atom accepts an electron to form a mono-valent anion.
    The values of electron gain enthalpy with atomic number of halogens are given below:

Element	At. No.	$\Delta_{eg}H$ in kJ/mol
F	9	328
Cl	17	349
Br	35	325
I	53	295

    i) Why electron gain enthalpy decreases from chlorine to iodine? (1)
    ii) Chlorine has more electron gain enthalpy than Fluorine. Why? (1)
    b) Identify the largest and smallest ion given below:
    O^{2-}, F^-, Na^+ and Mg^{2+} (2) [September 2012]
    Ans: a) i) Due to increase in atomic size and screening effect down the group.
    ii) Due to larger size and less electron-electron repulsion in chlorine.
    b) The largest ion is O^{2-} and the smallest is Mg^{2+}.
20. Moseley modified Mendeleev's periodic law based on his observations on the X-ray spectra of elements.
    a) State the modern periodic law. (1)

b) The IUPAC name of the element with atomic number 109 is …….. (1)

c) Analyse the following graph between ionization enthalpy and atomic number.



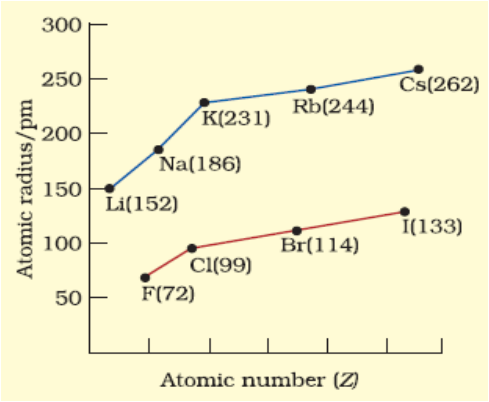
What do you observe from the graph? Give justification for your observation. (2) [March 2012]

Ans: a) The modern periodic law states that the properties of elements are the periodic functions of their atomic numbers.

b) *Unnilennium (Une)*

c) *Down a group, the ionisation enthalpy decreases. This is due to the increase in atomic size and shielding effect.*

21. a) A graph showing the variation of atomic radius with atomic number for alkali metals is given below.



Comment on the variation of atomic radius with increase in atomic number in a group. Give reason. (2)

b) What is meant by isoelectronic species? (1)

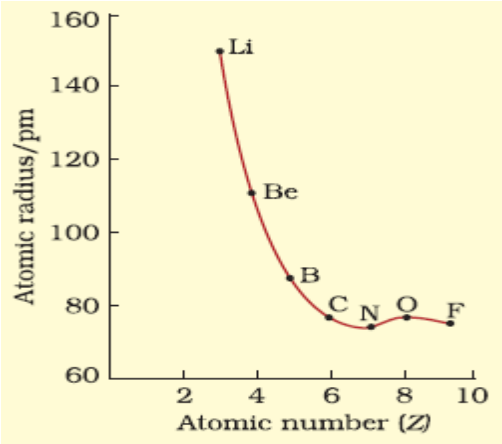
c) Select the isoelectronic species from the following. N, O^{2-}, F^-, Mg^{2+}, Al^{2+}, Na^+ (1) [October 2011]

Ans: a) Down a group, the atomic size increases due to increase in no. of shells and shielding effect.

b) *They are species having same no. of electrons.*

c) *O^{2-}, F^-, $Mg^{2+}$and Na^+*

22. A graph of atomic radius verses atomic number is given below:



a) What do you understand from this graph? (1)

b) Account for the observation that cations are always smaller than the parent atom while anions are always larger than the parent atom. (2)

c) Using the above graph, how will you account for the variation of ionization enthalpy in a period? (1) [March 11]

Ans: a) Along a period atomic radius decreases from left to right.

b) This is because of the greater effective nuclear charge in cations. But in anions, the addition of one or more electrons would result in an increased electronic repulsion and a decrease in effective nuclear charge.

c) In a period from left to right, the ionisation enthalpy increases due to decrease in atomic radius and increase in nuclear charge.

23. Development of periodic table has made the study of elements and their compounds easier.

a) Discuss about the main features of Mendeleev's periodic table. (2)

b) State the modern periodic law. (1)

c) Give the IUPAC name for the element with atomic number 112. (1) [September 2010]

Ans: a) Mendeleev classified the elements in the increasing order of their atomic weights. He proposed a periodic law which states that "the properties of elements are the periodic functions of their atomic weights"**.** *He arranged elements in horizontal rows (periods) and vertical columns (groups) in such a way that the elements with similar properties occupied in the same group. He mainly depended on the similarities in the empirical formulae and the properties of the compounds formed by the elements. He left some vacant places (gaps) for them in the periodic table and predicted some of their properties.*

b) Modern periodic law states that the properties of elements are the periodic functions of their atomic numbers.

c) Ununbium (Uub)

24. Account for the following:

a) Ionization enthalpy of nitrogen is greater than that of oxygen. (1)

b) Atomic radius decreases from left to right in a period. (1)

c) Electron gain enthalpy of F is less negative than that of Cl. (2) [March 2010]

Ans: a) Due to the stable half filled electronic configuration of Nitrogen.

b) Along a period, the no. of shells remains the same and the nuclear charge increases one by one. So the atomic radius decreases.

c) Due to small size and greater electronic repulsion in fluorine.

25. a) Who introduced the periodic law of elements for the first time? State the law. (2)

b) State the modern periodic law of elements? (2) [March 2009]

Ans: a) Mendeleev. It states that the properties of elements are the periodic functions of their atomic weights.

b) Modern periodic law states that the properties of elements are the periodic functions of their atomic numbers.

26. Elements have electron gain enthalpy and electronegativity.
    a) We two elements belong to the same group. One of us has the highest electronegativity and other, highest electron gain enthalpy. Identify us. (1)
    b) Define electron gain enthalpy? (1)
    c) Electron gain enthalpy values of noble gases are zero. Why? (1) [June 2008]

    Ans: a) The highest electronegativity - F and the highest electron gain enthalpy – Cl.

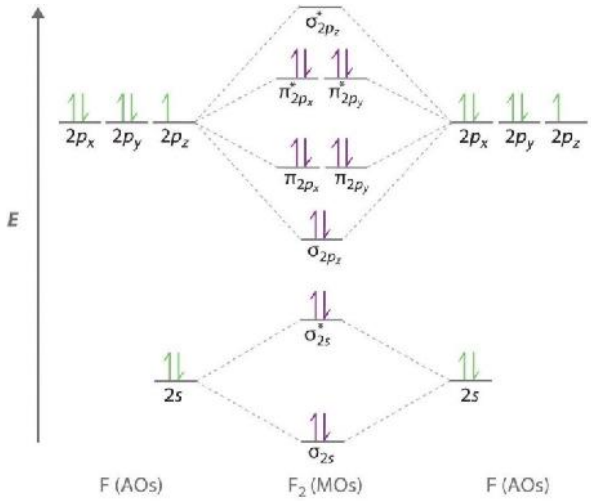
    b) It is the heat change (enthalpy change) when an electron is added to the outer most shell of an isolated gaseous atom.

    c) Due to their stable octet configuration.
27. A cation is smaller than the corresponding neutral atom while anion is larger. Justify. (3) [February 2008]

    Ans: Ref. the answer of the qn. No. 22 (b)

Previous HSE Questions And Answers Of The Chapter "Chemical Bonding And Molecular Structure"

1. The dipole moment of BeF_2 is zero, while that of H_2O is 1.85 D. Account for this the on basis of their molecular structure. (2)
   Ans: BeF_2 has linear shape and hence its bond dipole cancels each other. But water has a bent structure and hence its bond dipoles do not cancel each other. So it has a net bond dipole of 1.85D.
2. (a) A molecule of the type AB_4E has 4 bond pairs of electrons and 1 lone pair ofelectron. Predict the most stable structure of this compound. (1)
   (b) Hydrogen fluoride is a liquid, while hydrogen chloride is a gas. Why ? (1)
   Ans: (a) See-saw shape
   (b) This is because of the association of molecules through inter molecular hydrogen bonding in HF.
3. Draw the molecular orbital diagram for F_2 molecule. Account for its magnetic character. (3) [July 2019]
   Ans: M.O configuration of F_2 is $\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \sigma 2p_z^2\ \pi 2p_x^2\ \pi 2p_y^2\ \pi^* 2p_x^2\ \pi^* 2p_y^2$
   M.O Diagram is:

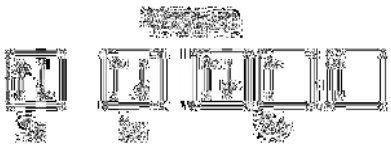


   Due to the presence of only paired electrons, F_2 is diamagnetic.
4. Represent the Lewis structure of Ozone (O_3) molecule and assign the formal charge on each atom. (2)
   Ans:

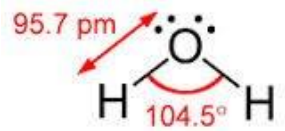
   Formal charge = Total number of valence electrons on the free atom – Total no. of lone pairs of electron – ½ [Total no. of bonding electrons]
   Formal charge on first O atom = 6 – 2 – ½ (6) = +1
   Formal charge on second O atom = 6 – 4 – ½ (4) = 0
   Formal charge on third O atom = 6 – 6 – ½ (2) = -1
5. Among NaCl, $BeCl_2$ and $AlCl_3$, which one is more covalent? Justify the answer. (2)
   Ans: $AlCl_3$. According to Fajans rule, smaller the size and greater the charge of the cation, greater will be the polarizing power and hence the covalent character. So $AlCl_3$ has the most covalent character.
6. Write the molecular orbital electronic configuration of N_2 and O_2 molecules. Compare the stability and magnetic behaviour of these molecules on the basis of M. O. theory. (3) [March 2019]

Ans: N_2 molecule contains 14 electrons.
Its M.O configuration is: $\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \pi 2p_x^2\ \pi 2p_y^2\ \sigma 2p_z^2$.
O_2 molecule contains 16 electrons.
Its M.O configuration is: $\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \sigma 2p_z^2\ \pi 2p_x^2\ \pi 2p_y^2\ \pi^* 2p_x^1\ \pi^* 2p_y^1$
Bond order (B.O) = ½ [Nb – Na]
For N_2, B.O = ½ [10 – 4] = ½ x 6 = 3
For O_2, B.O = ½ [10 – 6] = ½ x 4 = 2
Since N_2 has higher bond order than O_2, it is more stable.
N_2 is diamagnetic due to the absence of unpaired electrons, while O_2 is paramagnetic due to the presence of unpaired electrons.

7. If Z-axis is the internuclear axis, name the type of covalent bond formed by the overlapping of two p_y-orbitals. (1)
   Ans: π bond
8. Write any two limitations of octet rule. (2)
   Ans: a) It could not explain the stability of compounds containing less than 8 electrons around the central atom. E.g. LiCl, BeH_2, BCl_3 etc.
   b) It could not explain the stability of molecules containing odd number of electrons like NO, NO_2 etc.
9. The diatomic species Ne_2, does not exist, but Ne_2^- can exist. Explain on the basis of molecular orbital theory. (4) [August 2018]
   Ans: M.O. configuration of Ne_2 is $\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \sigma 2p_z^2\ \pi 2px^2\ \pi 2p_y^2\ \pi^* 2p_x^2\ \pi^* 2p_y^2\ \sigma^* 2\ p_z^2$
   Bond order (B.O) = ½ [Nb – Na]
   For Ne_2, B.O = ½ [10 – 10] = ½ x 0 = 0
   For Ne_2^-, B.O = ½ [11 – 10] = ½ x 1 = 0.5
   Since B.O of Ne_2 is zero, it does not exist. But Ne_2^- has a +ve bond order, so it exists.
10. Predict the shape of XeF_4 molecule, according to VSEPR theory. (1)
    Ans: XeF_4 contains 6 VSEPs, out of them 4 are bond pairs and 2are lone pairs of electrons.
    So the shape is square planar.
11. By using the concept of hybridization, explain the structure of H_2O molecule. (2)
    Ans: In H_2O, the central atom O has the electronic configuration $1s^2 2s^2 2p^4$.



Now the one s-orbital and three p-orbitals of O undergo sp^3 hybridisation to form 4 sp^3 hybrid orbitals. Two of these sp^3 hybrid orbitals are occupied by lone pairs and the other two sp^3 hybrid orbitals overlap with 1s orbital of hydrogen to form 2 O-H bonds. Due to the greater repulsion between lone pairs, the shape is distorted to angular shape or bent structure or inverted 'v' shape and the bond angle becomes 104.5^0.



12. Write the molecular orbital electronic configurations of N_2 and O_2 and calculate their bond orders. Give a comparison of their stability and magnetic behaviour. (4) [March 2018]
    Ans: M.O configuration of N_2 is: $\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \pi 2p_x^2\ \pi 2p_y^2 \sigma 2p_z^2$.
    Bond order (B.O) = ½ [Nb – Na]
    = ½ [10 – 4] = ½ x 6 = 3
    O_2 molecule contains 16 electrons.

Its M.O configuration is: $\sigma 1s^2$ $\sigma^* 1s^2$ $\sigma 2s^2$ $\sigma^* 2s^2$ $\sigma 2p_z^2$ $\pi 2p_x^2$ $\pi 2p_y^2$ $\pi^* 2p_x^1$ $\pi^* 2p_y^1$

B.O = ½ [10 – 6] = ½ x 4 = 2

Since B.O of N_2 is greater than that of O_2, N_2 is stabler than O_2.
Due to the absence of unpaired electrons, N_2 is diamagnetic, but O_2 is paramagnetic due to the presence of unpaired electrons.

13. a) The hybridization of C in ethene is .....

    i) sp ii) sp^2 iii) sp^3 iv) sp^3d (1)

    b) Explain sp^3d^2 hybridization with an example. (3)

    c) Calculate the bond order of Lithium molecule. (At. no. of Li is 3) (1) [July 2017]

    Ans: a) sp^2

    b) sp^3d^2 hybridization is the process of inter mixing of one s-orbital, three p-orbitals and two d-orbitals to form six new orbitals having equivalent energy and shape.

    E.g. Formation of SF_6

    In SF_6, the central atom S is in sp^3d^2 hybridisation. Thus 6 new sp^3d^2 hybrid orbitals are formed. These hybrid orbitals overlap with p- orbitals of fluorine atoms to form 6 S–F sigma bonds. Thus SF_6 molecule has a regular octahedral geometry with bond angle 90^0.

    c) M.O. configuration of Li_2 is $\sigma 1s^2$ $\sigma^* 1s^2$ $\sigma 2s^2$.

    Bond order (B.O) = ½ [Nb – Na]

    = ½ [4 – 2] = ½ x 2 = 1

14. The geometry of the molecule is decided by the type of hybridisation.

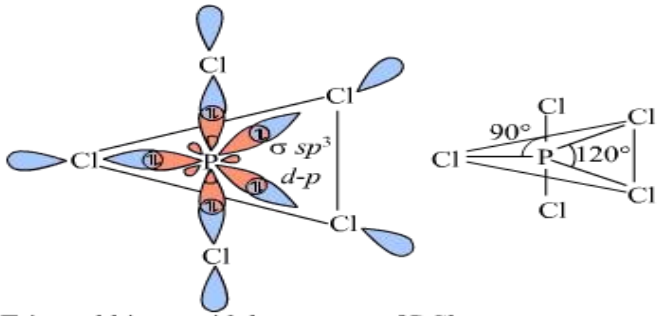
    a) Discuss the shape of PCl_5 molecule using hybridisation. (2)

    b) Give the reason for the high reactivity of PCl_5. (2)

    c) Isoelectronic species have the same bond order. Among the following choose the pair having same bond order.

    CN^-, O_2^-, NO^+, CN^+ (1) [March 2017]

    Ans: a) In PCl_5, the central atom is in sp^3d hydridisation. The 5 sp^3d hybrid orbitals formed are directed to the five corners of a regular trigonal bipyramid with bond angles 120^0 and 90^0.



Trigonal bipyramidal structure of PCl_5

    b) PCl_5 contains two types of P – Cl bonds - 3 equatorial bonds and 2 axial bonds. The axial bond pairs suffer more repulsion from the equatorial bond pairs. So the axial bond length is greater than the equatorial bond length. So PCl_5 is highly unstable and is very reactive.

    c) CN^- and NO^+.

15. VSEPR theory is used to predict the shape and bond angle of molecules.

    a) Write the postulates of VSEPR theory. (2)

    b) Explain the shape and bond angle of NH_3 molecule using VSEPR theory. (2)

    c) PCl_5 molecule is unsymmetric. Why? (2) [September 2016]

    Ans: a) The important postulates of this theory are:

i) The shape of the molecule depends on the no. of valence shell electron pairs around the central atom.
ii) The valence shell electron pairs repel each other.
iii) In order to reduce the repulsion, the electron pairs stay at maximum distance.
iv) Presence of lone pairs of electron causes distortion in the expected geometry of the molecule.
v) The repulsion between two lone pairs of electrons is different from those between two bond pairs or between a lone pair and bond pair. The repulsion decreases in the order lone pair - lone pair > lone pair – bond pair > bond pair - bond pair.
vi) As the angle between the electron pairs increases, the repulsion decreases. [Any 4 postulates required]

16. a) The electronic configuration of a molecule can give information about bond order.
    i) Write the molecular orbital configuration of F_2 molecule.
    ii) Find its bond order. (2)
    b) Give any two factors influencing the formation of an ionic bond. (2)
    c) Give the shape of the following species. i) NH_4^+ ii) $HgCl_2$ (1) [March 2016]

Ans: a) (i) M.O configuration of F_2 is $\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \sigma 2p_z^2\ \pi 2px^2\ \pi 2p_y^2\ \pi^* 2p_x^2\ \pi^* 2p_y^2$

(ii) Bond order (B.O) = ½ [Nb – Na]

= ½ [10 – 8] = ½ x 2 = 1

b) The factors favouring the formation of ionic bond are:

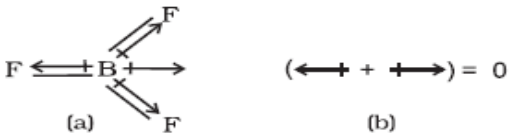
i) Low ionisation enthalpy of the electropositive atom (metal atom).

ii) High negative electron gain enthalpy of the electronegative atom (non-metal atom).

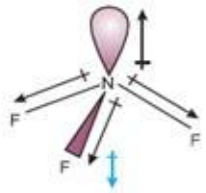
c) i) NH_4^+- Tetrahedral ii) $HgCl_2$ - Linear

17. a) The net dipole moment of a polyatomic molecule depends on the spatial arrangement of various bonds in the molecule. The dipole moment of BF_3 is zero while that of NF_3 is not zero. Justify. (2)
    b) The type of hybridization indicates the geometry of a molecule. In water molecule, the oxygen atom is sp^3 hybridized. But water molecule has no tetrahedral geometry. Explain (2)

Ans: a) BF_3 has planar triangular shape. Here the resultant of any 2 bond dipoles is equal and opposite to the third. So its net dipole moment is zero.



But NF_3 has pyramidal geometry. Here the bond dipoles and the orbital dipoles are in opposite direction but they do not get cancelled each other. So NF_3 has a net dipole moment.



b) Water molecule contains 2 bond pairs and 2 lone pairs of electrons. Due to the greater repulsion between lone pairs, the shape is distorted from tetrahedral to angular shape or bent structure or inverted 'v' shape.

18. The formation of molecular orbitals can be described bv the linear combination of atomic orbitals.
    a) Which one of the following correctly represents the formation of bonding molecular orbital from the atomic orbitals having wave functions ψ_A and ψ_B?
    i) $\psi_A \times \psi_B$ ii) ψ_A / ψ_B iii) $\psi_A + \psi_B$ iv) $\psi_A - \psi_B$ (1)

b) Write the electronic configuration of oxygen molecule on the basis of Molecular Orbital Theory. Justify the presence of double bond in it and account for its paramagnetic character. (2)

[October 2015]

Ans: a) $\psi_A + \psi_B$

b) O_2 molecule contains 16 electrons.

Its M.O configuration is: $\sigma 1s^2$ $\sigma^* 1s^2$ $\sigma 2s^2$ $\sigma^* 2s^2$ $\sigma 2p_z^2$ $\pi 2p_x^2$ $\pi 2p_y^2$ $\pi^* 2p_x^1$ $\pi^* 2p_y^1$

B.O = ½ [10 – 6] = ½ x 4 = 2

Since the B.O = 2, O_2 contains double bond.

Due to the presence of unpaired electrons, O_2 is paramagnetic.

19. Molecular orbital theory was developed by F. Hund and R.S. Mullikken.

a) One-half of the difference between the number of electrons in the bonding and antibonding molecular orbitals is called …….. (1)

b) i) Write the molecular electronic configuration of the N_2 molecule. (1)

ii) Predict the stability and magnetic property of N_2 with reasons. (3)

Ans: a) Bond order

b) i) M.O configuration of N_2 is: $\sigma 1s^2$ $\sigma^* 1s^2$ $\sigma 2s^2$ $\sigma^* 2s^2$ $\pi 2p_x^2$ $\pi 2p_y^2 \sigma 2p_z^2$.

ii) Bond order (B.O) = ½ [Nb – Na]

= ½ [10 – 4] = ½ x 6 = 3

Since bond order is +ve, N_2 is stable. Due to the presence of only paired electrons, N_2 is diamagnetic.

20. In order to explain the geometrical shapes of molecules, the concept of hybridisation was introduced.

a) The geometry of SF_6 molecule is ……..

i) Tetrahedral ii) Planar iii) Octahedral iv) Trigonal bipyramidal (1)

b) i) Define the term hybridisation. (1)

ii) Explain sp^3 hybridisation taking methane (CH_4) as an example. (3) [March 2015]

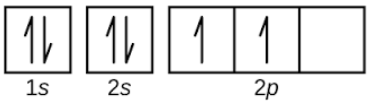
Ans: a) Octahedral

b) i) It is the process of inter mixing atomic orbitals having slightly different energies to form new orbitals having equivalent energy and identical shape.

ii) In CH_4, the central atom C has the electronic configuration

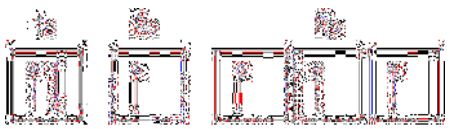
$_6C$ – $1s^2 2s^2 2p^2$

C (ground state) –

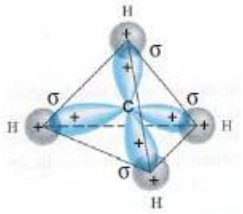


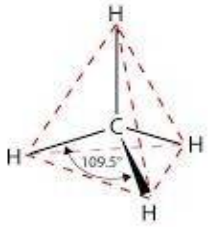
In order to explain the tetra valency of C, it is suggested that one of the electrons of 2s orbital is promoted to 2p orbital.

C (excited state) –



Now, one s-orbital and three p-orbitals undergo sp^3 hybridisation. These sp^3 hybrid orbitals are directed to the four corners of a regular tetrahedron with bond angle $109^0 28^l$. Each of these sp^3 hybrid orbitals overlap with 1s orbital of H to form four C-H σ bonds.





21. a) Molecular orbitals are formed by the linear combination of atomic orbitals (LCAO). Give the salient features of molecular orbital theory. (3)
    b) Explain sp^3d hybridisation with a suitable example. (2)

Ans: a) The important postulates of this theory are:

i) In molecules, the electrons are present in some special type of orbitals called molecular orbitals.
ii) The atomic orbitals of comparable energy and proper symmetry combine to form molecular orbitals.
iii) Atomic orbitals are monocentric, while molecular orbitals are polycentric.
iv) The number of molecular orbitals formed = the number of atomic orbitals combined. i.e. if 2 atomic orbitals combined, 2 molecular orbitals are formed. One is called bonding molecular orbital (BMO) and the other is called anti-bonding molecular orbitals (ABMO)
v) The BMO has lower energy and greater stability than the corresponding ABMO.
vi) The molecular orbitals give the electron probability distribution around a group of nuclei.
vii) The molecular orbitals are filled according to 3 rules – Aufbau principle, Pauli's exclusion principle and Hund's rule. [Any 6 required]

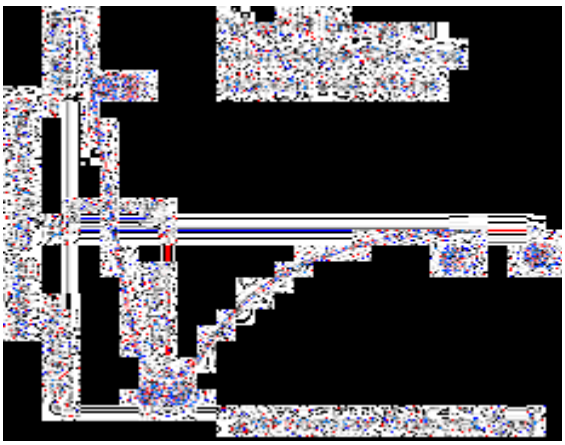
b) sp^3d hybridization is the process of inter mixing of one s-orbital, three p-orbitals and one d-orbital to form five new orbitals having equivalent energy and shape.

E.g. Formation of PCl_5. In PCl_5, the central atom is in sp^3d hydridisation. The 5 sp^3d hybrid orbitals formed are directed to the five corners of a regular trigonal bipyramid with bond angles 120^0 and 90^0.

22. a) The shape of the molecules is based on the VSEPR theory. Give the salient features of this theory. (3)
    b) Draw the potential energy curve for the formation of a hydrogen molecule on the basis of inter nuclear distance of the hydrogen atoms. (2) [August 2014]

Ans: a) Refer the ans. Of the qn. No. 15 (a)

b)



23. a) He_2 cannot exist as stable molecule. Justify this statement on the basis of bond order. (1)
    b) State Fajan's rule regarding the partial covalent character of an ionic bond. (1)
    c) Which has higher boiling point – o-nitrophenol or p-nitrophenol? Give reason. (3) [March 2014]

Ans: a) The bond order of He_2 is zero. So He_2 cannot exist.

b) Fajan's rule states that:

i) The smaller the size of the cation and the larger the size of the anion, the greater the covalent character of an ionic bond.

ii) The greater the charge on the cation, the greater the covalent character of the ionic bond.

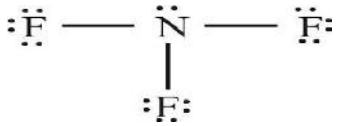
c) p-nitrophenol. This is because of the presence of inter molecular hydrogen bonding in p-nitrophenol.

24. a) Only valence electrons of atoms take part in chemical combination. Draw the Lewis representation of NF_3. (1)

b) Define dipole moment. The dipole moment of BF_3 is zero. Why? (2)

c) Based on bond order compare the relative stability of O_2 and O_2^{2-}. (2) [September 2013]

Ans: a)



b) Dipole moment is the product of the magnitude of charge at one end (Q) and the distance between the charges (r).

c) Ref. the ans. of qn. No. 17 (a).

25. The Valence Shell Electron Pair Repulsion (VSEPR) theory helps in predicting the shapes of covalent molecules.

a) Arrange the bond pair electron and lone pair electron in the decreasing order of the repulsive interactions among them. (1)

b) A molecule of the type AB_3E_2 has three bond pairs and two lone pairs of electrons. Predict the most stable arrangement of electron pairs in this molecule. (1)

c) The bond order value is an important property of a molecule. How is bond order related to bond length? (1)

d) Write the electronic configuration of an oxygen molecule and justify its magnetic character. (2) [March 2013]

Ans:

a) The decreasing order of repulsion is lone pair - lone pair > lone pair - bond pair > bond pair - bond pair.

b) T-shape

c) Bond order is inversely proportional to bond length.

d) Refer the ans. of the qn. No. 18 (b)

26. a) The ionic bonds have partial covalent character and the covalent bonds also show some ionic character.

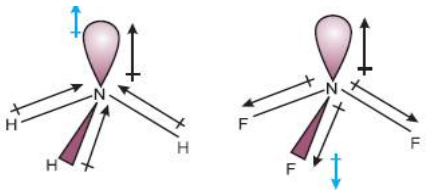
i) Explain the covalent character of Lithium chloride using Fajan's rule (1)

ii) NF_3 and NH_3 show dipole moment. But the dipole moment of NF_3 is less than that of NH_3. Why? (1)

b) The covalent bond can be explained by Molecular Orbital Theory (MOT). Using MO diagram explain the paramagnetic nature of oxygen molecule. (3) [September 2012]

Ans: a) i) LiCl is covalent due to the small size of the cation Li^+ and large size of the anion Cl^-.

ii) This is because in NH_3, the orbital dipole due to lone pair is in the same direction as the resultant dipole moment of the three N – H bonds. But in NF_3, the orbital dipole is in the opposite direction to the resultant dipole moment of the three N-F bonds. So the dipole moments get partially cancelled.



b) Refer the ans. of the qn. No. 18 (b)

27. Valence Bond Theory (VBT) and Molecular Orbital Theory (MOT) are the two important theories of chemical bonding.
    a) Out of the following which is the hybridisation of phosphorus in PCl_5? (sp^3, sp^2, dsp^2, sp^3d) (1)
    b) Explain the geometry of PCl_5 molecule and account for its high reactivity. (2)
    c) Write the molecular orbital configuration of the C_2 molecule and calculate its bond order. (2)
    [March 2012]

    Ans: a) sp^3d

    b) Refer the ans. of the qn. No. 14

    c) *M.O configuration of C_2 is: $\sigma 1s^2$ $\sigma^* 1s^2$ $\sigma 2s^2$ $\sigma^* 2s^2$ $\pi 2p_x^2$ $\pi 2p_y^2$*

    Bond order (B.O) = ½ [Nb – Na]

    = ½ [8 – 4] = ½ x 4 = 2

28. a) Hydrogen bonding plays an important role in determining the physical properties of substances.
    i) Illustrate hydrogen bonding using an example. (1½)
    ii) Compare the boiling points of o-nitro phenol and p-nitro phenol based on hydrogen bonding. (1½)
    b) Describe the hybridisation and structure of PCl_5 molecule. (2) [September 2011]

    Ans: a) i) The weak attractive force between Hydrogen atom of one molecule and electronegative atom (like F, O or N) of the same or different molecule is termed as Hydrogen bond.

    E.g. Hydrogen bonding in HF

    ....H-F ..... H-F ..... H-F ..... H-F .....

    ii) The molecules of p-nitrophenol are associated through inter molecular hydrogen bonding. So it has higher boiling point than o-nitrophenol.

    b) Refer the ans. of the qn. No. 14 (a)

29. The attractive force which holds atoms together in a molecule is called a chemical bond.
    a) Explain the formation of a H_2 molecule on the basis of the valence bond theory (VBT). (2½)
    b) Using the molecular orbital theory (MOT), explain why Ne_2 molecule does not exist? (1½)
    c) Calculate the bond order of dinitrogen (N_2). (1) [March 2011]

    Ans: a) Consider 2 hydrogen atoms. When the two atoms are at large distance from each other, there is no interaction between them. So their potential energy is zero. When the two atoms approach each other, new attractive and repulsive forces begin to operate. Experimentally it has been found that the magnitude of new attractive forces is more than the new repulsive forces. So the two atoms approach each other and potential energy decreases. At a particular stage, the net attractive force balances the net repulsive forces and the energy becomes minimum. At this stage, the hydrogen atoms are said to be bonded together to form a stable molecule.

    Or, Draw the potential energy diagram as in the ans. of the qn. No. 22 (b)

    b) B.O of Ne_2 is zero. So it does not exist.

    c) Ref. the answer of no. 19 (b)

30. VSEPR theory is used to predict the shape of covalent molecules.

a) State the main postulates of VSEPR theory. (3)

b) Based on VSEPR theory predicts the shape of H_2O and NH_3. (2) [October 2010]

Ans: a) Refer the ans. of the qn. No.15 (a)

b)Water molecule contains 4 VSEPs – 2 bond pairs and 2 lone pairs. Hence the expected shape of the molecule is tetrahedral. But due to the greater repulsion between lone pairs, the shape is distorted to bent or angular structure and the bond angle changes to 104.5^0.

NH_3 molecule also contains 4 VSEPs – 3 bond pairs and 1 lone pair. Due to the greater repulsion between lone pair and bond pairs of electrons, it has pyramidal geometry with bond angle 107^0.

31. The stability and magnetic properties of a molecule can be explained using the molecular orbital theory proposed by F. Hund and R.S. Mulliken.

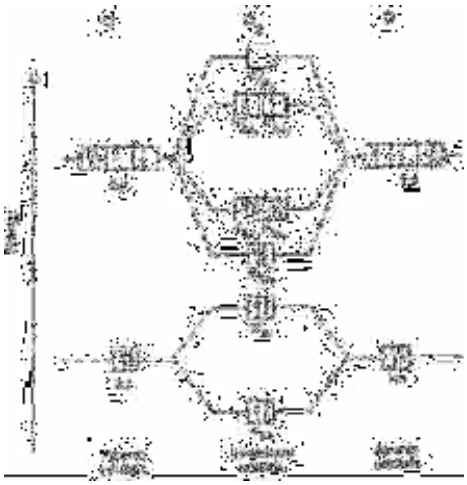
a) Define bond order according to the M.O theory.

b) Draw the energy level diagram for the formation of O_2 molecule.

c) Calculate the bond order and predict the magnetic character of O_2 molecule. [March 2010]

Ans: a) It is the half of the difference between the number of bonding electrons (N_b) and the number of anti-bonding electrons (N_a).

b)



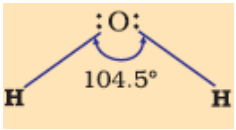
c) *Refer the ans. of the qn. No.18(b)*

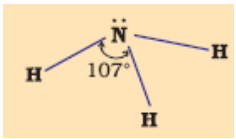
32. a) What do you understand by bond pair electrons and lone pair electrons? (2)

b) Explain the bond pair electrons and lone pair electrons H_2O and NH_3 molecules with suitable drawings. (3) [March 2009]

Ans: a)The valence electron pairs which particilate in bond formation are called bond pairs and which do not participate in bond formation are called lone pairs.

b) Refer the ans. of the qn. No. 30 (b)





33. Water is a liquid while H_2S is a gas.

a) Suggest the reason for the above fact. (1)

b) Explain the phenomenon. (2) [February 2008]

Ans: a)Water molecules are associated through inter molecular hydrogen bonding which is absent in H_2S.

b) It is the H bond formed by H atom of one molecule and the electronegative atom of another molecule.

E.g. Hydrogen bonding in HF

....H-F .... H-F .... H-F ...... H-F ......

%%

PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "STATES OF MATTER"

1. Which property of liquids is associated with fire polishing of glass? (1)
   Ans: Surface Tension
2. Real gases do not obey ideal gas equation under all conditions. Explain. (2)
   Ans: This is due to two wrong assumptions of kinetic molecular theory of gases. They are:
   i) The actual volume of the molecules is negligible compared to the volume of the gas.
   ii) There is no force of attraction between the gas particles.
   These two assumptions become wrong at high pressure and low temperature.
3. (a) State Dalton's law of partial pressures. (1)
   (b) Calculate the total pressure exerted by a mixture of 8 g of O_2, and 4g of H_2 enclosed in a vessel of 1 dm^3 at 27^0C. R = 0.083 bar dm^3 K^{-1} mol^{-1}. (2) [July 2019]
   Ans: (a) This law states that at constant temperature, the total pressure exerted by a mixture of non-reacting gases is equal to the sum of the partial pressures of the component gases.
   (b) Mass of O_2 (w_{O2}) = 8 g
   No. of moles of O_2 (n_{O2}) = 8/32 = 0.25 mol
   Mass of H_2 (w_{H2}) = 4 g
   No. of moles of H_2 (n_{H2}) = 4/2 = 2 mol
   Volume of the gas = 1 dm^3
   Temperature = 27^0C = 27 + 273 = 300 K
   R = 0.083 bar dm^3 K^{-1} mol^{-1}
   P_{Total} = (n_{O2}+n_{H2}) RT/V = (0.25 + 2) x 0.083 x 300/1 = 56.025 bar
4. The lowest hypothetical temperature at which gases are supposed to occupy zero volume is called ……. (1)
   Ans: Absolute zero of temperature
5. Give the relation between molar mass of a gas (m) and its density (d). How are the densities of O_2(g) and CH_4(g) related, if they are kept at the same temperature and pressure? (2)
   Ans: Molar mass (M) = dRT/P
   OR, molar mass (M) α density (d) at constant temperature and pressure.
   Molar mass of O_2 = 32 and that of CH_4 = 16. So O_2 is two times denser than CH_4.
   OR, $M_{O2}/M_{CH4} = d_{O2}/d_{CH4}$
   $32/16 = d_{O2}/d_{CH4}$
   $d_{O2}/d_{CH4} = 2$
   $d_{O2} = 2 \times d_{CH4}$.
6. (a) Why do real gases deviate from ideal behaviour? (1)
   (b) Write the conditions under which gases deviate from ideality. (1)
   (c) Define Boyle Point. (1) [March 2019]
   Ans: (a) See Answer of the question no. 2
   (b) at high pressure and low temperature.

(c) The temperature at which real gases obey ideal gas equation over an appreciable range of pressure is called Boyle temperature or Boyle point.

7. The critical temperatures of some gases are given in the following table :

Gas	H_2	He	O_2	N_2
Critical Temperature (K)	33.2	5.3	154.3	126

If the samples of the above given gases are cooled from 298 K, which one will liquify first by applying pressure? (1)

Ans: O_2

8. Derive an equation relating molar mass of an ideal gas with its density. (2)

Ans: The ideal gas equation is PV = nRT

But n = w/M

So, PV = wRT/M

Or, P = wRT/MV

Or, P= dRT/M

*Or, **M = dRT/P***

9. Calculate the total pressure in a mixture of 3.5 g of dinitrogen and 16 g of dioxygen confined in a vessel of 2 dm^3 at 27^0C. (R = 0.083 bar dm^3 $K^{-1}mol^{-1}$). (3) [March 2018]

Ans: Mass of N_2 (w_{N2}) = 3.5 g

No. of moles of N_2 (n_{N2}) = 3.5/28 = 0.125 mol

Mass of O_2 (w_{O2}) = 16 g

No. of moles of O_2 (n_{O2}) = 16/32 = 0.5 mol

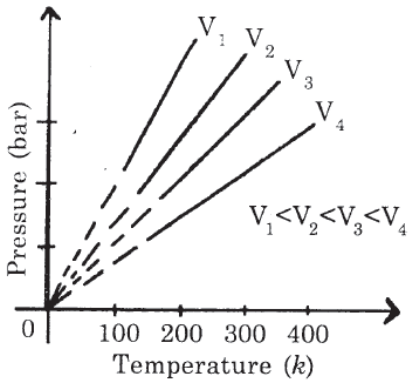
Volume of the gas = 2 dm^3

Temperature = 27^0C = 27 + 273 = 300 K

R = 0.083 bar dm^3 K^{-1} mol^{-1}

P_{Total} = (n_{N2}+n_{O2}) RT/V = (0.125 + 0.5) x 0.083 x 300/2 = 7.78 bar

10. Examine the following graph and name the gas law corresponding to it.



(1)

Ans: Gay Lussac's law

11. a) Define 'normal boiling point' of a liquid.

b) Give a reason for the use of pressure cooker to cook food, at high altitudes. (2)

*Ans: (a) The boiling point at 1 atm pressure is called **normal boiling point**.*

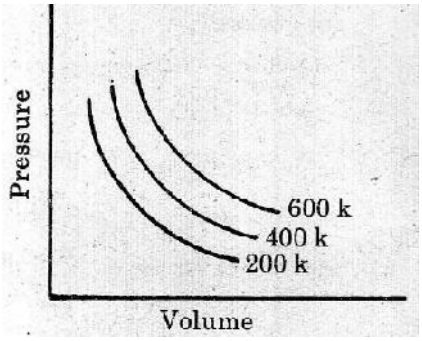
(b) At high altitudes, the atmospheric pressure is low. So liquids boil at lower temperatures than at sea level and hence a pressure cooker is used for cooking food.

12. Write the postulates of kinetic molecular theory of gases. (3) [August 2018]

Ans: The important postulates of this theory are:

- *Every gas contains a large number of minute and elastic particles (atoms or molecules). The actual volume of the particles is negligible compared to the volume of the gas.*
- *There is no force of attraction between the gas particles.*
- *The particles of a gas are in constant and random motion in straight line. During this motion, they collide with each other and also with the walls of the container.*
- *The pressure of a gas is due to the wall collisions of the particles.*
- *All collisions are perfectly elastic. i.e. the total energy of particles before and after collisions remains the same.*
- *The average kinetic energy of gas molecules is directly proportional to absolute temperature.*

13. a)



ii) Identify the law represented by the graph given above.

iii) State the law. (2)

b) Write down the ideal gas equation and explain the terms. (2)

Ans (a) i) Boyle's Law

ii) It states that at constant temperature, the volume of a fixed mass of gas is inversely proportional to its pressure.

(b) The ideal gas equation is PV = nRT.

Where P –Pressure, V – Volume, n – No. of moles, R – Universal gas constant and T – Absolute temperature.

14. a) Give the reason behind the following:

i) The glass window panels of old buildings are thicker at the bottom than at the top. (1)

ii) Sharp glass edges are heated for making them smooth. (1)

b) Maxwell and Boltzmann have shown that actual distribution of molecular speeds depends on temperature and molecular mass.

i) What do you mean by most probable velocity? (1)

ii) At the same temperature which will move faster, N_2 or Cl_2? (1) [March 2017]

Ans: (a) i) Glass is a very viscous liquid. So it has a tendency to flow very slightly. Hence the window panels of old buildings are thicker at the bottom than at the top.

ii) On heating, the glass melts and the surface of the liquid tends to take the rounded shape at the edges, due to surface tension.

(b) i) It is the velocity possessed by maximum number of gas molecules.

ii) N_2

15. An ideal gas is one which obeys gas laws.
    a) Derive an ideal gas equation. (2)
    b) At 27^0C a gas was compressed to half of its volume. To what temperature it must be heated, so that it would occupy double its original volume? (1)
    c) Liquid drops assume spherical shape. Why? (1) [September 2016]

    Ans: (a) According to Boyle's law: V α 1/P (At constant T and n)
    According to Charles' Law: $V \propto T$ (At constant p and n)
    According to Avogadro Law: $V \propto n$ (At constant p and T)
    On combining these three laws we get:
    $V \propto n \times T \times 1/P$
    *Or, V = R x n x T x 1/P (where R is a constant called **universal gas constant**)*
    *Or, **PV = nRT** ..... (1)*
    *This equation is known as **ideal gas equation**.*
    (b) Let the original volume of the gas be z.
    Then $T_1 = 27^0C = 300K$, $V_1 = z/2$, $V_2 = 2z$, $T_2 = ?$
    We know that $V_1/T_1 = V_2/T_2$
    So, $T_2 = V_2 \times T_1/V_1 = 2z \times 300/(z/2) = 300 \times 4 = 1200$ K
    (c) *Every liquid tries to reduce their energy by decreasing the surface area. For a given volume sphere has the minimum surface area. So liquid drops assume spherical shape.*

16. Ideal gas equation is true for ideal gases only. There is a modified form of ideal gas equation applicable to all gases.
    a) Give the name of the modified form of ideal gas equation and write down it. (2)
    b) Name the phenomenon behind cleansing action of soap. (1)
    c) What do you know about Dalton's law of partial pressures? (1) [March 2016]

    Ans: (a) van der Waals equation. The equation is $(P + n^2a/V^2)(V - nb) = nRT$
    (b) Surface tension
    (c) The law states that at constant temperature, the total pressure exerted by a mixture of non-reacting gases is equal to the sum of the partial pressures of the component gases.
    Its mathematical form is:
    $P_{Total} = P_1+P_2+P_3+$..... (at constant T, V)
    where P_{Total} is the total pressure of the mixture of gases and P_1, P_2, P_3 etc. are partial pressures of gases.

17. The Kinetic molecular theory provides a theoretical basis to experimentally observed facts related to gases.
    a) Which one of the following statements is CORRECT with regard to the gaseous state?
        i) Molecules have fixed positions.
        ii) Molecules are in constant random motion
        iii) All molecules have same speed at a given temperature
        iv) The average kinetic energy of the gas molecules is inversely proportional to the absolute temperature. (1)
    b) A sample of hydrogen gas occupies a volume of 300 ml at 1.2 bar pressure and 5^0 C. Calculate its volume at 0.45 bar pressure and 70^0 C. (3) [October 2015]

    Ans: (a) Molecules are in constant random motion
    (b) From combined gas law equation, $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
    Here $P_1 = 1.2$ bar, $V_1 = 300$ mL, $T_1 = 5 + 273 = 298$ K, $P_2 = 0.45$ bar, $T_2 = 70 + 273 = 343$ K, $V_2 = ?$

(1.2 x 300)/298 = (0.45 x V_2)/343

V_2 = 1.208 x 343/0.45 = <u>920.8 mL</u>

18. The gases which obey Gas Laws at all temperatures and pressure are called ideal gases.
    a) Give reason for the deviation of real gases from the ideal behaviour. (2)
    b) Calculate the minimum pressure required to compress 500 mL of air at 1 atm pressure to 300 mL at the same temperature. (2) [March 2015]

Ans: (a) Ref. the answer of the qn. No. 2

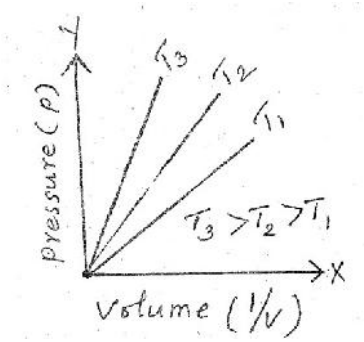
(b) From Boyle's law, $P_1V_1 = P_2V_2$

Here P_1 = 1 atm, V_1 = 500 mL, V_2 = 300 mL, P_2 = ?

So 1 x 500 = P_2x 300

P_2 = 500/300 = 1.67 atm

19.



a) Name the gas law shown by the above graph. (1)

b) State the gas law. (1)

c) At 35^{0}C and 700mm of Hg pressure, a gas occupies 500 ml volume. What will be its pressure when the temperature is 15^{0}C and the volume of the gas is 450 mL. (2) [August 2014]

Ans: (a) Boyle's law

(b) It states that at constant temperature, the volume of a fixed mass of gas is inversely proportional to its pressure.

(c) From combined gas law equation, $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Here P_1 = 700 mm of Hg, V_1 = 500 mL, T_1 = 35 + 273 = 308 K, P_2 = ?, T_2 = 15 + 273 = 288 K, V_2 = 450 mL

(700 x 500)/308 = (P_2x 450)/288

P_2 = 1136.4 x 288/450 = <u>727.27 mm of Hg</u>

20. a) Particles of soil at the bottom of a river remain separated, but they stick together when taken out. Name the property behind this. (2)
    b) Critical temperatures of ammonia and CO_2 are 405.5 K and 304 K respectively. On cooling these gases from 500 K, which gas will liquify first? (1)
    c) van der Waals' forces are attractive inter molecular forces. Write the names of any two types of van der Waals' forces. (2) [March 2014]

Ans: a) Surface Tension

b) NH_3 will liquify first because its critical temperature will be reached first.

c) London forces (Dispersion forces) and Dipole – Dipole forces.

21. a) What is Boyle point or Boyle temperature? (1)
    b) At high altitudes, a pressure cooker is used for cooking food. Why? (1)

c) A neon-dioxygen mixture contains 70.6g dioxygen and 167.5g neon. If the pressure of the mixture of gases in the cylinder is 25 bar, what are the partial pressures of O_2 and Ne in the mixture? (2) [March 2014]

Ans: (a) The temperature at which real gases obey ideal gas equation over an appreciable range of pressure is called Boyle temperature or Boyle point.

b) At high altitudes, the atmospheric pressure is low. So liquids boil at lower temperatures than at sea level and hence a pressure cooker is used for cooking food.

c) Mass of O_2 (w_{O2}) = 70.6 g

No. of moles of O_2 (n_{O2}) = 70.6/32 = 2.21 mol

Mass of Ne (w_{Ne}) = 167.5 g

No. of moles of Ne (n_{Ne}) = 167.5/20 = 8.375 mol

Mole fraction of O_2 = $n_{O2}/(n_{O2} + n_{Ne})$ = 2.21/(2.21 + 8.375) = 0.21

Mole fraction of Ne = 1 – Mole fraction of O_2 = 1 – 0.21 = 0.79

Partial pressures of O_2 = Total pressure x mole fraction of O_2

= 25 x 0.79 = 19.75 bar

Partial pressures of Ne = Total pressure - partial pressures of O_2 = 25 – 19.75 = 5.25 bar

22. a) van der Waals equation of state explains the behaviour of real gases. What does the van der Waal constant 'a' indicate? (1)

b) What is the critical temperature of a gas? (1)

c) At 25^{0}C and 760 mm of Hg pressure, a gas occupies 600 ml volume. What will be its pressure at a height where temperature is 10^{0}C and volume of the gas is 640 ml. (2) [Oct. 2013]

Ans: (a) a is a measure of magnitude of inter molecular attractive forces within the gas.

(b) The temperature below which a gas can be liquefied by the application of pressure is called Critical Temperature.

(c) From combined gas law equation, $P_1V_1 = P_2V_2$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Here P_1 = 760 mm of Hg, V_1 = 600 mL, T_1 = 25 + 273 = 298 K, P_2 = ?, T_2 = 10 + 273 = 283 K, V_2 = 640 mL

(760 x 600)/298 = (P_2 x 640)/283

P_2 = 1530.2 x 283/640 = 673.48 mm of Hg

23. a) What is the thermodynamic scale of temperature. (1)

b) Viscosity of liquids decreases as the temperature increases. Why? (1)

c) Gases deviate from ideal behaviour due to the faulty assumptions of Kinetic theory of gases. State those faulty assumptions. (2) [Oct. 2013]

Ans: (a) Kelvin scale

(b) Because at high temperature, molecules have high kinetic energy and can overcome the intermolecular forces.

(c) Ref. the answer of the qn. No. 2

24. Real gases behave ideally only at certain conditions.

a) What is Boyle point of a gas. (1)

b) Write the expression for compressibility factor. What is its value for an ideal gas? (1)

c) Density of a gas was found to be 5.5 g/L at 2 bar pressure and at 25^0C. Calculate its molar mass. (R=0.083 L bar/K/mol) (2) [March 2013]

Ans: (a) The temperature at which real gases obey ideal gas equation over an appreciable range of pressure is called Boyle temperature or Boyle point.

(b) Compressibility factor, z = PV/nRT. For ideal gases, z = 1

(c) Here d = 5.5 g/L, P = 2 bar, T = 25 + 273 = 298 K and R = 0.083 L bar/K/mol, M = ?

Molar mass (M) = dRT/P = 5.5 x 0.083 x 298/2 = 68.02 g/mol

25. a) The combonation of Boyle's law, Charle's law and Avogadro's law is known as ideal gas equation. But real gases deviate from ideal behaviour.
   i) Write the modified gas law equation. (1)
   ii) Name the above equation. (1)
   b) Give reason for the following:
      i) At hill station, pressure cooker is used for cooking. (1)
      ii) Window panes of the old buildings become thicker at the bottom than at the top. (1)
      [Sept. 2012]

Ans: (a) i) $(P + n^2a/V^2)(V- nb) = nRT$

ii) Van der Waal's Equation

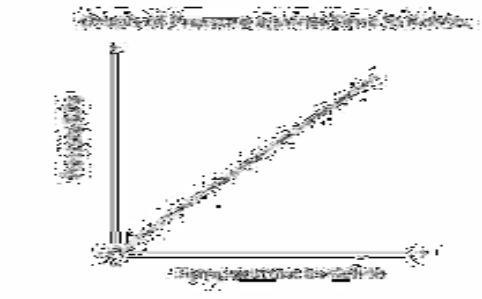
(b) i) Refer the ans. of the qn. No. 11 (b)

ii) Refer the ans. of the qn. No. 14 (a) i

26. Gas laws are relationships between the measurable properties of gases.
   a) Name the gas law which gives the relationship between the pressure and temperature of a fixed amount of gas at constant volume. (1)
   b) Draw the graph to illustrate the above gas law. (1)
   c) A definite quantity of an ideal gas is confined in a container of constant volume. When the container is immersed in a bath of melting ice, the pressure of the gas is 800 mm of Hg. Find the temperature when the gas pressure is 400 mm of Hg. (2) [March 2012]

Ans: (a) Gay Lussac's law

(b)



(c) P_1 = 800 mm of Hg, $T_1 = 0^0C = 273$ K, P_2 = 400 mm of Hg and T_2 = ?

From Gay Lussac's law, $P_1/T_1 = P_2/T_2$

So, $T_2 = P_2.T_1/P_1 = 400 \times 273/800 =$ 136.5 K

27. Consider the following isotherms of a gas:

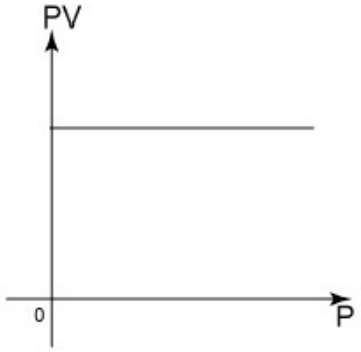
P P V

1/V V 1/P

a) Which gas law is illustrated by these diagrams? (1)
b) Draw the diagram when PV is plotted against P. (1)
c) An air filled balloon has a volume of 125L at 760 mm of mercury and 25^{0}C. What will be its volume when the pressure is 670 mm of mercury and temperature is 18^{0}C? (2) [Oct. 2011]

Ans: (a) Boyle's law

(b)



(c) From combined gas law equation, $P_1V_1 = P_2V_2$

T_1 T_2

Here P_1 = 760 mm of Hg, V_1 = 125 L, T_1 = 25 + 273 = 298 K, P_2 = 670 mm of Hg, T_2 = 18 + 273 = 291 K, V_2 = ?

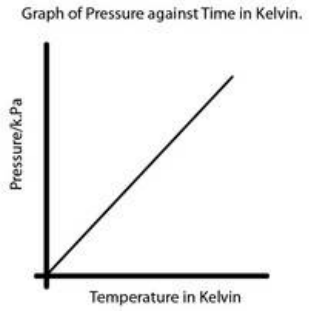
(760 x 125)/298 = (670 x V_2)/291
V_2 = 318.79 x 291/670 = 138.46 L

28. In the celsius scale, melting point of ice is 0^{0}C. Another scale of temperature is based on absolute zero.
a) Identify the scale. (1)
b) What is the volume of a gas at absolute zero of temperature? (1)
c) Draw a graph showing the relationship between volume and temperature of an ideal gas at constant pressure. (1)
d) Consider a gas at 0^{0}C. At what temperature will the volume be doubled if the pressure is kept constant? (1) [March 2011]

Ans: (a) Kelvin scale

(b) zero

(c)



(d) T_1 = 0+273 = 273 K, V_1 = z, V_2 = 2z, T_2 = ?

From Charle's law, $V_1/T_1 = V_2/T_2$

So, $T_2 = V_2 \times T_1/V_1 = 2z \times 273/z =$ 546 K

29. It is found that real gases do not obey ideal gas equation perfectly under all conditions.
    a) Write the ideal gas equation and mention the terms? (1)
    b) Why do real gases deviate from ideal behaviour? (2)
    c) What are the conditions under which real gases approach ideal behaviour? (1) [Sept. 2010]

    Ans: (a)The ideal gas equation is PV = nRT

    Where P –pressure, V – volume, n – no. of moles, R – Universal gas constant, T – absolute temperature.

    (b) Refer the ans. of the qn. No. 2

    (c) Real gases obey ideal gas equation at low pressure and high temperature.

30. The theory that attempts to explain the behaviour of gases is known as kinetic molecular theory.
    a) On the basis of this theory, explain the compressible nature of gases and the temperature dependence on kinetic energy. (2)
    b) Liquid drops assume spherical shape. Why? (1)
    c) How does temperature influence the viscosity of a liquid? (1) [March 2010]

    Ans: (a) According to kinetic molecular theory, gas molecules are point masses and there is a large space between them. So gases are highly compressible. Also on heating a gas, the speed of the molecules and hence their K.E increases.

    (b) Refer the ans. of the qn. No.15 (c)

    (c) When temperature increases, viscosity decreases.

31. Mercury drops are spherical in shape.
    a) Which property is responsible for the spherical shape of drops? Explain the property. (2)
    b) How does the above property depend on temperature? (2) [March 2009]

    Ans: (a) Surface tension. It is the force acting per unit length perpendicular to the line drawn on the surface of liquid.

    (b) When temperature increases, the force of attraction between the molecules decreases and hence the surface tension decreases.

32. 'R' is the universal gas constant in the ideal gas equation.
    a) Write down the values of R in two different units. (1)
    b) Calculate the mass of 500 ml of O_2 at 27^0c and 740 mm of Hg. (2) [June 2008]

Ans: (a)

	Unit of R	*Value of R*
1.	*L atm/K/mol*	*0.0821*
2.	*L bar/K/mol*	*0.08314 ($8.314x10^{-2}$)*

(b) From ideal gas equation, PV = nRT,

PV = wRT/M

So mass, w = PVM/(RT)

Here V = 500 mL = 0.5 L, T = 27+273 = 300K, P = 740 mm of Hg = 740/760 = 0.974 atm, M = 32g/mol, R = 0.0821 L atm/K/mol

Therefore, w = 0.974 x 0.5 x 32/(0.0821 x 300) = 0.632 g

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PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "THERMODYNAMICS"

1. In a process 701 J of heat is absorbed by a system and 394 J of work is done by the system. The change in internal energy for the process is ……. (1)
   Ans: 307 J [Here q = 701 J and w = -394 J. ΔU = q + w = 701 + -394 = 307 J]
2. The std. enthalpies of formation of CH_4 (g), CO_2 (g) and H_2O (l) at 298K are – 74.81 kJ mol^{-1}, - 393.5 kJ mol^{-1} and -285.8 kJ mol^{-1} respectively. Calculate the std. enthalpy of the reaction:
   $CH_4(g) + 2\ O_2(g) \longrightarrow CO_2(g) + 2H_2O\ (g)$ (2)
   Ans: $\Delta_rH^0 = \sum \Delta_fH^0_{(P)} - \sum \Delta_fH^0_{(R)}$ = $[\Delta_fH^0(CO_2) + 2 \times \Delta_fH^0(H_2O)] - [\Delta_fH^0(CH_4) + 2 \times \Delta_fH^0(O_2)]$
   = [-393.5 + 2 x -285.8] – [-74.81 + 2x 0] = - 890.29 kJ
3. (a) What is a spontaneous process? (1)
   (b) For the reaction, $4Fe(s) + 3O_2(g) \longrightarrow 2\ Fe_2O_3$ (s), the entropy change is - 549.4 J K^{-1} mol^{-1} at 298 K. Inspite of the negative entropy change, why is the reaction spontaneous? Given ΔH^o = - 1648 kJ mol^{-1}. (3)
   [July 2019]
   Ans: (a) It is a process that takes place without the help of any external agency.
   (b) Spontaneity of a reaction is mainly determined by ΔG not by ΔS.
   Here ΔH^o = - 1648 kJ mol^{-1} = -1648 x 10^3 J/mol. ΔS^o = - 549.4 J K mol^{-1} and T = 298 K
   We know that $\Delta G^0 = \Delta H^0 - T\Delta S^0$
   = -1648 x 10^3 – 298 x -549.4 = -1811.72 x 10^3 J/mol
   Since ΔG^0 is negative, the process is spontaneous.
4. According to the first law of thermodynamics, for an isolated system, ΔU = …… (1)
   Ans: Zero
5. What is meant by spontaneous processes? Give the criterion of spontaneity in terms of ΔG for a process taking place at constant temperature and pressure. (2)
   Ans: A process that takes place without the help of any external agency is called a spontaneous process.
   Or, it is a process that has a natural tendency to occur.
   For a spontaneous process $\Delta G_{(T,P)}$ or ΔG should be –ve. (Or, ΔG < 0)
6. (a) State Hess' law of constant heat summation. (1)
   (b) Calculate the standard enthalpy of formation from the following:
   $CH_3OH\ (l) + 3/2\ O_2\ (g) \longrightarrow CO_2\ (g) + 2\ H_2O\ (l)$; $\Delta rH^0 = -726 kJmol^{-1}$
   C (graphite) + O_2 (g) $\longrightarrow$ CO_2 (g); ΔrH^0 = - 393 kJ mol^{-1}
   H_2 (g) + ½ O_2 (g) $\longrightarrow$ H_2O (l); ΔrH^0 =- 286 $kJmol^{-1}$ (3) [March 2019]
   *Ans: (a) **Hess's Law:** It states that the total enthalpy change for a physical or chemical process is the same whether the reaction is taking place in a single step or in several steps.*
   Or, the total enthalpy change for a process is independent of the path followed.
   (b) The required equation is: $C(graphite) + 2H_2(g) + ½\ O_2(g) \longrightarrow CH_3OH(l)$
   The given datas are:
   $CH_3OH(l) + 3/2\ O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$; Δ_rH^0 = -726 kJ/mol …… (1)
   $C\ (graphite) + O_2(g) \longrightarrow CO_2(g)$; Δ_rH^0 = -393 kJ/mol …… (2)
   $H_2(g) + ½\ O_2(g) \longrightarrow H_2O(l)$; Δ_rH^0 = -286 kJ/mol …… (3)
   On reversing equation (1), we get

$CO_2(g) + 2H_2O(l) \longrightarrow CH_3OH(l) + 3/2\ O_2(g)$; $\Delta_rH^0 = 726$ kJ/mol …….. (4)

On multiplying eqn. (3) by 2, we get

$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$; $\Delta_rH^0 = -2 \times 286 = -572$ kJ/mol …….. (5)

Now add equations (2) + (4) + (5) and simplify. Then we get,

$C(graphite) + 2H_2(g) + ½\ O_2(g) \longrightarrow CH_3OH(l)$, $\Delta_rH^0 = -393 + 726 + -572 =$ ***<u>-239 kJ/mol</u>***

7. Differentiate state functions from path functions and give one example for each. (2)

Ans: A function or a property that depends only on the initial and final state of a system and not on the path followed is called a state function.

E.g. for state functions: T, P, V, U, H, S, G etc.

Path functions*: These are properties which depend on the path followed also.*

E.g. heat (q) and work (w)

8. First law of thermodynamics can be stated as ΔU = q + w. How can this equation be expressed for :
   a) An isothermal reversible change?
   b) A process carried out at constant volume? (2)

Ans: (a) For an isothermal reversible change, ΔU = 0. So q = -w

(b) For a process taking place at constant volume, ΔV = 0. So $\Delta U = q_v$

9. Enthalpies of formation of some compounds are given below :

Compound	CO	CO_2	N_2O	N_2O_4
Enthalpy of formation (kJ/mol)	-110.0	-393.0	81.0	9.7

Using these data, calculate the enthalpy of reaction for

$N_2O_4(g) + 3CO(g) \longrightarrow N_2O(g) + 3\ CO_2(g)$ (3) [August 2018]

Ans: $\Delta_rH^0 = \sum \Delta_fH^0_{(P)} - \sum \Delta_fH^0_{(R)} = [\Delta_fH^0(N_2O) + 3 \times \Delta_fH^0(CO_2)] - [\Delta_fH^0(N_2O_4) + 3 \times \Delta_fH^0(CO)]$

$= [81.0 + 3 \times -393.0] – [9.7 + 3x -110.0] =$ <u>-777.7 kJ/mol</u>

10. What is meant by entropy of a system? What happens to the entropy during the following changes?
    a) A gas condenses into liquid.
    b) $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$ (2)

Ans: It is a measure of degree of disorderness or randomness of a system.

a) Entropy decreases

b) Entropy increases.

11. Write the thermochemical equation corresponding to the standard enthalpy of formation of benzene.
    [Hint; Δ_fH^0 of benzene = + 49.0 $kJmol^{-1}$) (2)

Ans: $6C(s) + 3\ H_2(g) \longrightarrow C_6H_6(l)$; $\Delta_fH^0 = 49.0$ kJ mol^{-1}

12. The reaction of cyanamide (NH_2CN) with dioxygen was carried out in a bomb calorimeter and ΔU was found to be -742.7 kJ mol^{-1} at 298K. Calculate enthalpy change for the reaction at 298 K.

$$NH_2CN_{(g)} + \frac{3}{2}O_{2(g)} \rightarrow N_{2(g)} + CO_{2(g)} + H_2O_{(l)}$$

(3) [March 2018]

Ans:

Here ΔU = -742.7 kJ/mol = -742.7 x 10^3J/mol, $\Delta n = n_{P(g)} – n_{R(g)} = 2 – 5/2 = - ½$, T = 298 K, R = 8.314$JK^{-1}mol^{-1}$

$\Delta H = \Delta U + \Delta nRT$

$= -742.7 \times 10^3 + -1/2 \times 8.314 \times 298 =$ $\underline{-743.938 \times 10^3\ J/mol}$

13. a) i) State Hess's law.

ii) Calculate $\Delta_f H^0$ when diamond is formed from graphite.

$C(diamond) + O_2 \longrightarrow CO_2(g);\ \Delta_C H^0 = -395\ kJ$

$C(graphite) + O_2 \longrightarrow CO_2(g);\ \Delta_C H^0 = -393.5\ kJ$ (3)

b) An extensive property is.....

i) density ii) pressure iii) temperature iv) mass (1) [July 2017]

Ans: a) (i) It states that the total enthalpy change for a physical or chemical process is the same whether the reaction is taking place in a single step or in several steps.

Or, the total enthalpy change for a process is independent of the path followed.

(ii) The required equation is: C(graphite) $\longrightarrow$ C(diamond)

The given datas are:

i) $C(diamond) + O_2 \longrightarrow CO_2(g);\ \Delta_C H^0 = -395\ kJ$

ii) $C(graphite) + O_2 \longrightarrow CO_2(g);\ \Delta_C H^0 = -393.5\ kJ$

(ii) – (i) gives *$C(graphite) \longrightarrow C(diamond);\ \Delta_f H^0 = -393.5 - (-395) = +1.5\ kJ$*

b) Mass

14. a) Some macroscopic properties are given below. Help Reena to classify them into two groups under suitable titles.

[Heat capacity, Entropy, Refractive index, Surface tension] (2)

b) For the reaction $2A(g) + B(g) \longrightarrow 2D(g)$, $\Delta U^0 = -10.5$ kJ/mol, $\Delta S^0 = -44.1$ J/K/mol at 298K. Calculate ΔG^0 for the reaction. (2) [March 2017]

Ans: a) Extensive properties: Heat capacity, Entropy

Intensive properties: Refractive index, Surface tension

b) Given $\Delta U^0 = -10.5\ kJ/mol = -10.5 \times 10^3\ J/mol$, $\Delta S^0 = -44.1\ J/K/mol$, $R = 8.314\ J/K/mol$ and $T = 298K$.

$\Delta n = n_{P(g)} - n_{R(g)} = 2 - 3 = -1$

We know that $\Delta H^0 = \Delta U^0 + \Delta nRT = -10.5 \times 10^3 + -1 \times 8.314 \times 298 = -12977.6\ J/mol$

Also $\Delta G^0 = \Delta H^0 - T\Delta S^0$

$= -12977.6 - 298 \times -44.1 =$ $\underline{-26.119 \times 10^3\ J/mol}$

15. a) Which of the following is a process taking place with increase in entropy?

i) Freezing of water ii) Condensation of steam iii) Cooling of a liquid iv) Dissolution of a solute (1)

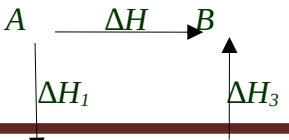
b) State and illustrate Hess's law. (3) [September 2016]

Ans: (a) Dissolution of a solute

(b) The law states that the total enthalpy change for a physical or chemical process is the same whether the reaction taking place in a single step or in several steps. Or, the total enthalpy change for a process is independent of the path followed.

Illustration:

Consider a process in which the reactant A is converted to product B in a single step by involving heat change ΔH. Let the same reactant A is first converted to C, then to D and finally to B involving heat changes



ΔH_1, ΔH_2 and ΔH_3 respectively.
Then according to Hess's law: $\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3$ *C* $\xrightarrow{\Delta H_2}$ *D*

16. The enthalpy change in a process is the same, whether the process is carried out in a single step or in several steps.
    a) Identify the law stated here. (1)
    b) Calculate the enthalpy of formation of CH_4 from the following data:
        i) $C(s) + O_2(g) \rightarrow CO_2(g)$; $\Delta H = -393.7$ kJ/mol
        ii) $H_2(g) + ½\ O_2(g) \rightarrow H_2O(l)$; $\Delta H = -285.8$ kJ/mol
        iii) $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$; $\Delta H = -890.4$ kJ/mol (3) [March 2016]

    Ans: (a) Hess's Law
    (b) The required equation is: $C(s) + 2H_2(g) \rightarrow CH_4(g)$
    Given: $C(s) + O_2(g) \rightarrow CO_2(g)$; $\Delta H = -393.7$ kJ/mol
    Multiply equation (ii) x 2; $2H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$; $\Delta H = -285.8 \times 2 = -571.6$ kJ/mol
    Reverse equation (iii) $CO_2(g) + 2H_2O(l) \rightarrow CH_4(g) + 2\ O_2(g)$; $\Delta H = 890.4$ kJ/mol
    Now add the above three equations we get $C(s) + 2H_2(g) \rightarrow CH_4(g)$; $\Delta H = -393.7 + -571.6 + 890.4$
    $= \underline{-74.9\ kJ/mol}$

17. Expansion of a gas in vacuum is called free expansion.
    a) Which one of the following represents free expansion of an ideal gas under adiabatic conditions?
    i) $q = 0, \Delta T \neq 0, w = 0$ ii) $q \neq 0, \Delta T = 0, w = 0$ iii) $q = 0, \Delta T = 0, w = 0$ iv) $q = 0, \Delta T < 0, w \neq 0$ (1)
    b) The enthalpy change for the reaction $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$ is -91.8 kJ at 298 K. Calculate the value of internal energy change. ($R = 8.314\ JK^{-1}\ mol^{-1}$) (3) [Oct. 2015]

    Ans: (a) i) $q = 0, \Delta T = 0, w = 0$ [For adiabatic process $q = 0$. For free expansion no work is done. So $w = 0$. On applying these values to the mathematical form 1st law, $\Delta U = q+w = 0$. Also since $\Delta U = q.\ \Delta T$, $\Delta T = 0$]
    (b) $\Delta H = \Delta U + \Delta nRT$
    Given $\Delta H = -91.8$ kJ $= -91.8 \times 10^3$ J, $\Delta n = 2-4 = -2$, $R = 8.314$ J/K/mol, $T = 298$ K
    $\Delta U = \Delta H - \Delta nRT = -91800 - -2 \times 8.314 \times 298 = \underline{-86844.86\ J/mol}$

18. a) Classify the following into intensive and extensive properties.
    i) Internal energy ii) Density iii) Heat capacity iv) Temperature (2)
    b) Calculate the standard free energy (ΔG^0) for the conversion of oxygen to ozone $3/2\ O_2(g) \rightarrow O_3(g)$ at 298K, if the equilibrium constant for the conversion is 2.47×10^{-29}. (Given $R = 8.314\ JK^{-1}mol^{-1}$). (2) [March 2015]

    Ans: (a) Intensive properties: Density, Temperature
    Extensive properties: Internal energy, Heat capacity
    (b) Here $K = 2.47 \times 10^{-29}$, $R = 8.314$ J/K/mol and $T = 298K$
    $\Delta G^0 = -2.303RT\log K$
    $= -2.303 \times 8.314 \times 298 \times \log(2.47 \times 10^{-29}) = 163000$ J/mol $= \underline{163\ kJ/mol}$

19. a) ΔG gives a criterion for spontaneity of reactions at a constant pressure and temperature. How is ΔG helpful in predicting the spontaneity of the reaction? (2)
    b) State and explain Hess's law of constant heat summation. (2) [August 2014]

Ans: (a) For a spontaneous process ΔG is negative. If ΔG^0 is +ve, the process is non-spontaneous and if it is zero, the process is at equilibrium.

(b) Ref. the ans. of the qn. No. 15 (b)

20. a) For the oxidation of iron 4 $Fe_{(s)}$ + 3 $O_{2(g)}$ → $2Fe_2O_{3(s)}$, entropy change ΔS is -549.4 J/K/mol at 298K. Inspite of the negative entropy change of this reaction, why is the reaction spontaneous? (Δ_rH^0 for the reaction is -1648 x 10^3 $Jmol^{-1}$). (2)

b) Write the differences between extensive and intensive properties. Give one example of each. (2) [March 2014]

Ans: (a) Spontaneity of a reaction is mainly determined by ΔG not by ΔS.

Here ΔH^o = -1648 x 10^3 J/mol. ΔS^o = - 549.4 J K mol^{-1} and T = 298 K

We know that $\Delta G^0 = \Delta H^0 - T\Delta S^0$

= -1648 x 10^3 – 298 x -549.4 = -1811.72 x 10^3 J/mol

Since ΔG^0 is negative, the process is spontaneous.

(b) Extensive properties depend on the amount of matter present in the system. Or, these are the properties which change when a system is divided. E.g.: Volume (v), internal energy (U), enthalpy (H), entropy (S), Gibb's energy (G), heat capacity etc.

Intensive properties are independent of the amount of matter present in the system. Or, these are the properties which do not change when a system is divided. E.g. : Temperature (T), Pressure (P), Volume (V), density, refractive index, molar heat capacity, viscosity, surface tension etc.

21. a) The enthalpy of combustion of $CH_{4(g)}$, C(graphite) and $H_{2(g)}$ at 298K are -890.3 kJ mol^{-1}, -393.5 kJ mol^{-1} and -285.8 kJ mol^{-1} respectively. Calculate the enthalpy of formation of $CH_{4(g)}$. (2)

b) Match the following:

1. W = - ΔU	a) Enthalpy change
2. ΔU = 0	b) Universal gas constant
3. C_p - C_v	c) Adiabatic process
4. q_P	d) Isothermal process
	e) Cyclic process

(2) [September 2013]

Ans: (a) Ref. the answer of the qn. No. 16(b)

(b)

1. W = - ΔU	*c) Adiabatic process*
2. ΔU = 0	*d) Isothermal process*
3. C_p - C_v	*b) Universal gas constant*
4. q_P	*a) Enthalpy change*

22. Most of the naturally occurring processes are spontaneous.

a) Give the criteria for spontaneity of a process in terms of free energy change (ΔG). (1)

b) Exothermic reactions associated with a decrease in entropy are spontaneous at lower temperatures. Justify on the basis of Gibbs equation. (1)

c) Find the temperature above which the reaction $MgO_{(s)} + C_{(s)} \rightarrow Mg_{(s)} + CO_{(g)}$ becomes spontaneous. (Given $\Delta_rH^0 = 490$ kJ mol^{-1} and $\Delta_rS^0 = 198$ JKmol^{-1}). (2) [March 2013]

Ans: a) For a spontaneous process ΔG is negative.

b) Here ΔH is –ve and ΔS is also –ve. So according to Gibb's eqn, ΔG = ΔH - TΔS, ΔG becomes –ve only when TΔS < ΔH. This is possible at low temperature.

c) *At equilibrium, $\Delta_rG^0 = 0$*

So the Gibb's equation, $\Delta_rG^0 = \Delta_rH^0 - T\Delta_rS^0$ becomes:

$0 = \Delta_rH^0 - T\Delta_rS^0$

Or, $\Delta_rH^0 = T\Delta_rS^0$

So, $T = \Delta_rH^0/\Delta_rS^0 = 490 \times 10^3/198 = 2474.74K$.

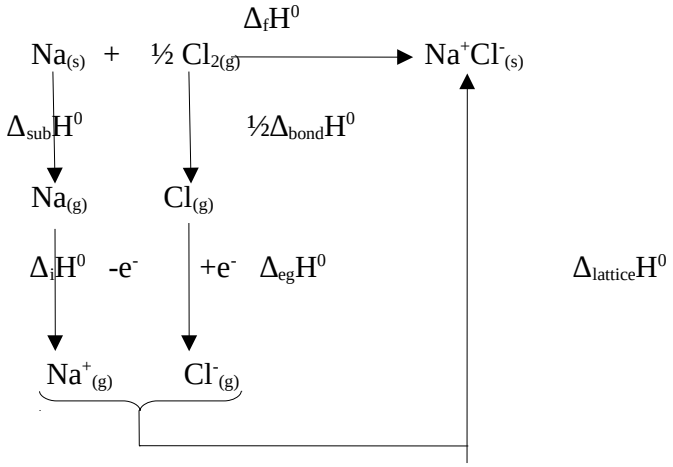
So at 2474.74K, the reaction is at equilibrium.

Above this temperature, the reaction becomes spontaneous. [Here both Δ_rH^0 and Δ_rS^0 are +ve. So Δ_rG^0 becomes –ve only when $T\Delta_rS^0 > \Delta_rH^0$. This is possible at high temperature.]

23. a) Construct an enthalpy diagram for the determination of lattice enthalpy of sodium chloride. (2)

b) Enthalpy and entropy changes of a reaction are 40.63 kJ/mol and 108.8 J/K/mol. Predict the feasibility of the reaction at 27^0C. (2) [September 2012]

Ans: a)



b) Given *ΔH = 40.63 kJ/mol = 40630 J/mol, ΔS = 108.8 J/K/mol and T = 27 + 273 = 300K.*

From Gibb's equation, ΔG = ΔH - TΔS

= 40630 – 300 x 108.8 = 7990 J/mol

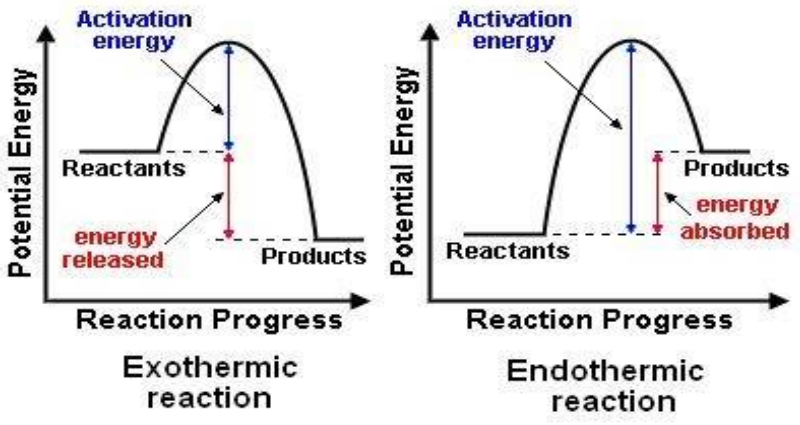
Since ΔG^0 is positive, the process is non-spontaneous at this temperature.

24. a) Explain the Hess's law of constant heat summation, with an example. (2)

b) Draw the enthalpy diagram for exothermic and endothermic reactions. (2) [September 2012]

Ans: (a) Ref. the answer of the qn. No. 15(b)

(b)



25. Thermodynamics deals with energy changes of macroscopic systems.
    a) Consider a chemical reaction taking place in a closed insulated vessel. To which type of thermodynamic system does it belong? (1)
    b) State the first law of thermodynamics. (1)
    c) 3 mol of an ideal gas at 1.5 atm and 25^0C expands isothermally in a reversible manner to twice its original volume against an external pressure of 1 atm. Calculate the work done. (R = 8.314 $JK^{-1}mol^{-1}$) (2) [March 2012]

Ans: (a) Adiabatic system

(b) It states that energy can neither be created nor be destroyed. Or, the total energy in the universe is always a constant. Or, the total energy of an isolated system is always a constant.

(c) Here n = 3 mol, R = 8.314 J/K/mol, V_1 = z, V_2 = 2z and T = 25 + 273 = 298 K

For isothermal reversible expansion, work done, $W_{exp} = -2.303nRT \log(V_2/V_1)$

$= -2.303 \times 3 \times 8.314 \times 298 \times \log(2z/z)$

$= \underline{-5152.38\ J}$

26. A spontaneous process is an irreversible process and may only be reversed by some external agency.
    a) Decrease in entropy is the only criterion for spontaneity. Do you agree? Why? (2)
    b) Calculate the work done for the reversible isothermal expansion of 1 mole of an ideal gas at 27^0C, from a volume of 10 dm^3 to a volume of 20 dm^3. (2) [October 2011]

Ans: (a) No. Decrease in entropy alone can't predict the spontaneity of a process. If during a process, the enthalpy of the system decreases and entropy increases, the process is spontaneous. Or decrease in Gibb's energy determines spontaneity.

(b) Here n = 1 mol, R = 8.314 J/K/mol, V_1 = 10 dm^3, V_2 = 20 dm^3 and T = 25 + 273 = 298 K

For isothermal reversible expansion, work done, $W_{exp} = -2.303nRT \log(V_2/V_1)$

$= -2.303 \times 1 \times 8.314 \times 298 \times \log(20/10)$

$= \underline{-1717.46\ J}$

27. The spontaneity of a process is expressed in terms of a change in Gibbs energy.
    a) What is mean by change in Gibbs energy of a system? (1)
    b) How is it related to the enthalpy and entropy of a system? (1)
    c) How is it useful in predicting the feasibility of a process? (2) [March 2011]

Ans: (a) It is defined as the maximum amount of available energy that can be converted to useful work. The change in Gibb's energy (ΔG) = $G_2 - G_1$

(b) $G = H - TS$ Or, $\Delta G = \Delta H - T\Delta S$

(c) For a spontaneous process ΔG should be negative.

28. Lattice enthalpy of an ionic salt is a factor that determines its stability.
    a) Define the lattice enthalpy. (1)
    b) Draw the Born-Haber cycle for the calculation of lattice enthalpy of the ionic crystal NaCl. (3) [September 2010]

Ans: (a) The lattice enthalpy of an ionic compound is the enthalpy change when one mole of an ionic compound dissociates into gaseous ions.

(b) Ref. answer of the Qn. No. 23 (a)

29. A system in thermodynamics refers to that part of the universe in which observations are made.
    a) What do you mean by an isolated system? Give an example. (1)
    b) Distinguish between intensive and extensive properties. Give two examples for each. (3) [March 2010]

Ans: (a) It is a system that cannot exchange both energy and matter with the surroundings.

E.g.: Hot water taken in a thermoflask.

(b) Ref. answer of the Qn. No. 20 (b)

30. a) State Hess's law of constant heat summation. (2)
    b) The equilibrium constant for a reaction is 5. What will be the value of ΔG^0? Given that R = 8.314 J/K/mol, T = 300K. (2) [March 2009]

Ans: (a) Ref. answer of the Qn. No. 15 (b)

(b) $\Delta G^0 = -2.303RT\log K$

$= -2.303 \times 8.314 \times 300 \times \log 5 =$ -4014.58 J/mol

31. Some properties are "state functions".
    a) q and w are not state functions, but (q+w) is a state function. Why? (1)
    b) What do you mean by saying that pressure is an intensive property? (1)
    c) What is the difference in internal energy of a system, if 100 kJ of energy is radiated out without doing any work? (1) [February 2008]

Ans: (a) $q + w = \Delta U$. Internal energy is a state function.

(b) Pressure of a system does not change when the system is divided. So it is an intensive property.

(c) From first law of Thermodynamics, $\Delta U = q+w = -100 + 0 =$ -100kJ (Since energy is radiated q is – ve)

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PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "EQUILIBRIUM"

1. (a) If the concentration of hydrogen ion in a soft drink is 3×10^{-3} M, calculate its pH. (2)
   (b) An aqueous solution of NaCl is neutral, while that of $CuCl_2$ is acidic. Why? (1)
   Ans: a) Here $[H^+] = 3 \times 10^{-3}$
   We know that $pH = -\log[H^+]$
   $= -\log (3 \times 10^{-3}) =$ 2.523
   b) NaCl is a salt of strong acid HCl and strong base NaOH. So it is neutral. But $CuCl_2$ is a salt of strong acid HCl and weak base $Cu(OH)_2$. So it is acidic.
2. For the equilibrium, $2\ NOCl\ (g) \rightleftharpoons 2\ NO(g) + Cl_2(g)$, the value of equilibrium constant Kp is 1.8×10^{-2} at 500 K. Calculate Kc for this reaction at the same temperature. (2)
   Ans: Here $Kp = 1.8 \times 10^{-2}$, $R = 0.083$ L bar/K/mol, $\Delta n = n_{P(g)} - n_{R(g)} = 3-2 = 1$ and $T = 500K$
   $Kp = Kc(RT)^{\Delta n}$
   $1.8 \times 10^{-2} = Kc(0.083 \times 500)^1$
   $Kc = 1.8 \times 10^{-2}/(0.083 \times 500)$
   $= 4.33 \times 10^{-4}$
3. Give the Lewis concept of acids and bases with suitable example. (2) [July 2019]
   Ans: According to this concept, acids are electron pair acceptors and bases are electron pair donors.
   Example for Lewis acids are BF_3, $AlCl_3$ etc.
   Example for Lewis bases are NH_3, H_2O etc.
4. Calculate the pH of 1×10^{-2} molar aqueous solution of H_2SO_4. (2)
   Ans: $H_2SO_4 \rightleftharpoons 2H^+ + SO_4^{2-}$
   1×10^{-2} $2x10^{-2}$
   Here $[H^+] = 2 \times 10^{-2}$
   We know that $pH = -\log[H^+]$
   $= -\log (2 \times 10^{-2})$
   $=$ 1.6989
5. Examine the chemical equilibrium, $4\ NH_3(g) + 5\ O_2(g) \rightleftharpoons 4\ NO(g) + 6\ H_2O(l)$.
   Write the expression for equilibrium constant (Kc) for the above equilibrium. What happens to Kc, if the balanced equation is multiplied throughout by a factor of 2. (2)
   Ans: $Kc = \dfrac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$
   If the balanced equation is multiplied throughout by 2, then $Kc' = Kc^2$.
6. Explain the hydrolysis of different types of salts with the help of examples and comment on the pH of the resulting solutions in each case. (3) [March 2019]
   *Ans: **Hydrolysis of salt of strong base and weak acid:** Sodium acetate (CH_3COONa), sodium carbonate (Na_2CO_3), potassium cyanide (KCN) etc. are examples for such type of salts. Here only the anion of the weak base undergoes hydrolysis. So the solution of such salts will be basic. i.e. $pH > 7$.*
   ***Hydrolysis of salt of weak base and strong acid:** NH_4Cl, NH_4NO_3, $CuSO_4$ etc are examples for such type of solutions. Here only cation of weak base undergoes hydrolysis. So the solution is acidic.*

Hydrolysis of salt of weak base and weak acid: *Ammonium acetate (CH_3COONH_4), ammonium carbonate [$(NH_4)_2CO_3$] etc. are examples for such type of salts. Here both cation and anion undergo hydrolysis and hence weak acid and weak base are produced in solution. So the solution may be neutral, acidic or basic depending upon the relative strength of acid and base formed.*

pH of such a solution is given by ***pH = 7 + ½ (pKa + pKb)****.*

7. Give the relation between Kp and Kc, for the reaction given below.

   $2NOCl\ (g) \rightleftharpoons 2NO(g) + Cl_2(g)$ (2)

   Ans: $Kp = Kc(RT)^{\Delta n}$

   Here $\Delta n = n_{P(g)} - n_{R(g)} = 3 - 2 = 1$

   So, $Kp = Kc.RT$

8. H_2O and HSO_4^- can act both as Bronsted acids and bases. For each case give the corresponding conjugate acid and conjugate base. (2)

   Ans: Conjugated acid = H_3O^+, H_2SO_4

   Conjugate base = OH^-, HSO_4^-

9. The ionization constant of nitrous acid is 4.5×10^{-4}. Calculate the pH of 0.04 M solution of nitrous acid in water.

   (Hint: $HNO_2 + H_2O \rightleftharpoons H_3O^+ + NO_2^-$; $K_a = C\alpha^2$) (3) [August 2018]

   Ans: $Ka = 4.5 \times 10^{-4}$, $C = 0.04M$

   $K_a = C\alpha^2$

   $\alpha = \sqrt{Ka/C} = \underline{\sqrt{(4.5 \times 10^{-4}/0.04)}} = 0.106$

   $[H_3O^+] = c\alpha = 0.04 \times 0.106 = 0.00424$

   $pH = -\log[H_3O^+] = -\log(0.00424) = \underline{\underline{2.373}}$

10. Explain the effects of temperature and pressure on the following equilibrium.

    $2NO_2(g) \rightleftharpoons N_2O_4\ (g);\ \Delta H = -57.2\ kJ\ mol^{-1}$ (2)

    Ans:

    Effect of temperature: Here the forward reaction is exothermic. So low temperature favours this process.

    Effect of pressure: As a result of forward reaction, the no. of moles of gaseous species decreases. So high pressure favours the forward reaction.

11. Define buffer solutions and write one example for an acidic buffer. (2)

    Ans: Solutions which resist the change in pH on dilution or with the addition of small amount of acid or alkali is called Buffer solution.

    E.g. A mixture of acetic acid and sodium acetate acts as an acidic buffer around p^H 4.75.

12. The value of equilibrium constant is useful to predict the extent of reaction and the direction of the reaction at a given stage. Explain. (3) [March 2018]

    Ans: ***Prediction of the extent of a reaction:*** *We can predict the extent of reaction from the value of equilibrium constant. Generally, if $Kc > 10^3$, the reaction proceeds nearly to completion, If $Kc < 10^{-3}$, the reaction proceeds rarely and if the value of Kc is in between 10^3 and 10^{-3} appreciable concentrations of both reactants and products are present.*

    Prediction of the direction of the reaction: *By knowing the values of Kc and Qc, we can predict the direction of a reaction. If Qc > Kc, the reaction will proceed in the direction of reactants (reverse direction).*

If Qc < Kc, the reaction will proceed in the direction of products (forward direction). If Qc = Kc, the reaction mixture is at equilibrium.

13. a) Classify the following into Lewis acid and Lewis base. i) H_2O ii) NH_3 iii) $AlCl_3$ iv) H^+ (1)

b) Explain the term common ion effect with suitable example. (2)

c) The concentration of H^+ ion in a soft drink is 2×10^{-13}. Calculate its pH. Identify whether the solution is acidic or basic. (2) [July 2017]

Ans: a) i) H_2O – Lewis base ii) NH_3 - Lewis base iii) $AlCl_3$ – Lewis acid iv) H^+ – Lewis acid

b) It is the suppression of the dissociation of a weak electrolyte by the addition of a strong electrolyte containing a common ion. For e.g. consider the dissociation of acetic acid (a weak electrolyte).

$$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$$

If we add some sodium acetate (CH_3COONa) to the above equilibrium reaction, the concentration of acetate ion increases. Then according to Le-Chatlier's principle, the equilibrium will shift towards left or, the rate of forward reaction decreases. i.e. the dissociation rate of acetic acid decreases.

c) Here $[H^+] = 2 \times 10^{-13}$

We know that $pH = -\log[H^+]$

$$= -\log (2 \times 10^{-13}) = 12.699$$

Since the pH > 7, the solution is basic.

14. a) Classify the following solutions into acidic, basic and neutral.

NaCl, NH_4NO_3, NaCN, $NaNO_2$ (2)

b) pH of blood remains constant inspite of variety of goods and spices we eat. Give a reason. (1)

c) The solubility of $Mg(OH)_2$ at 298K is 1.5×10^{-4}. Calculate the solubility product. (2) [March 2017]

Ans: a) NaCl – Neutral, NH_4NO_3 – Acidic, NaCN – Basic, $NaNO_2$ – Basic

b) Because of the presence of H_2CO_3/HCO_3^- buffer system in the blood.

c) Let the solubility of $Mg(OH)_2$ is S. The dissociation of $Mg(OH)_2$ can be represented as:

$$Mg(OH)_{2\,(s)} \rightleftharpoons Mg^{2+}_{(aq)} + 2\,(OH)^-_{2\,(aq)}$$

Eqm. Concn: S S 2S

$$K_{SP} = [Mg^{2+}][OH^-]^2 = S \times (2S)^2$$

i.e. $K_{SP} = 4S^3$

Here $S = 1.5 \times 10^{-4}$

So $K_{SP} = 4 \times (1.5 \times 10^{-4})^3 = \underline{1.35 \times 10^{-11}}$

15. a) The solubility product of salt is related to its solubility.

i) Give the relation between solubility product and solubility of $BaSO_4$. (1)

ii) The solubility product of $BaSO_4$ is 1.2×10^{-10} at 298K. Calculate the solubility of $BaSO_4$ at 298K. (2)

b) Differentiate between homogeneous and heterogeneous equilibria. (2) [September 2016]

Ans: a) i) $BaSO_{4\,(s)} \rightleftharpoons Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$

So, $K_{SP} = S^2$

ii) Here $K_{SP} = 1.2 \times 10^{-10}$

So, $S = \sqrt{K_{SP}} = \sqrt{(1.2 \times 10^{-10})} = 0.109\ M$

b) In homogeneous equilibrium, all the reactants and products are in the same phase or state.

e.g. $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

In heterogeneous equilibrium the reactants and products are in different phases.

e.g. $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

16. a) Write the expression for equilibrium constant Kc for the following equilibrium.

$CuSO_4.5H_2O(s) \rightleftharpoons CuSO_4.3H_2O(s) + 2\ H_2O(g)$ (2)

b) The solubility product of $Al(OH)_3$ is 1×10^{-36}. Calculate the solubility of $Al(OH)_3$. (3)

Ans: a) $K_c = \dfrac{[CuSO_4.3H_2O][H_2O]^2}{[CuSO_4.5H_2O]}$

b) Let the solubility of $Al(OH)_3$ *be S*

$Al(OH)_{3\,(s)} \rightleftharpoons Al^{3+}_{(aq)} + 3OH^-_{(aq)}$

Eqm. Concn: $S \qquad S \qquad 3S$

$K_{SP} = [Al^{3+}][OH^-]^3 = S \times (3S)^3 = 27S^4$

i.e. $K_{SP} = 27S^4$

Here $K_{SP} = 1 \times 10^{-36}$.

So, $S = \sqrt[4]{(1 \times 10^{-36})} = 10^{-9}\ M$

17. a) Explain the concept of Lewis acid and Lewis bases with suitable examples. (3)

b) Write the Henderson – Hasselbalch equation for an acidic buffer. Calculate the pH of an acidic buffer containing

0.1 M CH_3COOH and 0.5 M CH_3COONa. [Ka for CH_3COOH is 1.8×10^{-6}]. (2) [March 2016]

Ans: a) Refer the Answer of Qn. No. 3

b) For an acidic buffer Henderson – Hasselbalch equation, $p^H = p^{Ka} + \log[Salt]/[Acid]$

Here [Acid] = 0.1M, [Salt] = 0.5M and $Ka = 1.8 \times 10^{-6}$

$pKa = -\log Ka = -\log(1.8 \times 10^{-6}) = 5.7447$

$p^H = p^{Ka} + \log[Salt]/[Acid]$

$= 5.7447 + \log(0.5/0.1) = \underline{6.444}$

18. Equilibrium constant helps in predicting the direction in which a given reaction will proceed at any stage.

a) In which one of the following conditions a chemical reaction Proceeds in the forward direction?

i) $Q_C < K_C$ ii) $Q_C > K_C$ iii) $Q_C = 1/K_C$ IV) $Q_C = -K_C$ (1)

b) Write whether the following statement is true or false:
"High value of equilibrium constant suggests high concentration of the reactants in the equilibrium mixture". (1)

c) State the Le-Chatlier's principle. Applying this principle, explain the effect of pressure in the following equilibrium.

$CO(g) + 3\ H_2(g) \rightarrow CH_4(g) + H_2O(g)$ (3) [September 2015]

Ans: a) $Q_C < K_C$

b) False. Greater the value of equilibrium constant, greater will be the concentration of products.

c) It states that whenever there is a change in concentration, pressure or temperature of a system at equilibrium, the system will try to readjust in such a way so as to cancel the effect of that change.

$CO(g) + 3\,H_2(g) \rightarrow CH_4(g) + H_2O(g)$

Here as a result of forward reaction, the no. of moles of gaseous species decreases. So high pressure favours forward reaction.

19. a) i) Give the Arrhenius concept about acids and bases. (1)

ii) Give one example each for Arrhenius acid and base. (1)

b) i) Write the expression for equilibrium constant Kp for the following equilibrium.

$2NOCl_{(g)} \rightleftharpoons 2NO_{(g)} + Cl_{2(g)}$ (1)

ii) Find the value of Kc for the above equilibrium if the value of Kp is 1.8×10^{-2} atm at 600 K.

(R= 0.0821 L atm $K^{-1}mol^{-1}$) (2) [March 2015]

Ans: a) i) According to Arrhenius concept acids are substances which give hydrogen ion (H^+) or hydronium ion (H_3O^+) in aqueous solution and bases are substances which give hydroxyl ion (OH^-) in aqueous solution.

ii) e.g. HCl is an acid since it produces H_3O^+ in aqueous solution.

$HCl_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)}$

e.g. for base is NaOH

$NaOH_{(s)} + H_2O_{(l)} \rightleftharpoons Na^+_{(aq)} + OH^-_{(aq)}$

b) i) $Kp = P^2_{NO}.P_{Cl_2}/P^2_{NOC}$

ii) Here $Kp = 1.8 \times 10^{-2}$, R = 0.0821 atm/K/mol, $\Delta n = n_{P(g)} - n_{R(g)} = 3-2 = 1$ and T = 600K

$Kp = Kc(RT)^{\Delta n}$

$1.8 \times 10^{-2} = Kc(0.0821 \times 600)^1$

$Kc = 1.8 \times 10^{-2}/(0.0821 \times 600)$

$= \underline{\underline{3.65 \times 10^{-4}}}$

20. Le-Chatlier's principle makes a qualitative prediction about the change in conditions on equilibrium.

a) State Le-Chatlier's principle. (1)

b) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$.

What is the effect of pressure on the above equilibrium? (2)

c) The species HCO_3^- and HSO_4^- can act both as Bronsted acids and bases. Write the corresponding conjugate acid and conjugate base of the above species. (2) [August 2014]

Ans: a) Refer the answer of the question no. 18 (c)

b) Here the no. of moles of gaseous reactants = no. of moles of gaseous products. So pressure has no effect in this reaction.

c) Conjugate acids: H_2CO_3 and H_2SO_4

Conjugate base: CO_3^{2-} and SO_4^{2-}

21. a) Write an equation for equilibrium constant in terms of concentration (K_c) for the equilibrium reaction given below.

$Ag_2O(s) + 2HNO_3(aq) \rightleftharpoons 2\,AgNO_3(aq) + H_2O(l)$ (1)

b) What are buffer solutions? Give an example for a buffer solution. (2)

c) The concentration of H^+ ion in a sample of soft drink is 3.8×10^{-3}M. Determine its pH. (2) [March 2014]

Ans: a) $Kc = \frac{[AgNO_3]^2[H_2O]}{[Ag_2O][HNO_3]^2}$

b) Ref. the Ans. Of the qn. No. 11

c) Here $[H^+] = 3.8 \times 10^{-3}$

We know that $pH = -\log[H^+]$

$= -\log (3.8 \times 10^{-3}) = 2.42$

22. a) What is conjugate acid – base pair? Illustrate with an example. (1)
    b) Define the pH scale. The pH of a soft drink is 2.42. Give the nature of the solution. (2)
    c) An aqueous solution of $CuSO_4$ is acidic while that of Na_2SO_4 is neutral. Explain. (2) [September 2013]

Ans: a) Acid - base pairs which are differed by a proton (H^+) are called conjugate acid -base pair. E.g. NH_4^+ *is the conjugate acid of the base* NH_3.

b) p^H *is defined as the negative logarithm of the hydrogen ion or hydronium ion concentration in moles per litre (i.e. molarity). i.e.* $p^H = -\log[H^+]$ *or* $p^H = -\log[H_3O^+]$

Here pH = 2.42

i.e. $2.42 = -\log[H^+]$

$[H+]$ *= Antilog (-2.42) =* 3.8×10^{-3} *M*

c) $CuSO_4$ *is a salt of strong acid and weak base. So it is acidic. While* Na_2SO_4 *is a salt of strong acid and strong base. So it is neutral.*

23. Equilibrium is possible only in a closed system at a given temperature.
    a) Write the expression for equilibrium constant, Kc for the reaction
    $4\ NH_3(g) + 5\ O_2(g) \rightleftharpoons 4\ NO(g) + 6\ H_2O(l)$ (1)
    b) What happens to the value of the equilibrium constant (Kc) when the above reaction is reversed? (1)

Ans: a) $Kc = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$

b) When the reaction is reversed, the new equilibrium constant (Kc') = 1/Kc.

24. Weak acids are partially ionized in aqueous solutions.
    a) The ionization constants of some acids are given below:

Acid	Ionisation constant (Ka)
Formic acid (HCOOH)	1.8×10^{-4}
Hypochlorous acid (HClO)	3.0×10^{-8}
Nitrous acid (HNO_2)	4.5×10^{-4}
Hydrocyanic acid (HCN)	4.9×10^{-10}

Arrange the above acids in the increasing order of their acid strength. (1)

    b) Calculate the pH of a 0.01 M acetic acid solution with the degree of ionization 0.045. (2)

Ans: a) $HCN < HClO < HNO_2 < HCOOH$

b) $Ka = 0.045 = 4.5 \times 10^{-2}$, $C = 0.01M$

$K_a = C\alpha^2$

$\alpha = \sqrt{Ka/C} = \sqrt{(4.5 \times 10^{-2}/0.01)} = 2.12$

$[H_3O^+] = c\alpha = 0.01 \times 2.12 = 2.12 \times 10^{-2}$

$pH = -\log[H_3O^+] = -\log(2.12 \times 10^{-2}) = \underline{\underline{1.673}}$

25. Salts can be classified into different categories on the basis of their solubility.
    a) Identify the solubility range of sparingly soluble salts from the following: (Between 0.01 M and 0.1 M, less than 0.01 M, greater than 0.1 M). (1)
    b) Calculate the solubility (S) of $CaSO_4$ at 298 K, if its solubility product constant (Ksp) at this temperature is 9×10^{-6}. (2) [March 2013]

Ans: a)

Solubility in between 0.01M and 0.1M	*Slightly Soluble*
Solubility < 0.01M	*Sparingly Soluble*
Solubility > 0.1M	*Soluble*

b) $CaSO_{4\,(s)} \rightleftharpoons Ca^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)}$

$K_{SP} = S^2$. Here $K_{SP} = 9 \times 10^{-6}$

So, $S = \sqrt{K_{SP}} = \sqrt{(9 \times 10^{-6})} = 3 \times 10^{-3}$

26. a) During a class room discussion one of your friends argues that equilibrium constant is not altered with change in temperature. What is your view towards this argument? Justify. (2)
    b) Dissociation of $CaCO_3$ in a closed vessel is given as $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$
    i) Write an expression for Kc. (1)
    ii) Explain the effect of increase in pressure on the above reaction. Name the principle behind this. (2)
    [September 2012]

Ans: a) This statement is wrong. The value of equilibrium constant depends on temperature. Based on the value of ΔH, it may increase or decrease with temperature.

c) *b) (i) $Kc = [CaO][CO_2]/[CaCO_3]$*

(ii) Here the no. of moles of gaseous species increases during forward reaction. So low pressure favours forward reaction. When pressure increases, the rate of backward reaction increases.

27. Le-Chatlier's principle helps to explain the effect of change in conditions on equilibrium. Discuss the effect of pressure in the following equilibrium on the basis of Le-Chatlier's principle:
    $CO(g) + 3\,H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ (2)

Ans: Here the forward reaction results in the decrease in no. of moles of gaseous species. So increase in pressure favours forward reaction.

28. The behaviour of acids and bases can be explained by using different concepts.
    a) Select the Lewis acid from the following: (NH_3, OH^-, BCl_3, Cl^-) (1)
    b) What are conjugate acid – base pairs? Illustrate using a suitable example. (2)

Ans: a) BCl_3

b) Refer the answer of the question no. 22 (a)

29. The pH of a salt solution depends on the hydrolysis of its ions.
    a) Out of the following, which can produce an acidic solution in water? (CH_3COONa, NH_4Cl, CH_3COONH_4, NaCl) (1)
    b) Explain the phenomenon of common ion effect with a suitable example. (2) [March 2012]

Ans: a) NH_4Cl

b) Refer the answer of the question no. 13 (b)

30. The principal goal of chemical synthesis is to maximize the conversion of reactants into products. Le-Chatlier's principle can be applied to achieve this goal.

a) State Le-Chatlier's principle. (1)

b) Predict the conditions to be applied to maximize the production of ammonia in the following reaction.

$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$; $\Delta H = -92.38$ kJ/mol (3)

c) Comment on the effect of increasing pressure in the reaction, $2\ SO_3(g) \rightleftharpoons 2\ SO_2(g) + O_2(g)$ (1)

[October 2011]

Ans: a) Refer the answer of the question no. 18 (c)

b) Concentration: Increase the concentration of N_2 or H_2 or both, ore remove the ammonia formed from the reaction mixture.

Temperature: Since the forward reaction is exothermic, low temperature favours the reaction.

Pressure: Here the forward reaction results in the decrease in no. of moles of gaseous species. So high pressure favours forward reaction.

c) *Here the forward reaction results in increase in no. of moles of gaseous species. So low pressure favours forward reaction.*

31. Common ion effect is a phenomenon based on Le-Chatlier's principle.

a) Illustrate the common ion effect with an example. (2)

b) If the concentration of hydrogen ion in a soft drink is 3×10^{-3} M, calculate its pH. (2)

c) Identify the Lewis acids from the following: OH^-, BCl_3, NH_3, H^+ (1) [March 2011]

Ans: a) Refer the answer of the question no. 13 (b)

b) Refer the answer of the question no. 1 (a)

c) BCl_3

32. Lowry-Bronsted concept of acid and bases is based on the exchange of H^+ during a reaction.

a) Illustrate with an example of the conjugate acid – base pair. (1½)

b) Explain the Lewis concept of acids and bases. (1½)

c) According to Lewis theory, classify the following into acids and bases:
H_2O, NH_3, $AlCl_3$, OH^- (2) [September 2010]

Ans: a) Refer the answer of the question no. 22 (a)

b) Refer the answer of the question no. 3

c) Lewis acids – $AlCl_3$ Lewis base - H_2O, NH_3, OH^-

33. When some sodium acetate is added to a solution of acetic acid, the concentration of unionized acetic acid increases.

a) What is the phenomenon involved? Substantiate. (2)

b) Consider the equilibrium, $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$
The solubility of AgCl is 1.06×10^{-5} mol/L at 298K. Find out its Ksp at this temperature. (2)

c) What happens to the value of solubility and solubility product when HCl is passed through AgCl solution? (1)

[March 2010]

Ans: a) Common ion effect. Refer the answer of the question no. 13 (b)

b) Here $S = 1.06 \times 10^{-5}$ mol/L

$K_{SP} = S^2$

$= (1.06 \times 10^{-5})^2 = \underline{1.124 \times 10^{-10}}$

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

When HCl is passed through the above solution, the concentration of Cl^- increases and hence the equilibrium shifts to the backward direction.

34. The aqueous solutions of the ionic compounds NaCl, CH_3COONa and NH_4Cl show different pH.
    a) Identify the acidic, basic and neutral solutions among these. (2)
    b) Justify your answer. (3) [March 2009]

    Ans: a) Acidic – NH_4Cl, basic – CH_3COONa and neutral – NaCl

    b) NH_4Cl is a salt of strong acid HCl and weak base NH_4OH. So it is acidic.

    CH_3COONa is a salt of weak acid CH_3COOH and strong base NaOH. So it is basic.

    NaCl is a salt of strong acid HCl and strong base NaOH. Since the cation of the strong base and anion of the strong acid do not undergo hydrolysis, the solution is neutral.

35. $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$
    a) Write down the expression for Kp. (1)
    b) What is the relation between Kp and Kc in the above reaction? (1) [June 2008]

    Ans: a) $Kp = P_{CO_2}$ [Since $CaCO_3$ and CaO are solids they do not contribute to Kp]

    b) Here $\Delta n = n_{P(g)} - n_{R(g)} = 1 - 0 = 1$

    So $Kp = Kc.RT$

36. $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$
    a) What happens to Kp of the above system if more chlorine is added to the system in equilibrium. (1)
    b) Give the relation between Kp and Kc in the above system. (1) [February 2008]

    Ans: a) The reaction shifts to the backward reaction.

    b) Here $\Delta n = n_{P(g)} - n_{R(g)} = 3-2 = 1$

    So $Kp = Kc.RT$

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PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "REDOX REACTIONS"

1. (a) In the reaction: Pb (s) + PbO_2(s) + $2H_2SO_4$ (aq) → 2 $PbSO_4$(s) + $2H_2O$ (l), identify the following. (2)
   (i) The substance oxidised (ii) The substance reduced (iii) The oxidising agent (iv) The reducing agent
   (b) What is disproportionation reaction? (1) [July 2019]

   Ans: (a) (i) The substance oxidised: Pb
   (ii) The substance reduced: Pb in PbO_2
   (iii) The oxidising agent: Pb in PbO_2
   (iv) The reducing agent: Pb
   (b) In a disproportionation reaction, an element in one oxidation state is simultaneously oxidised and reduced.

2. Balance the following Redox process by ion-electron method or oxidation number method :
   P_4(s) + OH-(aq) ⟶ PH_3(g) + HPO_2^- (aq) (3) [March 2019]

   Ans: ***Ion-electron method:***
   Step-1: Assign the oxidation number of each element and find out the substance oxidised and reduced.
   0 -3 +2
   $P_4 + OH^- \longrightarrow PH_3 + HPO_2^-$
   Here P_4 is simultaneously oxidised and reduced.
   Step-2: Separate the equation into oxidation half reaction and reduction half reaction.
   Oxidation half: $P_4 \longrightarrow HPO_2^-$ Reduction half: $P_4 \longrightarrow PH_3$
   Step-3: Balance the atoms other than O and H in each half reaction individually.
   Oxidation half: $P_4 \longrightarrow 4HPO_2^-$ Reduction half: $P_4 \longrightarrow 4PH_3$
   Step-4: Now balance O and H atoms. Add H_2O to balance O atoms and H^+ to balance H atoms. Since the reaction occurs in basic medium also add equal number of OH^- ions on both sides of the equation.
   Oxidation half: $P_4 + 8H_2O + 12OH^- \longrightarrow 4HPO_2^- + 12\,H^+ + 12\,OH^-$
   Or, $P_4 + 12OH^- \longrightarrow 4HPO_2^- + 4H_2O$
   Reduction half: $P_4 + 12\,H^+ + 12\,OH^- \longrightarrow 4PH_3 + 12\,OH^-$
   Or, $P_4 + 12\,H_2O \longrightarrow 4PH_3 + 12OH^-$
   Step -5: Now balance the ionic charges. For this add electrons to one side of the half reaction.
   Oxidation half: $P_4 + 12OH^- \longrightarrow 4HPO_2^- + 4H_2O + 8e^-$
   Reduction half: $P_4 + 12\,H_2O + 12e^- \longrightarrow 4PH_3 + 12OH^-$
   Step-6: Now add the two half reactions after equating the electrons.
   Oxidation half: $(P_4 + 12OH^- \longrightarrow 4HPO_2^- + 4H_2O + 8e^-)x3$
   Reduction half: $(P_4 + 12\,H_2O + 12e^- \longrightarrow 4PH_3 + 12OH^-)x2$
   Overall reaction is: $5\,P_4 + 12\,OH^- + 12\,H_2O \longrightarrow 12\,HPO_2^- + 8\,PH_3$
   OR
   Oxidation number method:

   Step 1*: Write the skeletal equation. $P_4 + OH^- \longrightarrow PH_3 + HPO_2^-$*
   Step 2*: Assign the oxidation number of each elements and identify the atoms which undergo change in oxidation number.*
   0 0 -3 +2

$P_4 + P_4 + OH^- \longrightarrow PH_3 + HPO_2^-$

***Step 3**: Calculate the change in oxidation number per atom and equate them by multiplying with suitable coefficients.*

O.N decreased by 3

0 0 -3 +2

$P_4 + P_4 + OH^- \longrightarrow PH_3 + HPO_2^-$

O.N increased by 2

$2P_4 + 3P_4 + OH^- \longrightarrow PH_3 + HPO_2^-$

***Step 4**: Balance all the atoms except oxygen and hydrogen.*

$2P_4 + 3P_4 + OH^- \longrightarrow 8\ PH_3 + 12\ HPO_2^-$

***Step 5**: Now equate the ionic charges on both sides. Since the reaction occurs in in basic medium, add 11 OH^- ions on LHS.*

$2P_4 + 3P_4 + OH^- + 11OH^- \longrightarrow 8\ PH_3 + 12\ HPO_2^-$

***Step 6**: Now balance the hydrogen atoms by adding 12 water (H_2O) molecules on LHS.*

$5P_4 + 12OH^- + 12H_2O \longrightarrow 8\ PH_3 + 12\ HPO_2^-$

Now the equation becomes balanced.

3. Redox reactions are classified into four types. Describe any three of them with suitable examples. (3) [August 2018]

*Ans: **Combination reactions**: A combination reaction may be denoted as A + B → C*

Here either A or B or both A and B must be in the elemental form.

E.g. $C(s) + O_2(g) \longrightarrow CO_2(g)$

***Decomposition reactions:** Decomposition reactions are the opposite of combination reactions. It involves the breakdown of a compound into two or more components, in which at least one must be in the elemental state. It may be denoted as: C → A + B.*

E.g.: $2NH_3(g) \longrightarrow N_2(g) + 3H_2(g)$

***Displacement reactions**: Here an ion (or an atom) in a compound is replaced by an ion (or an atom) of another element. It may be denoted as: X + YZ → XZ + Y*

E.g.: $Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$

4. Balance the following Redox reaction by ion-electron method or oxidation number method (Acid medium)

$Cr_2O_7^{2-}(aq) + SO_3^{2-}(aq) \longrightarrow Cr^{3+}(aq) + SO_4^{2-}(aq)$ (3) [March 2018]

Ans:

5. a) The oxidation number of sulphur in SO_4^{2-} is ……. a) 3 b) 4 c) 5 d) 6

b) Balance the following equation using oxidation number method.

$Cr_2O_7^{2-}(aq) + SO_3^{2-}(aq) \longrightarrow Cr^{3+}(aq) + SO_4^{2-}(aq)$ [In acidic medium] [July 2017]

Ans: (a) 6

(b) Step 1: The skeletal equation is: $Cr_2O_7^{2-} + SO_3^{2-} \rightarrow Cr^{3+} + SO_4^{2-}$

Step 2: Assign oxidation number each element and identify the elements undergoing change in oxidation number. *+6 -2 +4 -2 +3 +6 -2*

$Cr_2O_7^{2-} + SO_3^{2-} \rightarrow Cr^{3+} + SO_4^{2-}$

Step 3: Calculate the change in oxidation number and make them equal by multiplying with suitable number. Here the oxidation number of Cr is decreased by 3 and that of S is increased by 2. In order to equate them multiply SO_3^{2-} by 3.

$$Cr_2O_7^{2-} + 3\ SO_3^{2-} \rightarrow Cr^{3+} + SO_4^{2-}$$

Step 4: Now balance all the atoms except Oxygen and Hydrogen

$$Cr_2O_7^{2-} + 3\ SO_3^{2-} \rightarrow 2\ Cr^{3+} + 3\ SO_4^{2-}$$

Step 5: Now balance the ionic charges on both sides. Here the net ionic charge on LHS is -8 and on RHS is 0. To equate them add $8H^+$ on LHS, since the reaction takes place in acidic medium.

$$Cr_2O_7^{2-} + 3\ SO_3^{2-} + 8H^+ \rightarrow 2\ Cr^{3+} + 3\ SO_4^{2-}$$

Step 6: Now balance hydrogen atoms by adding sufficient number of H_2O molecules. Here add 4 H_2O molecules on RHS.

$$Cr_2O_7^{2-} + 3\ SO_3^{2-} + 8H^+ \rightarrow 2\ Cr^{3+} + 3\ SO_4^{2-} + 4\ H_2O$$

Now the equation is balanced.

6. Permanganate ion reacts with bromide ion in basic medium to give manganese dioxide and bromated ion. Write the balanced equation for the reaction using oxidation number method. Skeletal equation is:

   $MnO_4^- + Br^- \longrightarrow MnO_2 + BrO_3^-$ (3) [March 2017]

   Ans: Oxidation number method

   Step 1: The skeletal equation is: $MnO_4^- + Br^- \rightarrow MnO_2 + BrO_3^-$

   Step 2: Assign oxidation number each element and identify the elements undergoing change in oxidation number. *+7 -2 -1 +4 -2 +5 -2*

   $$MnO_4^- + Br^- \rightarrow MnO_2 + BrO_3^-$$

   Here the oxidation number of Mn and Br are changed.

   Step 3: Calculate the change in oxidation number and make them equal by multiplying with suitable number. Here the oxidation number of Mn is decreased by 3 and that of Br is increased by 6. In order to equate them multiply MnO_4^- by 2.

   $$2\ MnO_4^- + Br^- \rightarrow MnO_2 + BrO_3^-$$

   Step 4: Now balance all the atoms except Oxygen and Hydrogen

   $$2\ MnO_4^- + Br^- \rightarrow 2\ MnO_2 + BrO_3^-$$

   Step 5: Now balance the ionic charges on both sides. Here the net ionic charge on LHS is -3 and on RHS is -1. To equate them add $2\ OH^-$ on RHS, since the reaction takes place in basic medium.

   $$2\ MnO_4^- + Br^- \rightarrow 2MnO_2 + BrO_3^- + 2OH^-$$

   Step 6: Now balance hydrogen atoms by adding sufficient number of H_2O molecules. Here add one H_2O molecule on LHS.

   $$2MnO_4^- + Br^- + H_2O \rightarrow 2MnO_2 + BrO_3^- + 2OH^-$$

   Now the equation is balanced.

7. In a redox reaction, reduction and oxidation takes place simultaneously.
   a) Write the redox reaction in Daniel cell. (1)
   b) When $CuSO_4$ solution stored in iron vessel, the blue colour changes to pale green. Do you agree with it? Justify. (2) [September 2016]

   Ans: (a) $Zn + Cu^{2+} \longrightarrow Zn^{2+} + Cu$

(b) Yes. Iron can displace copper from $CuSO_4$ solution and form $FeSO_4$. So the blue colour changes to pale green.

$$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$$

8. Redox reactions can be considered as electron transfer reactions. In an experiment a copper rod is dipped in $AgNO_3$ solution.
   a) What happens to the colour of the solution and why? (1)
   b) Identify the oxidising and reducing agents in this reaction. (1)
   c) Calculate the oxidation number of Cr in $K_2Cr_2O_7$ and P in $H_2P_2O_5$. (1) [March 2016]

   Ans: (a) The solution becomes pale blue in colour. This is because Cu displaces Ag from $AgNO_3$ solution. $Cu + 2AgNO_3 \longrightarrow Cu(NO_3)_2 + 2Ag$

   (b) Oxidising agent: $AgNO_3$

   Reducing agent: Cu

   (c) Oxidation no. of Cr in $K_2Cr_2O_7$ = +6

   Oxidation no. of P in $H_2P_2O_5$ = +4

9. Identify the oxidant and reductant in the following ionic equation and balance it using oxidation number method.

   $MnO_4^-(aq) + Br^-(aq) + H^+(aq) \longrightarrow Mn^{2+}(aq) + Br_2(l) + H_2O(l)$ (3) [Sept. 2015]

   Ans:

   Step 1: The skeletal equation is: $MnO_4^- + Br^- + H^+ \rightarrow Mn^{2+} + Br_2 + H_2O$

   Step 2: Assign oxidation number each element and identify the elements undergoing change in oxidation number.

   $\overset{+7\ -2}{MnO_4^-} + \overset{-1}{Br^-} + \overset{+1}{H^+} \rightarrow \overset{+2}{Mn^{2+}} + \overset{0}{Br_2} + \overset{+1\ -2}{H_2O}$

   Here the oxidation number of Mn and Br are changed.

   Step 3: Calculate the change in oxidation number and make them equal by multiplying with suitable number. Here the oxidation number of Mn is decreased by 5 and that of Br is increased by 1. In order to equate them multiply MnO_4^- by 2 and Br^- by 10 [Since Br is present as Br_2 in RHS]

   $2\ MnO_4^- + 10\ Br^- + H^+ \rightarrow Mn^{2+} + Br_2 + H_2O$

   Step 4: Now balance all the atoms except Oxygen and Hydrogen

   $2\ MnO_4^- + 10\ Br^- + H^+ \rightarrow 2\ Mn^{2+} + 5\ Br_2 + H_2O$

   Step 5: Now balance the ionic charges on both sides. Here the net ionic charge on LHS is -11 and on RHS is +4. To equate them add 15 more H^+ on LHS, since the reaction takes place in acidic medium.

   $2\ MnO_4^- + 10\ Br^- + 16\ H^+ \rightarrow 2\ Mn^{2+} + 5\ Br_2 + H_2O$

   Step6: Now balance hydrogen atoms by adding sufficient number of H_2O molecules. Here add 7 more H_2O molecule on RHS.

   $2\ MnO_4^- + 10\ Br^- + 16\ H^+ \rightarrow 2\ Mn^{2+} + 5\ Br_2 + 8\ H_2O$

   Now the equation is balanced.

10. a) Given the redox reaction:

    $CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(g)$

    i) Identify the species which undergo reduction and which undergo oxidation.

    ii) Identify the reductant and oxidant in the above reaction. (2)

b) Among the following reactions, identify the one which is NOT a redox reaction. (1)

I. $3Mg(s) + N_2(g) \xrightarrow{\Delta} Mg_3N_2(s)$

II. $Fe(s) + 2\,HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$

III. $CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$

IV. $2\,NaH(s) \xrightarrow{\Delta} 2Na(s) + H_2(g)$ [March 2015]

Ans: (a) i) Substance oxidised: H_2, Substance reduced: CuO

ii) Reductant: H_2, Oxidant: CuO

(b) $CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$

11. a) Using Stock notation, represent the following compounds: i) $HAuCl_4$ ii) MnO_2 (1)

b) i) Define the electronic concept of oxidation and reduction. (1)

ii) Find out the oxidiser and reducer in the following reaction on the basis of the electronic concept.

$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$ (1) [August 2014]

Ans: (a) (i) $HAu(III)Cl_4$ (ii) $Mn(IV)O_2$

(b) (i) According to electronic concept oxidation is the process of removal (losing) of electron and reduction is the process of addition (gaining) of electron.

(ii) Oxidiser: Cl_2 and Reducer: Na

12. a) Write the formula of the following compounds.

i) Nickel (II) sulphate

ii) Tin (IV) oxide(1)

b) Fluorine reacts with ice as given below:

$H_2O(s) + F_2(g) \longrightarrow HF(g) + HOF(g)$ Justify that this is a redox reaction. (2) [March 2014]

Ans: (a) (i) $NiSO_4$ (ii) SnO_2

(b) *-2 0 -1 0*

$H_2O(s) + F_2(g) \longrightarrow HF(g) + HOF(g)$

Here the oxidation no. of oxygen increases and that of F_2 decreases. So oxygen is oxidised and Fluorine is reduced. Hence it is a redox reaction.

13. a) Calculate the oxidation number of Cr in Cr_2O_3 and S in H_2SO_4. (1)

b) In disproportionation reaction an element in one oxidation state is simultaneously oxidised and reduced. Identify the element undergoing disproportionation in the following reaction:

$P_4 + 3\,OH^- + 3\,H_2O \longrightarrow PH_3 + 3\,H_2PO_2^-$ (2) {September 2013]

Ans: (a) Oxidation no. of Cr in Cr_2O_3 is +3 and the oxidation number of S in H_2SO_4 is +6.

(b) 0 -3 +1

$P_4 + 3\,OH^- + 3\,H_2O \longrightarrow PH_3 + 3\,H_2PO_2^-$

Here the P_4 is simultaneously oxidised and reduced. So it is disproportionate.

14. Competitive electron transfer reactions are utilized in the construction of Galvanic cells.

a) Write the redox reaction involved when metallic cobalt is placed in a nickel sulphate solution. (Note: Only the ionic reaction is required) (1)

b) In the reaction $Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \longrightarrow 2\,PbSO_4(s) + 2\,H_2O(l)$ Identify the following:

i) Substance oxidised ii) Substance reduced iii) Oxidising agent iv) Reducing agent (2) [March 2013]

Ans: (a) $Co + Ni^{2+} \rightarrow Co^{2+} + Ni$

(b) (i) The substance oxidised: Pb

(ii) The substance reduced: Pb in PbO_2

(iii) The oxidising agent: Pb in PbO_2

(iv) The reducing agent: Pb

15. a) Using stock notation, represent the following compounds - FeO and MnO_2. (1)

b) Redox reactions are those reactions in which oxidation and reduction takes place simultaneously. Write any two redox reactions. (2) [September 2012]

Ans: (a) Fe(II)O and Mn(IV)O_2

(b) $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

$Fe(s) + 2\,HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$

16. In redox reactions, oxidation and reduction occur simultaneously.

a) How are oxidation and reduction related to the oxidation number? (1)

b) During a group discussion, one of your friends argues that thermal decomposition of $KClO_3$ is a redox reaction while that of $CaCO_3$ is not a redox reaction. Give your opinion and substantiate. (2) [March 2012]

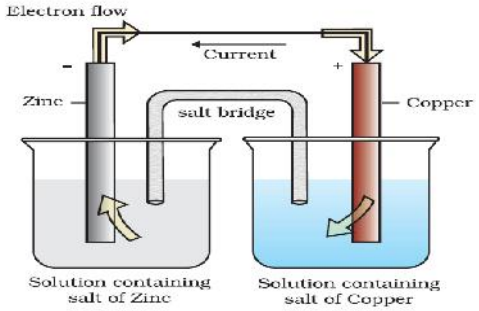
Ans: (a) Oxidation is the process of increase in the oxidation number of an element and reduction is the process of decrease in the oxidation number of an element.

(b) $\overset{+1\ +5\ -2}{2KClO_3} \rightarrow \overset{+1\ -1}{2KCl} + \overset{0}{3\,O_2}$ *Here Cl is reduced and O is oxidised. This reaction is a redox reaction since there is both oxidation and reduction.*

$\overset{+2\ +4\ -2}{CaCO_3(s)} \xrightarrow{\Delta} \overset{+2\ -2}{CaO(s)} + \overset{+4\ -2}{CO_2(g)}$

Here there is no change in oxidation number of any species. So it is not a redox reaction.

17. The chemical reactions taking place in electrochemical cells are redox reactions. A Daniel cell is represented below.



a) As the reaction proceeds in this cell, one of the metal rods gets dissolved in its solution and the other metal gets deposited from the solution to the metal rod. Which metal is getting deposited? (1)

b) Identify the metal which is acting as the oxidising agent in this reaction. (1)

c) Write the chemical equation of the reaction taking place at the first compartment. (1) [October 2011]

Ans: The chemical equation for the reaction is: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

(a) Copper

(b) Cu^{2+}

(c) Zn $\longrightarrow$ *$Zn^{2+} + 2e^-$*

18. Balance the following equation by the half reaction method.

$Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + H^+(aq) \longrightarrow Fe^{3+}(aq) + Cr^{3+}(aq) + H_2O(l)$ (3) [March 2011]

Ans: Half reaction method (Ion-electron method)

Step-1: Assign the oxidation number of each element and find out the substance oxidised and reduced.

$\overset{+2}{Fe^{2+}} + \overset{+6}{Cr_2O_7^{2-}} + H^+ \longrightarrow \overset{+3}{Fe^{3+}} + \overset{+3}{Cr^{3+}} + H_2O$

Here Fe is oxidised and Cr is reduced.

Step-2: Separate the equation into 2 half reactions -oxidation half reaction and reduction half reaction.

Oxidation half: $Fe^{2+} \longrightarrow Fe^{3+}$ Reduction half: $Cr_2O_7^{2-} \longrightarrow Cr^{3+}$

Step-3: Balance the atoms other than O and H in each half reaction individually.

Oxidation half: $Fe^{2+} \longrightarrow Fe^{3+}$ Reduction half: $Cr_2O_7^{2-} \longrightarrow 2\,Cr^{3+}$

Step-4: Now balance O and H atoms. Add H_2O to balance O atoms and H^+ to balance H atoms since the reaction occurs in acidic medium.

Oxidation half: $Fe^{2+} \longrightarrow Fe^{3+}$ Reduction half: $Cr_2O_7^{2-} + 14H^+ \longrightarrow 2\,Cr^{3+} + 7\,H_2O$

Step -5: Now balance the ionic charges. For this add electrons to one side of the half reaction.

Oxidation half: $Fe^{2+} \longrightarrow Fe^{3+} + e^-$ Reduction half: $Cr_2O_7^{2-} + 14H^+ + 6\,e^- \longrightarrow 2\,Cr^{3+} + 7\,H_2O$

Step-6: Now add the two half reactions after equating the electrons.

Oxidation half: $(Fe^{2+} \longrightarrow Fe^{3+} + e^-) \times 6$

Reduction half: $(Cr_2O_7^{2-} + 14H^+ + 6\,e^- \longrightarrow 2\,Cr^{3+} + 7\,H_2O) \times 1$

Overall reaction is: $6\,Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \longrightarrow 6\,Fe^{3+} + 2\,Cr^{3+} + 7\,H_2O$

Now the equation is balanced.

19. A farmer prepared 1% solution of copper sulphate using iron rod as the stirrer for preparing Bordeaux mixture. Next day he noticed that the blue colour almost disappeared and the iron rod get coated with reddish brown material.
    a) What is the reddish brown material deposited on the iron rod? (1)
    b) Account for the colour change of the solution. (1)
    c) Justify the above phenomenon as a redox reaction. (1) [September 2010]

    Ans: (a) Copper

    b) Here iron displaces copper from $CusO_4$ solution and form $FeSO_4$. So the blue colour disappears.

    c) $\overset{0}{Fe} + \overset{+2\ +6\ -2}{CuSO_4} \longrightarrow \overset{+2\ -6\ -2}{FeSO_4} + \overset{0}{Cu}$

    Here the oxidation number of Fe increases and hence it is oxidised, while that of Cu decreases, so it is reduced. Since there is both oxidation and reduction, it is a redox reaction.

20. Chemical reactions which involve oxidation and reduction are called redox reactions. The unbalanced equation in the ionic form of a redox reaction is shown below.

$Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) \xrightarrow{\text{acidic medium}} Fe^{3+}(aq) + Cr^{3+}(aq)$

    a) Identify the oxidising agent in this reaction. (1)
    b) Name the species getting oxidized in the above reaction. (1)

c) Balance the above equation by oxidation number method. (3) [March 2010]

Ans: (a) Oxidising agent – Cr in $Cr_2O_7^{2-}$

(b) Fe^{2+}

(c) Oxidation number method

Step 1: The skeletal equation is: $Fe^{2+} + Cr_2O_7^{2-} \rightarrow Fe^{3+} + Cr^{3+}$

Step 2: Assign oxidation number each element and identify the elements undergoing change in oxidation number. $\overset{+2}{Fe^{2+}} + \overset{+6\ -2}{Cr_2O_7^{2-}} \rightarrow \overset{+3}{Fe^{3+}} + \overset{+3}{Cr^{3+}}$

Step 3: Calculate the change in oxidation number and make them equal by multiplying with suitable number. Here the oxidation number of Cr is decreased by 3 and that of Fe is increased by 1. In order to equate them multiply Fe^{2+} by 6.

$$6\,Fe^{2+} + Cr_2O_7^{2-} \rightarrow Fe^{3+} + Cr^{3+}$$

Step 4: Now balance all the atoms except Oxygen and Hydrogen

$$6\,Fe^{2+} + Cr_2O_7^{2-} \rightarrow 6\,Fe^{3+} + 2\,Cr^{3+}$$

Step 5: Now balance the ionic charges on both sides. Here the net ionic charge on LHS is +11 and on RHS is +24. To equate them add 13 more H^+ on LHS, since the reaction takes place in acidic medium.

$$6\,Fe^{2+} + Cr_2O_7^{2-} + 14\,H^+ \rightarrow 6\,Fe^{3+} + 2\,Cr^{3+}$$

Step 6: Now balance hydrogen atoms by adding sufficient number of H_2O molecules. Here add 7 H_2O molecules on RHS.

$$6\,Fe^{2+} + Cr_2O_7^{2-} + 14\,H^+ \rightarrow 6\,Fe^{3+} + 2\,Cr^{3+} + 7\,H_2O$$

Now the equation is balanced.

21. Fill in the blanks.
    a) The oxidation state of Cl in $HClO_4$ is …….. (1)
    b) A reducing agent is a substance which ……. electrons in a chemical reaction. (1)
    c) Among the elements Fluorine and Iodine, …… exhibit both positive and negative oxidation states. (1) [March 2009]

    Ans: (a) +7

    (b) donates or loses

    (c) Iodine

22. a) Both HCl and NaH contain H, but the oxidation states of H in them are different. What is the oxidation state of H in each compound? (2)
    b) What is the oxidation state of 'S' in SO_4^{2-}? (1) [June 2008]

    Ans: (a) Oxidation state of H in HCl is +1 and in NaH is -1.

    (b) +6

23. a) A compound is formed between oxygen and fluorine. Do you know whether it is oxygen fluoride or fluorine oxide? Explain. (2)
    b) NO and HNO_3 are two compounds of nitrogen. In which of them N is more oxidised? (1) [February 2008]

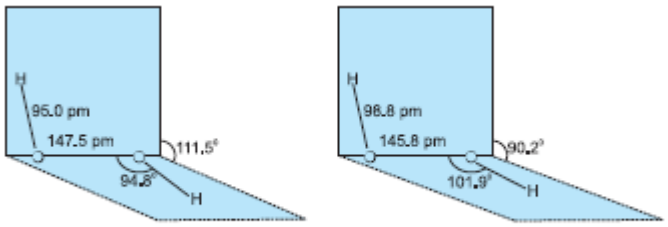
Ans: (a) Oxygen fluoride (OF_2), since F is more electronegative than Oxygen.

(b) In HNO_3, since here the oxidation number of N is +5.

PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "HYDROGEN"

1. Name the compound used in Clark's method for the removal of hardness of water. (1)
   Ans: Slaked lime [$Ca(OH)_2$]
2. (a) Substantiate the amphoteric nature of water with suitable chemical equations. (2)
   (b) What is meant by 100 volume H_2O_2? (1) [July 2019]

   Ans: (a) Water can act both as acid and base. So it is an amphoteric substance.
   e.g. $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
   acid
   $HNO_3 + H_2O \rightleftharpoons H_3O^+ + NO_3^-$
   Base
   (b) 30% solution of hydrogen peroxide is called 100 volume H_2O_2. i.e. 1 mL of 30% H_2O_2 solution will give 100V of oxygen at STP.
3. Which among the following is a molecular hydride?
   a) LiH b) NH_3 c) CrH d) $LaH_{2.87}$ (1)
   Ans: b) NH_3
4. Give the structure, preparation and a chemical reaction of H_2O_2. (3) [March 2019]
   Ans: Structure of H_2O_2.



(a) Gas phase (b) Solid phase

   Preparation: It is prepared by acidifying barium peroxide and removing excess water by evaporation under reduced pressure. $BaO_2.8H_2O(s) + H_2SO_4(aq) \rightarrow BaSO_4(s) + H_2O_2(aq) + 8H_2O(l)$
   ***OR**, By the auto-oxidation of 2-alklylanthraquinols.*
   2 ethylanthraquinol $\rightleftharpoons$ *H_2O_2 + oxidised product*
   Chemical reaction: When exposed to sunlight, it decomposes slowly and forms O_2.
   $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$
5. Briefly explain the different types of hydrides. (3) [August 2018]

   Ans: Hydrides are classified into three:
   ***i) Ionic or saline or salt-like hydrides**:*
   These are stoichiometric compounds of H_2 with s-block elements. They are crystalline, non-volatile solids and conduct electricity in the molten state or in aqueous solution state.
   e.g. NaH, KH, CaH_2, BaH_2 etc.
   ***ii) Covalent or Molecular Hydrides**:*

These are the hydrides of p-block elements. Examples are CH_4, NH_3, H_2O and HF. Being covalent, they are volatile compounds. Molecular hydrides are further classified into 3 according to the relative numbers of electrons and bonds in their Lewis structure - (i) electron-deficient, (ii) electron-precise and (iii) electron-rich hydrides.

***iii) Metallic or interstitial Hydrides**: These are formed by d-block and f-block elements. However, the metals of group 7, 8 and 9 do not form this hydride. They are almost always nonstoichiometric, being deficient in hydrogen.*

They conduct heat and electricity.

e.g. $LaH_{2.87}$, $YbH_{2.55}$, $TiH_{1.5–1.8}$, $ZrH_{1.3–1.75}$, $VH_{0.56}$, $NiH_{0.6–0.7}$, $PdH_{0.6–0.8}$ etc.

6. Give a reason for the following :
   a) H_2O_2 is stored in wax-lined glass or plastic vessels in dark. (2)
   b) Hard water is not suitable for laundry. (1) [March 2018]

Ans: a) This is because in presence of light, H_2O_2 decomposes slowly and forms water and dioxygen.

$$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$$

b) Hard water does not readily form lather with soap. So it is not suitable for laundry.

7. a) There are two types of hardness of water – temporary hardness and permanent hardness.
   i) Give the reason for temporary hardness. (1)
   ii) Suggest one method to remove permanent hardness. (1)
   b) H_2O_2 is an important chemical.
   i) Write a method to prepare H_2O_2. (1)
   ii) Represent the structure of H_2O_2. (1) [July 2017]

Ans: a) i) Temporary hardness is due to the presence of dissolved bicarbonates of Ca^{2+} and Mg^{2+} in water.

ii) By treating with washing soda: Washing soda reacts with soluble calcium and magnesium chlorides and sulphates in hard water to form insoluble carbonates.

$$CaCl_2 + 2Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2NaCl$$

$$MgCl_2 + 2Na_2CO_3 \rightarrow MgCO_3 \downarrow + 2NaCl$$

b) Refer the Ans. of the qn. No. 4.

8. Hydrogen is the most abundant element in the universe. But in free state it is almost not found in earth's atmosphere.
   a) Suggest any three methods for the preparation of H_2 gas by selecting suitable substance given below.
   Na, Zn, CaH_2, H_2O, Al, NaOH, HCl (3)
   b) Do you expect carbon hydrides of the type C_nH_{2n+2} to act as Lewis acid or base? Why? (1) [March 2017]

Ans: a)

$$2\,Na + 2\,H_2O \rightarrow 2\,NaOH + H_2$$

$$Zn + HCl \rightarrow ZnCl_2 + H_2$$

$$CaH_2 + HCl \rightarrow CaCl_2 + H_2$$

b) They cannot act as Lewis acid or Lewis base because they do not contain vacant orbitals or lone pairs of electrons. They are electron precise hydrides.

9. a) Discuss the position of hydrogen in the periodic table. (2)
   b) Account for the following:

i) H_2O_2 is a bleaching agent.

ii) Density of ice is lower than that of water. (2) [September 2016]

Ans: a) Hydrogen shows resemblance with both Alkali metals of the first group and halogens of the 17th group. Like alkali metals it has one electron in the outer most shell and forms unipositive ions.
Like halogens, it requires only one electron to complete the valence shell configuration and form uninegative ion. It exists as diatomic molecule and combines with metals.
At the same time it shows some differences from alkali metals and halogens. So it is placed separately in the periodic table.
b) i) H_2O_2 decomposes to form nascent hydrogen which is responsible for its bleaching action.

$$H_2O_2 \longrightarrow H_2O + [O]$$

ii) Due to the presence of hydrogen bonding, there is a large no. of vacant spaces in ice. So it has lower density than water.

10. a) Hydrogen peroxide restores the colour of lead paintings. Give a reason. (2)
    b) How does the atomic hydrogen torch function for cutting and welding purposes? (2) [March 2016]

Ans: a) It is due to the oxidising action of H_2O_2. It oxidises black PbS to white $PbSO_4$ as follows:

$$PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$$

b) Here H atoms are allowed to recombine on the surface to be welded to generate the temperature of 4000K.

11. Hydrogen reacts with most of the metals and nonmetals to form hydrides.
    a) Elements in which one of the following group/groups of the periodic table do not form hydrides?
    i) Groups I5, 16, 17 ii) Group 18 iii) Groups 7, 8, 9 iv) Group 14 (1)
    b) Explain the different types of covalent hydrides with suitable examples. (3) [October 2015]

Ans: a) (iii) Groups 7, 8, 9

*b) Covalent hydrides are of three types - electron-deficient, electron-precise and electron-rich hydrides. An **electron-deficient hydride** has very few electrons for writing its Lewis structure. E.g. Diborane (B_2H_6). All elements of group 13 will form electron-deficient compounds. They act as Lewis acids (i.e. they accept electron pairs). **Electron-precise hydrides** have the required number of electrons to write their Lewis structures. All elements of group 14 form such compounds (e.g., CH_4, SiH_4 etc.) **Electron-rich hydrides** have excess electrons which are present as lone pairs. Elements of group 15 to 17 form such compounds. They behave as Lewis bases (i.e., electron donors).*

12. a) 'Syn gas' is a mixture of ……..
    i) CO and H_2O ii) CO and H_2 C) CO_2 and H_2iv) CH_4 and CO (1)
    b) i) A sample of river water does not give lather with soap easily when it is cold, but on heating gives ready lather with soap. Why? (2)
    ii) Draw the structure of a hydrogen peroxide molecule. (1) [March 2015]

Ans: a) CO and H_2

b) i) It is due to temporary hardness. Bicarbonate of calcium or magnesium is dissolved in this water. On heating the bicarbonates decomposes and form insoluble carbonates.

ii) See the Answer of the qn. No 4

13. a) Give one reaction supporting the amphoteric nature of water. (2)
    b) Write the names of any two electron-rich hydrides. (1)

c) Complete the following reaction

$Ca(HCO_3)_2$ heating ……. + H_2O + …….. (1) [August 2014]

Ans: a) Refer the answer of the question no. 2 (a)

b) NH_3, H_2O

c) $Ca(HCO_3)_2$ heating $CaCO_3 + H_2O + CO_2$

14. a) H_2O_2 is a bleaching agent. Why? (1)

b) Complete the following reaction.

Zn(s) + NaOH(aq) heat …….. (1)

c) In a seminar, if you are asked to present a paper on hydrogen economy, write any two points you are going to include in your paper. (2) [March 2014]

Ans:

a) H_2O_2 decomposes to form nascent hydrogen which is responsible for its bleaching action.

$H_2O_2 \rightarrow H_2O + [O]$

b) $Zn(s) + NaOH(aq) \xrightarrow{heat} Na_2ZnO_2 + H_2$

c) The basic principle of hydrogen economy is the transportation and storage of energy in the form of liquid or gaseous dihydrogen. Advantage of hydrogen economy is that energy is transmitted in the form of dihydrogen and not as electric power. Dihydrogen is also used in fuel cells for generation of electric power.

15. a) Water is an amphoteric substance. Justify. (2)

b) Hydrides are binary compounds of hydrogen with other elements. Give one example each for electron deficient and electron rich hydrides. (2) [September 2013]

Ans:

a) Refer the answer of the question no. 2 (a)

b) Electron deficient hydride: B_2H_6

Electron rich hydride: NH_3

16. About 18% of the total production of dihydrogen is from coal.

a) What is ‘coal gasification’? (1)

b) How is dihydrogen produced by ‘water gas shift reaction’? (2)

c) Write any two uses of dihydrogen. (1) [March 2013]

Ans:

*a) The process of producing 'syngas' from coal is called **'coal gasification'**.*

$C(s) + H_2O(g)$ 1270K $CO(g) + H_2(g)$

*b) When steam is passed over syngas mixture in the presence of iron chromate as catalyst, we get more amount of H_2. This is called **water-gas shift reaction**.*

$CO(g) + H_2O(g)$ 673K, catalyst $CO_2(g) + H_2(g)$

c) Dihydrogen is mainly used for the synthesis of ammonia.

It is also used in the manufacture of vanaspathi fat.

17. a) Hard water contains calcium and magnesium salts. Therefore it does not lather with soap.

i) Hard water is harmful for boilers. Why? (1)

ii) How will you remove the hardness from water by using washing soda? (1)

iii) Which method is more suitable to get pure demineralised water? (1)

b) Hydrogen peroxide is stored in plastic vessels in dark. Why? (1) [September 2012]

Ans: a) i) Hard water results in scale formation in boilers, which leads to boiler explosion.

ii) Washing soda reacts with soluble calcium and magnesium chlorides and sulphates in hard water to form insoluble carbonates.

$CaCl_2 + 2Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2NaCl$

$MgCl_2 + 2Na_2CO_3 \rightarrow MgCO_3 \downarrow + 2NaCl$

iii) Synthetic resins method.

b) This is because in presence of light, H_2O_2 decomposes slowly and forms water and dioxygen.

$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$

18. Permanent hardness of water can be removed only by chemical methods.

a) Write the name of any one salt responsible for the permanent hardness of water. (1)

b) Sodium hexametaphosphate is commercially called …….. (1)

c) How is sodium hexametaphosphate useful in removing the permanent hardness of water? (1)

d) Suggest a disadvantage of hard water. (1) [March 2012]

Ans: a) $CaCl_2$

b) Calgon

c) When calgon is added to hard water, the Ca and Mg ions in hard water are replaced by Na^+ ions

$Na_6P_6O_{18} \rightarrow 2Na^+ + Na_4P_6O_{18}^{2-}$

$M^{2+} + Na_4P_6O_{18}^{2-} \rightarrow [Na_2MP_6O_{18}]^{2-} + 2Na^+$ *[Where* $M^{2+} = Ca^{2+}$ *or* Mg^{2+}*]*

d) It is not suitable for laundry. Also it reduces the efficiency of boilers.

19. a) Vegetable oil is converted into vanaspathi fat by …….. process. (½)

b) D_2O is generally called …… (½)

c) Hydrogen peroxide is an important chemical used in pollution control treatment of domestic and industrial effluents.

i) Write the formula of hydrogen peroxide. (½)

ii) Draw the structure of hydrogen peroxide (1)

iii) Explain with suitable chemical equation, why hydrogen peroxide is stored in wax-lined glass or plastic vessel in dark. (1½) [October 2011]

Ans: a) Hydrogenation

b) Heavy water

i) H_2O_2

ii) and iii) Refer the answer of the question no. 4

20. a) Account for the following observations:

i) The density of ice is lower than that of water. (1)

ii) Hard water does not give ready lather with soap. (1)

b) Justify the position of hydrogen in the periodic table. (2) [March 2011]

Ans:

a) i) Due to the presence of hydrogen bonding, there is a large no. of vacant spaces in ice. So it has lower density than water.

ii) Hard water does not readily form lather with soap. So it is not suitable for laundry.

b) Refer the answer of the question no. 9 (a)

21. The efficiency of a boiler is found to decrease when boiler scales are formed.

a) Which are the possible compounds present in water for scale formation? (1)

b) Write the chemistry of scale formation. (1)

c) Suggest a suitable chemical method to prevent the scale formation. (2) [September 2010]

Ans: a) $Ca(HCO_3)_2$ or $Mg(HCO_3)_2$

b) On heating the bicarbonates decomposes to form carbonates, which are responsible for scale formation.

$Mg(HCO_3)_2 \xrightarrow{\Delta} Mg(OH)_2 \downarrow + 2CO_2 \uparrow$

$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 \downarrow + H_2O + CO_2 \uparrow$

c) Clark's method: In this method calculated amount of lime is added to hard water. It precipitates out calcium carbonate and magnesium hydroxide.

$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$

$Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + Mg(OH)_2 \downarrow + 2H_2O$

22. Match the following by selecting the items from columns B and C which are most suitable to those in column A.

A	B	C
a) Protium, Tritium	1) Hard water	i) Fertilizer
b) Ca^{2+}, Mg^{2+}	2) Heavy water	ii) Hydrogen
c) H_2O_2	3) Isotopes	iii) Moderator in nuclear reactor
d) D_2O	4) Perhydrol	iv) No lather with soap
	5) Phenol	v) Antiseptic

(4) [March 2010]

Ans:

A	*B*	*C*
a) Protium, Tritium	*3) Isotopes*	*ii) Hydrogen*
b) Ca^{2+}, Mg^{2+}	*1) Hard water*	*iv) No lather with soap*
c) H_2O_2	*4) Perhydrol*	*v) Antiseptic*
d) D_2O	*2) Heavy water*	*iii) Moderator in nuclear reactor*

23. a) What is heavy water? Mention one of its uses? (2)

b) Explain why hydrogen peroxide is not stored in glass vessels. (1)

c) What is calgon? What is its use? (1) [March 2009]

Ans: a) D_2O is called heavy water. It is used as moderator in Nuclear reactors.

b) Refer the answer of the question no. 6 (a)

c) Calgon is sodium hexametaphosphate. It is used for removing permanent hardness of water.

24. a) Name the isotopes of hydrogen. (1)

b) What is heavy water? (1)

c) What is a moderator? (1) [June 2008]

Ans: a) Protium, Deuterium and Tritium

b) D_2O is called heavy water.

c) They slow down the speed of neutrons.

25. Hard water does not give ready lather with soap.

a) What is the reason for hardness? (1)

b) What are the two types of hardness? (1)

c) Suggest one method to remove hardness. (1) [February 2008]

Ans: a) Presence of dissolved chlorides, sulphates and bicarbonates of calcium and magnesium.

b) Temporary hardness and permanent hardness

c) Addition of washing soda.

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PREVIOUS HSE QUESTIONS AND ANSWRES OF THE CHAPTER "S-BLOCK ELEMENTS"

1. The alkali metal which has the highest reducing power is …….. (1)
   Ans: Lithium
2. (a) Lithium shows some properties which are different from other alkali metals. Give reason. (1)
   (b) Match the following: (2)

Compound	Use
(i) Baking soda	(a) Purification of Bauxite
(ii) Caustic soda	(b) Tooth paste
(iii) Plaster of Paris	(c) Anti-septic for skin infection
(iv) Lime stone	(d) Purification of sugar
	(e) Dentistry

[July 2019]

Ans: a) Li shows some anomalous properties due to its small size and high polarizing power.
b)

Compound	Use
(i) Baking soda	(c) Anti-septic for skin infection
(ii) Caustic soda	(d) Purification of Bauxite
(iii) Plaster of Paris	(e) Dentistry
(iv) Lime stone	(b) Tooth paste

3. Predict the product obtained by the reaction of Li with O_2. (1)
   Ans: Li_2O
4. Give reasons for the anomalous behaviour of Li. Write any four points of similarities between Li and Mg. (3)

[March 2019]

Ans: Li shows some anomalous properties due to its small size and high polarizing power.
Similarities between Li and Mg:

- *Both Li and Mg are harder but lighter than other elements of the respective group.*
- *They do not form superoxides.*
- *Their carbonates decompose easily on heating to form oxides and CO_2.*
- *Their bicarbonates are stable only in solution.*

5. Name the commercial process used to prepare sodium carbonate and write the chemical equations of the steps involved in it. (4) [August 2018]
   Ans: Solvay Process.
   The various chemical equations involved in this process are:

$$2NH_3 + H_2O + CO_2 \rightarrow (NH_4)_2CO_3$$

$$(NH_4)_2CO_3 + H_2O + CO_2 \rightarrow 2NH_4HCO_3$$

$$NH_4HCO_3 + NaCl \rightarrow NH_4Cl + NaHCO_3$$

$$2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2 + H_2O$$

6. Account for the following :
   a) Blue coloured solutions are obtained when alkali metals are dissolved in liquid ammonia.
   b) ' Li' and 'Mg' show similar properties.
   c) Aqueous solution of Na_2CO_3 is alkaline.
   d) $BeSO_4$ and $MgSO_4$ are readily soluble in water. (4 x 1 = 4) [March 2018]

   Ans: a) It is due to the formation of ammoniated electrons.

   b) Due to their similar size and same electronegativity.

   c) Carbonate part of sodium carbonate gets hydrolysed to form OH^- ion. So the aqueous solution of Na_2CO_3 is alkaline.

   $CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$

   d) This is due to the greater hydration enthalpy of Be^{2+} and Mg^{2+} ions.

7. Lithium and Magnesium show diagonal relationship.
   a) Give any two similarities between Li and Mg. (2)
   b) What happens when Na is treated with i) water and ii) NH_3? [July 2017]

   Ans: a) Refer the answer of the question no. 4

   b) $Na + H_2O \rightarrow NaOH + ½ H_2$

   $Na + (x+y) NH_3 \rightarrow [Na(NH_3)_x]^+ + [e(NH_3)_y]^-$

8. The s-block elements of periodic table constitute alkali metals and alkaline earth metals.
   a) The hydroxides and carbonates of sodium and potassium are more soluble than that of corresponding salts of magnesium and calcium. Explain. (2)
   b) Write the chemical name of the following:

      i) Caustic soda ii) Baking soda iii) Slaked lime iv) Milk of lime (2)

      [March 2017]

   Ans: a) This is due to the smaller size and higher hydration enthalpy of Na^+ and K^+ compared to Mg^{2+} and Ca^{2+}.

   b) i) Caustic soda – $NaOH$

   ii) Baking Soda – $NaHCO_3$

   iii) Slaked lime – $Ca(OH)_2$

   iv) Milk of Lime – $Ca(OH)_2$

9. a) Match the following:

A		B	
i)	Caustic soda	1)	Antacid
ii)	Sodium carbonate	2)	Mild antiseptic
iii)	Magnesium hydroxide	3)	Castner kellner cell
iv)	Sodium bicarbonate	4)	Solvay process

   b) Cement is an important building material. Explain the manufacture of cement. (4)

   [September 2016]

   Ans: a)

A	*B*

i)	*Caustic soda*	*3) Castner Kellner cell*
ii)	*Sodium carbonate*	*4) Solvay process*
iii)	*Magnesium hydroxide*	*1) Antacid*
iv)	*Sodium bicarbonate*	*2) Mild antiseptic*

b) The raw materials for the manufacture of cement are limestone and clay. When clay and lime are strongly heated together they fuse and react to form 'cement clinker'. This clinker is mixed with 2-3% by weight of gypsum ($CaSO_4 \cdot 2H_2O$) to form cement.

10. a) Alkali metals dissolve in liquid ammonia to give blue coloured solutions. Why? (2)
    b) Plaster of Paris is an important compound of calcium.
    i) Give the chemical formula of plaster of Paris. (1)
    ii) Identify the property of plaster of Paris which helps in plastering of broken bones. (1)
[March 2016]

Ans: a) Alkali metals dissolve in liquid ammonia and form ammoniated electron, which absorbs energy in the visible region and gives blue colour to the solution.

$M + (x+y)NH_3 \rightarrow [M(NH_3)_x]^+ + e[(NH_3)_y]^-$

b) i) $CaSO_4$. ½ H_2O

ii) Setting of plaster of Paris

11. Alkali metals are highly reactive due to their low ionization enthalpies.
    a) The alkali metal which acts as the strongest reducing agent in aqueous solution is …… (1)
    b) How sodium carbonate is prepared using Solvay process? Is this method suitable for the preparation of potassium carbonate? Justify. (3) [October 2015]

Ans: a) Lithium

b) Solvay process: In this process, CO_2 is passed through a concentrated solution of NaCl saturated with ammonia. Ammonium carbonate first formed then converted to ammonium bicarbonate and finally reacts with NaCl to form $NaHCO_3$.

$2NH_3 + H_2O + CO_2 \rightarrow (NH_4)_2CO_3$

$(NH_4)_2CO_3 + H_2O + CO_2 \rightarrow 2NH_4HCO_3$

$NH_4HCO_3 + NaCl \rightarrow NH_4Cl + NaHCO_3$

Sodium bicarbonate crystals are separated and heated to get sodium carbonate.

$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

Solvay process cannot be used for the preparation of K_2CO_3 because potassium bicarbonate ($KHCO_3$) formed is highly soluble in water. So it does not get precipitated by the addition of NH_4HCO_3.

12. a) The metal present in the chlorophyll of plants is ……. (1)
    b) Give any two uses of caustic soda. (1)
    c) When sodium metal dissolves in liquid ammonia, it gives a deep blue coloured solution. Explain the reason.(2) [March 2015]

Ans: a) Magnesium (Mg)

b) Uses of Caustic soda are:

1) Manufacture of soap, artificial silk, paper and a number of chemicals.

2) In petroleum refining.

3) In the purification of bauxite.

4) In textile industry.

5) As a laboratory reagent. [Any 2 required]

c) Refer the answer of the question no. 10 (a)

13. a) The reactivity of alkali metals towards air is different for different metals. How do alkali metals react with air? (2)

b) Match the following: (2)

A	B
1) Sodium hydroxide	a) Dead burnt plaster
2) Anhydrous calcium sulphate	b) Slaked lime
3) Calcium hydroxide	c) Quick lime
4) Sodium bicarbonate	d) Caustic soda
	e) Baking soda

[August 2014]

Ans: a) Alkali metals react with air to form oxides, peroxides and super oxides. Li forms only monoxide, sodium forms monoxide and peroxide and other alkali metals form monoxide, peroxide and super oxide.

$4Li + O_2 \rightarrow 2Li_2O$

$2Na + O_2 \rightarrow Na_2O_2$

$M + O_2 \rightarrow MO_2$ *(where M = K, Rb, Cs)*

b)

A	B
1) Sodium hydroxide	c) Caustic soda
2) Anhydrous calcium sulphate	a) Dead burnt plaster
3) Calcium hydroxide	b) Slaked lime
4) Sodium bicarbonate	d) Baking soda

14. a) Give reasons.

i) KO_2 is paramagnetic. (1)

ii) Solutions of alkali metals in liquid ammonia are blue in colour. (1)

b) Match the following: (2)

A	B
Quick lime	$Ca(OCl)_2$
Plaster of Paris	CaO
Bleaching powder	$Ca(OH)_2$

Slaked lime	$CaSO_4$. ½ H_2O
	$CaCl_2$
	$CaCO_3$

(March 2014)

Ans: a) i) Due to the presence of unpaired electrons in peroxide ion.

ii) It is due to the formation of ammoniated electrons.

b)

A	B
Quick lime	CaO
Plaster of Paris	CaSO4. ½ H2O
Bleaching powder	$Ca(OCl)_2$
Slaked lime	$Ca(OH)_2$

15. a) Fill in the blanks:

i) The suspension of a magnesium compound in water is used as an antacid. The compound is …… (1)

ii) A mixture of calcium oxide (Quick lime) and caustic soda (NaOH) is called …….. (1)

b) When CO_2 is passed through lime water it turns milky. On passing excess of CO_2, the milky colour disappears. Give the chemical reactions involved in these processes. (2) [September 2013]

Ans: a) i) $Mg(OH)_2$

ii) Soda lime

b) It is due to the formation of $CaCO_3$. On passing CO_2 continuously, the solution becomes clear due to the formation of soluble calcium bicarbonate $[Ca(HCO_3)_2]$

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

16. Alkali metals and alkaline earth metals belong to the s-block of the periodic table.

a) Name the process used for the industrial preparation of sodium carbonate. (1)

b) The above method is not suitable for the preparation of potassium carbonate. Give the reason. (1)

c) Draw the chain structure of beryllium chloride in solid state. (1)

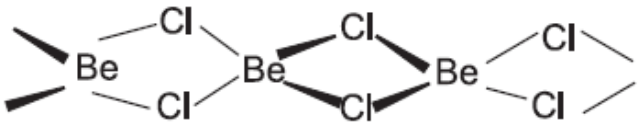
d) Write the chemical equation showing the preparation of Plaster of Paris from gypsum. (1) [March 2013]

Ans:

a) Solvay Process or Ammonia Soda process

b) Because potassium bicarbonate ($KHCO_3$) formed is highly soluble in water. So it does not get precipitated by the addition of NH_4HCO_3.

c)



d) *Plaster of Paris is obtained when gypsum [$CaSO_4 \cdot 2H_2O$] is heated to 393 K.*

$CaSO_4.2H_2O \xrightarrow{393K} CaSO_4.\frac{1}{2}H_2O + 3/2\ H_2O$

17. a) Lithium and Magnesium belong to 1st and 2nd groups in the periodic table. They resemble each other in many respects.

i) Name such relationship. (1)

ii) Give one similarity between Li and Mg. (1)

b) A compound of calcium is used in hospitals for setting fracture of bones.

i) Write the name and formula of the above compound. (1)

ii) What is dead burnt plaster? (1) [September 2012]

Ans: a) i) Diagonal relationship

ii) Both Li and Mg are harder but lighter than other elements of the respective group.

b) i) Plaster of Paris ($CaSO_4.\frac{1}{2}H_2O$)

ii) Anhydrous $CaSO_4$

18. Beryllium shows diagonal relationship with aluminium.

a) Mention any two similarities between beryllium and aluminium. (2)

b) Match the following: (2) [March 2012]

A	B
Sodium carbonate	Chain structure in the solid state
Beryllium chloride	Mild antiseptic
Sodium hydroxide	Solvay process
Sodium hydrogen carbonate	Castner-Kellner cell

Ans: a)

- *Like Al, Beryllium is not readily attacked by acids because of the presence of an oxide film on the surface of the metal.*
- *The chlorides of both the elements have bridged structure in vapour phase.*

b)

A	*B*
Sodium carbonate	*Solvay process*
Beryllium chloride	*Chain structure in the solid state*
Sodium hydroxide	*Castner-Kellner cell*
Sodium hydrogen carbonate	*Mild antiseptic*

19. Match the following:

A	B	C
a) Gypsum	1) Magnesium	i) Solvay process
b) Milk of	2) Magnesium	ii) Nerve signal

magnesia	hydroxide	transmission
c) Washing soda	3) Sodium	iii) Cement
d) Alkali metal	4) Calcium sulphate	iv) Antacid
	5) Sodium carbonate	v) Violet flame

(4) [October 2011]

Ans:

A	*B*	*C*
a) Gypsum	*4) Calcium sulphate*	*iii) Cement*
b) Milk of magnesia	*2) Magnesium Hydroxide*	*iv) Antacid*
c) Washing soda	*5) Sodium Carbonate*	*i) Solvay process*
d) Alkali metal	*3) Sodium*	*v) Violet flame*

20. Monovalent Na^+, K^+ ions and divalent Ca^{2+}, Mg^{2+} ions are found in large proportions in biological fluids.
    a) In which part of our body are sodium and potassium ions permanently located? (1)
    b) What are the major roles of these Na^+ and K^+ ions in our body? (1)
    c) For making which part of our body is calcium mainly used? (1)
    d) Give the name of the metal present in chlorophyll. (1) [March 2011]

    Ans:

    a) Cell fluid

    b) Both Na^+ and K^+ ions participate in the transmission of nerve signals. K^+ ions activate many enzymes.

    c) Bones and teeth

    d) Magnesium (Mg)

21. I) State whether the following sentences are true or false:
    a) Metals in the 2nd group are called alkali metals.
    b) Alkali metals are not found in free state in nature.
    c) Baking soda is chemically sodium hydrogen carbonate.
    d) Portland cement is basically silicates and aluminates of calcium. (2)

    II) Fill in the blanks:
    a) Molecular formula of Plaster of Paris is ……
    b) Beryllium shows diagonal relationship with ……..
    c) The metal present in chlorophyll is ……
    d) Solvay process is associated with the preparation of …….. (2) [September 2010]

    Ans: I)

    a) False

    b) True

    c) True

    d) True

    II)

    a) $CaSO_4.\ ½\ H_2O$

b) Al

c) Mg

d) Na_2CO_3

22. The group 1 metals of the periodic table of elements are collectively called alkali metals.
    a) Write the general electronic configuration of alkali metals. (1)
    b) Identify the alkali metal exhibiting anomalous properties. Explain (1)
    c) Alkali metals are normally kept in kerosene. Why? (1)
    d) Alkali metals are never found free in nature. Give reason. (1) [March 2010]

    Ans:

    a) [Noble gas] ns^1

    b) Lithium. It is due to the small size and high polarizing power of Li

    c) Because it readily reacts with air and water.

    d) Due to their high reactivity.

23. a) How will you prepare $Ca(OH)_2$ and $CaCO_3$ from quick lime (CaO)? (2)
    b) Complete the following reactions:
    i) $CaCO_3$ 1200K ?
    ii) $CaCO_3 + H_2SO_4$? (2) [March 2009]

    Ans: a) When CO_2 is passed through quick lime, $CaCO_3$ is formed.

    $CaO + CO_2 \rightarrow CaCO_3$

    When water is added to CaO, we get $Ca(OH)_2$.

    $CaO + H_2O \rightarrow Ca(OH)_2$

    b) i) $CaCO_3$ 1200K $CaO + CO_2$

    ii) $CaCO_3 + H_2SO_4$ $CaSO_4 + CO_2 + H_2O$

24. When CO_2 is passed through lime water it turns milky.
    a) What is the reaction in the above case? (1)
    b) What happens when more CO_2 is passed to the milky solution? Why? (2) [June 2008]

    Ans: Refer the Answer of the qn. No. 15 (b)

25. Lithium of the 1st group resembles Magnesium of 2nd group in the periodic table.
    i) What is the name of this relationship? (1)
    ii) What is the reason for it? (1)

    Ans: i) Diagonal relationship

    ii) Due to the small size, high electronegativity and polarizing power of Li

26. List any two similarities between Li and Mg. (1) [February 2008]

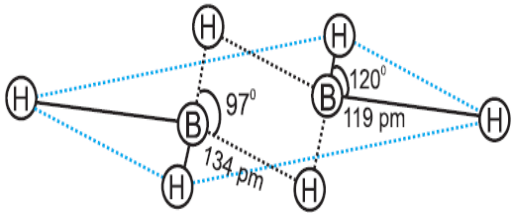
    Ans: Refer the answer of the question no. 4

    ##########

PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "THE p-BLOCK ELEMENTS"

1. Name the colourless toxic gas that is produced when BF_3 is heated with Sodium hydride (NaH) at 450K. Draw its structure. (2)

   Ans: B_2H_6.



2. Write a short note on (a) Fullerenes and (b) Silicates (4) [July 2019]

   Ans:

   a) Fullerene: These are the cage like spherical molecules of formula C_{60}, C_{70}, C_{76}, C_{84} etc. They are prepared by heating graphite in an electric arc in the presence of inert gases like helium or argon. The most commonly known fullerene is C_{60}, which is known as Buckminster fullerene. It contains twenty six- membered rings and twelve five membered rings.

   b) Silicates: These are compounds of Si in which each silicon atom is bonded to four oxygen atoms in tetrahedral manner. The basic structural unit of silicate is SiO_4^{4-} tetrahedra. They exist in different forms like chain, ring, sheet or three-dimensional structures.
   E.g. Zeolites, mica, feldspar, asbestos etc.

3. Draw the structure of Diborane. Write a note on the nature of bonds present in it. (2)

   Ans: Refer the answer of the question no. 1
   Here the four terminal B-H bonds are regular two centre-two electron bonds while the two bridge (B-H-B) bonds are three centre- two electron (3c-2e) bonds or banana bonds.

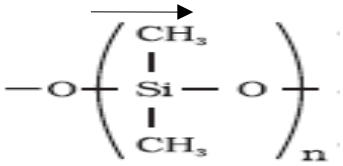
4. a) What are silicones? (1)
   b) Write the chemical equations showing the steps involved in the manufacture of silicones. (2)
   c) How can the chain length of silicones be controlled during their synthesis? (1) [March 2019]

   Ans: a) Silicones are organosilicon polymers, which have $(-R_2SiO-)$ as a repeating unit.

   b) When methyl chloride reacts with silicon in the presence of copper as a catalyst at 573K temperature, dimethyl dichlorosilane $[(CH_3)_2SiCl_2]$ and other methyl substituted chlorosilanes are formed. Hydrolysis of dichlorosilane followed by condensation gives straight chain polymers.

   OR, $2CH_3Cl + Si \xrightarrow{Cu;\ 573K} (CH_3)_2SiCl_2 \xrightarrow{2H_2O} (CH_3)_2Si(OH)_2$

   $n(CH_3)_2Si(OH)_2 \xrightarrow{polymerisation}$

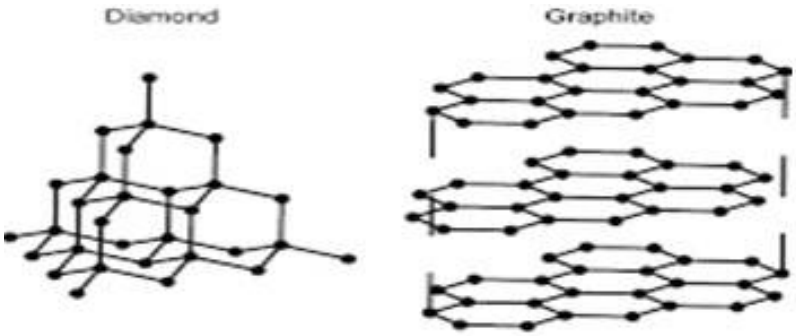


   c) The chain length of the polymer can be controlled by adding $(CH_3)_3SiCl$ which blocks the ends of the polymer chain.

5. Write the formula of the basic structural unit of silicates. (1)

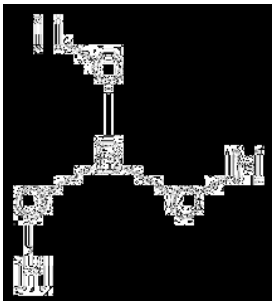
Ans: SiO_4^{4-}

6. What are zeolites? Give any two uses of zeolites. (2)
   Ans: Zeolites are aluminosilicates of metals in which Na^+, K^+, Ca^{2+} etc. acts as cations.
   They are widely used as a catalyst in petrochemical industries and for removing hardness of water.
7. Sketch the structures of graphite and diamond. What is the impact of structure on physical properties of these allotropes? (3) [August 2018]
   Ans:



Graphite has a layered structure. Different layers are held by weak van der Waals forces of attraction. So it is very soft and slippery. Diamond has a a rigid three dimensional network of carbon atoms. It is very difficult to break covalent bonds and, therefore, diamond is very hard.

8. The allotrope of carbon with the highest thermodynamic stability is…….. (1)
   Ans: Graphite
9. Draw the structure of orthoboric acid. Why it is not a protonic acid? (2)
   Ans:



It is non-protic acid since it acts as a Lewis acid by accepting electrons from a hydroxyl ion.

$$B(OH)_3 + 2H_2O \rightarrow [B(OH)_4]^- + H_3O^+$$

10. Explain any one method of preparation and structure of diborane. (3) [March 2018]
    Ans: Diborane is prepared by treating BF_3 with Lithium aluminium hydride ($LiAlH_4$) in ether.

$$4BF_3 + 3\,LiAlH_4 \rightarrow 2B_2H_6 + 3LiF + 3AlF_3$$

    Structure: Refer the Answer of the qn. No. 1
11. a) Diborane is an electron deficient compound. Explain the structure of diborane. (2)
    b) What is water gas? (1)
    c) Inorganic benzene is …… (1) [July 2017]

Ans: a) In diborane, each boron atoms is in sp^3 hybridisation. The two boron atoms and 4 hydrogen atoms lie in one plane. These four H atoms are called terminal hydrogen atoms. The other two hydrogen atoms lie one above and one below this plane. These H atoms are called bridging hydrogen atoms. The four terminal B-H bonds are regular two centre-two electron bonds while the two bridge (B-H-B) bonds are three centre-two electron (3c-2e) bonds or banana bonds. Thus diborane is an electron deficient compound.
Or, Draw the structure as given in the answer of the qn. No. 1

b) A mixture of CO and H_2

c) Borazine ($B_3N_3H_6$)

12. Borax is an important compound of Boron.
    a) The solution of borax is alkaline. Give reason. (2)
    b) Give any two uses of borax. (1)
    c) Diamond has covalent bonding. Yet it has high melting point. Give a reason. (1) [March 2017]

Ans: (a) Borax dissolves in water to give NaOH and orthoboric acid. Since NaOH is a strong alkali and orthoboric acid is weak acid, the solution is basic in nature.
Or, The equation: $Na_2B_4O_7 + 7H_2O \rightarrow 2NaOH + 4H_3BO_3$
(b) Borax is used for the detection of transition elements by Borax bead test. It is used for the manufacture of heat resistant glasses, glass-wool and fibre glass. It is also used as a flux for soldering metals, for heat, scratch and stain resistant glazed coating to earthenwares and as a constituent of medicinal soaps.
*[**Any one use required**]*
(c) Diamond has a three dimensional network structure with extended covalent bonding. Since it is very difficult to break these covalent binds, it has high m.p.
OR, Due to the tetrahedral (sp^3) hybridisation of carbon atoms in diamond.

13. a) CCl_4 does not undergo hydrolysis but $SiCl_4$ undergoes hydrolysis. Why? (2)
    b) Differentiate between silicates and silicones. (2) [September 2016]

Ans: a) In CCl_4, there is no vacant d-orbitals in carbon. So it cannot accommodate the lone pair of electrons donated by oxygen atom of water molecule.

b) *Refer the Answer of the qn. No. 2 (b) and 4 (a)*

14. Carbon has many allotropes.
    a) Write the name of any two allotropic forms of carbon. (1)
    b) Briefly explain the structure of any one of the above mentioned allotrope. (2)
    c) CCl_4 does not undergo hydrolysis. Give reason. (1)

Ans: a) Diamond and graphite

b) Refer the Answer of the qn. No. 7

c) Refer the Answer of the qn. No. 13 (a)

15. When BF_3 is treated with LiH at 450K, a hydride of boron is formed.
    a) Identify the hydride of boron formed in the above reaction. (1)
    b) Briefly explain the structure of the above mentioned hydride. (2)
    c) Boron compounds behave as Lewis acids. Why? (1) [March 2016]

Ans: a) Diborane (B_2H_6)

b) *Refer the Answer of the qn. No. 11 (a)*

c) Boron compounds are electron deficient. So they behave as Lewis acids.

16. Orthoboric acid is an important compound of boron. Prepare a short note on orthoboric acid highlighting the following aspects.
    - Method of preparation * Acidic nature *Action of heat *structure (4) [October 2015]

Ans: It is prepared by acidifying an aqueous solution of borax.

$Na_2B_4O_7 + 2HCl + 5H_2O \rightarrow 2NaCl + 4H_3BO_3$

It is a weak monobasic non-protic acid. It acts as a Lewis acid by accepting electrons from a hydroxyl ion.

$B(OH)_3 + 2H_2O \rightarrow [B(OH)_4]^- + H_3O^+$

On heating above 370K, it forms metaboric acid (HBO_2) which on further heating gives boric oxide (B_2O_3).

$H_3BO_3 \xrightarrow{\Delta} HBO_2 \xrightarrow{\Delta} B_2O_3$

Structure: Refer the Answer of the qn. No. 9

17. a) Thermodynamically, the most stable allotrope of carbon is …….. (1)
    b) Carbon is the first member of group 14 in the periodic table.
    i) Why does carbon differ from the rest of the members of its group? (1)
    ii) Write any two anomalous properties of carbon. (2) [March 2015]

Ans: a) Graphite

b) i) Due to its small size, high electronegativity and unavailability of vacant d-orbitals

ii) The anomalous properties shown by C are:

- *The maximum covalency of C is four. While other elements of group 14 can extend their covalency beyond 4 due to the presence of vacant d-orbitals.*
- *Carbon has unique ability to form pπ– pπ multiple bonds with itself and with other atoms .*

18. Give reason for the following:
    a) CO_2 is a gas while SiO_2 is a solid. (1)
    b) CCl_4 cannot be hydrolyzed but $SiCl_4$ can be hydrolyzed. (1)
    c) Borax bead test can be used to identify metaborates in the laboratory. (1)
    d) Graphite is used as a lubricant in machines. (1) [August 2014]

Ans: a) In CO_2 molecule has a linear shape and hence it exists as discrete (separate) molecules. So it is a gas. But in silica (SiO_2), each Si atom is tetrahedrally surrounded by 4 oxygen atoms. So it has a three dimensional network structure and hence it is a solid.

b) Due to the absence of vacant d-orbitals in C.

c) Since the metaborates of most of the transition metals are coloured.

d) Because of its layered structure and slippery nature.

19. a) What is dry ice? (1)
    b) Why does BF_3 behave as a Lewis acid? (1)
    c) Carbon forms millions of compounds due to its self-linking property to form long chains and big rings.
    i) Name the above property of carbon. (1)
    ii) Give the reason for the above property of carbon. (1) [March 2014]

Ans: a) Solid CO_2.

b) Because of the presence of vacant d-orbitals in Boron.

c) i) Catenation

ii) This is because C – C bonds are very strong.

20. a) i) Boric acid (H_3BO_3) is considered as a weak acid. Why? (1)
ii) Carbon monoxide is highly poisonous. Why? (1)
b) What are zeolites? What is its use? (2) [September 2013]

Ans: a) i) Boric acid is a weak Lewis acid since it accepts electrons from a hydroxyl ion of water molecule.
ii) CO can easily form a stable complex with haemoglobin (carboxy haemoglobin). This prevents haemoglobin in RBC from carrying oxygen round the body. Hence it is poisonous.
b) Refer the Answer of the qn. No. 6

21. The group 14 elements have four electrons in the outermost shell.
a) $SiCl_4$ can be easily hydrolyzed by water while CCl_4 cannot be hydrolyzed. Why? (1)
b) How are fullerenes prepared? (1)
c) Distinguish between silicones and silicates? (2)` [March 2013]

Ans: a) Refer the Answer of the qn. No. 13 (a)
b) Fullerenes are prepared by heating graphite in an electric arc in the presence of inert gases like helium or argon.
c) *Silicones are organosilicon polymers containing -R_2SiO- as repeating unit. While silicates are compounds of Si in which SiO_4^{4-} tetrahedra as basic structural unit.*

22. a) Diborane is an electron deficient compound.
i) Name the special bonds that present in Diborane. (1)
ii) How will you convert Diborane into inorganic benzene? (1)
b) What are silicones? Write its general formula. (2) [September 2012]

Ans: a)
i) 3 centre-2 electron (3C-2e) bond or banana bond
ii) When diborane is heated with ammonia, we get Borazine commonly called inorganic benzene.
b) Silicones are organosilicon polymers containing -R_2SiO- as repeating unit. General formula is (-R_2SiO-)$_n$.

23. Borax, orthoboric acid and diborane are some useful compounds of boron.
a) Write the chemical formula of borax. (1)
b) Boric acid is not a protonic acid but acts as a Lewis acid. Justify. (1)
c) Explain the structure of diborane using a diagram. (2) [March 2012]

Ans: a) $Na_2B_4O_7.10H_2O$ or $Na_2[B_4O_5(OH)_4].8H_2O$.
b) *Refer the Answer of the qn. No. 9*
c) *Refer the Answer of the qn. No. 11 (a) and 1.*

24. a) Some elements can exist in different crystalline forms and are called allotropes.
i) What are the important allotropic forms of carbon? (1)
ii) Which allotropic form of carbon is used as a dry lubricant in machines running at high temperature? (1)
b) When sodium borohydride ($NaBH_4$) is treated with iodine (I_2), two gaseous products were obtained. One is hydrogen and the other is a highly toxic gas X, which catches fire upon exposure to air. When the gas X is heated with ammonia for a long time, a compound Y of ring structure is obtained. Identify X and Y. (Name and molecular formula are expected) (2) [October 2011]

Ans: a)

i) Diamond, Graphite and Fullerene are the important crystalline allotropes of carbon.

ii) Graphite

b) X is diborane (B_2H_6) and Y is Borazine ($B_3N_3H_6$)

25. Two important compounds of carbon are carbon monoxide and carbon dioxide.
    a) Why carbon monoxide is called a poisonous gas? (1)
    b) How is CO_2 responsible for global warming? (1½)
    c) What are producer gas and water gas? Mention their uses? (1½) [March 2011]

Ans: a)

a) *Refer the Answer of the qn. No. 20 (a) ii*

b) CO_2 absorbs earth radiation which results in increase in temperature of the atmosphere.

c) Producer gas is a mixture of carbon monoxide and nitrogen while water gas is a mixture of carbon monoxide and hydrogen. Both are used as industrial fuels.

26. Match the following:

A	B	C
1. Inorganic benzene	a) Allotrope	i) Aluminium
2. Glass like beads	b) Borax	ii) Carbon
3. Fullerene	c) Borazine	iii) B_2H_6
4. Zeolites	d) Dry ice	iv) $B_3N_3H_6$
	e) Softening of hard water	v) $Na_2[B_4O_5(OH)_4].8H_2O$

(4) [September 2010]

Ans: a)

A	B	C
1. Inorganic benzene	d) Borazine	iv) $B_3N_3H_6$
2. Glass like beads	b) Borax	v) $Na_2[B_4O_5(OH)_4].8H_2O$
3. Fullerene	a) Allotrope	ii) Carbon
4. Zeolites	e) Softening of hard water	i) Aluminium

27. Boron, Aluminium, Gallium, Indium and Thalium belong to group 13 of the periodic table of elements.
    a) How can you explain the higher stability of BCl_3 as compared to $TlCl_3$? (1)
    b) While Aluminium can be form the ion $[AlF_6]^{3-}$, Boron is unable to form $[BF_6]^{3-}$ ion. Explain. (1)
    c) State whether the compound BCl_3 is acidic or basic. (1)
    d) Write the hybridization state of B in BF_3 and BH_4^-. (1) [March 2010]

Ans: a) Due to inert pair effect Tl mainly shows +1 oxidation state. $TlCl_3$ is less stable.

b) Due to the lack of vacant d-orbitals in B.

c) Acidic. Since it contains vacant orbitals, BCl_3 can act as Lewis acid.

d) BF_3 – sp^2 hybridisation, BH_4^- – sp^3 hybridisation.

28. a) Briefly describe the structure of diborane. (2)
    b) What is inorganic benzene? Why is it so called? (2) [March 2009]

Ans: a) Refer the Answer of the qn. No. 11 (a) and 1.

b) Borazine ($B_3N_3H_6$). It is called inorganic benzene since its structure is similar to that of benzene.

29. Some elements show allotropy.
    a) Define allotropy. (1)
    b) Diamond is hard and non-conducting, while graphite is soft and conducting. Explain. (2)
    [June 2008]

    Ans: a) The existance of an element in two or more forms with same chemical properties but with different physical properties is known as allotropy.

    b) Diamond has a three dimensional net-work structure and there is no free electron. So it is hard and non- conducting. But graphite has a layered structure in which there is only a weak van der Waal's force of attraction between different layers. Also it contains free electrons. So it is soft and conducting.

30. Carbon and silicon belong to the same group and have many similarities. But …….
    a) CO_2 is a gas while SiO_2 is a solid. Explain (2)
    b) CCl_4 cannot be hydrolysed, but $SiCl_4$ can be. Why? (1) [February 2008]

    Ans: a) Refer the Answer of the qn. No. 18 (a)

    b) Refer the Answer of the qn. No. 13 (a)

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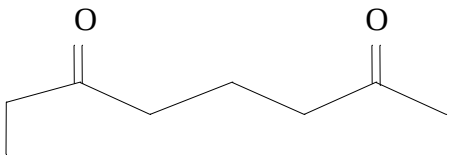
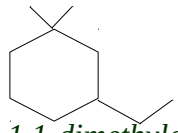
PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "ORGANIC CHEMISTRY – SOME BASIC PRINCIPLES AND TECHNIQUES"

1. Name any one method used for the estimation of nitrogen present an organic compound. (1)
   Ans: Dumas method or Kjeldahl's method
2. Write the IUPAC names of the following compounds :

   i) CH_3-CH_2-CH-CH(CH_3)-CH_2-CH_3
   CH_2-CH_3

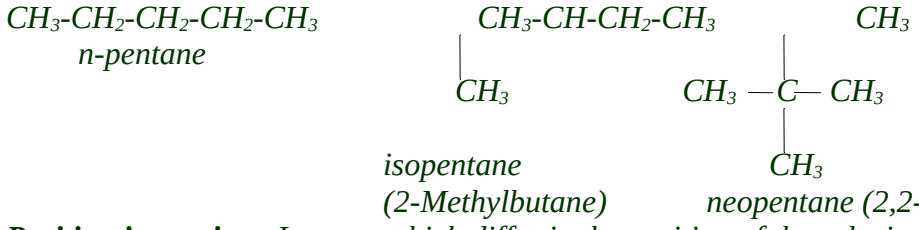
   ii) 

   (2)

   Ans: i) 3-Ethyl-4-methylhexane
   ii) 5-Oxohexanoic acid
3. (a) Arrange the following carbocation in the increasing order of their stability.
   CH_3-CH_2^+, CH_3^+, $(CH_3)_3C^+$, $(CH_3)_2CH^+$
   Justify your answer on the basis of hyper conjugation. (3)
   (b) Define homolytic bond fission. (1) [July 2019]
   Ans: (a) $CH_3^+ < CH_3$-$CH_2^+ < (CH_3)_2CH^+ < (CH_3)_3C^+$. As the number of hyper conjugative structures increases, the stability of the carbocation also increases. Here $(CH_3)_3C^+$ has 9, $(CH_3)_2CH^+$ has 6, CH_3-CH_2^+ has 3 and CH_3^+ has zero hyper conjugative structures.
   (b) It is a type of bond fission in which each of the bonded atoms gets one of the shared pair of electrons.
4. Give the IUPAC name of
    (1)
   Ans: 3-Ethyl-1,1-dimethylcyclohexane
5. Differentiate homolytic cleavage from heterolytic cleavage of covalent bonds. (2)
   *Ans: In homolysis or homolytic cleavage, each of the bonded atoms gets one of the electrons of the shared pair. Here the movement of a single electron takes place. The species formed as a result of homolysis is called **free radical**.*
   In heterolysis or heterolytic cleavage, the bond breaks in such a manner that the shared pair of electrons remains with one of the parts. After heterolysis, one atom has a sextet of electron and a positive charge and the other atom has an octet of electron with atleast one lone pair and a negative charge.
6. Briefly explain the different types of structural isomerism shown by organic compounds with suitable examples.
   (4) [March 2019]
   Ans: There are mainly four types of structural isomerism:

***a) Chain Isomerism**: Isomers differ in carbon chain or skeleton are called chain isomers and the phenomenon is called chain isomerism.*

E.g.: Pentane (C_5H_{12})



***b) Position isomerism**: Isomers which differ in the position of the substituent or side chain are called position isomers and the phenomenon is called position isomerism.*

E.g. : Alcohol with molecular formula $C_4H_{10}O$ may be 1-butanol or 2-butanol

CH_3-CH_2-CH_2-CH_2-OH (1-Butanol) *CH_3-CHOH-CH_2-CH_3* (2-Butanol)

***c) Functional group isomerism**: Isomers which differ in the functional group are called functional group isomers and the phenomenon is called functional group isomerism. This isomerism is shown by alcohols and ethers and aldehydes and ketones.*

E.g. compound with the molecular formula C_2H_6O may be an alcohol ethanol (CH_3-CH_2OH) or an ether methoxymethane (CH_3-O-CH_3).

***d) Metamerism**: Isomers which differ in the carbon chain (alkyl groups) around the functional group are called metamers and the phenomenon is called metamerism. It is commonly shown by ethers.*

E.g.: Ether with molecular formula $C_5H_{12}O$ may be methoxybutane (CH_3-O-CH_2-CH_2-CH_2-CH_3) or ethoxypropane (CH_3-CH_2-O-CH_2-CH_2-CH_3).

7. What is metamerism? Write the metamers of $C_4H_{10}O$. (2)

Ans: Isomers which differ in the carbon chain (alkyl groups) around the functional group are called metamers and the phenomenon is called metamerism.

The metamers of $C_4H_{10}O$ are CH_3-O-CH_2-CH_2-CH_3 and CH_3-CH_2-O-CH_2-CH_3.

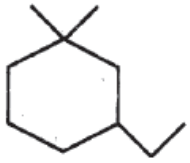
8. What is 'sodium fusion extract'? How the presence of N, S and halogens in organic compounds are detected? (4) [August 2018]

*Ans: Nitrogen, sulphur and halogens present in an organic compound are detected by "**Lassaigne's test**". Here the organic compound is fused with metallic sodium in a fusion tube. It is then plunged into distilled water taken in a china dish. The solution is boiled and filtered. The filtrate is known as sodium fusion extract.*

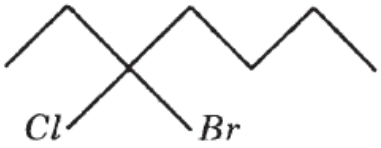
No.	***Experiment***	***Observation***	***Inference***
1.	*To one part of sodium fusion extract add freshly prepared ferrous sulphate ($FeSO_4$) solution. Heated to boiling, cooled and acidified with dil. H_2SO_4.*	*Blue or green coloration or precipitate (ppt)*	*Presence of nitrogen*
2.	*A little of the sodium fusion extract is acidified with dil. HNO_3 and then silver nitrate ($AgNO_3$) is added.*	*White ppt soluble in ammonium hydroxide (NH_4OH)*	*Presence of Chlorine*
		Pale yellow ppt slightly soluble in NH_4OH	*Presence of Bromine*

		Yellow ppt insoluble in NH_4OH	*Presence of Iodine*
3.	*To a little of the sodium fusion extract, add sodium nitroprusside solution*	*Violet colouration*	*Presence of sulphur*

9. Give the IIJPAC names of the following compounds.



(a)



(b)

(2)

Ans: (a) 3-Ethyl-1,1-dimethylcyclohexane
(b) 3-Bromo-3-chloroheptane

10. Briefly describe the principles of the following techniques, taking an example in each case.
    a) Crystallization
    b) Simple distillation
    c) Distillation under reduced pressure
    d) Paper chromatography (4 x 1 = 4) [March 2018]

    Ans:

    (a) Crystallisation: *It is based on the difference in the solubilities of the compound and the impurities in a suitable solvent. The impure compound is dissolved in a solvent in which it is sparingly soluble at room temperature but appreciably soluble at higher temperature. The solution is concentrated to get a nearly saturated solution. On cooling the solution, pure compound crystallises out and is removed by filtration.*

    (b) Simple distillation: *This method is used to separate (i) volatile liquids from non-volatile impurities and (ii) the liquids having sufficient difference in their boiling points. The principle of this method is that liquids having different boiling points vaporise at different temperatures. The vapours are cooled and the liquids so formed are collected separately.*

    (c) Distillation under reduced pressure: *This method is used to purify liquids having very high boiling points and those, which decompose at or below their boiling points. Such liquids are made to boil at a temperature lower than their normal boiling points by reducing the pressure on their surface. The pressure is reduced with the help of a water pump or vacuum pump.*

    (d) *Paper chromatography:* *It is a type of partition chromatography. Here a strip of chromatography paper, spotted at the base with the solution of the mixture, is suspended in a suitable solvent or a mixture of solvents. This solvent acts as the mobile phase. The solvent rises up the paper by capillary action and flows over the spot. The paper selectively retains different components according to their differing partition in the two phases.*

11. a) A Method used to purify organic compound is chromatography. Explain adsorption chromatography. (2)
    b) Compounds having same molecular formula but different structures are called structural isomers. Explain any two structural isomerism. (2)
    c) Differentiate between nucleophiles and electrophiles. (2) [July 2017]

Ans: (a) Adsorption chromatography is based on the fact that different compounds are adsorbed on an adsorbent in different degrees. Commonly used adsorbents are silica gel and alumina. Here a mobile phase is allowed to move over a stationary phase (adsorbent). Based on the adsorbing power, the components of the mixture are adsorbed at different places over the stationary phase.

(b) Refer the Answer of the question no. 6

(c) A reagent that brings an electron pair is called a nucleophile. Or, nucleophiles are electron rich species attack at electron deficient centre. E.g. OH^-, CN^-, NO_2^-, Cl^-, Br^-, I^-, H_2O

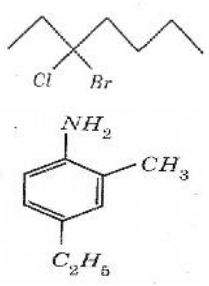
A reagent that takes away an electron pair is called an electrophile. Or, electrophiles are electron deficient species attack at electron rich centre. E.g. carbocations (R^+), -CHO, >CO etc.

12. a) Give the structural formula of the following compounds:
    i) 2,4,7 – Trimethyloctane
    ii) 2-Chloro-4-methylpentane (2)
    b) $CH_3CH_2^-$ or $(CH_3)_2CH^-$ which is more stable? Explain. (2)
    c) Explain the chemistry behind crystallisation. (2) [March 2017]

    Ans: a) (i) CH_3-$CH(CH_3)$-CH_2-$CH(CH_3)$-CH_2-CH_2-$CH(CH_3)$-CH_3

    (ii) CH_3-$CH(Cl)$-CH_2-$CH(CH_3)$-CH_3

    (b) $CH_3CH_2^-$ is stabler. This is because the stability of carbanion follows the order $1^0 > 2^0 > 3^0$ due to inductive effect.

    (c) Refer the Answer of the question no. 10
13. a) Give the IUPAC names of the following:
    i)
    ii) 

    (2)
    b) Which is more stable $(CH_3)_3C^+$ or $CH_3CH_2^+$? Give a reason. (2)
    c) Give the chemistry behind distillation under reduced pressure. (2) [March 2017]

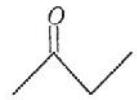
    Ans: a) i) 3-Bromo-3-chloroheptane

    ii) 4-Ethyl-2-methylaniline

    b) $(CH_3)_3C^+$ is more stable. This is because the stability of carbocation follows the order $3^0 > 2^0 > 1^0$ due to inductive effect and hyper conjugation.

    c) Refer the Answer of the question no. 10
14. a) Bond line notations of some organic compounds are given below. Write the condensed formula and IUPAC names.

i) 

ii)  (2)

b) Give the principle of estimation of nitrogen by Dumas method. (2)

c) Explain the concept of resonance with an example. (2) [September 2016]

Ans: a) (i) CH_3-CH_2-CH=CH_2 (But-1-ene)

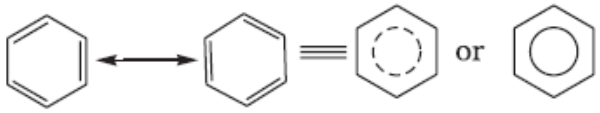
(ii) CH_3-CO-CH_2-CH_3 (Butan-2-one or Butanone)

b) Here the organic compound is heated with copper oxide in an atmosphere of carbon dioxide so that free nitrogen, carbon dioxide and water are produced.

$$C_xH_yN_z + (2x + y/_2)\,CuO \rightarrow x\,CO_2 + y/_2\,H_2O + z/_2\,N_2 + (2x + y/_2)\,Cu$$

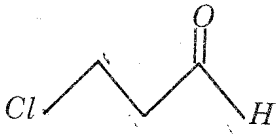
c) All the observed properties of some compounds cannot be explained by a single structure. Here more than one structures are used to explain the properties of the compound. These different structures are called resonance structures or canonical structures or contributing structures. The phenomenon is known as resonance.

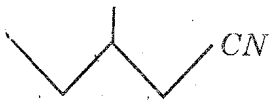
Benzene (C_6H_6)



(A) (B) (C)

15. a) Give the IUPAC names of the following:

i) 

ii) 

(2)

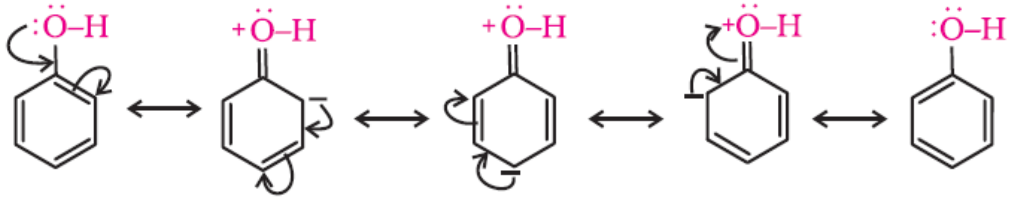
b) Phenol exhibit resonance.

i) Draw the resonance structures of phenol. (2)

ii) Predict the directive influence of –OH group in benzene ring. (2)

Ans: a) i) 3-chloropropanal ii) 3-methylpentanenitrile

b) i) Resonance structures of phenol



ii) – OH group is an ortho-para directing group, since in the resonating structures, the electron density is greater in these positions.

16. a) Write the structural formula of the following compounds:

i) Pent-4-en-2-ol

ii) 6-Hydroxyheptanal (2)

b) Reagents which attack organic compounds may be classified as electrophiles, nucleophiles and free radicals.

i) Explain the nucleophiles and electrophiles with suitable examples. (3)

ii) Name the type of the fission of a covalent bond which gives free radicals. (1) [March 2016]

Ans: a) (i) $CH_2 = CH – CH_2 – CH(OH) – CH_3$

(ii) CH_3-CH(OH)-CH_2-CH_2-CH_2-CHO

b) i) A reagent that brings an electron pair is called a nucleophile. Or, nucleophiles are electron rich species attack at electron deficient centre.

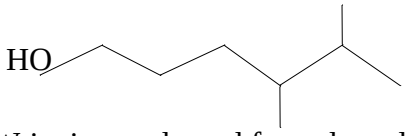
Example for nucleophiles are OH^-, CN^-, NO_2^-, Cl^-, Br^-, I^-, H_2O, NH_3, R-NH_2 etc.

A reagent that takes away an electron pair is called an electrophile. Or, electrophiles are electron deficient species attack at electron rich centre.

Example for electrophiles are carbocations (R^+), -CHO, >CO etc.

ii) Homolysis or homolytic fission

17. The bond-line formula of a compound is given below.



Write its condensed formula and give the IUPAC name. (2)

Ans: HO-CH_2-CH_2-CH_2-$CH(CH_3)$-$CH(CH_3)$-CH_3

IUPAC Name: 4,5-Dimethylhexan-1-ol

18. Explain the different types of electron displacement effects in covalent bonds.
(Hint: Inductive effect, resonance effect, electromeric effect, hyper conjugation). (4)

*Ans: **Inductive effect:** It is a permanent effect arising due to the shifting of sigma electrons through a carbon chain in presence of an atom or group of atom (having different electronegativity) attached to a carbon chain. This effect propagates only through C – C σ bonds.*

***Electromeric effect:** It is defined as the complete transfer of a shared pair of π-electrons to one of the atoms joined by a multiple bond in presence of an attacking reagent. It is a temporary effect. It is possible only in compounds containing multiple bonds.*

***Resonance effect:** It is defined as the polarity produced in the molecule by the interaction of two π-bonds or between a π-bond and lone pair of electrons present on an adjacent atom.*

***Hyper conjugation:** It is a permanent effect. In this effect the σ electrons of C—H bond of the alkyl group enter into partial conjugation with the unsaturated system or with the unshared p orbital. i.e. the σ electrons of C –H bonds get delocalised.*

19. How is sodium fusion extract prepared? Using this, how will you detect the presence of Nitrogen, Sulphur and Halogen in an organic compound? (4) [October 2015]

Ans: Refer the Answer of the question no. 8

20. What do you mean by the following terms?

a) Homolytic fission b) Heterolytic fission c) Nucleophiles d) electrophiles (4)

Ans: Refer the Answer of the question no. 5 and 11 (c).

21. Various methods for the purification of organic compounds are based on the nature of the compound and the impurity present in it. Explain the principle involved in the following methods of purification:
    a) Distillation b) Steam distillation (4) [March 2015]

Ans: a) ***Distillation:*** *This method is used to separate (i) volatile liquids from non-volatile impurities and (ii) the liquids having sufficient difference in their boiling points. The principle of this method is that liquids having different boiling points vaporise at different temperatures. The vapours are cooled and the liquids so formed are collected separately.*

b) ***Steam distillation:*** *This technique is applied to separate substances which are steam volatile and are immiscible with water. In steam distillation, steam from a steam generator is passed through a heated flask containing the liquid to be distilled. The mixture of steam and the volatile organic compound is condensed and collected. The compound is later separated from water using a separating funnel.*

22. a) Give the IUPAC names of the following compounds: (2)

i) CH_3-CH_2-CH-CH_2-CH_2-CH-CH_2-CH_3
   | OH | CH_3

ii) CH_3-CH_2-CH=CH-CH_2-COOH

b) How many 'σ' and 'π' bonds are present in the following compounds?

$CH_2 = C = CH - CH_3$ (1)

c) Write the name of the test used to detect nitrogen, sulphur, halogens and phosphorous present in an organic compound. (1)

d) Explain any one method for the estimation of nitrogen present in an organic compound. (2) [August 2014]

Ans: a) i) 6-Methyloctan-3-ol

ii) Hex-3-en-1-oic acid

b) σ bonds - 9

π bonds – 2

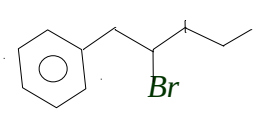
c) Lassaigne's test

23. a) Draw the structures of the following compounds.
    i) 2,3-Dibromo-1-phenylpentane
    ii) 4-Ethyl-1-fluoro-2-nitrobenzene (3)

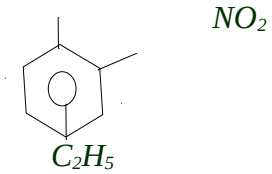
b) Write all the possible chain isomers of the compound with molecular formula C_5H_{12}. (3)

Ans: a)

i)

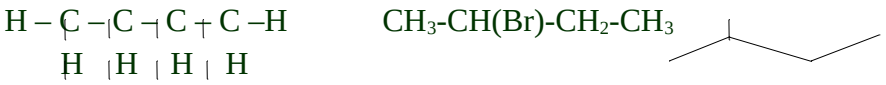


ii)



b) CH_3-CH_2-CH_2-CH_2-CH_3 , CH_3-$CH(CH_3)$-CH_2-CH_3 and CH_3-$C(CH_3)_2$-CH_3

24. a) Write the complete, condensed and bond line structural formulae of 2-bromobutane. (3)
b) In the Carius method of estimation of halogen, 0.15g of an organic compound gave 0.12g of AgBr. Find the percentage of Br in the compound. (3) [March 2014]

Ans: a) 

Complete structural formula CH_3-$CH(Br)$-CH_2-CH_3 *Condensed structural formula* *Bond line formula*

b) Mass of organic compound (m) = 0.15 g
Mass of AgBr formed (m_1) *= 0.12 g*
Atomic mass of Br = 80
Molar mass of AgBr = 108+ 80 = 188 g/mol

$$\text{Percentage of Br} = \frac{\text{Atomic mass of Br} \times m_1 \times 100\ \%}{\text{Molecular mass of AgBr} \times m} = \frac{80 \times 0.12 \times 100}{188 \times 0.15} = \underline{34.04\ \%}$$

25. i) Different methods are used to purify organic compounds. Name any three methods of purification. (3)
ii) On complete combustion, 0.246g of an organic compound gave 0.198g of CO_2 and 0.1014g of H_2O. Determine the percentage composition of carbon and hydrogen in the compound. (3)

Ans: i) Sublimation, Crystallisation, Distillation etc.

ii) Mass of organic compound (m) = 0.246 g
Mass of CO_2 *formed* (m_1) *= 0.198 g*

$$\text{Percentage of carbon} = \frac{12 \times m_1 \times 100}{44 \times m} = \frac{12 \times 0.198 \times 100}{44 \times 0.246} = 21.95\%$$

Mass of water formed (m_2) *= 0.1014 g*

$$\text{Percentage of hydrogen} = \frac{2 \times m_2 \times 100}{18 \times m} = \frac{2x\ 0.1014 \times 100}{18 \times 0.246} = 4.58\%$$

26. i) What is homologous series? (1)
ii) Hyper conjugation is a general stabilizing interaction. Write the hyper-conjugative structures of CH_3-CH_2^+ (ethyl cation) (2)
iii) Write the structures of the following organic compounds.
a) 2,5,6 – Trimethyloctane
b) Hexane-2,4-dione
c) 5-oxohexanoic acid (3) [September 2013]

Ans: i) A series of organic compounds in which adjacent members are differed by a $-CH_2$ *group is called a homologous series.*

ii)

iii) *a)* $CH_3 - CH(CH_3) - CH_2 - CH_2 - CH(CH_3) - CH(CH_3) - CH_2 - CH_3$

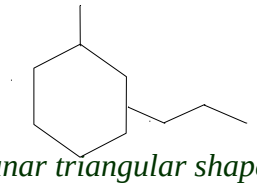
b) $CH_3 - CO - CH_2 - CO - CH_2 - CH_3$

c) $CH_3 - CO - CH_2 - CH_2 - CH_2 - COOH$

27. The IUPAC names of alkanes are based on their chain structure.
    a) Give the IUPAC name of
    $CH_3 - CH_2 - CH(CH_2-CH_3) - CH_2 - CH(CH_3) - CH_2 - CH_3$ (1)
    b) Represent 1-Methyl-3-propylcyclohexane using bond line notation. (1)
    c) What is the type of hybridization of C in CH_3^+? Also predict its shape. (1)
    d) Name the type of bond fission resulting in the formation of free radicals? (1)

    Ans: a) 3-Ethyl-5-methylheptane

    b)



    c) sp^2 , Planar triangular shape.

    d) Homolysis

28. Organic compounds have to be purified before analysis.
    a) Which type of liquids can be purified using distillation under reduced pressure? Suggest an example. (1)
    b) Name the two main types of chromatographic techniques based on the principle of differential adsorption. (1)
    c) In the Lassaigne's test for halogens, they are precipitated as ……. (1)
    d) In what form is nitrogen estimated in the Dumas method? (1) [March 2013]

    Ans: a) Liquids having very high boiling points and those, which decompose at or below their boiling points. E.g. Glycerol can be separated from spent-lye using this method.

    b) Column chromatography and Thin layer chromatography.

    c) Silver halide (AgX)

    d) Dinitrogen (N_2)

29. Many chemical properties of organic compounds can be explained on the basis of electron displacement effects.
    a) What is resonance effect? (1)
    b) Categorize the following functional groups into those having +R effect and –R effect: (1)
    $-NH_2$, $-NO_2$, -COOH, -OH (1) [March 2013]

Ans: a) It is defined as the polarity produced in the molecule by the interaction of two π-bonds or between a π-bond and lone pair of electrons present on an adjacent atom.

b) + R Effect groups: -NH_2, -OH

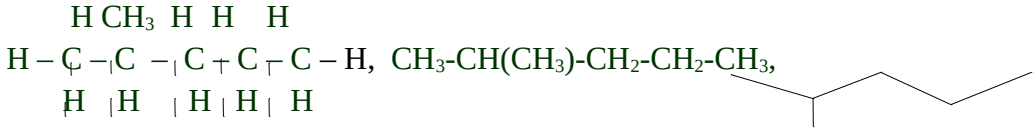
–R Effect groups: -NO_2, -COOH.

30. i) Give the complete, condensed and bond line formula of 2-methyl pentane and chlorocyclohexane. (3)

ii) Write the IUPAC name of the following compounds:

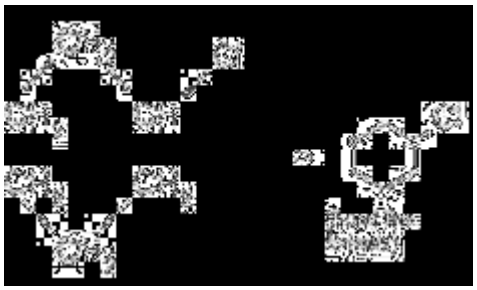
$CH_3 - CH_2 – CH(OH) - CH_2 - CHO$ and $CH_3 – CH = CH - CH_2 - C \equiv C - CH_3$ (3)

Ans: i) 2- Methylpentane



CH_3-$CH(CH_3)$-CH_2-CH_2-CH_3,

Chlorocyclohexane



ii) 3-Hydroxypentanal and Hept-2-en-5-yne

31. i) Give any three types of structural isomers. Give examples. (3)

ii) How will you identify the presence of Halogen by using sodium fusion extract? (2)

iii) Name the method for estimation of Halogen. (1) [September 2012]

Ans: i) Refer the Answer of the question no. 6

ii) Refer the Answer of the question no. 8

iii) Carius method

32. A group of organic compounds, each containing a characteristic functional group forms a homologous series.

a) Give an example for a homologous series. (1)

b) Give the IUPAC name of the following compound: CH_3-CH_2-CO-CH_2-CH_2-COOH

c) Write the metamers corresponding to the molecular formula $C_4H_{10}O$. (2)

Ans: (a) Alkane

(b) 4-oxohexanoic acid

(c) $CH_3 – O – CH_2 – CH_2 – CH_3$ and $CH_3 – CH_2 – O – CH_2 – CH_3$

33. Different techniques are used for the purification of organic compounds based on their nature.

a) Suggest a suitable method for the separation of a mixture of aniline and water. (1)

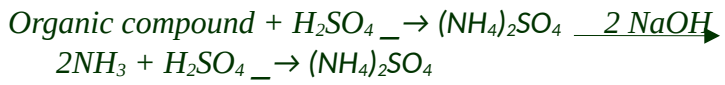
b) Give the chemical name of the compound responsible for the blue colour in the Lassaigne's test for nitrogen. (1)

c) Briefly explain the principle involved in Kjeldahl's method for the estimation of nitrogen. (2) [March 2012]

Ans: a) Steam distillation

b) Ferriferrocyanide or Iron (III) hexacyanoferrate (II) or Prussian blue.

c) Here the organic compound containing nitrogen is heated with concentrated sulphuric acid. Nitrogen in the compound gets converted to ammonium sulphate. The resulting acid mixture is then heated with excess of sodium hydroxide. The liberated ammonia gas is absorbed in an excess of standard solution of sulphuric acid. The amount of ammonia produced is determined by estimating the amount of sulphuric acid consumed in the reaction. It is done by estimating unreacted sulphuric acid left after the absorption of ammonia by titrating it with standard alkali solution.



34. Carbocations are formed by the heterolytic cleavage of a covalent bond.
    a) What is heterolytic bond fission? (1)
    b) Arrange the following carbocations in the increasing order of stability:
    $(CH_3)_2CH^+$, CH_3^+, $(CH_3)_3C^+$, $CH_3\text{-}CH_2^+$ (1) [March 2012]

    Ans: a) In heterolytic bond fission, the bond breaks in such a manner that the shared pair of electrons remains with one of the parts.

    b) $CH_3^+ < CH_3\text{-}CH_2^+ < (CH_3)_2CH^+ < (CH_3)_3C^+$

35. A series of organic compounds containing a characteristic functional group and represented by a general formula is called a homologous series.
    a) Classify the following into homologous series and name the series.
    C_3H_8, C_2H_5Cl, C_6H_{14}, C_4H_9Cl, C_2H_5OH, $CH_3\text{-}CH_2\text{-}CH_2\text{-}Cl$, $CH_3\text{-}CHOH\text{-}CH_3$ (3)
    b) Write the general formulae of the following homologous series.
    i) Alkynes ii) Alcohols iii) Chloroalkanes (3) [October 2011]

Ans: a) Alkanes - C_3H_8, C_6H_{14}

Alkyl chlorides (Chloroalkanes) - C_2H_5Cl, C_4H_9Cl, $CH_3\text{-}CH_2\text{-}CH_2\text{-}Cl$

Alcohols - $CH_3\text{-}CHOH\text{-}CH_3$, C_2H_5OH

b) i) Alkynes – C_nH_{2n-2} ii) Alcohols - $C_nH_{2n+1}OH$ iii) Chloroalkanes – $C_nH_{2n+1}Cl$

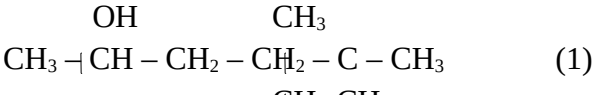
36. Hybridization influences the bond length and bond enthalpy in organic compounds:
    a) Compare the bond length and bond strength of C-H bonds formed by sp and sp^3 hybridized carbon atoms. Give reason (2)
    b) How many 'σ' and 'π' bonds are present in the following compounds?
    i) $CH_3\text{-}CH_2\text{-}CH_3$
    ii) $CH_3\text{-}C\equiv CH$ (1)

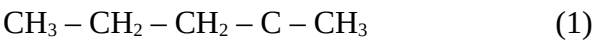
Ans: a) sp hybridized carbon has 50% s-character, while sp^3 hybridized carbon has only 25% s-character. Greater the s-character, greater will be the electronegativity. So the C – H bond attached to sp hybridized carbon has the shortest bond length. Since the electron pairs are more shifted to Carbon atom, that C-H bond can easily dissociated.

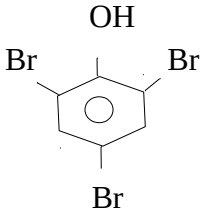
b) i) $CH_3\text{-}CH_2\text{-}CH_3$ No. of σ bonds – 10, No of π bonds – 0

ii) CH_3-C≡CH No. of σ bonds – 6, No of π bonds – 2

37. Give the IUPAC names of the following:

a) 

b) 

c)  (1) [March 2011]

Ans: a) 5,5-Dimethylheptan-2-ol

b) Pentan-2-one

c) 2,4,6-Tribromophenol

38. Detection of elements like nitrogen, halogens and sulphur are done by using Lassaigne's test. Discuss the chemistry of Lassaigne's test for the above elements. (6) [September 2010]

Ans: Refer the Answer of the question no. 8

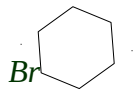
39. The bond line representation of cyclopropane is  . Write the bond line structures of

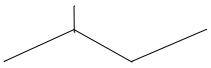
a) Cyclohexane

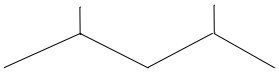
b) 2-Bromobutane

c) $CH_3 – CH(OH) – CH_2 – CHBr – CH_3$ (3)

Ans: a)

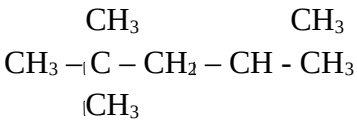


b) 

c) 

40. The IUPAC name of an organic compound is derived by identifying the functional group and the parent hydrocarbon chain.

a) Write the IUPAC name of the following:

i) 

ii) $CH_3 – CH = CH – CH_2 – CH_2 – COOH$ (2)

b) Give the structures of the following compounds:

i) 3–Ethyl-4,4-dimethylpentane

ii) 6-Methyloctan-3-ol (2) [March 2010]

Ans: a) i) 2,2,4-Trimethylpentane

ii) Hex-4-en-1-oic acid (Hex-4-enoic acid)

b) i) $CH_3 - CH_2 + CH(C_2H_5) - C(CH_3)_2 - CH_3$

ii) $CH_3 - CH_2 - CH(CH_3) - CH_2 - CH_2 - CH(OH) - CH_2 - CH_3$

41. a) Write the IUPAC name of the following compounds :

i) $CH_3 - CH(CH_3) - CH_2 - CH(CH_2-CH_3) - CH_3$

ii) $(CH_3)_2CH - CH_2 - CH(Cl) - CH_3$

iii) 

(3)

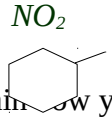
b) Draw the structure of the molecules represented by the IUPAC names – pent-4-en-2-ol and nitrocyclohexane. (2)

[March 2009]

Ans: a) i) 2,4-Dimethylhexane

ii) 2-Chloro-4-methylpentane

iii) Cyclohex-2-en-1-ol

b) $CH_2 = CH - CH_2 - CH(OH) - CH_3$ *and* 

42. You are given a compound containing nitrogen. Explain how you will proceed to determine the Nitrogen content. (4) [June 2008]

Ans: Refer the Answer of the question no. 8

43. C_2H_6 and C_5H_{12} are members of a homologous series.

a) What is a homologous series? (1)

b) What is the general molecular formula of the above homologous series? (1)

c) What is the significance of $–CH_2-$ group in homologous series? (1) [February 2008]

Ans: a) Refer the Answer of the question no. 26 (a)

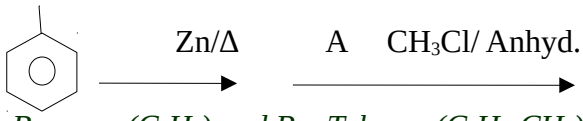
b) C_nH_{2n+2}

c) In homologous series, if add $–CH_2-$ *group to a member, we get the next member.*

##########

PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER "HYDROCARBONS"

1. Identify A and B in the following reaction :



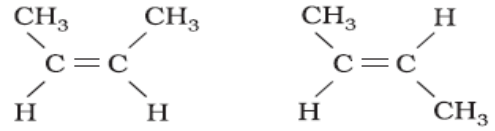
(2)

Ans: A – Benzene (C_6H_6) and B – Toluene (C_6H_5-CH_3)

2. An alkene on ozonolysis gives two molecules of ethanal. Identify the alkene. Draw its geometrical isomeric forms. (2)

Ans: But-2-ene (CH_3-CH=CH-CH_3)

Its geometrical isomers are:

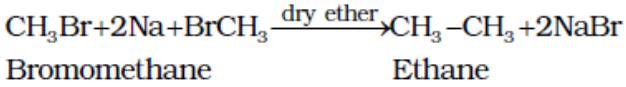


cis-But-2-ene *trans*-But-2-ene

3. Briefly describe the following with suitable chemical equations :

(a) Wurtz reaction (b) Kharash effect (3) [July 2019]

Ans: (a) Wurtz reaction: Alkyl halides react with metallic sodium in dry ether to form alkanes. This reaction is known as Wurtz reaction.



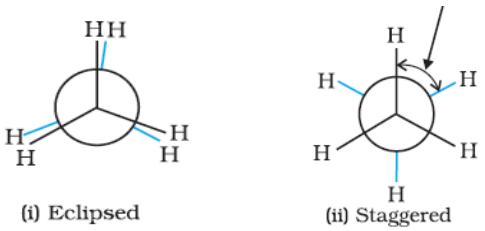
(b) Kharash Effect: In presence of organic peroxide, addition of HBr to unsymmetrical alkenes takes place against Markovnikov rule. This is known as ***peroxide or Kharash effect.***

e.g. CH_3-CH= CH_2 + HBr Org. peroxide CH_3-CH_2-CH_2Br

Propene ⇢ 1-bromopropane

4. Draw the Newman Projections of the eclipsed and staggered conformations of ethane molecule. (2)

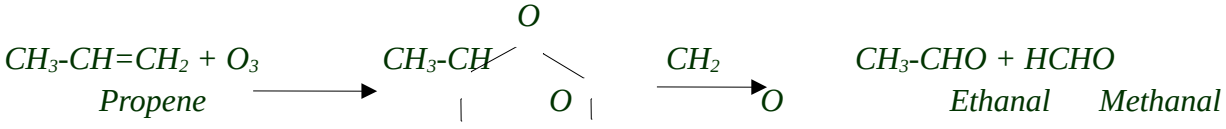
Ans:



(i) Eclipsed (ii) Staggered

5. Give the chemical equations for the steps involved in the ozonolysis of propene. (2)

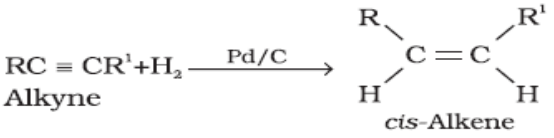
Ans:



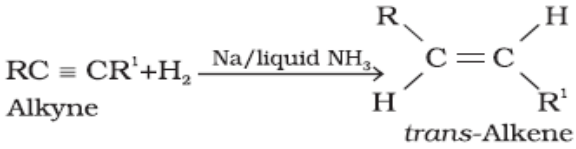
6. Alkynes can be converted selectively into cis-alkenes and trans-alkenes. ExpIain with suitable examples. (3)

[March 2019]

Ans: Alkynes on partial reduction with dihydrogen in the presence of palladised charcoal partially deactivated with sulphur compounds or quinoline give cis-alkenes.

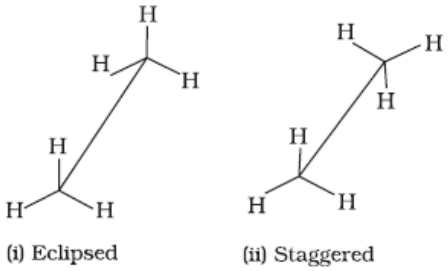


If we use sodium in liquid ammonia as the reducing agent, we get trans alkene.



7. Draw the 'sawhorse' projections of the eclipsed and staggered conformations of ethane. (2)

Ans:



8. Give the chemical equation for the conversion of hexane to benzene. Write the name of the process. (2)

Ans:

$CH_3\text{-}(CH_2)_4\text{-}CH_3 \xrightarrow[773K,\ 10\text{-}20\ atm]{Cr_2O_3\ or\ V_2O_5\ or\ Mo_2O_3}$ Benzene

n-hexane

The process is known as Aromatisation.

9. Predict the Products :

a) $CH_3 - CH = CH_2 + HB_r \xrightarrow{(C_6H_5CO)_2O_2} ?$

b) $3CH \equiv CH \xrightarrow[873K]{\text{Red hot Iron tube}} ?$

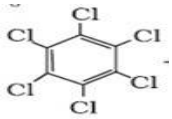
c)  $+ 6Cl_2 \xrightarrow[dark,\ cold]{Anhy.AlCl_3} ?$

(3) [August 2018]

Ans: a) 1-Bromopropane ($CH_3\text{-}CH_2\text{-}CH_2Br$)

b) Benzene (C_6H_6)

c) Hexachlorobenzene (C_6Cl_6) Or,



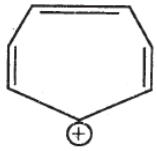
10. What is Wurtz reaction? Give an example. (2)

Ans: Alkyl halides react with metallic sodium in dry ether to form alkanes. This reaction is known as Wurtz reaction.

$$CH_3Br + 2Na + BrCH_3 \xrightarrow{\text{dry ether}} CH_3-CH_3 + 2NaBr$$

Bromomethane Ethane

11. Cycloheptatrienyl cation is given below :



Is this ion aromatic or not? Justify the answer. (2)

Ans: This compound is aromatic since it contains 6 delocalised π electrons according to Huckel's rule.

12. Identify X, Y and Z in the following sequence of reactions :

$$CH_3-CH_2-CH_2Br \xrightarrow{\text{Alcoholic KOH}} X \xrightarrow{O_3} Y \xrightarrow{Zn/H_2O} Z + HCHO$$ (3) [March 2018]

Ans: X is CH_3-CH=CH_2, Y is CH_3-C(=O)-CH(=O) CH_2 and Z –isCH_3-CHO

13. a)

Cyclopentadienyl anion is aromatic. Why? (1)

b) Explain the following reactions: i) Substitution ii) Addition (2)

c) Ethyne is acidic in nature. Explain. (2) [July 2017]

Ans: a) This compound is aromatic since it contains 6 delocalised π electrons according to Huckel's rule.

b) ***i) Substitution Reaction:*** *It is the replacement of an atom or group of atom by another atom or atom group. E.g.: Halogenation* $CH_4 + Cl_2 \xrightarrow{h\upsilon} CH_3Cl + HCl$

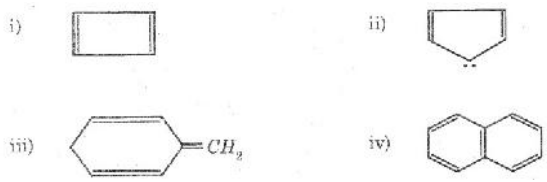
ii) Addition Reaction: *It is the process of addition of simple molecules like* H_2, X_2, *HX etc. to an unsaturated system.*

$CH_2 = CH_2 + HBr \rightarrow CH_3$-$CH_2Br$

c) In Ethyne, the H atoms are attached to sp hybridized carbon atoms. Due to the greater s-character and electronegativity of sp hybridized C, it attracts the electron pairs of C – H bonds strongly. So the hydrogen atom is readily removed as H^+ *and hence ethyne is acidic.*

14. Benzene and benzeniod compounds show aromatic character.

a) Select the aromatic compounds from the following:

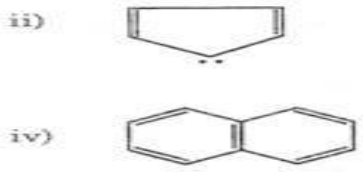


b) Suggest a method to convert ethyne to benzene.(2)

c) Give the products formed when benzene reacts with the following:

i) $CH_3Cl/AlCl_3$ ii) Cl_2/hv [March 2017]

Ans: a)

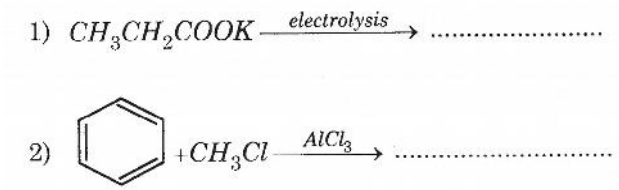


b) $3\,C_2H_2 \xrightarrow{\text{Red hot iron tube \& 873K}} C_6H_6$

c) i) Toluene

ii) Chlorobenzene

15. a) i) Complete the following reactions:



ii) Write the names of the above reactions? (2)

b) Baeyer's reagent is used to find whether the compound is unsaturated or not. What is Baeyer's reagent? (1)

c) What is the product formed when ethylene is treated with Baeyer's reagent? (2) [September 2016]

Ans: a) i)

1) $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3$

2) $C_6H_5\text{-}CH_3$

ii) 1) Kolbe's Electrolysis 2) Friedel Craft's reaction

b) Cold dilute aqueous $KMnO_4$

c) Ethylene glycol

$$CH_2=CH_2 + H_2O + O \xrightarrow[273\ K]{\text{dil. } KMnO_4} \underset{\text{Ethane-1, 2-diol (Glycol)}}{\overset{OH}{\underset{OH}{CH_2-CH_2}}}$$

16. a) 1-Alkynes are weakly acidic in nature. Give any two reactions to show the acidic character of ethyne. (2)

b) From the following, select the one in which Markownikoff's rule is best applicable.

i) $C_2H_4 + HCl$ ii) $C_3H_6 + Br_2$ iii) $C_3H_6 + HBr$ iv) $C_3H_8 + Cl_2$ (1)

c) Hydrocarbons exhibit isomerism.

i) Name the type of isomerism exhibited by 2-Butene.

ii) Draw the structure of the isomers of 2-butene and select the one which is more polar. (2) [March 2016]

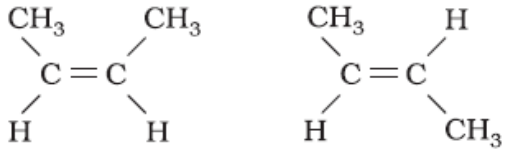
Ans: a) $CH{\equiv}CH + Na \rightarrow CH{\equiv}C^-Na^+ + ½\ H_2$

$CH_3\text{-}C{\equiv}CH + Na \rightarrow CH_3\text{-}C{\equiv}C^-Na^+ + ½\ H_2$

b) iii) $C_3H_6 + HBr$

c) i) Geometrical isomerism

ii)



cis-But-2-ene *trans*-But-2-ene

Cis-But-2-ene is more polar than the trans form.

17. Controlled oxidation of alkanes in the presence of suitabie catalysts give a variety of products.

a) Complete the following reaction :

$CH_4 + O_2$ Mo_2O_3/heat ……. + H_2O (1)

b) Free rotation about a carbon-carbon single bond is permitted in an alkane molecule.

What are conformers? Draw the structure of the eclipsed and staggered conformers of ethane in Sawhorse and Newman projections and explain their relative stability. (4) [October 2015]

Ans: a) HCHO

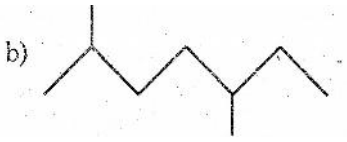
b) The different spatial arrangements of atoms arising due to free rotation around a C-C single bond are called conformations.

For projection formulas refer Question no. 4 and 7.

Staggered conformation is stabler than eclipsed form due to minimum repulsive forces between the electron clouds of C-H bonds.

18. Write the IUPAC names of the following compounds:

a) $CH_2{=}CH-CH_2-\underset{\displaystyle OH}{\underset{|}{CH}}-CH_3$

b) 

Ans: a) Pent-4-en-2-ol

b) 2,5-Dimethylheptane

19. a) Complete the following chemical equations:

i) $CH_3CH_2Br + 2Na + BrCH_2CH_3 \xrightarrow{dry\ ether} .....$ (1)

ii) $CH_3CH_2I \xrightarrow[\Delta]{alc.\ KOH} .....$ (1)

iii)  $+ CH_3Cl \xrightarrow{anhydrous\ AlCl_3} ..... + HCl$ (1)

b) Explain the geometrical isomerism taking 2-Butene as an example. (2) [March 2015]

Ans: a)

i) CH_3-CH_2-CH_2-CH_3

ii) CH_2=CH_2

iii) C_6H_5-CH_3 *(Toluene)*

b) Refer the answer of the question number 2.

20. a) Draw the cis and trans isomers of the following compound:

C_2H_5-$C(CH_3)$ = $C(CH_3)$-C_2H_5. (2)

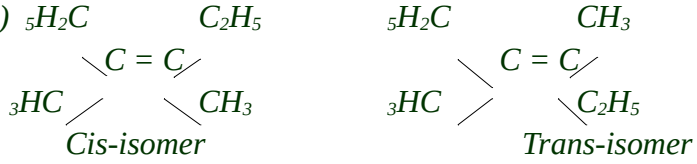
b) Complete the following reactions.(1)

i. $3CH \equiv CH$ Red hot iron tube at 873 K ……

ii. $CaC_2 + 2H_2O \longrightarrow Ca(OH)_2 +$ …….

c) Draw the sawhorse projections for eclipsed and staggered forms of an ethane molecule. (2)

Ans: a)



b) i) C_6H_6 (Benzene)

ii) C_2H_2 (Ethyne or acetylene)

c) Refer the answer of the question number 7.

21. a) How is alkane prepared by Kolbe's electrolytic method?(2)

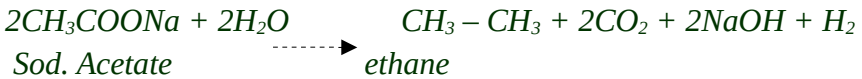
b) Select the activating groups from the following: (1)

i) $-NH_2$ ii) $-SO_3H$ iii) $-CH_3$ iv) $-COOH$

c) What is ozonolysis? Write the names of the products obtained when propene undergoes ozonolysis? (2)

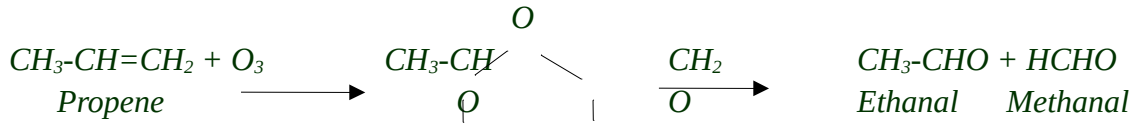
[August 2014]

Ans: a) In Kolbe's electrolytic method, an aqueous solution of sodium or potassium salt of a carboxylic acid is electrolysed to get an alkane.



b) $-NH_2$ and $-CH_3$

c) Alkenes add ozone to form an ozonide which on hydrolysis in presence of Zn to form aldehydes or ketones. This reaction is known as ozonolysis.



22. a) Write the products of the following chemical reactions and also name them.

i) $2CH_3 – Br + 2Na$ dry ether ……..

ii) $CH_3 – CH_2Br$ alcoholic KOH ……..

iii) $CH_3 – COONa$ NaOH/CaO …… (3)

b) An alkene 'A' on ozonolysis gave two molecules of formaldehyde. Write the name of 'A' and the chemical equation of ozonolysis. (2) [March 2014]

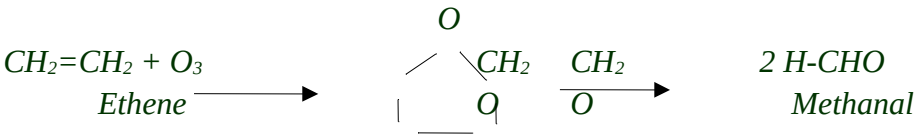
Ans: a)

i) *CH_3-CH_3 [Ethane]*

ii) *CH_2=CH_2 [Ethene or Ethylene]*

iii) *CH_4 (Methane)*

b) *CH_2=CH_2 [Ethene or Ethylene]*



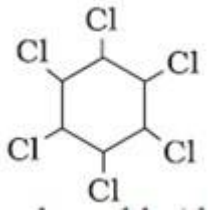
23. a)  + $3Cl_2$ uv /500K A

Name the product A. (1)

b) Draw the Newman's projections for the eclipsed and staggered conformations of n-butane. (2)

c) What is Baeyer's reagent? Write the chemical equation of its reaction with ethylene (CH_2=CH_2). (2) [Sept. 2013]

Ans: a) Benzene hexachloride (BHC)



b) Refer the answer of the question number 4.

c) Refer the answer of the question number 15 (b) and (c)

24. Free rotation is possible with respect to a C – C bond in the case of alkanes.

a) The repulsive interaction between the adjacent bonds in a conformation is called ……. (1)

b) Draw Newman's projections of the two conformers of ethane. Which among these is more stable? Justify. (2)

c) An alkene on ozonolysis followed by reduction of the ozonide formed with zinc and water gave a mixture of ethanal and methanal.

i) Identify the alkene. (1)

ii) Illustrate the above mentioned reaction using the chemical equation. (1) [March 2013]

Ans: a) Torsional strain

b) Refer the answer of the question number 4.

Staggered conformation is stabler than eclipsed form due to minimum repulsive forces between the electron clouds of C-H bonds.

c) i) Propene

ii) Refer the answer of the question number 5.

25. a) Name the following reactions:

i) C_6H_{14} (n-hexane) —Anhydrous $AlCl_3$/HCl→ $CH_3 – CH – CH_2 – CH_2 – CH_3$ (2-Methyl pentane)

ii) C_6H_{14} —V_2O_5/773K→ 

10 – 20 atm

Benzene

iii) C_6H_{14} 773K C_4H_8 + C_2H_6

butene ethane (3 x 1 = 3)

b) Naphthalene is an aromatic compound. Explain its aromaticity using Huckel's rule. (2) [September 2012]

Ans: a) i) Isomerisation

ii) Aromatisation

iii) Pyrolysis

b) According to Huckel's rule, cyclic, planar, conjugated systems containing (4n+2) π electrons are aromatic. Naphthalene contains 10 π electrons and follows this rule. So it is aromatic.

26. Hydrocarbons are organic compounds containing carbon and hydrogen only.

a) Complete the following chemical reactions:

i) $2CH_3Br + 2\ Na$ dry ether …… + 2 NaBr

ii) …… + Zn heat C_6H_6 + ZnO

iii) + $3Cl_2$ UV, 500K ……. (3 x 1 = 3)

b) Analyze the following reaction:

$CH_3 – CH = CH_2 + H – Br$ 'A' + 'B'

If 'A' is the major product and 'B' is the minor product, identify 'A' and 'B'. Also name the related rule. (2)

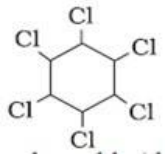
[March 2012]

Ans: a)

i) $CH_3 – CH_3$ (Ethane)

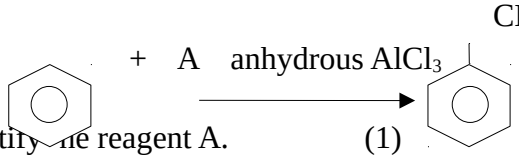
ii) C_6H_5-OH (Phenol)

iii) Benzene hexachloride or,



b) A is CH_3-CHBr-CH_3 (2-Bromopropane) and B is CH_3-CH_2-CH_2Br (1-Bromopropane). The rule behind the selection of the major product is Markownikoff's rule.

27. The higher homologue of benzene can be prepared by the following reaction.



a) Identify the reagent A. (1)

b) Which named reaction is this? (1)

c) Write the reaction mechanism of this reaction. (3) [October 2011]

Ans:

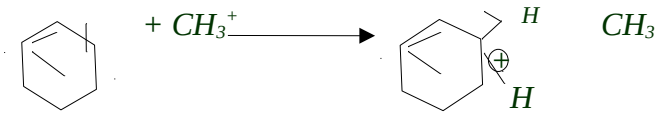
a) CH_3-Cl (Chloromethane)

b) Friedel Craft's reaction

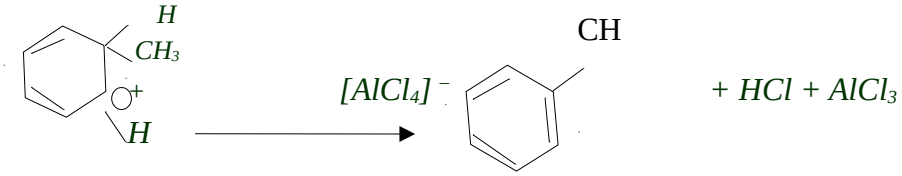
c) The mechanism involves the following steps:

i) Generation of Electrophile: $CH_3\text{-}Cl + AlCl_3 \longrightarrow CH_3^+ + [AlCl_4]^-$

ii) Formation of carbocation:



iii) Removal of a proton:



28. a) Complete the following reactions:

i) $CH_3 - Br + Na \xrightarrow{\text{dry ether}} ?$

ii) $CaC_2 + H_2O \longrightarrow ?$

iii) $3CH \equiv CH \xrightarrow[873\ K]{\text{Red hot iron tube}} ?$ (3 x 1 = 3)

b) Illustrate Markovnikov's rule taking the example of propene. (2) [March 2011]

Ans: a)

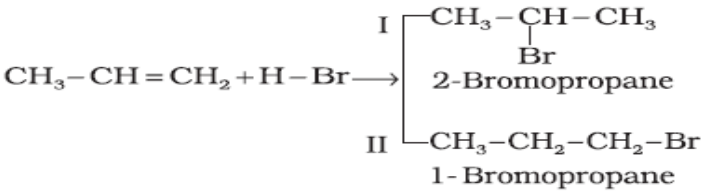
i) $CH_3\text{-}CH_3$ (Ethane)

ii) C_2H_2 (Ethyne or Acetylene)

iii) C_6H_6 (Benzene)

b) Markownikoff's (Markovnikov's) rule states that when an unsymmetrical reagent is added to an unsymmetrical alkene, the negative part of the addendum (adding molecule) gets attached to the carbon containing lesser number of hydrogen atoms.

E.g. When HBr is added to propene, we get 2 products – 1-bromopropane and 2-bromopropane.



Here 2-bromopropane is the major product.

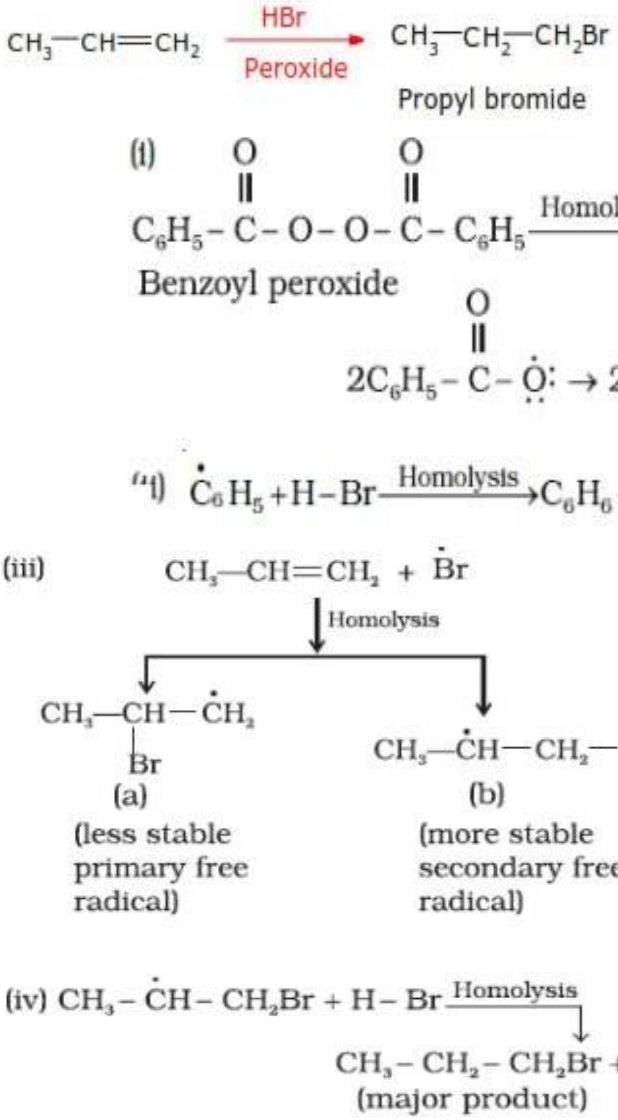
29. In a special condition, addition of HBr to unsymmetrical alkene takes place contrary to Markovnikov's rule.

a) What is the special condition? (1)

b) Give the mechanism of anti Markovnikov's addition of HBr to propene. (4) [September 2010]

Ans: a) The special condition is the presence of organic peroxide.

b) Mechanism of anti Markovnikov's addition



30. a) The spacial arrangements of atoms which can be converted into one another by rotation around a C – C single bond are called conformations.

i) Represent Sawhorse and Newman projection formulae of staggered and eclipsed conformations of ethane. (2)

ii) Compare the stabilities of staggered and eclipsed conformations. (1)

b) Consider the reaction given below:

$CH_3 – CH = CH_2 + HBr \rightarrow CH_3 – CHBr – CH_3 + CH_3 – CH_2 – CH_2Br$

i) Identify the major product obtained. (1)

ii) Name the rule governing the formation of the major product. (1) [March 2010]

Ans: a)

i) Refer the answer of the question number 4 and 7.

ii) Staggered conformation is stabler than eclipsed form due to minimum repulsive forces between the electron clouds of C-H bonds.

b) i) $CH_3 – CHBr – CH_3$ (2-Bromopropane)

ii) Markovnikov's rule.

31. a) How will you prepare ethane by Kolbe's electrolytic method? (2)

b) Expalin the Markovnikov's rule for the addition reaction using a suitable example. (3) [March 2009]

Ans: a) By the electrolysis of aqueous solution of sodium or potassium acetate.

$2CH_3COONa + 2H_2O \dashrightarrow CH_3 - CH_3 + 2CO_2 + 2NaOH + H_2$

Sod. Acetate *Ethane*

b) Refer the answer of the question number 28 (b)

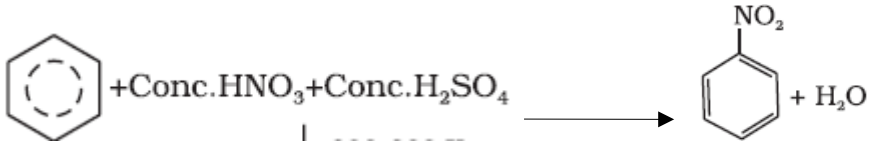
32. a) Consider the reaction between benzene and nitrating mixture.

$+ HNO_3 \xrightarrow{\text{Conc. } H_2SO_4}$? (1)

b) What is the reacting species in the above reaction? (1)

c) How is the species formed in the system? (1) [[June 2008]

Ans: a)



b) Nitronium ion (NO_2^+)

c) It is produced by the transfer of a proton from H_2SO_4 to HNO_3 followed by dehydration of the resulting product.

##########

PREVIOUS HSE QUESTIONS AND ANSWERS OF THE CHAPTER 'ENVIRONMENTAL CHEMISTRY'

1. a) Differentiate between classical smog and photochemical smog. (2)
   b) Suggest any two methods to control photochemical smog. (1) [July 2019]

   Ans: a) Classical smog occurs in cool and humid climate. It is a mixture of smoke, fog and sulphur dioxide. It is also called reducing smog.

   Photochemical smog occurs in warm, dry and sunny climate. The main components of the photochemical smog are nitrogen oxides, unburnt hydrocarbons, formaldehyde etc. It is also called oxidising smog.

   b) We can control photochemical smog by the following methods:
   - *Use catalytic converters in automobiles, which prevent the release of nitrogen oxide and hydrocarbons to the atmosphere.*
   - *Certain plants like Pinus, can metabolise nitrogen oxide. So their plantation helps to reduce these oxides.*
2. a) What is meant by acid rain? (1)
   b) Explain the chemistry behind the formation of acid rain.(1)
   c) What are the harmful effects of acid rain? (1) [March 2019]

   Ans: a) When the pH of the rain water is below 5.6, it is called acid rain.

   b) Oxides of nitrogen and sulphur (e.g. SO_2 and NO_2) are mainly responsible for acid rain. These gases dissolve in rain water and forms strong acids as follows:

   $2SO_2\,(g) + O_2\,(g) + 2H_2O\,(l) \longrightarrow 2H_2SO_4\,(aq)$

   $4NO_2\,(g) + O_2\,(g) + 2H_2O\,(l) \longrightarrow 4HNO_3\,(aq)$

   c) The harmful effects of acid rain are:
   - *Acid rain is harmful for agriculture, trees and plants.*
   - *It causes respiratory ailments and skin cancer in human beings and animals.*
   - *It affects plants and animal life in aquatic ecosystem.*
   - *It corrodes water pipes resulting in the dissolution of heavy metals into the drinking water.*
   - *Acid rain damages buildings and other structures made of stone or metal.* ***[Any 2 required]***
3. Which pollutant in water causes brown mottling of teeth? (1)

   Ans: Fluoride (F^-) ion.
4. Define the terms, Biochemical Oxygen Demand (BOD) and Eutrophication. (2) [August 2018]

   Ans: The amount of oxygen required by bacteria to break down the organic matter present in a certain volume of a sample of water, is called Biochemical Oxygen Demand (BOD).

   Nutrient enriched water bodies support a dense plant population, but kills animal life by reducing the amount of free oxygen. This results in the loss of biodiversity and is known as Eutrophication.
5. Name the type of smog generally formed during cool and humid climate. (1)

   Ans: Classical smog
6. Write any two applications of green chemistry in day-to-day life. (2) [March 2018]

   Ans: Applications of green chemistry are:

- ***Dry Cleaning of Clothes**: Liquefied carbondioxide, with a suitable detergent is used for dry cleaning clothes.*
- ***Bleaching of Paper**: Hydrogen peroxide (H_2O_2) with suitable catalyst is used for bleaching paper.*

7. Ozone layer plays a significant role in protecting earth from harmful UV radiation.
   a) What is mean by ozone layer depletion?
   b) What are the effects of ozone layer depletion? (3) [July 2017]

   Ans: a) The decomposition of ozone layer in the stratosphere by the action of certain substances like chlorofluorocarbons (CFC's or freons) is called ozone layer depletion.

   b) *The effects of ozone layer depletion are:*
      - *It leads to ageing of skin, cataract, sunburn, skin cancer, killing of many phytoplanktons, damage to fish productivity etc.*
      - *It leads to the harmful mutation of cells.*
      - *It also increases evaporation of surface water through the stomata of the leaves and decreases the moisture content of the soil.*
      - *Increase in UV radiations damage paints and fibres, causing them to fade faster.*
8. Environmental pollution is the effect of undesirable changes in surroundings that have harmful effects on plants, animals and human beings.
   a) Explain the adverse effect of global warming. (2)
   b) Choose the one which is not a component of photochemical smog.
      i) NO_2 ii) O_3 iii) SO_2 (1) [March 2017]

   Ans: (a) Due to global warming, the average global temperature will increase. This will lead to the melting of polar ice caps and flooding of low lying areas all over the earth. Increase in the global temperature results in the infectious diseases like dengue, malaria, yellow fever, sleeping sickness etc. (b) ii) SO_2
9. The phenomenon of global warming is due to green house effect.
   a) What is green house effect?
   b) What are the consequences of green house effect? (3) [September 2016]

   Ans: a) When *the concentration of carbon dioxide in the atmosphere is above the normal level (0.03%), it absorbs more infra-red radiation from the solar energy and hence the temperature of the earth's atmosphere increases. This is known as Green house effect. It results in global warming.*

   b) Due to Green house effect (global warming),
      - *the average global temperature will increase. This will lead to the melting of polar ice caps and flooding of low lying areas all over the earth.*
      - *Increase in the global temperature results in the infectious diseases like dengue, malaria, yellow fever, sleeping sickness etc.*

10. a) Match the following: (2)

A	B
CFC's	Blue baby syndrome

Oxides of nitrogen	Kidney damage
Cadmium	Eutrophication
Nitrates	Ozone depletion
	Red haze in the traffic

b) Write any contributions of green chemistry in day to day life. (1) [March 2016]

Ans: a)

A	***B***
CFC's	*Ozone depletion*
Oxides of nitrogen	*Red haze in the traffic*
Cadmium	*Kidney damage*
Nitrates	*Blue baby syndrome*

b) ***Dry Cleaning of Clothes****: Liquefied CO_2, with a suitable detergent is used for dry cleaning clothes.*

Bleaching of Paper*: Hydrogen peroxide (H_2O_2) with suitable catalyst is used for bleaching paper.*

11. 'Smog' is the most common example of air pollution.
    a) The smog that occurs in cool humid climate is called ……. (1)
    b) Explain the cause of 'Green House Effect'. (2) [October 2015]

    Ans: a) Classical smog

    b) Presence of certain gases like CO_2, methane, water -vapour, chlorofluorocarbons (CFC's), nitrous oxide, ozone etc in excess concentration is responsible for Green house effect.
12. The Taj Mahal in India has been affected by 'acid rain'. Explain the causes and harmful effects of acid rain. (3) [March 2015]

    Ans: Refer the Answer of the Question no. 2 (c)
13. a) Carbon monoxide is one of the most serious air pollutants. How does it pollute the atmosphere? (2)

    b) Give any two applications of Green Chemistry in day-to-day life. (1) [August 2014]

    Ans: a) Refer the Answer of the Question no. 9 (a)

    b) Refer the Answer of the Question no. 10(b)
14. There are international standards regarding drinking water. Write any three among them. (3) [March 2014]

    Ans: The International Standards for drinking water are given below:

    - *Fluoride: For drinking purposes, water should contain fluoride upto 1 ppm (parts per million).*
    - *Lead: The upper limit concentration of lead in drinking water is about 50 ppb (parts per billion).*

- *Sulphate: Less than 500 ppm*
- *Nitrate: The maximum limit of nitrate in drinking water is 50 ppm.*

15. Suppose that your teacher asks you to conduct a seminar on ozone depletion. Give any three harmful effects of ozone depletion that you would present in the seminar. (3) [September 2013]
Ans: Refer the Answer of the Question no.7 (b)
16. Pollution of water originates mainly from human activities.
    a) What do you mean by the term PCB? (1)
    b) How do chemical pollutants cause eutrophication? (1)
    c) Mention the adverse effects of high fluoride concentration in drinking water. (1) [March 2013]
    Ans: a) Polychlorinated biphenyls [Pollution Control Board]
    b) Some bacteria fed the chemical pollutants in water and grow rapidly. They use all the dissolved oxygen in water. The lack of oxygen kills all other aquatic life and cause Eutrophication.
    c) Fluoride concentration above 2ppm causes brown mottling of teeth. Excess fluoride (above 10ppm) causes harmful effect to bones and teeth.
17. a) Write any two differences between classical smog and photochemical smog. (2)
    b) How the Green Chemistry is useful in bleaching of paper? (1) [September 2012]
    Ans: a) Refer the Answer of the Question no. 1 (a)
    b) Hydrogen peroxide (H_2O_2) with suitable catalyst is used for bleaching paper in Green Chemistry.
18. Particulate pollutants are the minute solid particles or liquid droplets in air.
    a) Suggest two examples for non-viable particulate pollutants. (1)
    b) Write any two adverse effects of photochemical smog. (2) [March 2012]
    Ans: a) smoke, fumes, mist, dust etc.
    b) The adverse effects of photochemical smog are:
        - *It leads to cracking of rubber and extensive damage to plant life.*
        - *It also causes corrosion of metals, stones, building materials, rubber and painted surfaces.*
19. Ozone in the stratosphere is produced by the help of ultraviolet radiations. It protects us from harmful ultraviolet radiations.
    a) Write equation for the formation of ozone in stratosphere. (1)
    b) Explain with chemical equation, the destruction of ozone by chlorofluro carbons causing ozone hole. (2)
    [October 2011]
    Ans: a) Ozone is formed in the upper stratosphere by the interaction of uv radiation on dioxygen.
    $O_2(g)$ *sun light* $O(g) + O(g)$
    $O(g) + O_2(g) \rightleftharpoons O_3(g)$

    b) In stratosphere, CFC's get broken down by UV radiations, releasing chlorine free radical.
    $CF_2Cl_2(g) \xrightarrow{uv} Cl^{\bullet}(g) + {}^{\bullet}CF_2Cl(g)$
    The chlorine radical then react with ozone to form chlorine monoxide radicals and molecular oxygen. $Cl^{\bullet}(g) + O_3(g) \longrightarrow ClO^{\bullet}(g) + O_2(g)$
    Reaction of chlorine monoxide radical with atomic oxygen produces more chlorine radicals.
    $ClO^{\bullet}(g) + O(g) \longrightarrow Cl^{\bullet}(g) + O_2(g)$
    The chlorine radicals are continuously regenerated and cause the breakdown of ozone.
20. Organic matters such as leaves, grass, trash etc. are major pollutants in water.

a) How do organic pollutants affect aquatic life? (2)
b) What is Biological Oxygen Demand (BOD)? (1) [March 2011]

Ans: a) As the amount of organic matter in water increases, more oxygen is required to decompose them by bacteria. So the amount of dissolved oxygen in water decreases. This causes oxygen dependent aquatic life to die.

b) The amount of oxygen required by bacteria to break down the organic matter present in a certain volume of a sample of water, is called Biochemical Oxygen Demand (BOD).

21. When the pH of the rain water drops below 5.6, it is called acid rain.
    a) What are the major compounds responsible for acid rain? (1)
    b) What are the harmful effects of acid rain? (2) [September 2010]

    Ans: Refer the Answer of the Question no. 2
22. Atmospheric pollution increases the global average temperature and the phenomenon is called global warming.
    a) What are the major gases which contribute towards global warming? (1)
    b) What can we do to reduce global warming? (2) [March 2010]

    Ans: a) CO_2, methane, water -vapour, chlorofluorocarbons (CFC's), nitrous oxide and ozone.

    b) Global warming can be reduced by the following methods:
    - *Reduce the burning of fossil fuels by minimizing the use of automobiles.*
    - *Plant trees and encourage afforestation.*
    - *Avoid burning of dry leaves, wood etc.*
    - *Aware the public about the bad effects of global warming.*
23. a) What is mean by the green house effect? (1½)
    b) Explain what is mean by green house gases? (1½) [March 2009]

    Ans: a) Refer the Answer of the Question no. 9 (a)

    b) The gases responsible for green house effect are called green house gases. They are CO_2, methane, water -vapour, chlorofluorocarbons (CFC's), nitrous oxide and ozone.
24. How do pollutants that reach the stratosphere affect life on earth? (2) [June 2008]

    Ans: Pollutants like CFC's reach the stratosphere and cause the depletion of ozone layer. Due to this, more UV radiation reaches into troposphere and leads to the following harmful effects:
    - *It leads to ageing of skin, cataract, sunburn, skin cancer, killing of many phytoplanktons, damage to fish productivity etc.*
    - *It leads to the mutation of cells.*
25. 'Use of DDT pollutes the environment.' Justify. (2) [February 2008]

    Ans: DDT is water insoluble and non-biodegradable. Therefore it is transferred from lower trophic level to higher trophic level through food chain. It results in serious metabolic and physiological disorder in higher animals.

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