1

Some Basic Concepts of Chemistry

Topic 1 Mole Concept

Objective Questions I (Only one correct option)

1. 5 moles of AB_2 weight 125×10^{-3} kg and 10 moles of A_2B_2 weight 300×10^{-3} kg. The molar mass of $A(M_A)$ and molar mass of $B(M_B)$ in kg mol^{-1} are **(2019 Main, 12 April I)**

(a) $M_A = 10 \times 10^{-3}$ and $M_B = 5 \times 10^{-3}$

(b) $M_A = 50 \times 10^{-3}$ and $M_B = 25 \times 10^{-3}$

(c) $M_A = 25 \times 10^{-3}$ and $M_B = 50 \times 10^{-3}$

(d) $M_A = 5 \times 10^{-3}$ and $M_B = 10 \times 10^{-3}$

2. The minimum amount of $O_2(g)$ consumed per gram of reactant is for the reaction (Given atomic mass : Fe = 56, O = 16, Mg = 24, P = 31, C = 12, H = 1) **(2019 Main, 10 April II)**

(a) $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$

(b) $P_4(s) + 5O_2(g) \longrightarrow P_4O_{10}(s)$

(c) $4Fe(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s)$

(d) $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$

3. At 300 K and 1 atmospheric pressure, 10 mL of a hydrocarbon required 55 mL of O_2 for complete combustion and 40 mL of CO_2 is formed. The formula of the hydrocarbon is **(2019 Main, 10 April I)**

(a) C_4H_7Cl (b) C_4H_6 (c) C_4H_{10} (d) C_4H_8

4. 10 mL of 1 mM surfactant solution forms a monolayer covering 0.24 cm^2 on a polar substrate. If the polar head is approximated as a cube, what is its edge length? **(2019 Main, 9 April II)**

(a) 2.0 pm (b) 0.1 nm (c) 1.0 pm (d) 2.0 nm

5. For a reaction, $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$, identify dihydrogen ($H_2$) as a limiting reagent in the following reaction mixtures. **(2019 Main, 9 April I)**

(a) 56 g of N_2 + 10 g of H_2 (b) 35 g of N_2 + 8 g of H_2

(c) 14 g of N_2 + 4 g of H_2 (d) 28 g of N_2 + 6 g of H_2

6. The percentage composition of carbon by mole in methane is **(2019 Main, 8 April II)**

(a) 75% (b) 20% (c) 25% (d) 80%

7. 8 g of NaOH is dissolved in 18 g of H_2O. Mole fraction of NaOH in solution and molality (in mol kg^{-1}) of the solution respectively are **(2019 Main, 12 Jan II)**

(a) 0.2, 11.11 (b) 0.167, 22.20

(c) 0.2, 22.20 (d) 0.167, 11.11

8. The volume strength of 1 M H_2O_2 is (Molar mass of H_2O_2 = 34 g mol^{-1}) **(2019 Main, 12 Jan II)**

(a) 16.8 (b) 22.4 (c) 11.35 (d) 5.6

9. The amount of sugar ($C_{12}H_{22}O_{11}$) required to prepare 2 L of its 0.1 M aqueous solution is **(2019 Main, 10 Jan II)**

(a) 17.1 g (b) 68.4 g (c) 136.8 g (d) 34.2 g

10. For the following reaction, the mass of water produced from 445 g of $C_{57}H_{110}O_6$ is :

$2C_{57}H_{110}O_6(s) + 163O_2(g) \rightarrow 114CO_2(g) + 110\,H_2O(l)$ **(2019 Main, 9 Jan II)**

(a) 490 g (b) 495 g (c) 445 g (d) 890 g

11. A solution of sodium sulphate contains 92 g of Na^+ ions per kilogram of water. The molality of Na^+ ions in that solution in mol kg^{-1} is **(2019 Main, 9 Jan I)**

(a) 16 (b) 4 (c) 132 (d) 8

12. The most abundant elements by mass in the body of a healthy human adult are oxygen (61.4%), carbon (22.9%), hydrogen (10.0 %), and nitrogen (2.6%). The weight which a 75 kg person would gain if all ^1H atoms are replaced by ^2H atoms is **(2017 JEE Main)**

(a) 15 kg (b) 37.5 kg

(c) 7.5 kg (d) 10 kg

13. 1 g of a carbonate (M_2CO_3) on treatment with excess HCl produces 0.01186 mole of CO_2. The molar mass of M_2CO_3 in g mol^{-1} is **(2017 JEE Main)**

(a) 1186 (b) 84.3 (c) 118.6 (d) 11.86

14. At 300 K and 1 atm, 15 mL of a gaseous hydrocarbon requires 375 mL air containing 20% O_2 by volume for complete combustion. After combustion, the gases occupy 330 mL. Assuming that the water formed is in liquid form and the volumes were measured at the same temperature and pressure, the formula of the hydrocarbon is **(2016 Main)**

(a) C_3H_8 (b) C_4H_8 (c) C_4H_{10} (d) C_3H_6

15. The molecular formula of a commercial resin used for exchanging ions in water softening is $C_8H_7SO_3Na$ (molecular weight = 206). What would be the maximum uptake of Ca^{2+} ions by the resin when expressed in mole per gram resin? **(2015 Main)**

(a) $\frac{1}{103}$ (b) $\frac{1}{206}$ (c) $\frac{2}{309}$ (d) $\frac{1}{412}$

16. 3 g of activated charcoal was added to 50 mL of acetic acid solution (0.06 N) in a flask. After an hour it was filtered and the strength of the filtrate was found to be 0.042 N. The amount of acetic acid adsorbed (per gram of charcoal) is **(2015 Main)**

(a) 18 mg (b) 36 mg (c) 42 mg (d) 54 mg

17. The ratio mass of oxygen and nitrogen of a particular gaseous mixture is 1 : 4. The ratio of number of their molecule is **(2014 Main)**

(a) 1 : 4 (b) 7 : 32 (c) 1 : 8 (d) 3 : 16

18. The molarity of a solution obtained by mixing 750 mL of 0.5 M HCl with 250 mL of 2 M HCl will be **(2013 Main)**

(a) 0.875 M (b) 1.00 M (c) 1.75 M (d) 0.0975M

19. Dissolving 120 g of urea (mol. wt. 60) in 1000 g of water gave a solution of density 1.15 g/mL. The molarity of the solution is **(2011)**

(a) 1.78 M (b) 2.00 M (c) 2.05 M (d) 2.22 M

20. Given that the abundances of isotopes $_{54}Fe$, $_{56}Fe$ and $_{57}Fe$ are 5%, 90% and 5%, respectively, the atomic mass of Fe is **(2009)**

(a) 55.85 (b) 55.95
(c) 55.75 (d) 56.05

21. Mixture X = 0.02 mole of $[Co(NH_3)_5SO_4]Br$ and 0.02 mole of $[Co(NH_3)_5Br]SO_4$ was prepared in 2 L solution.

1 L of mixture X + excess of $AgNO_3$ solution $\longrightarrow Y$

1 L of mixture X + excess of $BaCl_2$ solution $\longrightarrow Z$

Number of moles of Y and Z are **(2003, 1M)**

(a) 0.01, 0.01 (b) 0.02, 0.01
(c) 0.01, 0.02 (d) 0.02, 0.02

22. Which has maximum number of atoms? **(2003, 1M)**

(a) 24 g of C (12) (b) 56 g of Fe (56)
(c) 27 g of Al (27) (d) 108 g of Ag (108)

23. How many moles of electron weighs 1 kg?

(a) 6.023×10^{23} (b) $\frac{1}{9.108} \times 10^{31}$ **(2002, 3M)**

(c) $\frac{6.023}{9.108} \times 10^{54}$ (d) $\frac{1}{9.108 \times 6.023} \times 10^{8}$

24. The normality of 0.3 M phosphorus acid (H_3PO_3) is **(1999, 2M)**

(a) 0.1 (b) 0.9 (c) 0.3 (d) 0.6

25. In which mode of expression, the concentration of a solution remains independent of temperature? **(1988, 1M)**

(a) Molarity (b) Normality (c) Formality (d) Molality

26. A molal solution is one that contains one mole of solute in **(1986, 1M)**

(a) 1000 g of solvent (b) 1.0 L of solvent
(c) 1.0 L of solution (d) 22.4 L of solution

27. If 0.50 mole of $BaCl_2$ is mixed with 0.20 mole of Na_3PO_4, the maximum number of moles of $Ba_3(PO_4)_2$ that can be formed is **(1981, 1M)**

(a) 0.70 (b) 0.50 (c) 0.20 (d) 0.10

28. 2.76 g of silver carbonate on being strongly heated yields a residue weighing **(1979, 1M)**

(a) 2.16 g (b) 2.48 g (c) 2.32 g (d) 2.64 g

29. When the same amount of zinc is treated separately with excess of sulphuric acid and excess of sodium hydroxide, the ratio of volumes of hydrogen evolved is **(1979, 1M)**

(a) 1 : 1 (b) 1 : 2 (c) 2 : 1 (d) 9 : 4

30. The largest number of molecules is in **(1979, 1M)**

(a) 36 g of water
(b) 28 g of CO
(c) 46 g of ethyl alcohol
(d) 54 g of nitrogen pentaoxide (N_2O_5)

31. The total number of electrons in one molecule of carbon dioxide is **(1979, 1M)**

(a) 22 (b) 44 (c) 66 (d) 88

32. A gaseous mixture contains oxygen and nitrogen in the ratio of 1:4 by weight. Therefore, the ratio of their number of molecules is **(1979, 1M)**

(a) 1 : 4 (b) 1 : 8 (c) 7 : 32 (d) 3 : 16

Numerical Answer Type Questions

33. A 100 mL solution was made by adding 1.43 g of $Na_2CO_3 \cdot xH_2O$. The normality of the solution is 0.1 N. The value of x is …… .

(The atomic mass of Na is 23 g/mol) **(2020 Main, 4 Sep II)**

34. Galena (an ore) is partially oxidised by passing air through it at high temperature. After some time, the passage of air is stopped, but the heating is continued in a closed furnace such that the content undergo self-reduction. The weight (in kg) of Pb produced per kg of O_2 consumed is …… .

(Atomic weights in g mol^{-1} : O = 16, S = 32, Pb = 207) **(2018 Adv.)**

35. To measure the quantity of $MnCl_2$ dissolved in an aqueous solution, it was completely converted to $KMnO_4$ using the reaction,

$MnCl_2 + K_2S_2O_8 + H_2O \longrightarrow KMnO_4 + H_2SO_4 + HCl$

(equation not balanced).

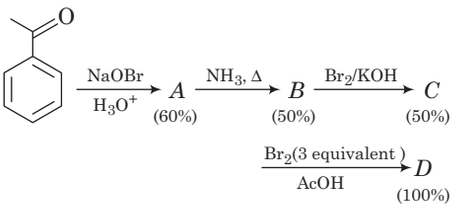
Few drops of concentrated HCl were added to this solution and gently warmed. Further, oxalic acid (225 mg) was added in portions till the colour of the permanganate ion disappeared. The quantity of $MnCl_2$ (in mg) present in the initial solution is …… .

(Atomic weights in g mol^{-1}: Mn = 55, Cl = 35.5)

(2018 Adv.)

36. In the following reaction sequence, the amount of ***D*** (in gram) formed from 10 moles of acetophenone is …….

(Atomic weights in g mol^{-1} : H = 1, C = 12, N = 14, O = 16, Br = 80. The yield (%) corresponding to the product in each step is given in the parenthesis)



(2018 Adv.)

Fill in the Blanks

37. The weight of 1×10^{22} molecules of $CuSO_4 \cdot 5H_2O$ is …… . **(1991, 1M)**

38. 3.0 g of a salt of molecular weight 30 is dissolved in 250 g water. The molarity of the solution is ……. **(1983, 1M)**

39. The total number of electrons present in 18 mL of water is …… . **(1980, 1M)**

40. The modern atomic mass unit is based on the mass of …… . **(1980, 1M)**

Integer Answer Type Questions

41. The mole fraction of a solute in a solution is 0.1. At 298 K, molarity of this solution is the same as its molality. Density of this solution at 298 K is 2.0 g cm^{-3}. The ratio of the molecular weights of the solute and solvent, $\left(\frac{m_{\text{solute}}}{m_{\text{solvent}}}\right)$ is ... . **(2016 Adv.)**

42. A compound H_2X with molar weight of 80 g is dissolved in a solvent having density of 0.4 g mL^{-1}. Assuming no change in volume upon dissolution, the molality of a 3.2 molar solution is **(2014 Adv.)**

43. 29.2% (*w*/*W*) HCl stock solution has density of 1.25g mL^{-1}. The molecular weight of HCl is 36.5 g mol^{-1}. The volume (mL) of stock solution required to prepare a 200 mL solution 0.4 M HCl is **(2012)**

Subjective Questions

44. 20% surface sites have adsorbed N_2. On heating N_2 gas evolved from sites and were collected at 0.001 atm and 298 K in a container of volume is 2.46 cm^3. Density of surface sites is $6.023 \times 10^{14}/cm^2$ and surface area is 1000 cm^2, find out the number of surface sites occupied per molecule of N_2. **(2005, 3M)**

45. In a solution of 100 mL 0.5 M acetic acid, one gram of active charcoal is added, which adsorbs acetic acid. It is found that the concentration of acetic acid becomes 0.49 M. If surface area of charcoal is $3.01 \times 10^2 m^2$, calculate the area occupied by single acetic acid molecule on surface of charcoal. **(2003)**

46. Find the molarity of water. Given: $\rho = 1000$ kg/m^3 **(2003)**

47. A plant virus is found to consist of uniform cylindrical particles of 150 Å in diameter and 5000 Å long. The specific volume of the virus is 0.75 cm^3/g. If the virus is considered to be a single particle, find its molar mass. **(1999, 3M)**

48. 8.0575×10^{-2} kg of Glauber's salt is dissolved in water to obtain 1 dm^3 of solution of density 1077.2 kg m^{-3}. Calculate the molality, molarity and mole fraction of Na_2SO_4 in solution. **(1994, 3M)**

49. *A* is a binary compound of a univalent metal. 1.422 g of *A* reacts completely with 0.321 g of sulphur in an evacuated and sealed tube to give 1.743 g of a white crystalline solid *B*, that forms a hydrated double salt, *C* with $Al_2(SO_4)_3$. Identify *A, B* and *C*. **(1994, 2M)**

50. Upon mixing 45.0 mL 0.25 M lead nitrate solution with 25.0 mL of a 0.10 M chromic sulphate solution, precipitation of lead sulphate takes place. How many moles of lead sulphate are formed? Also calculate the molar concentrations of species left behind in the final solution. Assume that lead sulphate is completely insoluble. **(1993, 3M)**

51. Calculate the molality of 1.0 L solution of 93% H_2SO_4, (weight/volume). The density of the solution is 1.84 g/mL. **(1990, 1M)**

52. A solid mixture (5.0 g) consisting of lead nitrate and sodium nitrate was heated below 600°C until the weight of the residue was constant. If the loss in weight is 28.0 per cent, find the amount of lead nitrate and sodium nitrate in the mixture. **(1990, 4M)**

53. *n*-butane is produced by monobromination of ethane followed by Wurtz's reaction.Calculate volume of ethane at NTP required to produce 55 g *n*-butane, if the bromination takes place with 90% yield and the Wurtz's reaction with 85% yield. **(1989, 3M)**

54. A sugar syrup of weight 214.2 g contains 34.2 g of sugar ($C_{12}H_{22}O_{11}$). Calculate (i) molal concentration and (ii) mole fraction of sugar in syrup. **(1988, 2M)**

55. An unknown compound of carbon, hydrogen and oxygen contains 69.77% C and 11.63% H and has a molecular weight of 86. It does not reduces Fehling's solution but forms a bisulphate addition compound and gives a positive iodoform test. What is the possible structure(s) of unknown compound? **(1987, 3M)**

56. The density of a 3 M sodium thiosulphate solution ($Na_2S_2O_3$) is 1.25 g per mL. Calculate (i) the percentage by weight of

sodium thiosulphate (ii) the mole fraction of sodium thiosulphate and (iii) the molalities of Na^+ and $S_2O_3^{2-}$ ions. **(1983, 5M)**

57. (a) 1.0 L of a mixture of CO and CO_2 is taken. This mixture is passed through a tube containing red hot charcoal. The volume now becomes 1.6 L. The volumes are measured under the same conditions. Find the composition of mixture by volume.

(b) A compound contains 28 per cent of nitrogen and 72 per cent of a metal by weight. 3 atoms of metal combine with 2 atoms of nitrogen. Find the atomic weight of metal. **(1980, 5M)**

58. 5.00 mL of a gas containing only carbon and hydrogen were mixed with an excess of oxygen (30 mL) and the mixture exploded by means of electric spark. After explosion, the volume of the mixed gases remaining was 25 mL.

On adding a concentrated solution of KOH, the volume further diminished to 15 mL, the residual gas being pure oxygen. All volumes have been reduced to NTP. Calculate the molecular formula of the hydrocarbon gas. **(1979, 3M)**

59. In the analysis of 0.5 g sample of feldspar, a mixture of chlorides of sodium and potassium is obtained, which weighs 0.1180 g. Subsequent treatment of the mixed chlorides with silver nitrate gives 0.2451 g of silver chloride. What is the percentage of sodium oxide and potassium oxide in the sample? **(1979, 5M)**

60. The vapour density (hydrogen = 1) of a mixture consisting of NO_2 and N_2O_4 is 38.3 at 26.7°C. Calculate the number of moles of NO_2 in 100 g of the mixture. **(1979, 5M)**

61. Accounts for the following. Limit your answer to two sentences, "Atomic weights of most of the elements are fractional". **(1979, 1M)**

62. Naturally occurring boron consists of two isotopes whose atomic weights are 10.01 and 11.01. The atomic weight of natural boron is 10.81. Calculate the percentage of each isotope in natural boron. **(1978, 2M)**

Topic 2 Equivalent Concept, Neutralisation and Redox Titration

Objective Questions I (Only one correct option)

1. An example of a disproportionation reaction is **(2019 Main, 12 April I)**

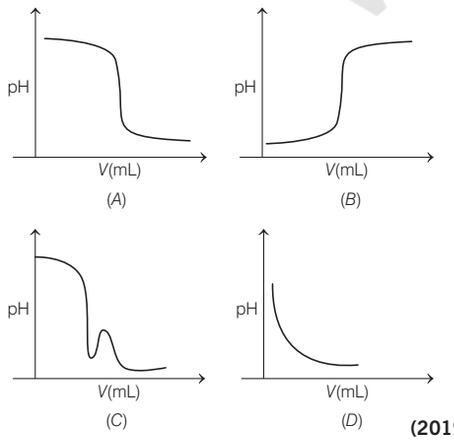
(a) $2MnO_4^- + 10I^- + 16H^+ \longrightarrow 2Mn^{2+} + 5I_2 + 8H_2O$

(b) $2NaBr + Cl_2 \longrightarrow 2NaCl + Br_2$

(c) $2KMnO_4 \longrightarrow K_2MnO_4 + MnO_2 + O_2$

(d) $2CuBr \longrightarrow CuBr_2 + Cu$

2. In an acid-base titration, 0.1 M HCl solution was added to the NaOH solution of unknown strength. Which of the following correctly shows the change of pH of the titration mixture in this experiment? **(2019 Main, 9 April II)**



(a) (*D*) (b) (*A*)

(c) (*B*) (d) (*C*)

3. 0.27 g of a long chain fatty acid was dissolved in 100 cm^3 of hexane. 10 mL of this solution was added dropwise to the surface of water in a round watch glass. Hexane evaporates and a monolayer is formed. The distance from edge to centre of the watch glass is 10 cm. What is the height of the monolayer? [Density of fatty acid = 0.9 g cm^{-3}; $\pi = 3$] **(2019 Main, 8 April II)**

(a) 10^{-6} m (b) 10^{-4} m

(c) 10^{-8} m (d) 10^{-2} m

4. In order to oxidise a mixture of one mole of each of FeC_2O_4, $Fe_2(C_2O_4)_3$, $FeSO_4$ and $Fe_2(SO_4)_3$ in acidic medium, the number of moles of $KMnO_4$ required is **(2019 Main, 8 April I)**

(a) 2 (b) 1 (c) 3 (d) 1.5

5. 100 mL of a water sample contains 0.81 g of calcium bicarbonate and 0.73 g of magnesium bicarbonate. The hardness of this water sample expressed in terms of equivalents of $CaCO_3$ is (molar mass of calcium bicarbonate is 162 g mol^{-1} and magnesium bicarbonate is 146 g mol^{-1}) **(2019 Main, 8 April I)**

(a) 5,000 ppm (b) 1,000 ppm

(c) 100 ppm (d) 10,000 ppm

6. 50 mL of 0.5 M oxalic acid is needed to neutralise 25 mL of sodium hydroxide solution. The amount of NaOH in 50 mL of the given sodium hydroxide solution is **(2019 Main, 12 Jan I)**

(a) 40 g (b) 80 g (c) 20 g (d) 10 g

7. 25 mL of the given HCl solution requires 30 mL of 0.1 M sodium carbonate solution. What is the volume of this HCl solution required to titrate 30 mL of 0.2 M aqueous NaOH solution? **(2019 Main, 11 Jan II)**

(a) 75 mL (b) 25 mL

(c) 12.5 mL (d) 50 mL

8. In the reaction of oxalate with permanganate in acidic medium, the number of electrons involved in producing one molecule of CO_2 is **(2019 Main, 10 Jan II)**
(a) 2 (b) 5 (c) 1 (d) 10

9. The ratio of mass per cent of C and H of an organic compound ($C_xH_yO_z$) is 6 : 1. If one molecule of the above compound ($C_xH_yO_z$) contains half as much oxygen as required to burn one molecule of compound C_xH_y completely to CO_2 and H_2O. The empirical formula of compound $C_xH_yO_z$ is **(2018 Main)**
(a) $C_3H_6O_3$ (b) C_2H_4O (c) $C_3H_4O_2$ (d) $C_2H_4O_3$

10. An alkali is titrated against an acid with methyl orange as indicator, which of the following is a correct combination? **(2018 Main)**

	Base	Acid	End point
(a)	Weak	Strong	Colourless to pink
(b)	Strong	Strong	Pinkish red to yellow
(c)	Weak	Strong	Yellow to pinkish red
(d)	Strong	Strong	Pink to colourless

11. From the following statements regarding H_2O_2 choose the incorrect statement. **(2015 Main)**
(a) It can act only as an oxidising agent
(b) It decomposed on exposure to light
(c) It has to be stored in plastic or wax lined glass bottles in dark
(d) It has to be kept away from dust

12. Consider a titration of potassium dichromate solution with acidified Mohr's salt solution using diphenylamine as indicator. The number of moles of Mohr's salt required per mole of dichromate is **(2007, 3M)**
(a) 3 (b) 4 (c) 5 (d) 6

13. In the standardisation of $Na_2S_2O_3$ using $K_2Cr_2O_7$ by iodometry, the equivalent weight of $K_2Cr_2O_7$ is **(2001, 1M)**
(a) (molecular weight)/2 (b) (molecular weight)/6
(c) (molecular weight)/3 (d) same as molecular weight

14. The reaction, $3ClO^-(aq) \longrightarrow ClO_3^-(aq) + 2Cl^-(aq)$ is an example of **(2001)**
(a) oxidation reaction
(b) reduction reaction
(c) disproportionation reaction
(d) decomposition reaction

15. An aqueous solution of 6.3 g oxalic acid dihydrate is made up to 250 mL. The volume of 0.1 N NaOH required to completely neutralise 10 mL of this solution is **(2001, 1M)**
(a) 40 mL (b) 20 mL (c) 10 mL (d) 4 mL

16. Among the following, the species in which the oxidation number of an element is + 6 **(2000)**
(a) MnO_4^- (b) $Cr(CN)_6^{3-}$
(c) NiF_6^{2-} (d) CrO_2Cl_2

17. The oxidation number of sulphur in S_8, S_2F_2, H_2S respectively, are **(1999)**
(a) 0, +1 and –2 (b) +2, +1 and –2
(c) 0, +1 and +2 (d) –2, +1 and –2

18. The number of moles of $KMnO_4$ that will be needed to react completely with one mole of ferrous oxalate in acidic medium is **(1997)**
(a) $\frac{2}{5}$ (b) $\frac{3}{5}$ (c) $\frac{4}{5}$ (d) 1

19. The number of moles of $KMnO_4$ that will be needed to react with one mole of sulphite ion in acidic solution is **(1997)**
(a) $\frac{2}{5}$ (b) $\frac{3}{5}$ (c) $\frac{4}{5}$ (d) 1

20. For the redox reaction

$$MnO_4^- + C_2O_4^{2-} + H^+ \longrightarrow Mn^{2+} + CO_2 + H_2O$$

The correct coefficients of the reactants for the balanced reaction are **(1992)**

	MnO_4^-	$C_2O_4^{2-}$	H^+
(a)	2	5	16
(b)	16	5	2
(c)	5	16	2
(d)	2	16	5

21. The volume strength of 1.5 N H_2O_2 is **(1990, 1M)**
(a) 4.8 (b) 8.4 (c) 3.0 (d) 8.0

22. The oxidation number of phosphorus in $Ba(H_2PO_2)_2$ is **(1988)**
(a) +3 (b) +2
(c) +1 (d) –1

23. The equivalent weight of $MnSO_4$ is half of its molecular weight, when it converts to **(1988, 1M)**
(a) Mn_2O_3 (b) MnO_2
(c) MnO_4^- (d) MnO_4^{2-}

Objective Question II (More than one correct option)

24. For the reaction, $I^- + ClO_3^- + H_2SO_4 \longrightarrow Cl^- + HSO_4^- + I_2$ the correct statement(s) in the balanced equation is/are **(2014 Adv.)**
(a) stoichiometric coefficient of HSO_4^- is 6
(b) iodide is oxidised
(c) sulphur is reduced
(d) H_2O is one of the products

Numerical Answer Type Questions

25. 5.00 mL of 0.10 M oxalic acid solution taken in a conical flask is titrated against NaOH from a burette using phenolphthalein indicator. The volume of NaOH required for the appearance of permanent faint pink color is tabulated below for five experiments. What is the concentration, in molarity, of the NaOH solution?

Exp. No.	Vol. of NaOH (mL)
1	12.5
2	10.5
3	9.0
4	9.0
5	9.0

(2020 Adv.)

26. Aluminium reacts with sulphuric acid to form aluminium sulphate and hydrogen. What is the volume of hydrogen gas in litre (L) produced at 300 K and 1.0 atm pressure, when 5.4 g of aluminium and 50.0 mL of 5.0 M sulphuric acid are combined for the reaction?

(Use molar mass of aluminium as 27.0 g mol^{-1}, $R = 0.082$ atm L mol^{-1} K^{-1}) **(2020 Adv.)**

27. A 20.0 mL solution containing 0.2 g impure H_2O_2 reacts completely with 0.316 g of $KMnO_4$ in acid solution. The purity of H_2O_2 (in%) is ..... (molecular weight of H_2O_2 = 34; molecular weight of $KMnO_4$ = 158).

(2020 Main, 4 Sep I)

28. The ammonia prepared by treating ammonium sulphate with calcium hydroxide is completely used by $NiCl_2 \cdot 6H_2O$ to form a stable coordination compound. Assume that both the reactions are 100% complete. If 1584 g of ammonium sulphate and 952 g of $NiCl_2 \cdot 6H_2O$ are used in the preparation, the combined weight (in grams) of gypsum and the nickel-ammonia coordination compound thus produced is____

(Atomic weights in g mol^{-1} : H = 1, N = 14, O = 16, S = 32, Cl = 35.5, Ca = 40, Ni = 59) **(2018 Adv.)**

Assertion and Reason

Read the following questions and answer as per the direction given below :

(a) Statement I is true; Statement II is true; Statement II is the correct explanation of Statement I.

(b) Statement I is true; Statement II is true; Statement II is not the correct explanation of Statement I.

(c) Statement I is true; Statement II is false.

(d) Statement I is false; Statement II is true.

29. **Statement I** In the titration of Na_2CO_3 with HCl using methyl orange indicator, the volume required at the equivalence point is twice that of the acid required using phenolphthalein indicator.

Statement II Two moles of HCl are required for the complete neutralisation of one mole of Na_2CO_3. **(1991, 2M)**

Fill in the Blanks

30. The compound $YBa_2Cu_3O_7$, which shows super conductivity, has copper in oxidation state ……. Assume that the rare earth element yttrium is in its usual + 3 oxidation state. **(1994, 1M)**

Integer Answer Type Questions

31. The difference in the oxidation numbers of the two types of sulphur atoms in $Na_2S_4O_6$ is **(2011)**

32. Among the following, the number of elements showing only one non-zero oxidation state is O, Cl, F, N, P, Sn, Tl, Na, Ti **(2010)**

33. A student performs a titration with different burettes and finds titrate values of 25.2 mL, 25.25 mL, and 25.0 mL. The number of significant figures in the average titrate value is **(2010)**

Subjective Questions

34. Calculate the amount of calcium oxide required when it reacts with 852 g of P_4O_{10}. **(2005, 2M)**

35. Hydrogen peroxide solution (20 mL) reacts quantitatively with a solution of $KMnO_4$ (20 mL) acidified with dilute H_2SO_4. The same volume of the $KMnO_4$ solution is just decolourised by 10 mL of $MnSO_4$ in neutral medium simultaneously forming a dark brown precipitate of hydrated MnO_2. The brown precipitate is dissolved in 10 mL of 0.2 M sodium oxalate under boiling condition in the presence of dilute H_2SO_4. Write the balanced equations involved in the reactions and calculate the molarity of H_2O_2. **(2001)**

36. How many millilitres of 0.5 M H_2SO_4 are needed to dissolve 0.5 g of copper (II) carbonate? **(1999, 3M)**

37. An aqueous solution containing 0.10 g KIO_3 (formula weight = 214.0) was treated with an excess of KI solution. The solution was acidified with HCl. The liberated I_2 consumed 45.0 mL of thiosulphate solution decolourise the blue starch-iodine complex. Calculate the molarity of the sodium thiosulphate solution. **(1998, 5M)**

38. To a 25 mL H_2O_2 solution, excess of acidified solution of potassium iodide was added. The iodine liberated required 20 mL of 0.3 N sodium thiosulphate solution. Calculate the volume strength of H_2O_2 solution. **(1997, 5M)**

39. A 3.00 g sample containing Fe_3O_4, Fe_2O_3 and an inert impure substance, is treated with excess of KI solution in presence of dilute H_2SO_4. The entire iron is converted into Fe^{2+} along with the liberation of iodine. The resulting solution is diluted to 100 mL . A 20 mL of the diluted solution requires 11.0 mL of 0.5 M $Na_2S_2O_3$ solution to reduce the iodine present. A 50 mL of the dilute solution, after complete extraction of the iodine required 12.80 mL of 0.25 M $KMnO_4$ solution in dilute H_2SO_4 medium for the oxidation of Fe^{2+}. Calculate the percentage of Fe_2O_3 and Fe_3O_4 in the original sample. **(1996, 5M)**

40. A 20.0 cm^3 mixture of CO, CH_4 and He gases is exploded by an electric discharge at room temperature with excess of oxygen. The volume contraction is found to be 13.0 cm^3.

A further contraction of 14.0 cm^3 occurs when the residual gas is treated with KOH solution. Find out the composition of the gaseous mixture in terms of volume percentage. **(1995, 4M)**

41. A 5.0 cm^3 solution of H_2O_2 liberates 0.508 g of iodine from an acidified KI solution. Calculate the strength of H_2O_2 solution in terms of volume strength at STP. **(1995, 3M)**

42. One gram of commercial $AgNO_3$ is dissolved in 50 mL of water. It is treated with 50 mL of a KI solution. The silver iodide thus precipitated is filtered off. Excess of KI in the filtrate is titrated with (M/10) KIO_3 solution in presence of 6 M HCl till all I^- ions are converted into ICl. It requires 50 mL of (M/10) KIO_3 solution, 20 mL of the same stock solution of KI requires 30 mL of (M/10) KIO_3 under similar conditions. Calculate the percentage of $AgNO_3$ in the sample.

Reaction $KIO_3 + 2KI + 6HCl \longrightarrow 3ICl + 3KCl + 3H_2O$

(1992, 4M)

43. A 2.0 g sample of a mixture containing sodium carbonate, sodium bicarbonate and sodium sulphate is gently heated till the evolution of CO_2 ceases. The volume of CO_2 at 750 mm Hg pressure and at 298 K is measured to be 123.9 mL. A 1.5 g of the same sample requires 150 mL of (M/10) HCl for complete neutralisation. Calculate the percentage composition of the components of the mixture. **(1992, 5M)**

44. A 1.0 g sample of Fe_2O_3 solid of 55.2% purity is dissolved in acid and reduced by heating the solution with zinc dust. The resultant solution is cooled and made up to 100.0 mL. An aliquot of 25.0 mL of this solution requires for titration. Calculate the number of electrons taken up by the oxidant in the reaction of the above titration. **(1991, 4M)**

45. A solution of 0.2 g of a compound containing Cu^{2+} and $C_2O_4^{2-}$ ions on titration with 0.02 M $KMnO_4$ in presence of H_2SO_4 consumes 22.6 mL of the oxidant. The resultant solution is neutralised with Na_2CO_3, acidified with dilute acetic acid and treated with excess KI. The liberated iodine requires 11.3 mL of 0.05 M $Na_2S_2O_3$ solution for complete reduction. Find out the mole ratio of Cu^{2+} to $C_2O_4^{2-}$ in the compound. Write down the balanced redox reactions involved in the above titrations. **(1991, 5M)**

46. A mixture of $H_2C_2O_4$ (oxalic acid) and $NaHC_2O_4$ weighing 2.02 g was dissolved in water and the solution made up to one litre. Ten millilitres of the solution required 3.0 mL of 0.1 N sodium hydroxide solution for complete neutralisation. In another experiment, 10.0 mL of the same solution, in hot dilute sulphuric acid medium, required 4.0 mL of 0.1 N potassium permanganate solution for complete reaction. Calculate the amount of $H_2C_2O_4$ and $NaHC_2O_4$ in the mixture. **(1990, 5M)**

47. An organic compound *X* on analysis gives 24.24 per cent carbon and 4.04 per cent hydrogen. Further, sodium extract of 1.0 g of *X* gives 2.90 g of silver chloride with acidified silver nitrate solution. The compound *X* may be represented by two isomeric structures *Y* and *Z*. *Y* on treatment with aqueous potassium hydroxide solution gives a dihydroxy compound while *Z* on similar treatment gives ethanal. Find out the molecular formula of *X* and gives the structure of *Y* and *Z*. **(1989, 5M)**

48. An equal volume of a reducing agent is titrated separately with 1 M $KMnO_4$ in acid, neutral and alkaline medium. The volumes of $KMnO_4$ required are 20 mL in acid, 33.3 mL in neutral and 100 mL in alkaline media. Find out the oxidation state of manganese in each reduction product. Give the balanced equations for all the three half reaction. Find out the volume of 1M $K_2Cr_2O_7$ consumed, if the same volume of the reducing agent is titrated in acid medium. **(1989, 5M)**

49. A sample of hydrazine sulphate ($N_2H_6SO_4$) was dissolved in 100 mL of water, 10 mL of this solution was reacted with excess of ferric chloride solution and warmed to complete the reaction. Ferrous ion formed was estimated and it, required 20 mL of M/50 potassium permanganate solution. Estimate the amount of hydrazine sulphate in one litre of the solution.

Reaction $4Fe^{3+} + N_2H_4 \longrightarrow N_2 + 4Fe^{2+} + 4H^+$

$MnO_4^- + 5Fe^{2+} + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

(1988, 3M)

50. 5 mL of 8 N nitric acid, 4.8 mL of 5 N hydrochloric acid and a certain volume of 17 M sulphuric acid are mixed together and made up to 2 L. 30 mL of this acid mixture exactly neutralise 42.9 mL of sodium carbonate solution containing one gram of $Na_2CO_3 \cdot 10H_2O$ in 100 mL of water. Calculate the amount in gram of the sulphate ions in solution. **(1985, 4M)**

51. 2.68×10^{-3} moles of a solution containing an ion A^{n+} require 1.61×10^{-3} moles of MnO_4^- for the oxidation of A^{n+} to AO_3^- in acidic medium. What is the value of *n* ? **(1984, 2M)**

52. 4.08 g of a mixture of BaO and unknown carbonate MCO_3 was heated strongly. The residue weighed 3.64 g. This was dissolved in 100 mL of 1 N HCl. The excess acid required 16 mL of 2.5 N NaOH solution for complete neutralisation. Identify the metal *M*. **(1983, 4M)**

Answers

Topic 1

1. (d)	**2.** (c)	**3.** (b)	**4.** (a)
5. (d)	**6.** (b)	**7.** (d)	**8.** (c)
9. (b)	**10.** (b)	**11.** (b)	**12.** (c)
13. (b)	**14.** (*)	**15.** (d)	**16.** (d)
17. (b)	**18.** (a)	**19.** (c)	**20.** (b)
21. (a)	**22.** (a)	**23.** (d)	**24.** (d)
25. (d)	**26.** (a)	**27.** (d)	**28.** (a)
29. (a)	**30.** (a)	**31.** (a)	**32.** (c)

33. (10.00) **34.** (6.47kg) **35.** (126 mg) **36.** (495 g)
37. (4.14 g) **38.** (0.4) **39.** (6.023×10^{24}) **40.** C-12 isotope
41. (9) **42.** (8) **43.** (8 mL) **44.** (2)
45. (5×10^{-19} m^2) **46.** (55.56 mol L^{-1}) **47.** (70.91×10^{6} g) **48.** (4.3×10^{-3})
51. (10.42) **52.** (1.7 g) **53.** (55.55 L) **54.** (9.9×10^{-3})
56. (i) (37.92), (ii) (0.065), (iii) (7.73m) **57.** (a) (0.6), (b) (24)
59. (i) (0.0179 g), (ii) (10.6 %) **60.** (0.437) **62.** (20 %)

Topic 2

1. (d) **2.** (b) **3.** (a) **4.** (a)
5. (d) **6.** (*) **7.** (b) **8.** (c)
9. (d) **10.** (c) **11.** (a) **12.** (d)
13. (b) **14.** (c) **15.** (a) **16.** (d)
17. (a) **18.** (b) **19.** (a) **20.** (a)
21. (b) **22.** (c) **23.** (b) **24.** (a,b,d)
25. (0.11) **26.** (6.15) **27.** (85)
28. (2992) **29.** (b) **30.** 7 / 3 **31.** (5)
32. (2) **33.** (3) **34.** (1008 g) **36.** (8.096 mL)
37. (0.062 M) **38.** (1.334 V) **42.** (85%) **44.** (1.04)
45. (1:2) **48.** (16.67 mL) **49.** ($6.5 g L^{-1}$) **50.** (6.5376 g)
51. (2) **52.** (Ca)

Hints & Solutions

Topic 1 Mole Concept

1. **Key Idea** To find the mass of A and B in the given question, mole concept is used.

$$\text{Number of moles}(n) = \frac{\text{given mass } (w)}{\text{molecular mass } (M)}$$

Compound	Mass of A (g)	Mass of B (g)
AB_2	M_A	$2M_B$
A_2B_2	$2M_A$	$2M_B$

We know that,

$$\text{Number of moles } (n) = \frac{\text{given mass } (w)}{\text{molecular mass } (M)}$$

$$n \times M = w \qquad \ldots(A)$$

Using equation (A), it can be concluded that

$$5(M_A + 2M_B) = 125\times10^{-3}\text{ kg} \qquad \ldots(i)$$

$$10(2M_A + 2M_B) = 300\times10^{-3}\text{ kg} \qquad \ldots(ii)$$

From equation (i) and (ii)

$$\frac{1}{2}\frac{(M_A + 2M_B)}{(2M_A + 2M_B)} = \left(\frac{125}{300}\right)$$

On solving the equation, we obtain

$$M_A = 5\times10^{-3}$$

and $$M_B = 10\times10^{-3}$$

So, the molar mass of $A(M_A)$ is 5×10^{-3} kg mol^{-1} and $B(M_B)$ is 10×10^{-3} kg mol^{-1}.

2. (a) $\underset{44g}{C_3H_8}(g) + \underset{160g}{5O_2}(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$

$\Rightarrow$ 1g of reactant $= \frac{160}{44}$ g of O_2 consumed = 3.64 g

(b) $\underset{124g}{P_4}(s) + \underset{160g}{5O_2}(g) \longrightarrow P_4O_{10}(s)$

$\Rightarrow$1 g of reactant $= \frac{160}{124}$ g of O_2 consumed = 1.29 g

(c) $\underset{244g}{4Fe}(s) + \underset{96g}{3O_2}(g) \longrightarrow 2Fe_2O_3(s)$

$\Rightarrow$ 1 g of reactant $= \frac{96}{224}$ g of O_2 consumed = 0.43 g

(d) $\underset{48\ g}{2Mg}(s) + \underset{32\ g}{O_2}(g) \longrightarrow 2MgO(s)$

$\Rightarrow$ 1 g of reactant $= \frac{32}{48}$ g of O_2 consumed = 0.67 g

So, minimum amount of O_2 is consumed per gram of reactant (Fe) in reaction (c).

3. In eudiometry,

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \xrightarrow[1\text{ atm}]{300\text{ K}} x\,CO_2 + \frac{y}{2}H_2O$$

1 mol	$\left(x+\frac{y}{4}\right)$mol	x mol
1 mL	$\left(x+\frac{y}{4}\right)$mL	x mL
10 mL	$\left(x+\frac{y}{4}\right)\times10$ mL	$10x$ mL

Given, (i) $V_{CO_2} = 10x = 40$ mL $\Rightarrow x = 4$

(ii) $V_{O_2} = 10\left(x + \frac{y}{4}\right)$ mL = 55 mL

$\Rightarrow$ $10\left(4 + \frac{y}{4}\right) = 55$ [$\because x = 4$]

$\Rightarrow$ $40 + \frac{y\times10}{4} = 55$

$\Rightarrow$ $y\times\frac{10}{4} = 15 \Rightarrow y = 15\times\frac{4}{10} = 6$

So, the hydrocarbon (C_xH_y) is C_4H_6.

4. Given, volume = 10 mL

Molarity = 1 mM = 10^{-3} M

$\therefore$ Number of millimoles = 10 mL $\times$ 10^{-3} M = 10^{-2}

Number of moles = 10^{-5}

Now, number of molecules

= Number of moles $\times$ Avogadro's number

= $10^{-5}\times6\times10^{23} = 6\times10^{18}$

3

Periodic Classification and Periodic Properties

Topic 1 History and Periodic Classification

Objective Questions I (Only one correct option)

1. The IUPAC symbol for the element with atomic number 119 would be **(2019 Main, 8 April II)**

(a) unh (b) uue
(c) uun (d) une

2. The element with $Z = 120$ (not yet discovered) will be an/a **(2019 Main, 12 Jan I)**

(a) transition metal (b) inner-transition metal
(c) alkaline earth metal (d) alkali metal

3. The statement that is not correct for the periodic classification of elements, is **(1992, 1M)**

(a) the properties of elements are the periodic functions of their atomic numbers
(b) non-metallic elements are lesser in number than metallic elements
(c) the first ionisation energies of elements along a period do not vary in a regular manner with increase in atomic number
(d) for transition elements the *d*-subshells are filled with electrons monotonically with increase in atomic number

Objective Question II
(One or more than one correct option)

4. The statements that is/are true for the long form of the periodic table is/are **(1988, 1M)**

(a) it reflects the sequence of filling the electrons in the order of sub-energy level *s*, *p*, *d* and *f*
(b) it helps to predict the stable valency states of the elements
(c) it reflects tends in physical and chemical properties of the elements
(d) it helps to predict the relative ionicity of the bond between any two elements

Topic 2 Periodic Properties

Objective Questions I (Only one correct option)

1. The correct order of the ionic radii of O^{2-}, N^{3-}, F^-, Mg^{2+}, Na^+ and Al^{3+} is **(2020 Main, 5 Sep II)**

(a) $N^{3-} < O^{2-} < F^- < Na^+ < Mg^{2+} < Al^{3+}$
(b) $Al^{3+} < Na^+ < Mg^{2+} < O^{2-} < F^- < N^{3-}$
(c) $Al^{3+} < Mg^{2+} < Na^+ < F^- < O^{2-} < N^{3-}$
(d) $N^{3-} < F^- < O^{2-} < Mg^{2+} < Na^+ < Al^{3+}$

2. Within each pair of elements F and Cl, S and Se, and Li and Na, respectively, the elements that release more energy upon an electron gain are **(2020 Main, 7 Jan II)**

(a) F, Se and Na (b) F, S and Li
(c) Cl, S and Li (d) Cl, Se and Na

3. The group number, number of valence electrons and valency of an element with atomic number 15, respectively, are **(2019 Main, 12 April I)**

(a) 16, 5 and 2 (b) 15, 5 and 3
(c) 16, 6 and 3 (d) 15, 6 and 2

4. The element having greatest difference between its first and second ionisation energy, is **(2019 Main, 9 April I)**

(a) Ca (b) Sc
(c) Ba (d) K

5. The correct option with respect to the Pauling electronegativity values of the elements is **(2019 Main, 11 Jan II)**

(a) P > S (b) Si < Al
(c) Te > Se (d) Ga < Ge

6. The correct order of the atomic radii of C, Cs, Al and S is **(2019 Main, 11 Jan I)**

(a) C < S < Al < Cs (b) C < S < Cs < Al

(c) S < C < Cs < Al (d) S < C < Al < Cs

7. In general, the properties that decrease and increase down a group in the periodic table, respectively are **(2019 Main, 9 Jan I)**

(a) electronegativity and atomic radius

(b) electronegativity and electron gain enthalpy

(c) electron gain enthalpy and electronegativity

(d) atomic radius and electronegativity

8. The ionic radii (in Å) of N^{3-}, O^{2-} and F^- respectively are **(2015 Main)**

(a) 1.36, 1.40 and 1.71 (b) 1.36, 1.71 and 1.40

(c) 1.71, 1.40 and 1.36 (d) 1.71, 1.36 and 1.40

9. Which one of the following alkaline earth metal sulphates has its hydration enthalpy greater than its lattice enthalpy? **(2015 Main)**

(a) $CaSO_4$ (b) $BeSO_4$

(c) $BaSO_4$ (d) $SrSO_4$

10. Which among the following is the most reactive? **(2015 Main)**

(a) Cl_2 (b) Br_2

(c) I_2 (d) ICl

11. Which one has the highest boiling point?

(a) He (b) Ne (c) Kr (d) Xe

12. The first ionisation potential of Na is 5.1 eV. The value of electron gain enthalpy of Na^+ will be **(2013 Main)**

(a) − 2.55 eV (b) − 5.1 eV

(c) − 10.2 eV (d) + 2.55 eV

13. Which of the following represents the correct order of increasing first ionisation enthalpy for Ca, Ba, S, Se and Ar? **(2013 Main)**

(a) Ca < S < Ba < Se < Ar (b) S < Se < Ca < Ba < Ar

(c) Ba < Ca < Se < S < Ar (d) Ca < Ba < S < Se < Ar

14. Identify the least stable ion amongst the following. **(2002, 3M)**

(a) Li^+ (b) Be^-

(c) B^- (d) C^-

15. The set representing the correct order of first ionisation potential is **(2001, 1M)**

(a) K > Na > Li (b) Be > Mg > Ca

(c) B > C > N (d) Ge > Si > C

16. The correct order of radii is **(2000, 1M)**

(a) N < Be < B (b) $F^- < O^{2-} < N^{3-}$

(c) Na < Li < K (d) $Fe^{3+} < Fe^{2+} < Fe^{4+}$

17. The incorrect statement among the following. **(1997(C), 1M)**

(a) The first ionisation potential of Al is less than the first ionisation potential of Mg

(b) The second ionisation potential of Mg is greater than the second ionisation potential of Na

(c) The first ionisation potential of Na is less than the first ionisation potential of Mg

(d) The third ionisation potential of Mg is greater than third ionisation potential of Na

18. Which of the following has the maximum number of unpaired electrons ? **(1996, 1M)**

(a) Mg^{2+} (b) Ti^{3+}

(c) V^{3+} (d) Fe^{2+}

19. Amongst the following elements (whose electronic configurations are given below), the one having the highest ionisation energy is **(1990, 1M)**

(a) [Ne] $3s^2\ 3p^1$ (b) [Ne] $3s^2\ 3p^3$

(c) [Ne] $3s^2\ 3p^2$ (d) [Ar] $3d^{10}\ 4s^2\ 4p^3$

20. Which one of the following is the smallest in size? **(1989, 1M)**

(a) N^{3-} (b) O^{2-}

(c) F^- (d) Na^+

21. The first ionisation potential of Na, Mg, Al and Si are in the order **(1988, 1M)**

(a) Na < Mg > Al < Si (b) Na > Mg > Al > Si

(c) Na < Mg < Al > Si (d) Na > Mg > Al < Si

22. The electronegativity of the following elements increases in the order **(1987, 1M)**

(a) C, N, Si, P (b) N, Si, C, P

(c) Si, P, C, N (d) P, Si, N, C

23. Atomic radii of fluorine and neon in Angstrom units are respectively given by **(1987, 1M)**

(a) 0.72, 1.60 (b) 1.60, 1.60

(c) 0.72, 0.72 (d) None of these

24. The first ionisation potential in electron volts of nitrogen and oxygen atoms are respectively given by **(1987, 1M)**

(a) 14.6, 13.6 (b) 13.6, 14.6

(c) 13.6, 13.6 (d) 14.6, 14.6

25. The hydration energy of Mg^{2+} is larger than that of **(1984, 1M)**

(a) Al^{3+} (b) Na^+

(c) Be^{2+} (d) Mg^{3+}

26. The element with the highest first ionisation potential is **(1982, 1M)**

(a) boron (b) carbon

(c) nitrogen (d) oxygen

27. The correct order of second ionisation potential of carbon, nitrogen, oxygen and fluorine is **(1981, 1M)**

(a) C > N > O > F (b) O > N > F > C

(c) O > F > N > C (d) F > O > N > C

Objective Questions II

(One or more than one correct option)

28. The option(s) with only amphoteric oxides is(are) **(2017 Adv.)**

(a) NO, B_2O_3, PbO, SnO_2 (b) Cr_2O_3, CrO, SnO, PbO

(c) Cr_2O_3, BeO, SnO, SnO_2 (d) ZnO, Al_2O_3, PbO, PbO_2

29. Ionic radii of **(1999, 3M)**

(a) $Ti^{4+} < Mn^{7+}$ (b) $^{35}Cl^- < {}^{37}Cl^-$

(c) $K^+ > Cl^-$ (d) $P^{3+} > P^{5+}$

30. The first ionisation potential of nitrogen and oxygen atoms are related as follows. **(1989, 1M)**

(a) The ionisation potential of oxygen is less than the ionisation potential of nitrogen
(b) The ionisation potential of nitrogen is greater than the ionisation potential of oxygen
(c) The two ionisation potential values are comparable
(d) The difference between the two ionisation potential is too large

31. Sodium sulphate is soluble in water whereas barium sulphate is sparingly soluble because **(1989, 1M)**

(a) the hydration energy of sodium sulphate is more than its lattice energy
(b) the lattice energy of barium sulphate is more than its hydration energy
(c) the lattice energy has no role to play in solubility
(d) the hydration energy of sodium sulphate is less than its lattice energy

Assertion and Reason

Read the following questions and answer as per the direction given below :

(a) Statement I is true; Statement II is true; Statement II is the correct explanation of Statement I.
(b) Statement I is true; Statement II is true; Statement II is not the correct explanation of Statement I.
(c) Statement I is true; Statement II is false.
(d) Statement I is false; Statement II is true.

32. **Statement I** Nitrogen and oxygen are the main components in the atmosphere but these do not react to form oxides of nitrogen.
Statement II The reaction between nitrogen and oxygen requires high temperature. **(2015 Main)**

33. **Statement I** Pb^{4+} compounds are stronger oxidising agents than Sn^{4+} compounds.
Statement II The higher oxidation states for the group 14 elements are more stable for the heavier members of the group due to 'inert pair effect'. **(2008, 3M)**

34. **Statement I** Band gap in germanium is small.
Statement II The energy spread of each germanium atomic energy level is infinitesimally small. **(2007, 3M)**

35. **Statement I** The first ionisation energy of Be is greater than that of B.
Statement II 2p-orbital is lower in energy than 2s. **(2000, (S), 1M)**

36. **Statement I** F-atom has a less negative electron affinity than Cl-atom.
Statement II Additional electrons are repelled more effectively by 3 *p*-electrons in Cl-atom than by 2 *p*-electrons in F-atom. **(1998, 2M)**

Numerical Answer Type Questions

37. The 1st, 2nd and 3rd ionisation enthalpies, I_1, I_2, and I_3, of four atoms with atomic numbers n, $n+1$, $n+2$, and $n+3$, where $n < 10$, are tabulated below. What is the value of n? **(2020 Adv.)**

Atomic number	Ionisation enthalpy (kJ/mol)		
	I_1	I_2	I_3
n	1681	3374	6050
$n+1$	2081	3952	6122
$n+2$	496	4562	6910
$n+3$	738	1451	7733

Fill in the Blanks

38. Compounds that formally contain Pb^{4+} are easily reduced to Pb^{2+}. The stability of the lower oxidation state is due to …… . **(1997, 1M)**

39. Ca^{2+} has a smaller ionic radius than K^+ because it has ..... **(1993, 1M**

40. On Mulliken scale, the average of ionisation potential and electron affinity is known as ..... **(1985, 1M)**

41. The energy released when an electron is added to a neutral gaseous atom is called …… . **(1982, 1M)**

True/False

42. The basic nature of the hydroxides of group 13 (III B) decreases progressively down the group. **(1993, 1M)**

43. The decreasing order of electron affinity of F, Cl, Br is F > Cl > Br. **(1993, 1M)**

44. In group IA of alkali metals, the ionisation potential decreases down the group. Therefore, lithium is a poor reducing agent. **(1987, 1M)**

45. The softness of group IA metals increases down the group with increasing atomic number. **(1986, 1M)**

Subjective Questions

46. Arrange the following ions in order of their increasing radii Li^+, Mg^{2+}, K^+, Al^{3+}. **(1997, 1M)**

47. Compare qualitatively the first and second ionisation potentials of copper and zinc. Explain the observation. **(1996, 2M**

48. Arrange the following as stated :
"Increasing order of ionic size'' N^{3-}, Na^+, F^-, O^{2-}, Mg^{2+} **(1991, 1M)**

49. Explain the following :
"The first ionisation energy of carbon atom is greater than that of boron atom whereas, the reverse is true for the second ionisation energy.'' **(1989, 2M)**

50. Arrange the following in the order of their increasing size: Cl^-, S^{2-}, Ca^{2+}, Ar **(1986, 1M)**

51. Arrange the following in order of their
(i) decreasing ionic size Mg^{2+}, O^{2-}, Na^+, F^-
(ii) increasing first ionisation energy Mg, Al, Si, Na
(iii) increasing bond length F_2, N_2, Cl_2, O_2 **(1985, 3M)**

Answers

Topic 1

1. (b) **2.** (c) **3.** (d) **4.** (b,c,d)

Topic 2

1. (c) **2.** (c) **3.** (b) **4.** (d)
5. (d) **6.** (a) **7.** (a) **8.** (c)
9. (b) **10.** (d) **11.** (d) **12.** (b)
13. (c) **14.** (b) **15.** (b) **16.** (b)
17. (b) **18.** (d) **19.** (b) **20.** (d)
21. (a) **22.** (c) **23.** (a) **24.** (a)
25. (b) **26.** (c) **27.** (c) **28.** (a,b)
29. (d) **30.** (a,b,c) **31.** (a,b) **32.** (a)
33. (c) **34.** (c) **35.** (c) **36.** (c)
37. (9) **38.** (inert pair effect)
39. (higher effective nuclear charge)
40. (electronegativity) **41.** (electron affinity)
42. F **43.** F **44.** F **45.** T

Hints & Solutions

Topic 1 History and Periodic Classification

1. Atomic number (119) = $\underset{\text{un}}{1}\ \underset{\text{un}}{1}\ \underset{\text{en}}{9}$

So, symbol of the element = uue

Name of the element = ununennium

It is expected to be *s*-block element an alkali metal and the first element in eighth period. It is the lightest element that has not yet been synthesised.

2. The element with $Z = 120$ will be an alkaline earth metal. Recently, oganesson (Og) with atomic number 118 is named by IUPAC is a noble gas and placed just two place before 120. So, the general electronic configuration is represented as [noble gas] ns^2 and element with $Z = 120$ exist as an alkaline earth metal.

3. (a) **Correct statement** According to Moseley's law, the properties of elements are the periodic function of their atomic numbers.

(b) **Correct statement** The whole *s*-block, *d*-block, *f*-block and heavier *p*-block elements are metal.

(c) **Correct statement** Trend is not regular, Be has higher first ionisation energy than B, nitrogen has higher first ionisation energy than oxygen.

(d) **Inccorrect statement** *d*-subshells are not filled monotonically, regularity break at chromium and copper.

4. (a) **Incorrect** Electrons are not filled in sub-energy levels *s*, *p*, *d* and *f* in the same sequence.

(b) **Correct** Number of valence shell electrons usually determine the stable valency state of an element.

(c) **Correct** Physical and chemical properties of elements are periodic function of atomic number which is the basis of modern, long form of periodic table.

(d) **Correct** Relative ionicity of the bond between any two elements is function of electronegativity difference of the bonded atoms which in turn has periodic trend in long form of periodic table.

Topic 2 Periodic Properties

1. Size of species $\propto \dfrac{1}{\text{Nuclear charge}}$

Iso-electronic species are those atoms or ions which has the same number of electrons.

Size of species decreases with increasing protons.

More is effective nuclear charge (Z_{eff}) lesser will be ionic size.

Correct order of ionic radii

$$Al^{3+} < Mg^{2+} < Na^{+} < F^{-} < O^{2-} < N^{3-}$$

2. The first electron gain enthalpy is exothermic (or negative).

Generally, electron gain enthalpy becomes less exothermic (or less negative) when comparing elements of a group from top to bottom.

Therefore, electron gain enthalpy of S > Se and Li > Na.

But there are some exceptions to this.

One of them is the case of a group 17 elements where electron gain is most negative for Cl instead of F, due to extra small size of fluorine.

∴ Upon an electron gain, energy releases in the order :

Cl > F, S > Se and Li > Na

3. The group number, number of valence electrons and valency of an element with atomic number 15 are 15, 5 and 3 respectively. Modern periodic table is based on the atomic number. Number of valence electrons present in an atom decides the group number. Electronic configuration of element having atomic number 15 = $1s^2\ 2s^2\ 2p^6\ \underbrace{3s^2\ 3p^3}_{\text{Valence electrons}}$

As five electrons are present in valence shell, its group number is 15. Valency of element having atomic number 15 is +3 (8 – 5 = 3).

4. The electronic configuration of given elements are as follows :

K(19) = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 4s^1$

4

Chemical Bonding

Topic 1 Preliminary Concepts of Electrovalent and Covalent Bonding

Objective Questions I (Only one correct option)

1. The isoelectronic set of ions is **(2019 Main, 10 April I)**
(a) F^-, Li^+, Na^+ and Mg^{2+}
(b) N^{3-}, Li^+, Mg^{2+} and O^{2-}
(c) Li^+, Na^+, O^{2-} and F^-
(d) N^{3-}, O^{2-}, F^- and Na^+

2. Which of the following compounds contain(s) no covalent bond(s)?
$KCl, PH_3, O_2, B_2H_6, H_2SO_4$ **(2018 Main)**
(a) KCl, B_2H_6, PH_3 (b) KCl, H_2SO_4
(c) KCl (d) KCl, B_2H_6

3. The intermolecular interaction that is dependent on the inverse cube of distance between the molecules is **(2015 Main)**
(a) ion-ion interaction (b) ion-dipole interaction
(c) London force (d) hydrogen bond

4. The nodal plane in the π-bond of ethene is located in
(a) the molecular plane **(2002, 3M)**
(b) a plane parallel to the molecular plane
(c) a plane perpendicular to the molecular plane which bisects the carbon-carbon σ-bond at right angle
(d) a plane perpendicular to the molecular plane which contains the carbon-carbon σ-bond

5. Amongst H_2O, H_2S, H_2Se and H_2Te, the one with the highest boiling point is **(2000, 1M)**
(a) H_2O because of hydrogen bonding
(b) H_2Te because of higher molecular weight
(c) H_2S because of hydrogen bonding
(d) H_2Se because of lower molecular weight

6. Arrange the following compounds in order of increasing dipole moment, toluene (I), *m*-dichlorobenzene (II), *o*-dichlorobenzene (III), *p*-dichlorobenzene (IV) **(1996, 1M)**
(a) I < IV < II < III (b) IV < I < II < III
(c) IV < I < III < II (d) IV < II < I < III

7. The number and type of bonds between two carbon atoms in CaC_2 are **(1996, 1M)**
(a) one sigma (σ) and one pi (π) bonds
(b) one sigma (σ) and two pi (π) bonds
(c) one sigma (σ) and one half pi (π) bonds
(d) one sigma (σ) bond

8. The molecule which has zero dipole moment is **(1989, 1M)**
(a) CH_2Cl_2 (b) BF_3 (c) NF_3 (d) ClO_2

9. Element X is strongly electropositive and element Y is strongly electronegative. Both are univalent. The compound formed would be **(1980, 1M)**
(a) X^+Y^- (b) X^-Y^+ (c) $X — Y$ (d) $X \rightarrow Y$

10. Which of the following compound is covalent? **(1980, 1M)**
(a) H_2 (b) CaO
(c) KCl (d) Na_2S

11. The total number of electrons that take part in forming the bonds in N_2 is **(1980, 1M)**
(a) 2 (b) 4 (c) 6 (d) 10

12. The compound which contains both ionic and covalent bonds is **(1979, 1M)**
(a) CH_4 (b) H_2 (c) KCN (d) KCl

Objective Questions II
(One or more than one correct option)

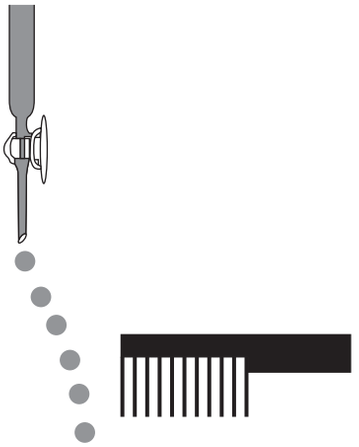
13. Each of the following options contains a set of four molecules. Identify the option(s) where all four molecules posses permanent dipole moment at room temperature.
(a) SO_2, C_6H_5Cl, H_2Se, BrF_5 **(2019 Adv.)**
(b) $BeCl_2$, CO_2, BCl_3, $CHCl_3$
(c) NO_2, NH_3, $POCl_3$, CH_3Cl
(d) BF_3, O_3, SF_6, XeF_6

14. Dipole moment is shown by **(1986, 1M)**
(a) 1, 4-dichlorobenzene (b) *cis*-1, 2-dichloroethene
(c) *trans*-1, 2-dichloroethene (d) *trans*-1, 2-dichloro-2- pentene

Numerical Answer Type Questions

15. Consider the following compounds in the liquid form : O_2, HF, H_2O, NH_3, H_2O_2, CCl_4, $CHCl_3$, C_6H_6, C_6H_5Cl

When a charged comb is brought near their flowing stream, how many of them show deflection as per the following figure? **(2020 Adv.)**



16. Among the species given below, the total number of diamagnetic species is____

H atom, NO_2 monomer, O_2^- (superoxide), dimeric sulphur in vapour phase, Mn_3O_4, $(NH_4)_2[FeCl_4]$, $(NH_4)_2[NiCl_4]$, K_2MnO_4, K_2CrO_4 **(2018 Adv.)**

Assertion and Reason

Read the following questions and answer as per the direction given below:

(a) Statement I is true; Statement II is true; Statement II is the correct explanation of Statement I

(b) Statement I is true; Statement II is true; Statement II is not the correct explanation of Statement I

(c) Statement I is correct; Statement II is incorrect

(d) Statement I is incorrect; Statement II is correct

17. **Statement I** LiCl is predominantly a covalent compound.

Statement II Electronegativity difference between Li and Cl is too small. **(1998, 2M)**

Fill in the Blank

18. There are …… π -bonds in a nitrogen molecule. **(1982, 1M)**

True/False

19. All molecules with polar bonds have dipole moment. **(1985, 1/2 M)**

20. Linear overlapping of two atomic *p*-orbitals leads to a sigma bond. **(1983, 1M)**

Subjective Questions

21. Arrange the following ions in order of their increasing radii: Li^+, Mg^{2+}, K^+, Al^{3+}. **(1997, 1M)**

22. Between Na^+ and Ag^+, which is stronger Lewis acid and why? **(1997, 3M)**

23. In the reaction, $I^- + I_2 \longrightarrow I_3^-$, which is the Lewis acid? **(1997, 1M)**

24. Explain the difference in the nature of bonding in LiF and LiI. **(1996, 2M)**

25. The dipole moment of KCl is 3.336×10^{-29} C-m which indicates that it is a highly polar molecule. The interatomic distance between K^+ and Cl^- in this molecule is 2.6×10^{-10} m. Calculate the dipole moment of KCl molecule if there were opposite charges of one fundamental unit located at each nucleus. Calculate the percentage ionic character of KCl. **(1993, 2M)**

26. Give reasons in two or three sentences only for the following :

"Hydrogen peroxide acts as an oxidising as well as a reducing agent.'' **(1992, 1M)**

27. State four major physical properties that can be used to distinguish between covalent and ionic compounds. Mention the distinguishing features in each case. **(1978, 2M)**

Topic 2 VBT, Hybridisation and VSEPR Theory

Objective Questions I (Only one correct option)

1. The correct statements among I to III are :

I. Valence bond theory cannot explain the color exhibited by transition metal complexes.

II. Valence bond theory can predict quantitatively the magnetic properties of transition metal complexes.

III. Valence bond theory cannot distinguish ligands as weak and strong field ones. **(2019 Main, 9 April II)**

(a) II and III only (b) I, II and III

(c) I and II only (d) I and III only

2. The correct statement about ICl_5 and ICl_4^- is **(2019 Main, 8 April II)**

(a) ICl_5 is square pyramidal and ICl_4^- is tetrahedral

(b) ICl_5 is square pyramidal and ICl_4^- is square planar

(c) Both are isostructural

(d) ICl_5 is trigonal bipyramidal and ICl_4^- is tetrahedral

3. The ion that has sp^3d^2-hybridisation for the central atom, is **(2019 Main, 8 April II)**

(a) $[ICl_2]^-$ (b) $[BrF_2]^-$ (c) $[ICl_4]^-$ (d) $[IF_6]^-$

4. The size of the iso-electronic species Cl^-, Ar and Ca^{2+} is affected by **(2019 Main, 8 April I)**
(a) azimuthal quantum number of valence shell
(b) electron-electron interaction in the outer orbitals
(c) principal quantum number of valence shell
(d) nuclear charge

5. In which of the following processes, the bond order has increased and paramagnetic character has changed to diamagnetic? **(2019 Main, 9 Jan II)**
(a) $O_2 \rightarrow O_2^+$ (b) $N_2 \rightarrow N_2^+$
(c) $O_2 \rightarrow O_2^{2-}$ (d) $NO \rightarrow NO^+$

6. Total number of lone pair of electron in I_3^- ion is **(2018 Main)**
(a) 3 (b) 6
(c) 9 (d) 12

7. The group having isoelectronic species is **(2017 Main)**
(a) O^{2-}, F^-, Na^+, Mg^{2+} (b) O^-, F^-, Na, Mg^+
(c) O^{2-}, F^-, Na, Mg^{2+} (d) O^-, F^-, Na^+, Mg^{2+}

8. The correct statement for the molecule, CsI_3 is **(2014 Main)**
(a) it is a covalent molecule
(b) it contains Cs^+ and I_3^- ions
(c) it contains Cs^{3+} and I^- ions
(d) it contains Cs^+, I^- and lattice I_2 molecule

9. The species having pyramidal shape is **(2010)**
(a) SO_3 (b) BrF_3 (c) SiO_3^{2-} (d) OSF_2

10. Assuming that Hund's rule is violated, the bond order and magnetic nature of the diatomic molecule $\mathbf{B_2}$ is **(2010)**
(a) 1 and diamagnetic (b) 0 and diamagnetic
(c) 1 and paramagnetic (d) 0 and paramagnetic

11. The species having bond order different from that in CO is
(a) NO^- (b) NO^+ **(2007, 3M)**
(c) CN^- (d) N_2

12. Among the following, the paramagnetic compound is **(2007, 3M)**
(a) Na_2O_2 (b) O_3 (c) N_2O (d) KO_2

13. Which of the following contains maximum number of lone pairs on the central atom? **(2005, 1M)**
(a) ClO_3^- (b) XeF_4 (c) SF_4 (d) I_3^-

14. Number of lone pair(s) in $XeOF_4$ is/are **(2004, 1M)**
(a) 0 (b) 1 (c) 2 (d) 3

15. Which of the following are isoelectronic and isostructural ?
NO_3^-, CO_3^{2-}, ClO_3^-, SO_3 **(2003, 1M)**
(a) NO_3^-, CO_3^{2-} (b) SO_3, NO_3^-
(c) ClO_3^-, CO_3^{2-} (d) CO_3^{2-}, SO_3

16. Among the following, the molecule with the highest dipole moment is **(2003, 1M)**
(a) CH_3Cl (b) CH_2Cl_2
(c) $CHCl_3$ (d) CCl_4

17. Which of the following molecular species has unpaired electron (s)? **(2002, 3M)**
(a) N_2 (b) F_2 (c) O_2^- (d) O_2^{2-}

18. Specify the coordination geometry around and hybridisation of N and B atoms in a 1 : 1 complex of BF_3 and NH_3.
(a) N : tetrahedral, sp^3 ; B: tetrahedral, sp^3 **(2002, 3M)**
(b) N : pyramidal, sp^3; B: pyramidal, sp^3
(c) N: pyramidal, sp^3; B: planar, sp^2
(d) N: pyramidal, sp^3; B: tetrahedral, sp^3

19. The correct order of hybridisation of the central atom in the following species NH_3, $[PtCl_4]^{2-}$, PCl_5 and BCl_3 is **(2001, 1M)**
(a) dsp^2, dsp^3, sp^2 and sp^3 (b) sp^3, dsp^2, sp^3d and sp^2
(c) dsp^2, sp^2, sp^3 and dsp^3 (d) dsp^2, sp^3, sp^2 and dsp^3

20. The common features among the species CN^-, CO and NO^+ are **(2001, 1M)**
(a) bond order three and isoelectronic
(b) bond order three and weak field ligands
(c) bond order two and acceptors
(d) isoelectronic and weak field ligands

21. The hybridisation of atomic orbitals of nitrogen in NO_2^+, NO_3^- and NH_4^+ are **(2000, 1M)**
(a) *sp*, sp^3 and sp^2 respectively
(b) *sp*, sp^2 and sp^3 respectively
(c) sp^2, *sp* and sp^3 respectively
(d) sp^2, sp^3 and *sp* respectively

22. In the compound $CH_2{=}CH{-}CH_2{-}CH_2{-}C{\equiv}CH$, the $C_2{-}C_3$ bonds is of **(1999, 2M)**
(a) sp - sp^2 (b) sp^3 - sp^3
(c) sp - sp^3 (d) sp^2 - sp^3

23. The geometry of H_2S and its dipole moment are **(1999, 2M)**
(a) angular and non-zero (b) angular and zero
(c) linear and non-zero (d) linear and zero

24. The geometry and the type of hybrid orbital present about the central atom in BF_3 is **(1998, 2M)**
(a) linear, *sp* (b) trigonal planar, sp^2
(c) tetrahedral, sp^3 (d) pyramidal, sp^3

25. Which one of the following compounds has sp^2- hybridisation? **(1997, 1M)**
(a) CO_2 (b) SO_2 (c) N_2O (d) CO

26. Among KO_2, AlO_2^-, BaO_2 and NO_2^+, unpaired electron is present in **(1997 C, 1M)**
(a) NO_2^+ and BaO_2 (b) KO_2 and AlO_2^-
(c) Only KO_2 (d) Only BaO_2

27. The cyanide ion CN^- and N_2 are isoelectronic, but in contrast to CN^-, N_2 is chemically inert because of **(1997 C, 1M)**
(a) low bond energy
(b) absence of bond polarity
(c) unsymmetrical electron distribution
(d) presence of more number of electron in bonding orbitals

28. Among the following species, identify the isostructural pairs.

$$NF_3, NO_3^-, BF_3, H_3O^+, N_3H$$

(1996, 1M)

(a) $[NF_3, NO_3^-]$ and $[BF_3, H_3O^+]$

(b) $[NF_3, N_3H]$ and $[NO_3^-, BF_3]$

(c) $[NF_3, H_3O^+]$ and $[NO_3^-, BF_3]$

(d) $[NF_3, H_3O^+]$ and $[N_3H, BF_3]$

29. Which one of the following molecules is planar? **(1996, 1M)**

(a) NF_3 (b) NCl_3 (c) PH_3 (d) BF_3

30. The maximum possible number of hydrogen bonds a water molecule can form is **(1992, 1M)**

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

31. The type of hybrid orbitals used by the chlorine atom in ClO_2^- is **(1992, 1M)**

(a) sp^3 (b) sp^2

(c) sp (d) None of these

32. The molecule which has pyramidal shape is **(1989, 1M)**

(a) PCl_3 (b) SO_3 (c) CO_3^{2-} (d) NO_3^-

33. Which of the following is paramagnetic? **(1989, 1M)**

(a) O_2^- (b) CN^- (c) CO (d) NO^+

34. The Cl—C—Cl angle in 1, 1, 2, 2-tetrachloroethene and tetrachloromethane respectively will be about **(1988, 1M)**

(a) 120° and 109.5° (b) 90° and 109.5°

(c) 109° and 90° (d) 109.5° and 120°

35. The molecule that has linear structure is **(1988, 1M)**

(a) CO_2 (b) NO_2 (c) SO_2 (d) SiO_2

36. The species in which the central atom uses sp^2-hybrid orbitals in its bonding is **(1988, 1M)**

(a) PH_3 (b) NH_3 (c) CH_3^+ (d) SbH_3

37. Of the following compounds, which will have a zero dipole moment ? **(1987, 1M)**

(a) 1, 1-dichloroethylene

(b) *cis*-1, 2-dichloroethylene

(c) *trans*-1, 2-dichloroethylene

(d) None of the above

38. The hybridisation of sulphur in sulphur dioxide is **(1986, 1M)**

(a) sp (b) sp^3

(c) sp^2 (d) dsp^2

39. The bond between two identical non-metal atoms has a pair of electrons **(1986, 1M)**

(a) unequally shared between the two

(b) transferred fully from one atom to another

(c) with identical spins

(d) equally shared between them

40. On hybridisation of one *s* and one *p*-orbital we get **(1984, 1M)**

(a) two mutually perpendicular orbitals

(b) two orbitals at 180°

(c) four orbitals directed tetrahedrally

(d) three orbitals in a plane

41. Carbon tetrachloride has no net dipole moment because of **(1983, 1M)**

(a) its planar structure

(b) its regular tetrahedral structure

(c) similar sizes of carbon and chlorine atoms

(d) similar electron affinities of carbon and chlorine

42. The ion that is isoelectronic with CO is **(1982, 1M)**

(a) CN^- (b) O_2^+ (c) O_2^- (d) N_2^+

43. Among the following, the linear molecule is **(1982, 1M)**

(a) CO_2 (b) NO_2 (c) SO_2 (d) ClO_2

44. If a molecule MX_3 has zero dipole moment, the sigma bonding orbitals used by M (atomic number < 21) are **(1981, 1M)**

(a) pure p (b) sp-hybridised

(c) sp^2-hybridised (d) sp^3-hybridised

Objective Questions II

(One or more than one correct option)

45. The molecules that will have dipole moment are **(1992, 1M)**

(a) 2, 2-dimethyl propane (b) *trans*-2-pentene

(c) *cis*-3-hexene (d) 2,2,3,3-tetramethyl butane

46. Which of the following have identical bond order? **(1992, 1M)**

(a) CN^- (b) O_2^-

(c) NO^+ (d) CN^+

47. The linear structure assumed by **(1991, 1M)**

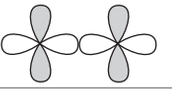
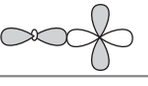
(a) $SnCl_2$ (b) CS_2 (c) NO_2^+ (d) NCO^-

48. CO_2 is isostructural with **(1986, 1M)**

(a) $HgCl_2$ (b) C_2H_2 (c) $SnCl_2$ (d) NO_2

Match the Columns

49. Match the orbital overlap figures shown in Column I with the description given in Column II and select the correct answer using the codes given below the Columns. **(2014 Adv.)**

	Column I		Column II
A.		1.	*p-d* π antibonding
B.		2.	*d-d* σ bonding
C.		3.	*p-d*π bonding
D.		4.	*d-d* σ antibonding

Codes

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

50. Match each of the diatomic molecules in Column I with its property/properties in Column II. **(2009)**

Column I		Column II	
A.	B_2	p.	Paramagnetic
B.	N_2	q.	Undergoes oxidation
C.	O_2^-	r.	Undergoes reduction
D.	O_2	s.	Bond order ≥ 2
		t.	Mixing of '*s*' and '*p*' orbitals

Codes

	A	B	C	D
(a)	q, r, s	p, r, t, s	q, r, t	p, q, t
(b)	p, q, r, t	q, r, s, t	p, q, r, t	p, r, s, t
(c)	q, r, s, t	p, q, r	r, s, t	p, q, r, t
(d)	p, q, s, t	p, q, s	p, t	q, r, t

Fill in the Blanks

51. Among N_2O, SO_2, I_3^+ and I_3^-, the linear species are …… and …… **(1997 C, 1M)**

52. When N_2 goes to N_2^+, the N—N bond distance … , and when O_2 goes to O_2^+ the O—O bond distance …… **(1996, 1M)**

53. The two types of bonds present in B_2H_6 are covalent and …… **(1994, 1M)**

54. The kind of delocalisation involving sigma bond orbitals is called..... **(1994, 1M)**

55. The valence atomic orbitals on C in silver acetylide is .....hybridised. **(1990, 1M)**

56. The shape of CH_3^+ is …… . **(1990, 1M)**

57. …… hybrid orbitals of nitrogen atom are involved in the formation of ammonium ion. **(1982, 1M)**

58. Pair of molecules which forms strongest intermolecular hydrogen bonds is …… . (SiH_4 and SiF_4, acetone and $CHCl_3$, formic acid and acetic acid) **(1981, 1M)**

59. The angle between two covalent bonds is maximum in …… . (CH_4, H_2O, CO_2) **(1981, 1M)**

True/False

60. The dipole moment of CH_3F is greater than that of CH_3Cl. **(1993, 1M)**

61. H_2O molecule is linear. **(1993, 1M)**

62. The presence of polar bonds in a polyatomic molecule suggests that the molecule has non-zero dipole moment. **(1990, 1M)**

63. sp^3 hybrid orbitals have equal *s* and *p* character. **(1987, 1M)**

64. In benzene, carbon uses all the three *p*-orbitals for hybridisation. **(1987, 1M)**

65. $SnCl_2$ is a non-linear molecule. **(1985, $\frac{1}{2}$M)**

Integer Answer Type Questions

66. The sum of the number of lone pairs of electrons on each central atom in the following species is

$[TeBr_6]^{2-}$, $[BrF_2]^+$, SNF_3 and $[XeF_3]^-$

(Atomic numbers : N = 7, F = 9, S = 16, Br = 35, Te = 52, Xe = 54) **(2017 Adv.)**

67. Among the triatomic molecules/ions $BeCl_2$, N_3^-, N_2O, NO_2^+, O_3, SCl_2, ICl_2^-, I_3^- and XeF_2, the total number of linear molecules(s)/ion(s) where the hybridisation of the central atom does not have contribution from the *d*-orbital(s) is [atomic number of S = 16, Cl = 17, I = 53 and Xe = 54] **(2015 adv.)**

68. A list of species having the formula XZ_4 is given below **(2014 Adv.)**

XeF_4, SF_4, SiF_4, BF_4^-, BrF_4^-, $[Cu(NH_3)_4]^{2+}$, $[FeCl_4]^{2-}$, $[CoCl_4]^{2-}$ and $[PtCl_4]^{2-}$

Defining shape on the basis of the location of *X* and *Z* atoms, the total number of species having a square planar shape is

69. The total number of lone-pair of electrons in melamine is **(2013 Adv.)**

70. Based on VSEPR theory, the number of 90° F—Br—F angles in BrF_5 is **(2010)**

Subjective Questions

71. Predict whether the following molecules are isostructural or not. Justify your answer.

(i) NMe_3 (ii) $N(SiMe_3)_3$ **(2005, 2M)**

72. On the basis of ground state electronic configuration, arrange the following molecules in increasing O—O bond length order. KO_2, O_2, $O_2[AsF_6]$ **(2004, 2M)**

73. Draw the shape of XeF_4 and OSF_4 according to VSEPR theory. Show the lone pair of electrons on the central atom. **(2004, Main, 2M)**

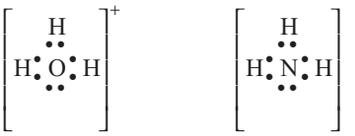
74. Using VSEPR theory, draw the shape of PCl_5 and BrF_5. **(2003, 2M)**

75. Draw the molecular structures of XeF_2, XeF_4 and XeO_2F_2, indicating the location of lone pair(s) of electrons. **(2000, 3M)**

76. Interpret the non-linear shape of H_2S molecule and non-planar shape of PCl_3 using valence shell electron pair repulsion (VSEPR) theory. (Atomic number : H = 1, P = 15, S = 16, Cl = 17) **(1998, 4M)**

77. Using the VSEPR theory, identify the type of hybridisation and draw the structure of OF_2. What are the oxidation states of O and F ? **(1997, 3M)**

78. Write the Lewis dot structural formula for each of the following. Give also, the formula of a neutral molecule, which has the same geometry and the same arrangement of the bonding electrons as in each of the following. An example is given below in the case of H_3O^+ and NH_3.



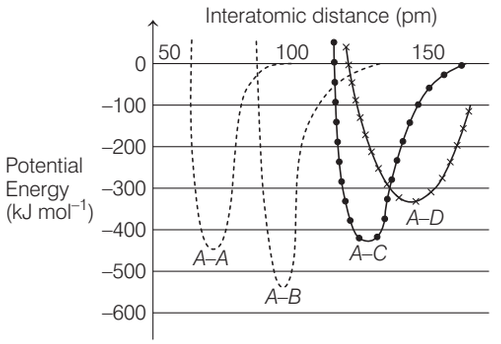
Lewis dot structure Neutral molecule **(1983, 4M)**

(i) O_2^{2-} (ii) CO_3^{2-} (iii) CN^- (iv) NCS^-

Topic 3 Resonance, LCAO, MOT, Other Bonding Types

Objective Questions I (Only one correct option)

1. The intermolecular potential energy for the molecules *A, B, C* and *D* given below suggests that: **(2020 Main, 4 Sep I)**



(a) *A*-*B* has the stiffest bond
(b) *D* is more electronegative than other atoms
(c) *A*-*A* has the largest bond enthalpy
(d) *A*-*D* has the shortest bond length

2. During the change of O_2 to O_2^-, the incoming electron goes to the orbital. **(2019 Main, 10 April I)**

(a) $\pi 2p_x$ (b) $\pi^* 2p_x$ (c) $\pi 2p_y$ (d) $\sigma^* 2p_z$

3. HF has highest boiling point among hydrogen halides, because it has **(2019 Main, 9 April II)**

(a) lowest ionic character
(b) strongest van der Waals' interactions
(c) strongest hydrogen bonding
(d) lowest dissociation enthalpy

4. Among the following species, the diamagnetic molecule is **(2019 Main, 9 April II)**

(a) CO (b) B_2 (c) NO (d) O_2

5. Among the following, the molecule expected to be stabilised by anion formation is C_2, O_2, NO, F_2. **(2019 Main, 9 April I)**

(a) C_2 (b) F_2
(c) NO (d) O_2

6. Among the following molecules/ions, C_2^{2-}, N_2^{2-}, O_2^{2-}, O_2

Which one is diamagnetic and has the shortest bond length? **(2019 Main, 8 April II)**

(a) C_2^{2-} (b) O_2 (c) O_2^{2-} (d) N_2^{2-}

7. Two pi and half sigma bonds are present in **(2019 Main, 10 Jan I)**

(a) O_2^+ (b) N_2 (c) N_2^+ (d) O_2

8. According to molecular orbital theory, which of the following is true with respect to Li_2^+ and Li_2^-? **(2019 Main, 9Jan I)**

(a) Both are unstable
(b) Li_2^+ is unstable and Li_2^- is stable
(c) Both are stable
(d) Li_2^+ is stable and Li_2^- is unstable

9. According to molecular orbital theory, which of the following will not be a viable molecule? **(2018 Main)**

(a) He_2^{2+} (b) He_2^+
(c) H_2^- (d) H_2^{2-}

10. Which of the following species is not paramagnetic? **(2017 Main)**

(a) NO (b) CO
(c) O_2 (d) B_2

11. Assuming 2*s*-2*p* mixing is not operative, the paramagnetic species among the following is **(2014 Adv.)**

(a) Be_2 (b) B_2
(c) C_2 (d) N_2

12. Stability of the species Li_2, Li_2^- and Li_2^+ increases in the order of **(2013 Main)**

(a) $Li_2 < Li_2^+ < Li_2^-$ (b) $Li_2^- < Li_2^+ < Li_2$
(c) $Li_2 < Li_2^- < Li_2^+$ (d) $Li_2^- < Li_2 < Li_2^+$

13. In which of the following pairs of molecules/ions both the species are not likely to exist? **(2013 Main)**

(a) H_2^+, He_2^{2-} (b) H_2^-, He_2^{2-}
(c) H_2^{2+}, He_2 (d) H_2^-, He_2^{2+}

14. Hyperconjugation involves overlap of which of the following orbitals? **(2008, 3M)**

(a) σ - σ (b) σ - *p*
(c) *p* - *p* (d) π - π

15. According to *M*O theory, **(2004, 1M)**

(a) O_2^+ is paramagnetic and bond order greater than O_2
(b) O_2^+ is paramagnetic and bond order less than O_2
(c) O_2^+ is diamagnetic and bond order is less than O_2
(d) O_2^+ is diamagnetic and bond order is more than O_2

16. Molecular shape of SF_4, CF_4 and XeF_4 are **(2000, 1M)**
(a) the same, with 2, 0 and 1 lone pair of electrons respectively
(b) the same, with 1, 1 and 1 lone pair of electrons respectively
(c) different, with 0, 1 and 2 lone pair of electrons respectively
(d) different, with 1, 0 and 2 lone pair of electrons respectively

17. In compounds of type ECl_3, where E = B, P, As or Bi, the angles Cl—E—Cl is in order **(1999, 2M)**
(a) B > P = As = Bi (b) B > P > As > Bi
(c) B < P = As = Bi (d) B < P < As < Bi

18. The correct order of increasing C—O bond length of CO, CO_3^{2-}, CO_2 is **(1999, 2M)**
(a) $CO_3^{2-} < CO_2 < CO$ (b) $CO_2 < CO_3^{2-} < CO$
(c) $CO < CO_3^{2-} < CO_2$ (d) $CO < CO_2 < CO_3^{2-}$

19. Which contains both polar and non-polar bonds? **(1997, 1M)**
(a) NH_4Cl (b) HCN
(c) H_2O_2 (d) CH_4

20. Which one among the following does not have the hydrogen bond? **(1983, 1M)**
(a) Phenol (b) Liquid NH_3
(c) Water (d) HCl

Objective Questions II
(One or more than one correct option)

21. According to molecular orbital theory, which of the following statements is(are) correct? **(2016 adv.)**
(a) C_2^{2-} is expected to be diamagnetic
(b) O_2^{2+} is expected to have a longer bond length than O_2
(c) N_2^+ and N_2^- have the same bond order
(d) He_2^+ has the same energy as two isolated He atoms

22. Hydrogen bonding plays a central role in which of the following phenomena? **(2014 Adv.)**
(a) Ice floats in water
(b) Higher Lewis basicity of primary amines than tertiary amines in aqueous solutions
(c) Formic acid is more acidic than acetic acid
(d) Dimerisation of acetic acid in benzene

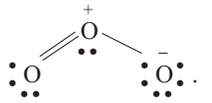
23. Which one of the following molecules is expected to exhibit diamagnetic behaviour? **(2013 Main)**
(a) C_2 (b) N_2 (c) O_2 (d) S_2

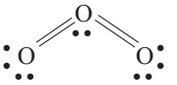
Assertion and Reason

Read the following questions and answer as per the direction given below:

(a) Statement I is correct; Statement II is correct; Statement II is the correct explanation of Statement I.
(b) Statement I is correct; Statement II is correct; Statement II is not the correct explanation of Statement I.
(c) Statement I is correct; Statement II is incorrect.
(d) Statement I is incorrect; Statement II is correct.

24. **Statement I** The electronic structure of O_3 is



Statement II  structure is not allowed because octet around O cannot be expanded. **(1998, 2M)**

Match the Columns

25. Match the reactions in Column I with nature of the reactions/type of the products in Column II. **(2007, 6M)**

	Column I		Column II
A.	$O_2^- \longrightarrow O_2 + O_2^{2-}$	1.	Redox reaction
B.	$CrO_4^{2-} + H^+ \longrightarrow$	2.	One of the products has trigonal planar structure
C.	$MnO_4^- + NO_2^- + H^+ \longrightarrow$	3.	Dimeric bridged tetrahedral metal ion
D.	$NO_3^- + H_2SO_4 + Fe^{2+} \longrightarrow$	4.	Disproportionation

Codes

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

Integer Answer Type Questions

26. Chlorine reacts with hot and concentrated NaOH and produces compounds (X) and (Y). Compound (X) gives white precipitate with silver nitrate solution. The average bond order between Cl and O atoms in (Y) is …… . **(2020 Main, 7 Jan I)**

27. Among H_2, He_2^+, Li_2, Be_2, B_2, C_2, N_2, O_2^- and F_2, the number of diamagnetic species is
(Atomic numbers : H = 1, He = 2, Li = 3, Be = 4, B = 5, C = 6, N = 7, O = 8, F = 9) **(2017 Adv.)**

Subjective Questions

28. Write the MO electron distribution of O_2. Specify its bond order and magnetic property. **(2000, 3M)**

29. Arrange the following as stated.
"Increasing strength of hydrogen bonding (X—H—X)."
O, S, F, Cl, N **(1991, 1M)**

30. What effect should the following resonance of vinyl chloride have on its dipole moment? **(1987, 1M)**
$CH_2=CH—Cl \longleftrightarrow CH_2^-—C^+HCl$

Answers

Topic 1

1. (d) **2.** (c) **3.** (b) **4.** (a)
5. (a) **6.** (b) **7.** (b) **8.** (b)
9. (a) **10.** (a) **11.** (c) **12.** (c)
13. (a, c) **14.** (a) **15.** (6) **16.** (1)
17. (c) **18.** (2) **19.** F **20.** T
25. (80.2%)

Topic 2

1. (d) **2.** (b) **3.** (c) **4.** (d)
5. (d) **6.** (c) **7.** (a) **8.** (d)
9. (d) **10.** (a) **11.** (a) **12.** (d)
13. (d) **14.** (b) **15.** (a) **16.** (a)
17. (c) **18.** (a) **19.** (b) **20.** (a)
21. (b) **22.** (d) **23.** (a) **24.** (b)
25. (b) **26.** (c) **27.** (b) **28.** (c)
29. (d) **30.** (b) **31.** (a) **32.** (a)
33. (a) **34.** (a) **35.** (a) **36.** (c)
37. (c) **38.** (c) **39.** (d) **40.** (b)
41. (b) **42.** (a) **43.** (a) **44.** (c)
45. (b, c) **46.** (a, c) **47.** (b, c, d) **48.** (a, b)
49. (c) A → 2; B → 3; C →1; D →4
50. (b) A → p, q, r, t; B → q, r, s, t; C → p, q, r, t; D → p, r, s, t
51. N_2O, I_3^- **52.** increases, decreases
53. three centre bond-two electrons
54. hyperconjugation
55. *sp* **56.** Triangular planar **57.** sp^3
58. HCOOH and CH_3COOH **59.** CO_2 **60.** F
61. F **62.** F **63.** F **64.** F
65. T **66.** (6) **68.** (4) **69.** (6)

Topic 3

1. (a) **2.** **(b)** **3.** **(c)** **4.** **(a)**
5. (a) **6.** (a) **7.** (c) **8.** (d)
9. (d) **10.** (b) **11.** (c) **12.** (b)
13. (c) **14.** (b) **15.** (a) **16.** (d)
17. (b) **18.** (a) **19.** (c) **20.** (d)
21. (a, c) **22.** (a, b, d) **23.** (a,b) **24.** (a)
25. (b) A → 1, 4; B → 3; C →1, 2; D →1 **26.** (1.67)
27. (6) **28.** (2)

Hints & Solutions

Topic 1 Preliminary Concepts of Electrovalent and Covalent Bonding

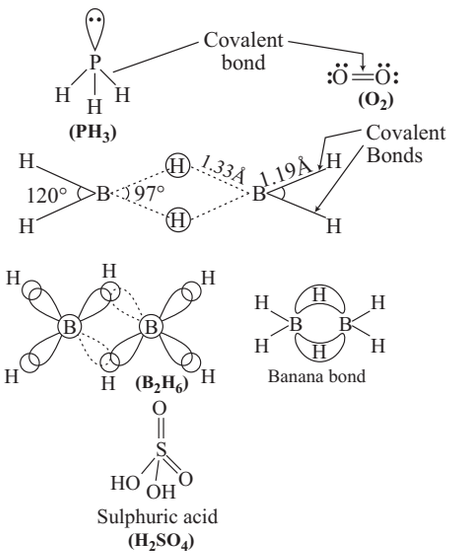
1. **Key Idea** Isoelectronic species contains same number of electrons.

The species with its atomic number and number of electrons are as follows :

Species (ions)	At. no. (*Z*)	No. of electrons
N^{3-}	7	7 + 3 = 10
O^{2-}	8	8 + 2 = 10
F^-	9	9 + 1 = 10
Na^+	11	11 – 1 = 10
Li^+	3	3 – 1 = 2
Mg^{2+}	12	12 – 2 = 10

Thus, option (d) contains isoelectronic set of ions.

2. KCl is the only ionic compound. The structure of PH_3, O_2, B_2H_6 and H_2SO_4 are given below



All bond between S and O atom are covalent bonds.