CSM—18/23

PART—II/PAPER—VI

CHEMISTRY

PAPER—I

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Time : 3 Hours

Full Marks : 250

The question paper contains **18 (Eighteen)** *questions in* **GROUP—A (12)** *and* **GROUP—B (06)** *together.*

GROUP—A

Candidates to attempt **10** ***(ten)*** *questions within word limit of* **250**. *Each question carries* **15** *marks.*

1. What are the four quantum numbers and what is their significance in determining the electronic structure of an atom? What are the four quantum numbers for an electron in the 2*s* orbital?

2. What is close packing in crystals? How are simple cubic (SC), body-centered cubic (BCC) and face-centered cubic (FCC) structures different in terms of atoms per unit cell, packing efficiency and coordination number? How does close packing influence the mechanical and electrical properties of metals and alloys?

3. How does the equation of state for real gases account for intermolecular interactions and how do these interactions influence the liquefaction process of gases? If you try to compress CO_2 above 31 °C, it will remain a gas no matter how much pressure is applied — explain.

4. Explain the concept of partition functions and their significance in statistical thermodynamics. How do microstates and macrostates relate to entropy? A system is maintained at 400 K with a partition function of $Z = 200$. Determine its average energy. Additionally, calculate the fraction of molecules with energy exceeding kT.

5. Draw and explain the phase diagram of a simple eutectic system, clearly labelling the different phase regions. Define and discuss the significance of the eutectic point. Further, describe the phase behaviour of the water-phenol system and describe how it changes with temperature.

6. What is heterogeneous catalysis? Discuss its major advantages over homogeneous catalysis. Explain the mechanism of reaction on heterogeneous catalysis. What factors affect the efficiency of heterogeneous catalysts?

7. What is nitrogen fixation and how does it impact the nitrogen cycle? Discuss the enzyme involved in nitrogen fixation, including its key components. Additionally, how do human activities, such as agriculture and industrial processes, influence nitrogen fixation and the overall nitrogen cycle?

8. Discuss the limitations of Valence Bond Theory (VBT) in explaining the spectral properties of coordination complexes. How does Crystal Field Theory address this? Calculate the Crystal Field Stabilization Energy (CFSE) for $[Fe(CN)_6]^{4-}$ in an octahedral field.

9. Discuss the effect of the entering group (Y) and the leaving group (X) on the substitution reactions of square planar complexes. Additionally, explain the trans effect series and its role in determining the reaction pathway in these complexes.

10. Why is lanthanide separation challenging and how do oxidation states influence actinide separation? Compare the oxidation states of uranium and neptunium. Discuss how the magnetic properties of lanthanides differ from actinides.

11. Draw the unit cell structures of Zinc Blende (ZnS) and Rutile (TiO_2). Discuss their structural features and calculate the total number of formula units present in each unit cell.

12. What is the working principle of ion-selective electrodes (ISEs) and how do they selectively detect specific ions in a solution? Explain the construction and functioning of a pH electrode.

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GROUP—B

Candidates to attempt **05** ***(five)*** *questions within word limit of* **300**.
Each question carries **20** *marks.*

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13. What is Heisenberg's Uncertainty Principle and how is it mathematically expressed? Explain its significance in quantum mechanics. Is the occurrence of zero-point energy for a particle in a one-dimensional box in accordance with the Heisenberg's Uncertainty Principle?

14. The complex ion $[MnBr_4]^{2-}$ has a spin-only magnetic moment of 5.9 BM. Based on this information, determine the most likely geometry of the complex using Valance Bond Theory (VBT). Additionally, discuss the structure of the NO molecule using Molecular Orbital (MO) theory, highlighting the advantages of the MO treatment in explaining the magnetic properties of the NO molecule.

15. Explain the first law of thermodynamics and its relation to energy conservation. Discuss the entropy change during the isothermal reversible expansion of an ideal gas. A 3 kg block of metal at 600 K is placed in contact with a 2 kg block at 350 K. The specific heat capacity of the metal is 0.5 kJ/kg·K. Assuming no heat loss to the surroundings, determine the final equilibrium temperature and the entropy change of the system in J/K.

16. What is the electrochemical series and how does it help in predicting the oxidizing and reducing abilities of elements? Explain the redox reaction between Cu^{2+} and Zn using electrochemical series. In an electrolysis experiment, 0.5 A of current is passed through a $CuSO_4$ solution for 30 minutes. Calculate the mass of copper deposited on the cathode.

17. What is an adsorption isotherm? Discuss the Freundlich adsorption isotherms in detail, explaining their assumptions, mathematical formulations and limitations. Which adsorption theory explains monolayer adsorption? Provide its empirical equation and discuss its key assumptions.

18. How does the Dewar-Chatt-Duncanson model explain the bonding in metal-olefin complexes? What is Zeise's salt and explain its structural features? How does hapticity (η) influence the stability in cyclopentadienyl metal complexes?

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SPACE FOR ROUGH WORK

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