FIRST SEMESTER UG DEGREE EXAMINATION, NOVEMBER 2024
(CUFYUGP)

CHE1MN102-Basic Inorganic and Bioinorganic Chemistry

2024 Admission onwards

Scheme of valuation

QP Code :D112833

Maximum Time:2 Hrs. **Maximum Marks: 70**

Section A

All question can be Answered, Each question carries 3 marks (Ceiling 24 Marks)

1. State Paulis exclusion principle. (3 marks)
   No two electrons in the same atom can have identical quantum numbers. This implies that an orbital can hold a maximum of two electrons with opposite spins. (3 mark)
2. Calculate the uncertainty in the position of an electron (mass = 9.1×10−31kg) moving with a velocity 300 ms−1 accurate upon 0.001%

(Equation: 1 mark, substitution: 1 mark correct answer with unit: 1mark)

$\Delta x\Delta p \geq 2\hbar$

Find the uncertainty in velocity (Δv)

Velocity $v=300\ ms^{-1}$ accurate to 0.001

$\Delta v=0.001\times300=0.003\ ms^{-1}$.

Calculate uncertainty in momentum (Δp):

Mass of the electron, $m=9.1\times10^{-31}$ kg

$\Delta p=m\cdot\ \Delta v=(9.1\times10^{-31})x(0.003)=2.73\times10^{-33}\ kg^{-1}ms^{-1}$

Use the uncertainty principle to find Δx

$\Delta x \geq \hbar\ /2x\Delta p$
Substituting $\hbar = 1.054\times10^{-34}$ Js and $\Delta p = 2.73\times10^{-33}$
$\Delta x\ \geq\ 1.054\times10^{-34}/2\ x\ 2.73\times10^{-33}$
$\Delta x \geq 1.93\times10^{-2}m$
$\Delta x \geq 1.93$ cm

3. Write Schrodinger wave equation and explain the terms in it **(1.5+1.5 marks)**

$$\frac{d^2\psi}{dx^2}+\frac{d^2\psi}{dy^2}+\frac{d^2\psi}{dz^2}+\frac{8\pi^2 m}{h^2}(E-V)\psi=0$$

ψ = wave function
m = mass
h = plank constant
E = total energy
V = potential energy

4. Explain VSEPR theory with water as an example **(1.5+1.5 marks)**

The oxygen atom in water is surrounded by two bonding pairs of electrons (from the O-H bonds) and two lone pairs.

1. **Electron Group Count**:
   There are 4 electron groups (2 bonding pairs + 2 lone pairs) around the central oxygen atom.
2. **Predicted Electron Geometry**:
   According to VSEPR theory, 4 electron groups arrange themselves in a **tetrahedral geometry** to minimize repulsion.
3. **Effect of Lone Pairs**:
   Lone pairs occupy more space than bonding pairs, compressing the bond angle between the hydrogen atoms. Instead of the ideal tetrahedral angle of 109.5 ℃, the H-O-H bond angle is reduced to about 104.5 ℃
4. **Molecular Shape**:
   The actual molecular shape is **bent (angular)** due to the presence of lone pairs, which are not part of the visible bonding framework.

Summary of Water's VSEPR Analysis:

- **Central Atom**: Oxygen (O).
- **Electron Groups**: 4 (2 bonding + 2 lone pairs).
- **Electron Geometry**: Tetrahedral.
- **Molecular Shape**: Bent (angular).
- **Bond Angle**: Approximately 104.5 ℃

Any three points with explanation

5. What is hybridization and shape of SF_6?

- **Central Atom**: Sulfur (S).
- **Bond Pairs**: 6 (S-F bonds).
- **Lone Pairs on Central Atom**: 0.
- **Hybridization**: sp^3d^2.
- **Shape/Molecular Geometry**: Octahedral.
- **Bond Angles**: All F-S-F bond angles are 90 ℃ or 180 ℃

- **Or pictorial representation** **(1+1+1)**

6. Describe the variation of oxidation state and valency along a period and a group

Along a Period (Left to Right):Oxidation State:

- The oxidation state generally increases from left to right across a period as elements gain or lose electrons to achieve a stable electronic configuration (usually the noble gas configuration).
- Metals (on the left side) tend to lose electrons, showing positive oxidation states.
- Non-metals (on the right side) tend to gain electrons, showing negative oxidation states.

Valency:

- The valency is determined by the number of electrons in the outermost shell.
- From left to right, the valency first increases (1 to 4 for Group 1 to Group 14) as elements tend to lose or share electrons.

Down a Group (Top to Bottom):

Oxidation State:

- The principal oxidation state remains the same within a group because the number of valence electrons (and hence the group number) does not change.

Valency:

- The valency remains constant down a group because the number of valence electrons is the same for all elements in the group. (1.5+1.5)

7. Compare the ionization enthalpies of group I alkali metals with explanation.

- Decrease down the group due to larger atomic radii and electron shielding. (1.5)
- Example (1.5)

8. Calculate the molarity of a solution of urea (molecular mass 60) prepared by dissolving 15 grams of urea in one liter of water.

$M = w_2/M_2*V$

$w_2 = 15g\ M_2= 60\ V= 1L$

$M + 15g/60g\ mol^{-1}*1= 0.25\ mol\ L^{-1}$

(Equation: 1 mark, substitution: 1 mark correct answer with unit: 1mark)

9. What are the advantages of using double burette titrations?

- No need for using pipette and thereby eliminating mouth pipetting
- The method saves a significant amount of chemicals.
- One drop of indicator is sufficient in the double burette methods

- No need for repetition to get concordant value. It save time.
- Since method is graphical, more accurate results are obtained.
  (Any 3 points)

10. Derive a relation between solubility and solubility product of lead iodide (PbI_2)

$$PbI_2(s) \leftrightarrow Pb^{2+}(aq) + 2I^{-}(aq)$$

Step 1: Define concentrations

- Let the solubility of PbI_2 be s, which represents the concentration of Pb^{2+} ions in solution.
- Since each formula unit of PbI_2 produces one Pb^{2+} ion and two I^{-} ions, the concentration of I^{-} ions will be 2s.

Step 2: Write the solubility product expression

The solubility product constant Ksp of PbI_2 is given by:
$Ksp=[Pb^{2+}][I^{-}]^2$
Substitute the concentrations of Pb^{2+} and I^{-} in terms of s:
$[Pb^{2+}]=s, [I^{-}]=2s$
$Ksp=(s)(2s)^2$

Step 3: Simplify the expression

$Ksp=s(4s^2)$ $Ksp=4s^3$

(Equation: 1 mark, substitution: 1 mark correct answer : 1mark)

Section B

All question can be Answered, Each question carries 6 marks (Ceiling 36 Marks)

11. Describe the role of haemoglobin in the transport of oxygen

1. Haemoglobin is a protein composed of four polypeptide chains, each with a haem group containing an iron (Fe^{2+}) ion. The iron remains in the ferrous (Fe^{2+}) state to bind oxygen reversibly. (1 mark)
2. In the lungs, at high partial pressure of oxygen, Fe^{2+} in the haem groups binds to oxygen molecules, forming oxyhaemoglobin. (1 mark)
3. HS and LS state of Fe2+ in deoxy and oxyhaemoglobin. (1 mark)
4. Haemoglobin exhibits cooperative binding: the binding of one oxygen molecule increases the affinity of the remaining haem groups for oxygen, leading to efficient oxygen loading. (1 mark)
5. Oxyhaemoglobin transports oxygen from the lungs to tissues via the circulatory system.

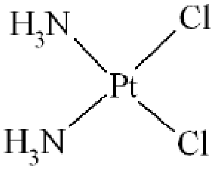
(1 mark)

6. At tissues, where the partial pressure of oxygen is low, haemoglobin releases oxygen. The cooperative effect facilitates easier release of oxygen as more oxygen is unloaded.

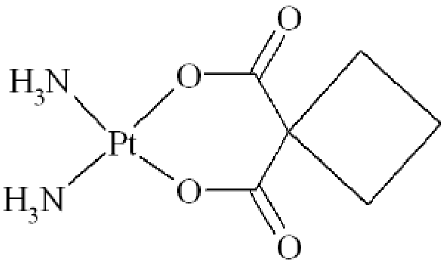
(1 mark)

Or pictorial representation

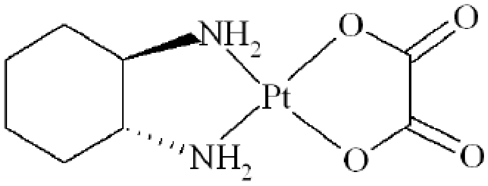
12. Draw the structure of any two anticancer drugs. (3 marks each)



Cisplatin



Carboplatin



Oxaliplatin

13. Explain the toxicity of heavy metals.

Heavy metals are non-biodegradable, accumulate in the food chain, and persist in human tissues, exacerbating their toxic effects over time. Heavy metals like lead, mercury, arsenic, cadmium, and others pose significant health risks due to their high reactivity and ability to interfere with biological systems.
Any two heavy metals and their toxic effects - 3 marks each

14.What is the color change of phenolphthalein and methyl orange during acid base titrations? Explain the theory of color change.

Phenolphthalein- basic solution pink colour and acidic medium colourless

Methyl orange - basic solution golden yellow and acidic medium orange red

Theory:

Ostwald's theory: According to this theory:

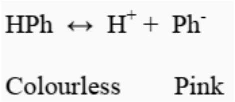
(a) The colour change is due to ionisation of the acid-base indicator. The unionised form has a different colour than the ionised form.

(b) The ionisation of the indicator is largely affected in acids and bases as it is either a weak acid or a weak base.

In case, the indicator is a weak acid, its ionisation is very much low in acids due to common H+ ions while it is fairly ionised in alkalies. Similarly if the indicator is a weak base, its ionisation is large in acids and low in alkalies due to common OH- ions.

Considering two important indicators phenolphthalein (a weak acid) and methyl orange (a weak base), Ostwald theory can be illustrated as follows:

Phenolphthalein: It can be represented as HPh. It ionises in solution to a small extent as:



$HPh \leftrightarrow H^+ + Ph^-$

Colourless Pink

The undissociated molecules of phenolphthalein are colourless while Ph- ions are pink in colour. In presence of an acid the ionisation of HPh is practically negligible as the equilibrium shifts to left hand side due to high concentration of H+ ions. Thus, the solution would remain colourless. On addition of alkali, hydrogen ions are removed by OH- ions in the form of water molecules and the equilibrium shifts to right hand side. Thus, the concentration of Ph- ions increases in solution and they impart pink colour to
the solution.

(2+4)

15. How molecular orbital theory explains the bonding, stability and magnetism of hydrogen molecule. (2+2+2)

Bonding in H2

- **Formation of Molecular Orbitals**: When two hydrogen atoms approach each other, their atomic 1s1s1s orbitals overlap to form two molecular orbitals:
    - **Bonding Molecular Orbital (σ1s)**: Formed by the constructive interference of atomic orbitals, resulting in an increase in electron density between the nuclei.
    - **Antibonding Molecular Orbital (σ*1s)**: Formed by destructive interference, with a node between the nuclei, resulting in reduced electron density between the atoms.
- **Electron Distribution**:
    - Each hydrogen atom contributes one electron, for a total of two electrons.
    - Both electrons occupy the lower-energy σ1s bonding orbital, as this minimizes the system's energy.
- **Bond Formation**: The increased electron density in the bonding orbital stabilizes the molecule, creating a covalent bond between the hydrogen atoms.

Stability of H2

- **Bond Order**:
  Bond Order={(Electrons in bonding MOs) - (Electrons in antibonding MOs)}/2
  For H2:
    - Electrons in σ1s: 2
    - Electrons in σ*1s: 0
    - Bond Order = (2−0)/2 =1
- A bond order of 1 indicates a single covalent bond, confirming the stability of the hydrogen molecule.
- **Energy Consideration**: The σ1s bonding orbital has lower energy than the individual atomic 1s orbitals, making the H2 molecule more stable than two separate hydrogen atoms.

Magnetism of H2

- **Spin Pairing**: In H2, the two electrons in the bonding σ1s\sigma_{1s}σ1s orbital are spin-paired (opposite spins). This results in no net magnetic moment.
- **Diamagnetic Nature**: Because all electrons are paired and there are no unpaired electrons, the hydrogen molecule is diamagnetic, meaning it is weakly repelled by a magnetic field.

16. The shape of SF4 is not tetrahedral and square planar why?

Electron Pair Arrangement (Trigonal Bipyramidal):

- The sulfur atom in SF_4 is surrounded by **five electron pairs**:
  - Four bonding pairs (from the four S-F bonds).
  - One lone pair.
- According to VSEPR (Valence Shell Electron Pair Repulsion) theory, five electron pairs arrange themselves in a **trigonal bipyramidal geometry** to minimize repulsion.

Effect of the Lone Pair:

- Lone pairs occupy more space than bonding pairs because they are localized closer to the central atom.
- The lone pair in SF_4 is placed in one of the equatorial positions of the trigonal bipyramid to minimize repulsion.
- This distorts the ideal geometry, giving SF_4 a **seesaw shape** rather than tetrahedral or square planar.

  (3+3)

17. Explain the statement "Shape of orbitals is determined by the azimuthal quantum number *l* and orientation by magnetic quantum number *m*".

Shape Determined by Azimuthal Quantum Number (*l*):

- The **azimuthal quantum number (*l*)** defines the angular momentum of an electron and determines the **shape of the orbital**.
- l can take values from 0 to n-1, where n is the principal quantum number.
- Each value of l corresponds to a specific **orbital shape**:
  - l=0: **s-orbital** (spherical shape).
  - l=1: **p-orbital** (dumbbell shape).
  - l=2: **d-orbital** (double dumbbell shapes).

Orientation Determined by Magnetic Quantum Number (m):

- The **magnetic quantum number (m)** determines the **orientation of the orbital in space** with respect to an external magnetic field.

- m can take integer values from −*l* to +*l*. Each value corresponds to a specific spatial orientation of the orbital.
- The number of possible orientations depends on the value of *l*, giving 2*l*+1 orientations.

Example:

- For *l*=1 (p-orbitals):
    - m= −1,0,+1, corresponding to three orientations: pxp_xpx, pyp_ypy, and pzp_zpz.
    - These represent p-orbitals oriented along the x, y, and z axes.
- For l=2 (d-orbitals):
    - m=−2,−1,0,+1,+2, corresponding to five d-orbitals with specific orientations in three-dimensional space.

(3+3)

18. Describe the features of modern periodic table.

(Any six points)

Periodic Law

- The properties of elements are periodic functions of their atomic numbers, meaning similar properties recur at regular intervals when elements are arranged by increasing atomic number.

Structure and Layout

- **Horizontal Rows (Periods):**
    - The periodic table consists of **7 periods**.
    - Each period corresponds to the filling of a principal energy level (n = 1 to 7).
    - Elements in the same period have the same number of electron shells.
- **Vertical Columns (Groups/Families):**
    - There are **18 groups**, numbered 1 to 18.
    - Elements in a group have similar outer electron configurations and exhibit similar chemical properties.

Classification of Elements

- **Blocks Based on Subshell Filling:**
    - **s-Block (Groups 1 & 2):** Alkali and alkaline earth metals.
    - **p-Block (Groups 13–18):** Includes metals, nonmetals, and metalloids.
    - **d-Block (Transition Elements, Groups 3–12):** Metals with variable oxidation states.
    - **f-Block (Lanthanides and Actinides):** Inner transition metals located separately at the bottom.

Trends in Properties

- **Atomic Radius:** Decreases across a period, increases down a group.
- **Ionization Energy:** Increases across a period, decreases down a group.
- **Electronegativity:** Increases across a period, decreases down a group.
- **Metallic and Nonmetallic Character:**
  - Metallic character decreases across a period and increases down a group.
  - Nonmetallic character shows the opposite trend.

Section C (Essay)

Answer any one, Each question carries 10 marks (1x 10= 10 marks)

19. Write an essay on a) common ion effect and its application in qualitative analysis
b) advantages of microanalysis.

a) The common ion effect is the suppression of the ionization of a weak electrolyte on the addition of a strong electrolyte having a common ion.

Application:
I) Precipitation of Sulphides:
Dil. HCl and H_2S are together used as the reagent for precipitating group II cations as their Sulphides.
When Dil. HCl is added to it, the dissociation is suppressed by the common ion effect of H^+ ions. As a result the concentration of S^{2-} ions which was already small becomes still smaller. But even then it is larger than that required to exceed the solubility product of the Sulphides of Cu, Cd,Bi,etc. Hence these are get precipitated as their Sulphides in group 2 of inorganic qualitative analysis. However the solubility product of Sulphides of Mn,Co,Ni and Zn are higher. The lower sulphide ion concentration in the acid medium is not sufficient to overcome their solubility products. Due to this these ions do not get precipitated in group 2.
ii) Precipitation of hydroxide:

The solubility product of hydroxide of group 3 cations are much smaller than group 4 cations.Hence these are precipitated by the addition of NH_4OH in the presence of NH_4Cl. On adding NH_4Cl, due to the common ion effect of NH_4^+, the dissociation is further suppressed and hence

b)Advantages of Microanalysis:

- Requires less time for sample preparation
- Requires only a very small quantity of the sample and solvent
- More cost effective and less waste
- Enable in situ analysis of the sample
- Has a very high spatial resolution and sensitivity
- Can be carried out in a reasonably short time (5+5)

20. Explain the theory of acid-base, redox, and complexometric titrations.

Any ten points

Acid-base or neutralization titration : (3 mark)

The titration which involves the acid-base reaction(i.e. neutralization reaction) is called acid-base titration.

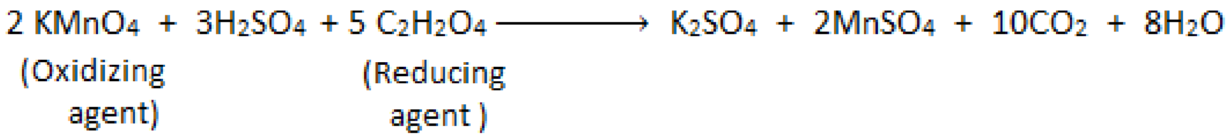
Acidimetry: The process of determining the strength of unknown acid by titrating it with the standard solution of alkali in presence of indicator is called acidimetry.

Alkalimetry: The process of determining the strength of unknown base by titrating it with the standard solution of acid in presence of indicator is called alkalimetry.

Oxidation-Reduction or Redox titration: (3 mark)

The process of determining the strength of an oxidizing agent by titrating it with the standard solution of reducing agent or vice-versa is called redox titration. For example:

Titration of potassium permanganate ($KMnO_4$) (i.e. oxidizing agent) with standard oxalic acid ($C_2H_2O_4$) (i.e. reducing agent) in acidic medium is a redox titration.



$$\underset{\text{(Oxidizing agent)}}{2\,KMnO_4} + 3H_2SO_4 + \underset{\text{(Reducing agent)}}{5\,C_2H_2O_4} \longrightarrow K_2SO_4 + 2MnSO_4 + 10CO_2 + 8H_2O$$

Theory of Complexometric Titrations (4 mark)

Complexometric titration is a type of volumetric analysis where a metal ion in solution reacts with a chelating agent (a ligand) to form a stable, soluble complex. This method is widely used to determine the concentration of metal ions in a solution.

Key Principles

1. **Formation of Complexes**:
   - In complexometric titrations, a metal ion (Mn^+) reacts with a ligand (e.g., EDTA) to form a coordination complex.
   - A common reaction can be represented as: $Mn^+ + L \rightarrow [ML]^{(n-x)+}$
   - **Ligand**: A molecule or ion that donates electron pairs to the metal ion.
   - **Chelation**: When the ligand has multiple donor atoms, it forms a chelate with the metal ion, enhancing the complex's stability.
2. **Chelating Agents**:
   - The most commonly used chelating agent is **EDTA** (ethylenediaminetetraacetic acid).
   - EDTA forms a 1:1 complex with most metal ions, regardless of the ion's charge, making it versatile.
3. **Endpoint Detection**:

  - The endpoint of the titration is determined using **metal ion indicators**, which change color when free metal ions are no longer available to react with the indicator.
  - Examples of indicators: Eriochrome Black T (used for calcium and magnesium titrations).
4. **Buffering**:
  - The pH of the solution is critical in complexometric titrations since the chelating agent's ability to bind the metal depends on the pH.
  - A buffer is often added to maintain a constant pH.