BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI - K.K. BIRLA GOA CAMPUS
First Semester 2024-2025, Mid-Semester Examination (Closed Book)

Course No: CHEM F111 **Date: 03/10/2024** **Total Marks: 90**
Course Title: General Chemistry **Duration: 90 min**

Name: _____ **ID No:** _____ **Marks Obtained:** _____

Recheck:

Instructions: *Write the* ***FINAL ANSWERS ONLY*** *with* **BLUE PEN** *in the boxes provided;* **DO NOT OVERWRITE!** ***Main answer book may be used for rough work only.*** ***Useful Information:*** $m_{electron} = 9.11 \times 10^{-31}$ kg, $m_{neutron} = 1.67 \times 10^{-27}$ kg, $h = 6.626 \times 10^{-34}$ J s, $c = 3 \times 10^8$ m s^{-1}, 1 eV = 1.602×10^{-19} J, R = 8.314 J K^{-1} mol^{-1}, Bohr Radius (a_o) = 52.9 pm, 1 kcal = 4.18 kJ, 1 kJ mol^{-1} = 83.7 cm^{-1}, R_H = 109678 cm^{-1}, 1 amu = 1.67×10^{-27} kg, $N_A = 6.023 \times 10^{23}$, $\psi_n(x) = N\sin(\frac{n\pi x}{L})$, $\int \sin^2 bx\,dx = x/2 - \sin(2bx)/4b$, $\Psi_{1s} = \left(\frac{1}{\sqrt{\pi}}\right)\left(\frac{Z}{a_0}\right)^{3/2} e^{-\frac{Zr}{a_0}}$, Atomic No. of Cr = 24, V = 23, Mn =25, Fe = 26, Ni = 28, Cu = 29, Co = 27, Pt = 78, Rh = 45; Atomic weight of Cr = 52; Cl = 35.5; C = 12; O = 16

1.	An acceptable wavefunction for the particle in a one-dimensional infinite depth box of length 'a' is $x(1-\frac{x}{a})$. What is the normalization constant (in $nm^{-3/2}$) if the length of the box is 3 nm? *(Answer up to three decimal places).* **[4]**	± 1.054
2.	Calculate the wavenumber *(in cm^{-1})* corresponding to (i) the highest and (ii) the lowest energy spectral line in the Paschen series for the hydrogen atom. *(Answer up to two decimal places)* **[2+2]**	**(i)** 12186.44 **(ii)** 5331.57
3.	A 5 mm cell was filled with a solution of a dye of concentration 18.5 mmol dm^{-3}. Calculate the (i) molar absorption coefficient of the dye (in dm^3 mol^{-1} cm^{-1}) when the % transmittance (%T) was 29 and (ii) the %T at the same wavelength when the same solution is placed in a 2.5 mm cell. **[2+2]**	**(i)** 58.12 **(ii)** 53.85
4.	The fundamental and first overtone transitions of a molecule are centered at 1500 cm^{-1} and 2977 cm^{-1}, respectively. Calculate the (i) vibrational frequency (ν_e) (in s^{-1}) and (ii) anharmonicity constant (x_e). **[2+2]**	**(i)** $4569 * 10^{10}$ **(ii)** 0.00755
5.	The mean distance $< r >_{n,\,l,\,m_l}$ (in pm) from the nucleus for the electron given by the wavefunction i) $\psi_{5,2,0}$ and ii) $\psi_{5,0,0}$ in B^{4+} ion are: *(Answer up to two decimal places)* **[2+2]** Here B represents Boron.	**(i)** 365.01 **(ii)** 396.75
6.	The orbital angular momentum (in J s) of an electron in (i) 3d and (ii) 2p levels, respectively are: *(Answer up to two decimal places)* **[2+2]**	**(i)** 3d $2.58 * 10^{-34}$ **(ii)** 2p $1.49 * 10^{-34}$

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7.	What are the ratios of the probability (P_H/P_{He+}) of locating the 1s-electron in a small spherical volume δV (in which the wavefunction can be considered constant) centered (i) at r= 0 and (ii) at r= a_0 in H-atom and He^+ ion? *(Answers up to two decimal places).* [2+2]	(i) $(P_H/P_{He+})_{r=0}$ = 0.125 (ii) $(P_H/P_{He+})_{r=ao}$ = 0.92
8.	The vibrational energy level of CO molecule is given by the expression E_v (in J mol^{-1}) = 25000 (v + ½) – 150 (v + ½)² where v is the vibrational quantum number. Calculate the force constant (*in N m^{-1}*) *(Answer up to two decimal places)* [4]	1773
9.	The energy of the electron present in 1-D box of length 1 Å is 602.5 eV. How many nodes are present for this level? [3]	03
10.	At what value of radius (r) (in pm), does the probability of finding an electron in a small volume located at a point in the ground state of an H-atom fall to 75% of its maximum value? *(Answer up to two decimal places)* [3]	7.61

11. Identify from the following molecule(s) that have (i) trigonal planar, (ii) trigonal pyramidal and (iii) octahedral geometry?
BF_3, NF_3, PCl_5, SF_6, CO_2, ethylene [1+1+1]

(i) Trigonal planar	(ii) Trigonal pyramidal	(iii) Octahedral
BF_3, Ethylene	NF_3	SF_6

12. Match **A, B & C** to **(i-iii)** provided in the box, based on the conditions given below.
A, the spacing between adjacent energy levels decreases with increasing energy
B, the spacing between adjacent energy levels remains constant
C, the spacing between adjacent energy levels increases with increasing energy [1+1+1]

i. particle in a one-dimensional box
ii. harmonic oscillator
iii. electron in hydrogen atom

	Answers
A	(iii)
B	(ii)
C	(i)

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13. The octahedral crystal field splitting (Δ_o) value for $[Cr(OH_2)_6]^{2+}$ is 13,900 cm^{-1}. The predicted (theoretical) hydration energy of octahedral Cr^{2+} is -1830 kJ mol^{-1}. What is the value for the experimentally determined hydration energy (in kJ mol^{-1})? *(Answer up to one decimal point)* *(Assume no distortion)* **[3]**

$\pm$ 1929.6

14. Three compounds **A**, **B** and **C** have empirical formula of $CrCl_3.6H_2O$. When 1 g of each compound separately kept in a container with dehydrating agent, showed a final weight of 0.865 g for **A**, and 0.932 g for **B**. No change in weight was observed for **C**. Write the molecular formula for **A**, **B** and **C**. **[1+1+1]**

(i) Molecular formula for **A**	(ii) Molecular formula for **B**	(iii) Molecular formula for **C**
$[Cr(H_2O)_4Cl_2]Cl.2H_2O$	$[Cr(H_2O)_5Cl]Cl_2.H_2O$	$[Cr(H_2O)_6]Cl_3$

15. For each of the following pairs of complex ions, identify the complex ion that has higher value of Δ_o? *(Assuming perfect octahedron geometry)*
(i) $[Co(NH_3)_6]^{3+}$ and $[Rh(NH_3)_6]^{3+}$
(ii) $[Fe(ox)_3]^{4-}$ and $[Fe(ox)_3]^{3-}$ (where ox=oxalate)
(iii) $[Cr(en)_3]^{3+}$ and $[Cr(ox)_3]^{3+}$ (where en=ethylenediamine) **[1+1+1]**

(i)	(ii)	(iii)
$[Rh(NH_3)_6]^{3+}$	$[Fe(ox)_3]^{3-}$	$[Cr(en)_3]^{3+}$

16. (i) Calculate the ratio of the CFSE values (in terms of Δ_o) for the octahedral and tetrahedral complexes of a d^7 metal ion in presence of strong field ligands. *(Answer up to two decimal places)*. (ii) Write the number of unpaired electrons in octahedral (n_{Oh}) and tetrahedral (n_{Td}) cases. *(Assume no distortion)* **[3+1+1]**

(i) $(CFSE_{Oh}/CFSE_{Td})$ = 3.377

(ii) n_{Oh} = 01

n_{Td} = 03

17. Match the following complexes **(A-D)** to their CFSEs **(i-iv)**. **[1+1+1+1]**

Complex	
A.	$[Co(NH_3)_6]^{3+}$
B.	$[Co(NH_3)_6]^{2+}$
C.	$[Co(H_2O)_6]^{3+}$
D.	$[Co(H_2O)_6]^{2+}$

CFSE	
i.	$-0.8\ \Delta_o$
ii.	$-0.4\ \Delta_o$
iii.	$-2.4\ \Delta_o$
iv.	$-1.8\ \Delta_o$

Complex	CFSE
A	iii
B	iv
C	ii
D	i

18. Predict the following, for the complexes: $[NiCl_4]^{2-}$, $[Ni(CN)_4]^{2-}$ and $Ni(CO)_4$. (BM = Bohr Magnetons) **[2+2+2]**

Complexes	No. of unpaired electrons	Magnetic moment (spin only) in BM
$[NiCl_4]^{2-}$	2	2.828
$[Ni(CN)_4]^{2-}$	0	0
$Ni(CO)_4$	0	0

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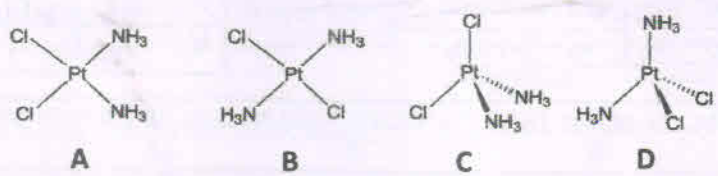
19.	Arrange the d-orbitals in increasing order of energy for copper ion (in octahedral environment) in K_2CuF_4 (solid state) when four fluoride ions are at 191 pm and two fluoride ions are at 237 pm from the copper ion. *(Use symbols = or < symbol wherever appropriate)* [3]	$d_{xz} \sim d_{yz} < d_{xy} < d_{z^2} < d_{x^2-y^2}$	
20.	Identify the complex(es) among the following that do not follow the effective atomic number (EAN) rule. (i) $[Fe(CN)_6]^{3-}$, (ii) $[Fe(CN)_6]^{4-}$, (iii) $[Cu(NH_3)_4]^{2+}$, (iv) $[Cu(CN)_4]^{3-}$ [4]	(i) & (iii)	
21.	How many normal modes of vibration are there for the following molecules? (i) XeF_2 (ii) B_2H_6 (iii) SO_2 (iv) CO_3^{2-} [1+1+1+1]		
	(i) XeF_2: 4	(ii) B_2H_6: 18	(iii) SO_2: 3	(iv) CO_3^{2-}: 6
22.	Consider the ML_6 complexes of Cr(II), Fe(II) and Co(II). Match these complexes to the relative extent of Jahn-Teller (J-T) distortion, considering the same strong field ligand (L). [1+1+1]	(i) Strong J-T distortion	Co (II)
		(ii) Weak J-T distortion	Cr (II)
		(iii) No J-T distortion	Fe (II)
23.	Arrange the following in the increasing order of ligands field strength *(Use symbol '<').* H_2O, CO, NH_3, I^-, F^- [3]	$I^{\ominus} < F^{\ominus} < H_2O < NH_3 < CO$	
24.	The (i) coordination number and (ii) oxidation state of Cr in $K[Cr(ox)_2(H_2O)_2]$ are: (ox=oxalate) [1+1]	(i) Coordination No.: 6	
		(ii) Oxidation State: +3	
25.	(i) Identify the correct geometrical isomer(s) of $[PtCl_2(NH_3)_2]$ from the given options.  A B C D (ii) Which of the possible isomer(s) has the highest dipole moment? [2+1]		
	(i) A & B	(ii) A (or) Cis isomer	

End