Inorganic 09348 2001

Answer Key
Friday Quiz 4

December 7, 2001

Question 1 – Complete the following equations representing reactions performed in liquid ammonia as a solvent.

a) $\mathbf{NH_4Br} + \mathbf{KNH_2} = \mathrm{KBr} + 2\mathrm{NH_3}$

b) $\mathbf{Na_{(s)}} + \mathbf{NH_{3(l)}} = \mathrm{Na^+}_{(\mathrm{NH_3})_x} + \mathrm{e^-}_{(\mathrm{NH_3})_y}$

c) $\mathbf{Mg_2Ge} + \mathbf{4NH_4Br} = \mathrm{GeH_4} + 2\mathrm{MgBr_2} + 4\mathrm{NH_3}$

Question 2 – Rank the following substances in order of ascending boiling points or enthalpy of vaporization:

(i) $\mathbf{H_2}$
(ii) **He**
(iii) **Ne**
(iv) $\mathbf{H_2O}$
(v) **HF**
(vi) $\mathbf{NH_3}$
(vii) $\mathbf{CH_4}$

	Boiling point (°C)	
He	-269	← Lowest Boiling Point
H_2	-253	
Ne	-246	
CH_4	-162	
NH_3	-33	
HF	20	
H_2O	100	← Highest Boiling Point

Question 3 – Consider the electrolysis of a solution of aqueous NaCl. This reaction is the basis of the chloralkali industry.

a) **Balance the half-reaction that occurs at the anode:**

$$2\mathrm{Cl^-}_{(aq)} = \mathrm{Cl_{2(g)}} + 2\mathrm{e^-}$$

a) **Balance the half-reaction that occurs at the cathode:**

$$\mathrm{H_2O_{(l)}} + 2\mathrm{e^-} = 2\left[\mathrm{OH}\right]^-_{(aq)} + \mathrm{H_{2(g)}}$$

Question 4 – Circle the relatively forms of the element in each case. Note: There may be more than one stable form. Relatively stable is meant to imply that the species can be isolated and sealed in an ampoule.

(a) H, H_2, H_4, H_6

(b) O, O_2, O_3, O_6, O_8

(c) S_2, S_6, S_8

(d) P_2, P_4, $P_{(n)}$

(e) N_2, N_4, N_6, N_{16}

(f) F_2, F_3, F_5, F_{60}

(g) Na_2, $Na_{(n)}$

(h) Ne, Ne_2, Ne_4

(i) C_2, C_{60}, C_n

Question 5 – Write down the d^n configurations for the metal center in the following complexes.

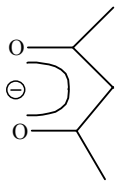
(a) $Co(en)_3^{3+}$ $\boxed{d^6}$

Co is from group IX. The compound is a cation so the oxiditation state of the metal is 3+. Thus, the number of d electrons is 9-3, which give the configuration d^6.

(b) ReF_8^{2-} $\boxed{d^1}$

Re is from group VII. The compound is an anion and the Re which as the oxidation state +n is bonded to 8 F^-. So, n – 8 = -2, giving n = 6. Thus, 7 – 6 = 1, giving the configuration d^1.

(c) $V(acac)_2O$ $\boxed{d^1}$

Where acac is 

Vanadium is from group V. The compound is neutral, but acac has a charge of -1, oxygen a charge of -2 and vanadium is on the oxidation state +n. So, n – 2 – 2 = 0, giving n = 4. Thus, 5 – 4 = 1, giving the configuration d^1.

(d) $\mathbf{Hf(BH_4)_4}$ $\boxed{d^o}$

Hf is from group IV. The compound is neutral, but BH_4 has a charge of -1 and Hf is on the oxidation state +n. So, n – 4 = 0, giving n = 4. Thus, 4 – 4 = 0, giving the configuration d^o.

Question 6 – Write down a minimal description that corresponds to most commonly observed geometrical arrangements of ligands about a metal center for each coordination number. Note, that for some coordination numbers, more than one geometry is required. Note also, that coordination 4 has been completed for you.

Coordination Number	Most Common Geometry
2	Linear
3	Trigonal Planar
4	**Tetrahedral**
4	**Square Planar**
5	Trigonal Bipyramidal
5	Square-based Pyramidal
6	Octahedral Based
7	Pentagonal Bipyramidal
7	Monocapped Trigonal Prismatic
8	Trigonal Dodecahedron
8	Square Antiprismatic
9	Tricapped Trigonal Prismatic

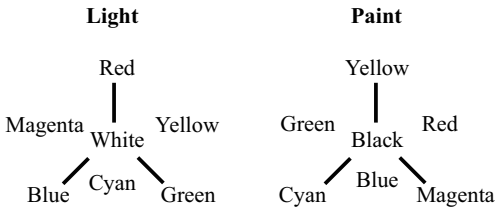
Question 7 – Complete the following "equations" concerning the mixing of colors by additions (lights) and by subtraction (paints).

(a) Red Light + Green Light = Yellow light

(b) **Blue Light + Yellow Light** = White light

(c) Green Paint + Magenta Paint = Black paint

(d) Magenta Paint + Cyan Paint = Blue paint



Question 8 – Arrange the following ligands in the order that you suspect they should appear in the Spectrochemical Series.

(i) en
(ii) I^-
(iii) Br^-
(iv) CN^-
(v) Ox^{2-}
(vi) H_2O
(vii) bipy

I^-	← Weakest
Br^-	
Ox^{2-}	
H_2O	
en	
bpy	
CN^-	← Strongest

Question 9 – Arrange the following ligands in the order that you suspect they should appear in the Spectrochemical Series.

(a) $Co(en)_3^{3+}$ **Point Group =** D_3

(b) $trans\text{-}Co(Cl)_2(NH_3)_4^{\oplus}$ **Point Group =** D_{4h}

(c) $fac\text{-}Co(NH_3)_3Cl_3$ **Point Group =** C_{3v}

Question 10 – A satisfactory set of styx numbers for $B_{10}H_{14}$ would be which of the following?

Recall for $[(BH)_p H_{q+c}]^c$ **we have that**

$$x = q + c - s$$
$$t = p + c - s$$
$$2y = s - 3c - s$$

Please circle the correct answer below.

(a) 2 8 0 2
(b) 3 6 2 1
(c) 4 1 -1 3
(d) -3 5 2 -1

$[(BH)_{10}H_4]^o$

So, p = 10, c = 0, q = 4. Thus x = 4 – s, t = 10 – s and y = s – 2.

s	t	y	x
-3	13	-5	7
-2	12	-4	6
-1	11	-3	5
0	10	-2	4
1	9	-1	3
2	8	0	2
3	7	1	1

Question 11 – Calculate the charge on the cyclic silicate $Si_3H_9^{n-}$.

Circle the correct answer.

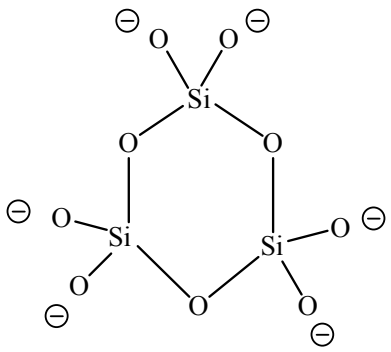
(a) -6

(b) -5

(c) -4

(d) -3

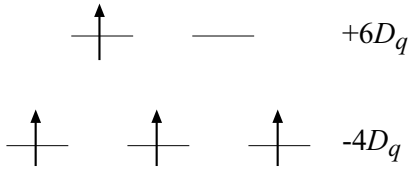
(e) -2



Question 12 – For the $Cr(H_2O)_6^{2+}$ ion, the mean pairing energy "P" is found to be 23,500 cm^{-1} and the magnitude of Δ_o is 13,900 cm^{-1}. Calculate the crystal field stabilization energy (CFSE) and the number of unpaired electrons (UPE) in the ground state.

Correct Answer (√)	Answer Letter	CFSE (cm^{-1})	UPE
	a.	1260	4
	b.	1260	2
	c.	8340	2
	d.	9600	4
	e.	9600	2
√	f.	8340	4

$Cr(H_2O)_6^{2+}$ has a d^4 configuration and, because Δ_o<P, the complex has a high spin configuration, which implies 4 UPE.



The CFSE is then given by

$$CFSE = 3\times 4D_q - 1\times 6D_q \quad \Leftrightarrow \quad CFSE = 6D_q$$

Knowing that $1D_q = 0.1\Delta_o$ one get

$$CFSE = 6\times 0.1\times 13{,}900 \quad \Leftrightarrow \quad \boxed{CFSE = 8340\,cm^{-1}}$$

Question 13 – For the $Cr(H_2O)_6^{2+}$ ion, the mean pairing energy "P" is found to be 23,500 cm^{-1} and the magnitude of Δ_o is 13,900 cm^{-1}. Calculate the crystal field stabilization energy (CFSE) and the number of unpaired electrons (UPE) in the ground state.

A.

$\overline{z^2}$

$\overline{xz}$ $\overline{yz}$

$\overline{xy}$ $\overline{x^2-y^2}$

B.

$\overline{z^2}$

$\overline{xz}$ $\overline{xy}$ $\overline{yz}$

$\overline{x^2-y^2}$

C.

$\overline{xy}$ $\overline{x^2-y^2}$ $\overline{z^2}$

$\overline{xz}$ $\overline{yz}$

D.

$\overline{xz}$ $\overline{yz}$

$\overline{x^2-y^2}$

$\overline{xy}$

$\overline{z^2}$

Question 14 – Which of the following transition metals form square planar complexes almost exclusively?

(i) Copper II
(ii) Platinum II
(iii) Cobalt III

Circle the correct answer.

(E) All of them
(F) (i) only
(G) (ii) only
(H) (iii) only
(A) (i) and (ii)
(B) (i) and (iii)
(C) (ii) and (iii)
(D) None of them

Question 15 – Which of the following compounds/ions would you suppose does *not* exhibit Jahn-Teller distortion.

Circle the correct answer.

A. CrF_2

B. $Cu(H_2O)_6^{2+}$

C. $Ti(H_2O)_6^{3+}$

D. CoF_2

E. $V(H_2O)_6^{2+}$

Question 16 – Use the spin selection rules and the Tanabe Sugano Diagram shown below to estimate the energy of the three spin allowed ligand field bands observed for $Cr(H_2O)_6^{3+}$. Given: B = 695 cm^{-1} and Δ_o = 17,000 cm^{-1}

Circle the correct answer.

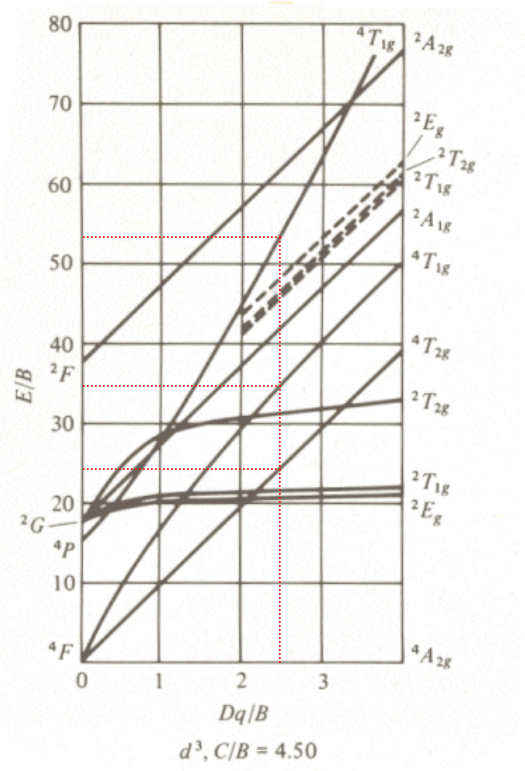
A. **45,000 cm^{-1}, 35,000 cm^{-1}, 25,000 cm^{-1}**

B. **20,000 cm^{-1}, 32,000 cm^{-1}, 53,000 cm^{-1}**

C. **8,000 cm^{-1}, 14,000 cm^{-1}, 19,000 cm^{-1}**

D. **13,000 cm^{-1}, 13,052 cm^{-1}, 13,121 cm^{-1}**

E. **17,000 cm^{-1}, 24,000 cm^{-1}, 37,000 cm^{-1}**



Note: In this solution, the values in the horizontal axis correspond to D_q/B. One have to remember that $1D_q = 0.1\Delta_o$.

The allowed transitions are ${}^4A_{2g} \leftarrow {}^4T_{2g}(F)$, ${}^4A_{2g} \leftarrow {}^4T_{1g}(F)$ and ${}^4A_{2g} \leftarrow {}^4T_{1g}(P)$.

Using the values given one obtain:

$$\frac{\Delta_o}{B} \approx 24.5 \quad \Rightarrow \quad \frac{D_q}{B} \approx 2.45$$

Drawing a vertical line (dot line) beginning on 2.45, one get three intersection points with the lines corresponding to ${}^4T_{2g}(F)$, ${}^4T_{1g}(F)$ and ${}^4T_{1g}(P)$. From each intersection point, one draws a horizontal line to obtain the E/B value for each transition.

The approximated E/B values obtain are: 24, 35 and 53. To obtain the three spin allowed ligand field bands observed, one must multiply each value of E/B by the value of B. The values obtain are 16,689 cm^{-1}, 24,325 cm^{-1} and 36,853 cm^{-1}.

Thus, the only set of values that resemble the approximated values obtain are 17,000 cm^{-1}, 24,000 cm^{-1} and 37,000 cm^{-1}.