Name: Key

May 1, 2007
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Chemistry 142 Exam #3 Practice

Question 1. Balance the following redox reactions.

a) $HI + HNO_3 \rightarrow I_2 + NO$

$(2I^- \rightarrow I_2 + 2e^-)3$

$(3e^- + 4H^+ + NO_3^- \rightarrow NO + 2H_2O)2$

$6I^- + 8H^+ + 2NO_3^- \rightarrow 3I_2 + 2NO + 4H_2O$

$6HI + 2HNO_3 \rightarrow 3I_2 + 2NO + 4H_2O$

b) $Ag + H_2SO_4 \rightarrow Ag_2SO_4 + SO_2$

$(Ag \rightarrow Ag^+ + e^-)2$

$2e^- + 4H^+ + SO_4^{2-} \rightarrow SO_2 + 2H_2O$

$2Ag + 4H^+ + SO_4^{2-} \rightarrow 2Ag^+ + SO_2 + 2H_2O$

$2Ag + 2H_2SO_4 \rightarrow Ag_2SO_4 + SO_2 + 2H_2O$

c) $MnCl_2 + KMnO_4 + KOH \rightarrow MnO_2 + KCl$

$(2H_2O + Mn^{2+} \rightarrow MnO_2 + 4H^+ + 2e^-)3$

$(3e^- + 4H^+ + MnO_4^- \rightarrow MnO_2 + 2H_2O)2$

$6H_2O + 3Mn^{2+} + 8H^+ + 2MnO_4^- \rightarrow 3MnO_2 + 12H^+ + 2MnO_2 + 4H_2O$

$+ 12OH^-$ $+ 12OH^-$

$3MnCl_2 + 2KMnO_4 + 4KOH \rightarrow 5MnO_2 + 6KCl + 2H_2O$

d) $H_3AsO_4 + Zn + HNO_3 \rightarrow AsH_3 + Zn(NO_3)_2$

$8e^- + 11H^+ + AsO_4^{3-} \rightarrow AsH_3 + 4H_2O$

$(Zn \rightarrow Zn^{2+} + 2e^-)4$

$11H^+ + AsO_4^{3-} + 4Zn \rightarrow AsH_3 + 4Zn^{2+} + 4H_2O$

$H_3AsO_4 + 8HNO_3 + 4Zn \rightarrow AsH_3 + 4Zn(NO_3)_2 + 4H_2O$

e) $P_4 + NaOH \rightarrow NaH_2PO_4 + PH_3$

$(16H_2O + P_4 \rightarrow 4H_2PO_4^- + 24H^+ + 20e^-)3$

$12e^- + 12H^+ + P_4 \rightarrow 4PH_3)5$

$48H_2O + 3P_4 + 60H^+ + 5P_4 \rightarrow 12H_2PO_4^- + 72H^+ + 20PH_3$

$+ 72OH^-$ $+ 72OH^-$

$108H_2O + 120H^- + 8P_4 \rightarrow 12H_2PO_4^- + 72H_2O + 20PH_3$

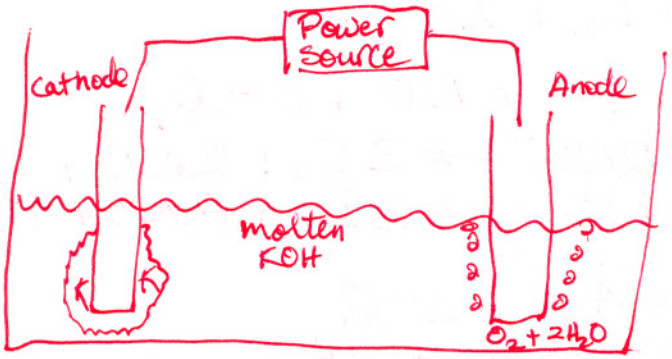
$36H_2O + 120H^- + 8P_4 \rightarrow 12H_2PO_4^- + 20PH_3$

$9H_2O + 2P_4 + 3NaOH \rightarrow 3NaH_2PO_4 + 5PH_3$

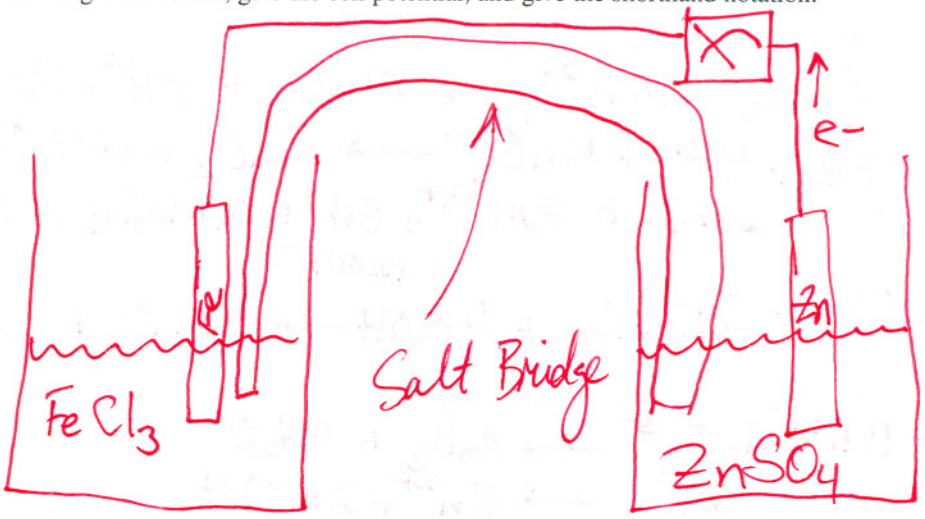
Question 2. Potassium was discovered by Sir Humphry Davy when he electrolyzed molten potassium hydroxide. Show this electrolytic cell and the electrode reactions.

$K^+(l) + e^- \rightarrow K(l)$ Cathode

$4OH^-(l) \rightarrow O_2(g) + 2H_2O(g) + 4e^-$ Anode



Question 3. An iron rod is placed in 1.0*M* iron(III) chloride solution and a zinc rod is placed in a 1.0*M* zinc sulfate solution. Diagram this cell, give the cell potential, and give the shorthand notation.



$Fe^{3+} + 3e^- \rightarrow Fe$

Cathode -0.04V

$Zn \rightarrow Zn^{2+} + 2e^-$

Anode 0.76V

$E_{cell} = 0.72$V

$Zn|Zn^{2+}||Fe^{3+}|Fe$

Question 4. Calculate the standard free energy change, using electrochemical potentials, for the reaction,

$$Na(s) + 1/2Cl_2(g) \rightarrow Na^+ + Cl^-$$

$Na \rightarrow Na^+ + e^- \quad +2.71v$

$\frac{1}{2}Cl_2 + 1e^- \rightarrow Cl^- \quad +1.36v$

$E^\circ_{cell} = 4.07v$

$\Delta G^\circ = -nFE^\circ = -1\left(96{,}500 \frac{C}{mole^-}\right) 4.07v$

$\Delta G^\circ = 393\ kJ$

Question 5. What is the emf of the following cell? @298 K

$$Ni(s)|Ni^{2+}(1.0M)||Sn^{2+}(1.0\times10^{-4}M)|Sn(s)$$

$Ni + Sn^{2+} \rightarrow Ni^{2+} + Sn$

$Q = \frac{[Ni^{2+}]}{[Sn^{2+}]}$ $\quad E^\circ_{cell} = 0.23V + (-0.14v) = 0.09V$

$E = E^\circ_{cell} - \frac{RT}{nF} \ln Q$

$E = 0.09V - \frac{(8.314)(298)}{2(96{,}500)} \ln \frac{1.0}{1.0\times10^{-4}} =$

Question 6. Calculate the equilibrium constant for the following reaction at 298 K.

$$Fe^{3+} + Sn^{2+} \rightarrow Fe^{2+} + Sn^{4+}$$ $2Fe^{3+} + Sn^{2+} \rightarrow 2Fe^{2+} + Sn^{4+}$

$E^\circ_{cell} = \frac{RT}{nF} \ln K$

$E^\circ_{cell} = 0.77v + (-0.15v) = 0.62v$

$0.62v = \frac{(8.314)(298K)}{2(96{,}500)} \ln K$

$48.3 = \ln K$

$K = 9.4\times10^{20}$

Question 7. The commercial production of Cl_2 involves the electrolysis of aqueous NaCl solutions. Give the products of this electrolysis at each electrode and calculate how long it will take to produce 1.18 kg of Cl_2 when a current of 5.00×10^2 A is applied.

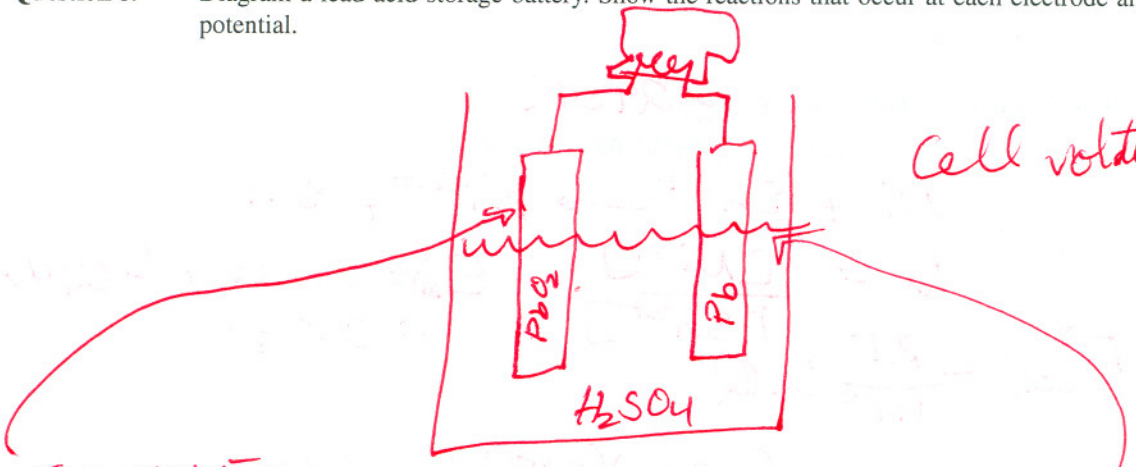
ANODE: $2Cl^- \longrightarrow Cl_2 + 2e^-$

CATHODE: $Na^+ + e^- \longrightarrow Na$

$Na^+ + 2Cl^- \longrightarrow Na + Cl_2$

$$1.18\,kg\,Cl_2 \times \frac{1000\,g}{1\,kg} \times \frac{1\,mol\,Cl_2}{71.1\,g\,Cl_2} \times \frac{2\,mol\,e^-}{1\,mol\,Cl_2} \times \frac{96{,}500\,C}{1\,mole^-} \times \frac{1\,s}{5.00\times10^2\,C} =$$

Question 8. Diagram a lead-acid storage battery. Show the reactions that occur at each electrode and calculate the cell potential.



Cell voltage ≈ 2V

CATHODE:

$PbO_2 + 3H^+ + HSO_4^- \longrightarrow PbSO_4 + 2H_2O$

ANODE:

$Pb + HSO_4^- \longrightarrow PbSO_4 + H^+$

Question 9. What is a sacrificial anode?

A sacrificial anode is a metal that is readily oxidized which is placed in electrical contact with another metal to be protected from oxidation. In this manner the sacrificial anode is oxidized rather than the metal to be protected. An example is the prevention of corrosion in steel by coating the surface with Zn (galvanizing). The Zn is oxidized while the Fe in steel is not. This is also known as cathodic protection

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Question 10 Write the formula for the complex ion, and the coordination compounds containing the indicated central atom, ligands, and counter ion.

a) central atom: Fe^{3+}, ligands: six CN^-, counter ion: K^+

$[Fe(CN)_6]^{3-}$

$K_3[Fe(CN)_6]$

b) central atom: Ag^+, ligands: two OH^-, counter ion: Na^+

$[Ag(OH)_2]^-$

$Na[Ag(OH)_2]$

c) central atom: Ni^{2+}, ligands: four NH_3, counter ion: SO_4^{2-}

$[Ni(NH_3)_4(H_2O)_2]^{2+}$

$[Ni(NH_3)_4(H_2O)_2]SO_4$

d) central atom: Pt^{4+}, ligands: four H_2O, two Cl^-, counter ion: Cl^-

$[Pt(H_2O)_4Cl_2]^{2+}$

$[Pt(H_2O)_4Cl_2]Cl_2$

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Question 11 Find the coordination number and oxidation number of the central atom in each coordination compound below.

	Central Atom	Oxidation No.	Coordination No.
$K_2[PtCl_6]$	Pt	+4	6
$[Fe(H_2O)_6](NO_3)_2$	Fe	+2	6
$Na_2[Ni(CN)_4]$	Ni	+2	4
$[Zn(H_2O)_2(OH)_2]$	Zn	+2	4

Question 12 In the blanks give the formula indicating the composition of the complex and the counter ions for the coordination compounds below.

Composition	moles Cl^-/mol compound	mole number	Formula of Coord. Compound
$PtCl_4(NH_3)_6$	four	five	$[Pt(NH_3)_6]Cl_4$
$PtCl_4(NH_3)_4$	two	three	$[Pt(NH_3)_4Cl_2]Cl_2$
$PtCl_4(NH_3)_2$	none	one	$[Pt(NH_3)_2Cl_4]$
$PtCl_4(NH_3)K$	none	two	$K[Pt(NH_3)Cl_5]$

Question 13 Complete the table below

Form. of Coord. Compound	Fornula of Complex Ion	Formula of Counter Ion	Total No. of Ions
$[Cr(H_2O)_6]Cl_3$	$[Cr(H_2O)_6]^{3+}$	Cl^-	4
$[Cr(H_2O)_5Cl]Cl_2$	$[Cr(H_2O)_5Cl]^{2+}$	Cl^-	3
$[Cr(H_2O)_4Cl_2]Cl$	$[Cr(H_2O)_4Cl_2]^+$	Cl^-	2
$NH_4[Cr(H_2O)_2Cl_4]$	$[Cr(H_2O)_2Cl_4]^-$	NH_4^+	2

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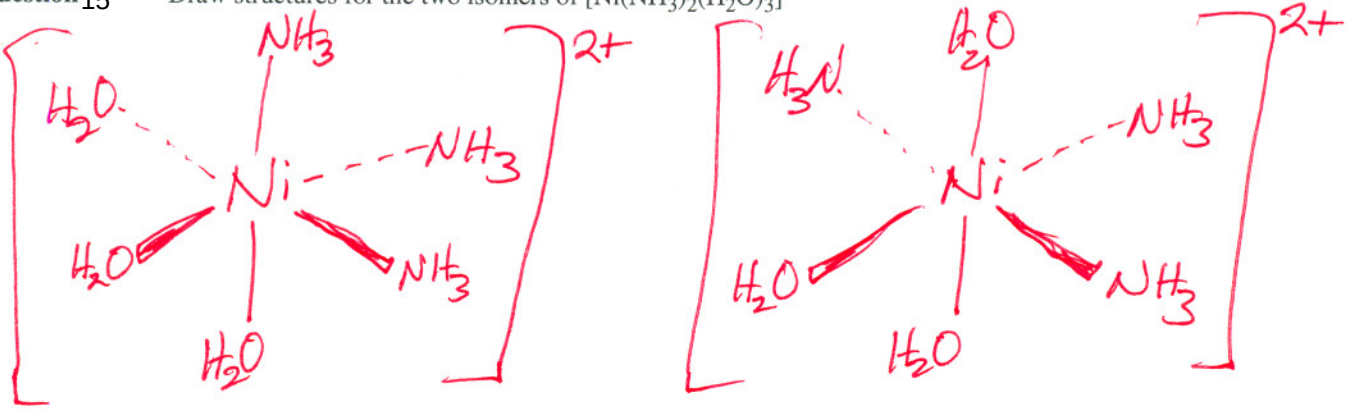
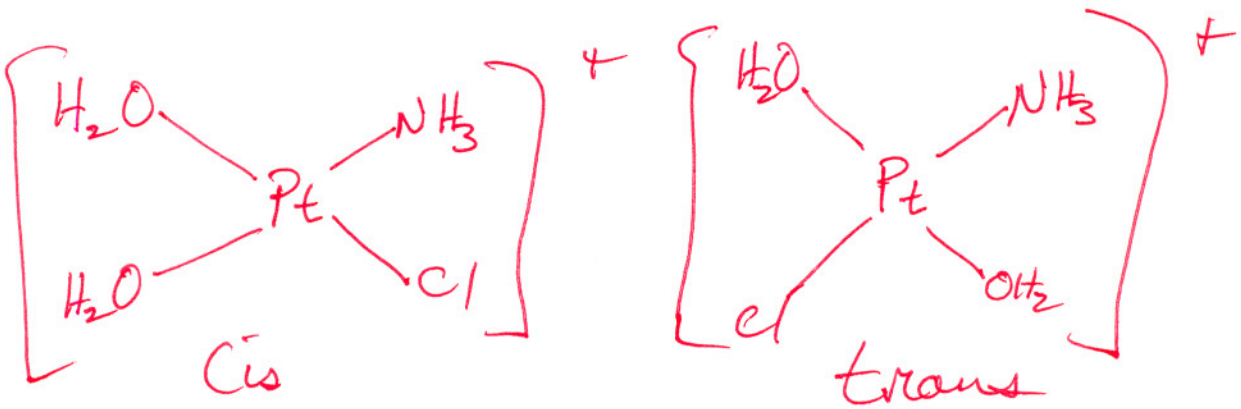
Question 14 For each complex below, give the coordination number of the central atom, and the expected geometry of the complex.

	Coord. No. of Central Atom	**Geom. of Complex**
$[Fe(H_2O)_6]^{3+}$	6	octahedral
$[Ni(NH_3)_2Cl_2]$ (only one isomer)	4	tetrahedral
$[Ni(H_2O)_3(NH_3)_3]^{2+}$	6	octahedral
$[Au(CN)_2Cl_2]^-$ (two isomers)	4	square planar

Question 15 Draw structures for the two isomers of $[Ni(NH_3)_2(H_2O)_3]^{2+}$.



Question 16 Draw structures for the two isomers of $[Pt(H_2O)_2(NH_3)Cl]^+$.



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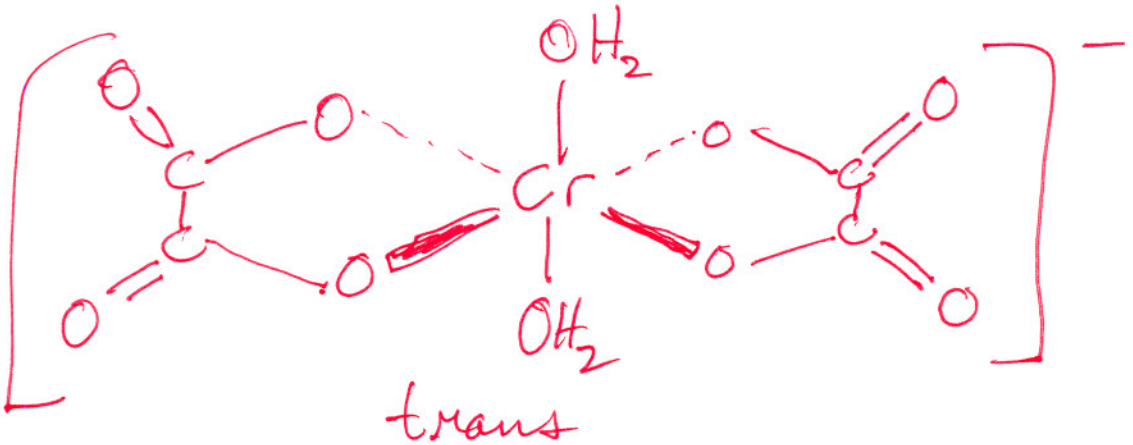
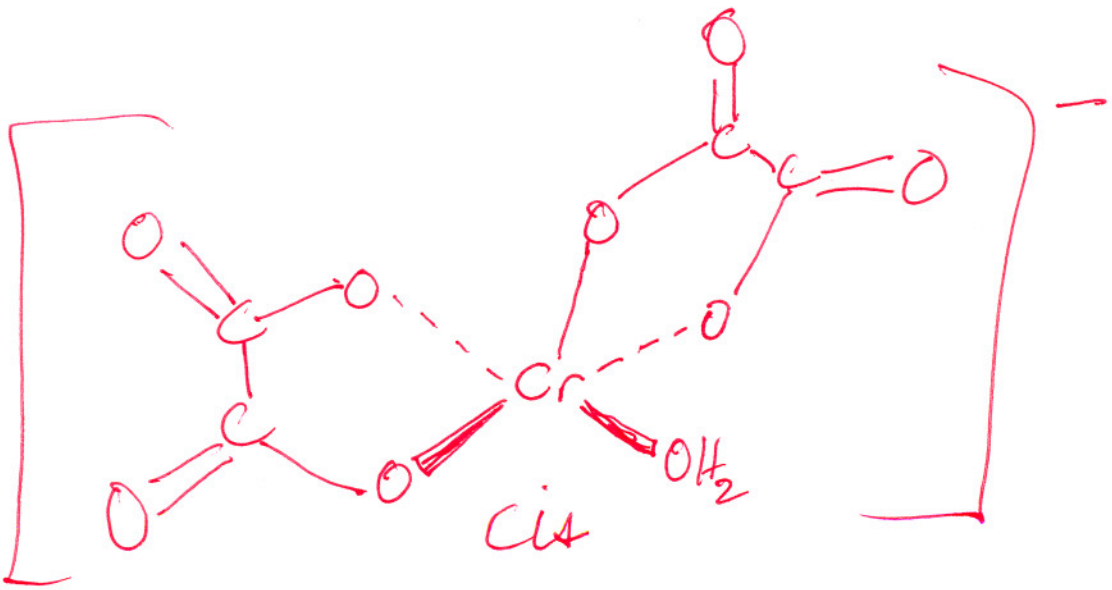
Question 17 Give the oxidation number and coordination number of the central atom in each complex below.

Complex	Ox. No. of Central Atom	Coord. No. of Central Atom
$[Ni(en)_3]^{2+}$	+2	6
$[Co(CO_3)_3]^{3-}$	+3	6
$[Pt(C_2O_4)_2]^{2-}$	+2	4
$[Ni(dmg)_2]$	+2	4

Question 18 Draw structures for the two isomers of $[Cr(C_2O_4)_2(H_2O)_2]^-$





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Question 19 Name each of the following.

$[Cu(NH_3)_4]SO_4$	tetraminne copper(II) sulfate
$[Co(H_2O)_4Br_2]Br$	tetraaquadibromocobalt(III) bromide
$K[Cr(NH_3)_2Cl_4]$	Potassium diamminetetrachlorochromate(III)
$Na_2[Zn(OH)_4]$	sodium tetrahydroxozincate(II)
$K_3[Co(C_2O_4)_3]$	Potassium trioxalatocobaltate(III)

Question 20 Write the formula for the following compounds.

a) hexaamminenickel(II) sulfate

$[Ni(NH_3)_6]SO_4$

b) dichlorobis(ethylenediamine)cobalt(III) chloride

$[CoCl_2(en)_2]Cl$

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Question 21 What is the color of a substance that absorbs yellow light?

violet

Question 22 The substance that gives leaves their green color is chlorophyll. Approximately what wavelength of light does chlorophyll absorb?

650nm – 700nm

Question 23 In each pair of substances below, circle the one that absorbs light of higher energy. The observed color of each substance is indicated.

a) Substance A (yellow), substance B (green)

b) Substance B (green), substance C (violet)

c) Substance D (red), substance E (blue)

d) Substance C (violet), substance F (orange)

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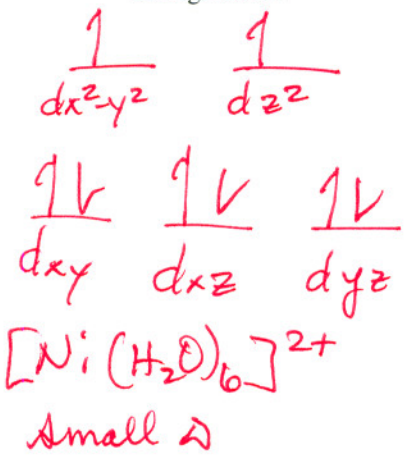
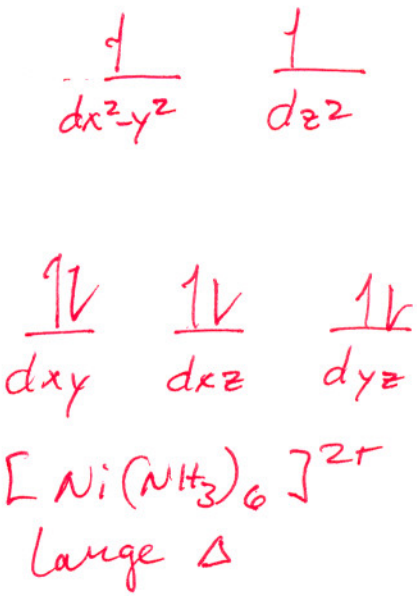
Question 24 Draw the crystal field splitting diagrams for $[Ni(H_2O)_6]^{2+}$, which is green, and $[Ni(NH_3)_6]^{2+}$, which is blue. Label the *d*-orbitals and place the nickel(II) valence electrons into the orbitals. Show only the ground state configuration.





Question 25 Which complex has the larger Δ?

$[Ni(NH_3)_6]^{2+}$

Question 26 What is the approximate value of Δ in kJ/mol for $[Ni(H_2O)_6]^{2+}$? Use the color of the complex to estimate the value.

$E = h\nu$ h = Planck's constant

This complex is green which means it absorbs red. Red is approximately 650 nm

$$\nu = \frac{c}{\lambda} = \frac{3.0\times10^{8}\ m/s}{650\times10^{-9}\ m} = 4.62\times10^{14}\ Hz$$

$$E = 6.626\times10^{-34}\ J/s\ (4.62\times10^{14}\ 1/s)\ 6.02\times10^{23} = 184\ kJ$$

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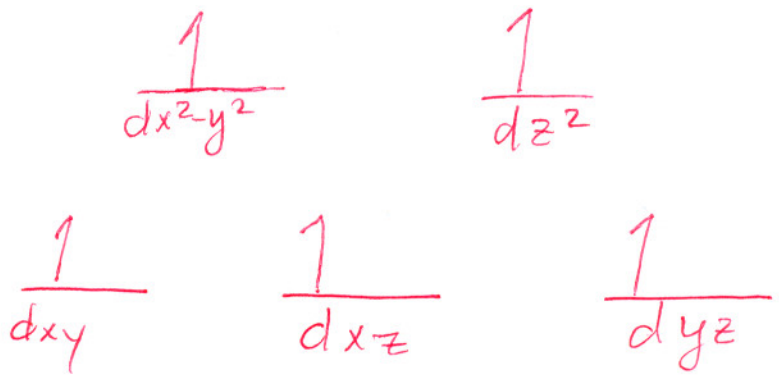
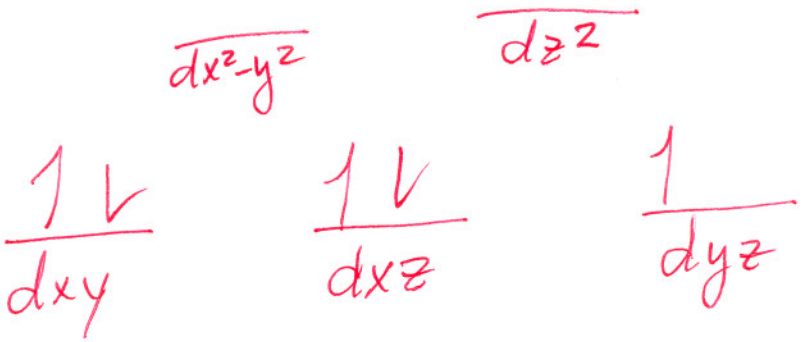
Question 27 Consider the two complex ions, $[Mn(H_2O)_6]^{2+}$ and $Mn[(CN)_6]^{4-}$. The first is pale red and is a high-spin complex, while the second is a low-spin complex.

a) Sketch the crystal field splitting energy diagram for $[Mn(H_2O)_6]^{2+}$. Label each orbital and put in the electron.



b) Do the same for $Mn[(CN)_6]^{4-}$.



c) What is the color of the light absorbed by $[Mn(H_2O)_6]^{2+}$?

green

d) Based on the magnitude of its Δ compared to that of the H_2O complex, what color of light might be absorbed by $[Mn(CN)_6]^{4-}$?

The absorbed light is higher in energy than green. Therefore, blue or violet

e) What color is a solution of $[Mn(CN)_6]^{4-}$ likely to be?

Orange or yellow

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Question 28 The magnitude of splitting of orbital energies of a transition metal ion depend upon the identity of the ligand. Based on the color of the complexes in the table below, arrange the ligands in order of the magnitude of splitting they cause, beginning with the ligand causing the smallest Δ.

Complex	Color	Complex	Color
$[Co(H_2O)_6]^{3+}$	pale red	$[Co(CN)_6]^{3-}$	yellow
$[Co(NH_3)_6]^{3+}$	pale orange	$[Co(CO_3)_3]^{3-}$	green

Least CO_3^{2-} < H_2O < NH_3 < CN^- Greatest

Question 29 $Ni(CN)_4^{2-}$ is yellow and has no unpaired electrons. $NiCl_4^{2-}$ is deep blue and has two unpaired electrons.

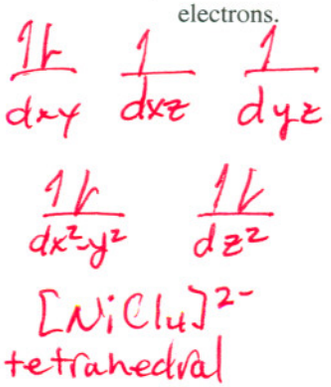
a) Which complex is high spin and which is low spin?

$[NiCl_4]^{2-}$ has more unpaired electrons. Therefore, $[NiCl_4]^{2-}$ is high spin.

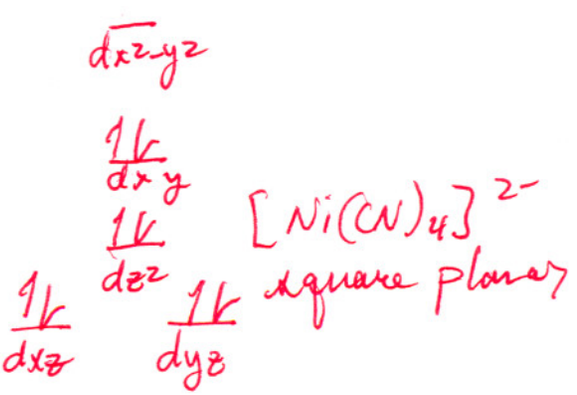
b) What is the correct geometry for each complex ion?

Tetrahedral complexes are high spin.

c) Sketch the correct splitting energy diagram for each complex ion. Label each orbital and fill in the electrons.



$[NiCl_4]^{2-}$
tetrahedral



$[Ni(CN)_4]^{2-}$ square planar