CHEMISTRY 123 – SUMMER 2011
SECOND MIDTERM EXAMINATION

Wednesday, August 10th, 2011. 6:30 – 7:48 pm

Time Limit: 1 hour 18 minutes

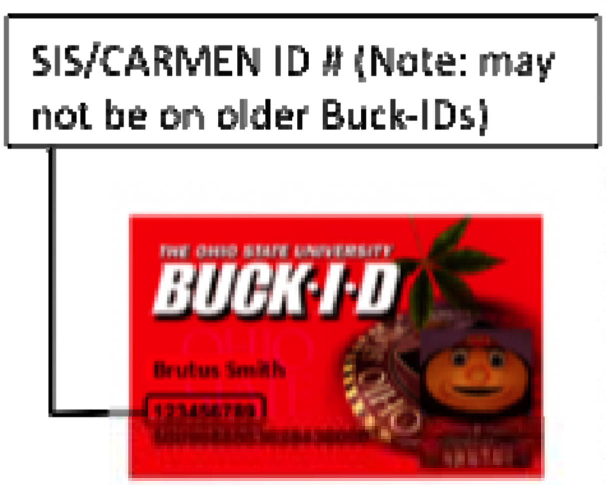
Your scan sheet must be completed using a PENCIL only.

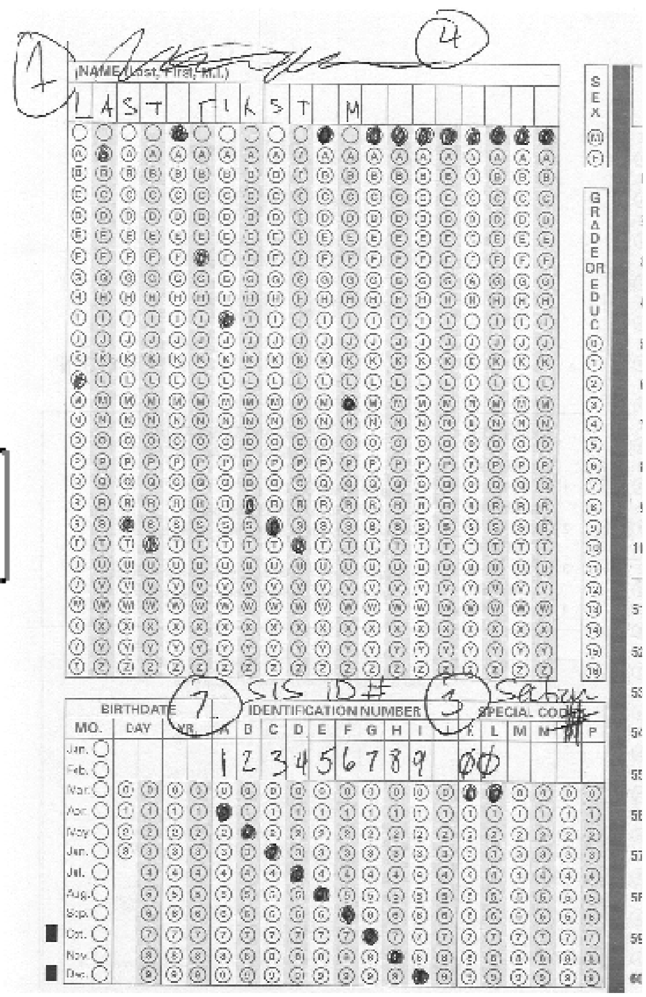
Fill your Scan Sheet in with the following items. Use the pictures below as a guide:

1. **NAME:** Write AND bubble in your last name, first name, and middle initial; each separated with a blank space.
2. **ID NUMBER:** Starting in column A, write AND bubble in your 9 digit SIS ID # (which is the same number as your Carmen ID #).
3. **SECTION:** Find your lab session day, time, and TA name from the exam booklet cover page. Write AND bubble this number columns K-L.
4. **SIGNATURE:** Sign the top of the scan sheet above your name.
5. Please do not fill in any additional information on your Scantron sheet.
6. Failing to properly bubble in your SIS/Carmen ID # will delay your official exam score result from being posted on Carmen for up to 1-2 weeks.
7. This exam consists of 25 multiple-choice questions for a total of 175 points.
8. When the proctor gives the signal, and not before, check to see there are 13 numbered pages.

SECTION # (K-L): Look up the code for your lab session day, time, and TA AND enter that code into columns K and L.

Georgia Efthimiopoulos	**=**	**13**
Xin Fang	**=**	**14**
Tushar Kabre	**=**	**15**
Chi-Yueh Kao	**=**	**16**
Ishika Sinha	**=**	**17**
Kelly Tulu	**=**	**18**





Useful equations:

$K_w=[H^+][OH^-]$ ($K_w = 1.00\times10^{-14}$ at 25°C), $K_aK_b=K_w$

$pX = -\log [X]$, $[X] = 10^{-pX}$, $\log(xy) = \log x + \log y$

$S = k_B \ln W$, $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$, $\Delta G = \Delta G^\circ + RT \ln Q$, $\Delta G^\circ = -RT \ln K$

$E^\circ_{cell} = E^\circ_{red}$ (cathode) $- E^\circ_{red}$ (anode), $\Delta G^\circ = -nFE^\circ_{cell}$, $E_{cell} = E^\circ_{cell} - \frac{0.0592V}{n}\log Q$

$N_A = 6.022 \times 10^{23}$, R = 8.314 J/mol·K = 0.08206 L·atm/mol·K

$c = 2.998 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J-s, $1\ e^- = 1.60 \times 10^{-19}$ C

1 V = 1 J / 1 C, 1 W = 1 J / 1 s, 1 kW·h=3.6×10^6 J

F = 96,485 J/V·mol = 96,486 C/mol e^-

$t_{1/2} = 0.693/k$ (first order), $\ln[A]_t - \ln[A]_0 = -kt$ (first order)

$\ln K = -\Delta H^\circ/R(1/T) + C$

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^+(aq) + e^-$
Potassium	$K(s) \longrightarrow K^+(aq) + e^-$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^-$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^-$
Sodium	$Na(s) \longrightarrow Na^+(aq) + e^-$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^-$
Aluminum	$Al(s) \longrightarrow Al^{3+}(aq) + 3e^-$
Manganese	$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^-$
Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^-$
Iron	$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^-$
Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^-$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^-$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^-$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^-$
Hydrogen	$H_2(g) \longrightarrow 2H^+(aq) + 2e^-$
Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$
Silver	$Ag(s) \longrightarrow Ag^+(aq) + e^-$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^-$
Platinum	$Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^-$
Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^-$

Potential (V)	Reduction Half-Reaction
+2.87	$F_2(g) + 2e^- \longrightarrow 2F^-(aq)$
+1.51	$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$
+1.36	$Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$
+1.33	$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$
+1.23	$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O(l)$
+1.06	$Br_2(l) + 2e^- \longrightarrow 2Br^-(aq)$
+0.96	$NO_3^-(aq) + 4H^+(aq) + 3e^- \longrightarrow NO(g) + 2H_2O(l)$
+0.80	$Ag^+(aq) + e^- \longrightarrow Ag(s)$
+0.77	$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$
+0.68	$O_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2O_2(aq)$
+0.59	$MnO_4^-(aq) + 2H_2O(l) + 3e^- \longrightarrow MnO_2(s) + 4OH^-(aq)$
+0.54	$I_2(s) + 2e^- \longrightarrow 2I^-(aq)$
+0.40	$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$
+0.34	$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$
0 [defined]	$2H^+(aq) + 2e^- \longrightarrow H_2(g)$
−0.28	$Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$
−0.44	$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$
−0.76	$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$
−0.83	$2H_2O(l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$
−1.66	$Al^{3+}(aq) + 3e^- \longrightarrow Al(s)$
−2.71	$Na^+(aq) + e^- \longrightarrow Na(s)$
−3.05	$Li^+(aq) + e^- \longrightarrow Li(s)$

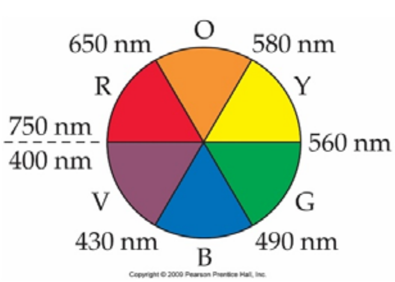
$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$ $E^\circ_{red} = -0.41$ V

Table of solubility product constants at 25˚C

Substance	K_{sp}
AgBr	5.4×10^{-13}
AgCl	1.8×10^{-10}
AgI	8.5×10^{-17}
Ag_2CO_3	8.1×10^{-12}
Ag_2CrO_4	1.1×10^{-12}
Ag_3PO_4	8.9×10^{-17}
Ag_2S*	6.7×10^{-50}
Ag_2SO_4	1.2×10^{-5}
$Al(OH)_3$	1.8×10^{-33}
$AlPO_4$	9.8×10^{-21}
$BaCO_3$	2.6×10^{-9}
$BaCrO_4$	1.2×10^{-10}
BaF_2	1.8×10^{-7}
$Ba_3(PO_4)_2$	1.3×10^{-29}
$BaSO_4$	1.1×10^{-10}
$Bi(OH)_3$	3.2×10^{-40}
$BiPO_4$	1.3×10^{-23}
Bi_2S_3*	1.8×10^{-99}
$CaCO_3$	5.0×10^{-9}
CaF_2	1.5×10^{-10}
$Ca(OH)_2$	5.0×10^{-6}
$Ca_3(PO_4)_2$	2.1×10^{-33}
$CaSO_4$	7.1×10^{-5}
$Cd(OH)_2$	2.5×10^{-14}
$CoCO_3$	8.0×10^{-13}
$Co(OH)_2$	1.1×10^{-15}
$Co_3(PO_4)_2$	2.1×10^{-35}
CoS*	4.0×10^{-21}
$Cr(OH)_3$	3.0×10^{-29}
$Cr_3(PO_4)_2$	2.4×10^{-23}
$CuCO_3$	2.5×10^{-10}
$Cu(OH)_2$	2.2×10^{-20}
$Cu_3(PO_4)_2$	1.4×10^{-37}
CuS*	1.3×10^{-36}

Substance	K_{sp}
$FeCO_3$	3.1×10^{-11}
$Fe(OH)_2$	4.9×10^{-17}
$Fe(OH)_3$	2.6×10^{-39}
FeS*	1.6×10^{-19}
Hg_2SO_4	6.5×10^{-7}
$Mg(OH)_2$	1.8×10^{-11}
MnS*	3.0×10^{-14}
$NiCO_3$	1.4×10^{-7}
$Ni(OH)_2$	2.8×10^{-16}
NiS*	1.1×10^{-21}
$PbBr_2$	6.3×10^{-6}
$PbCl_2$	1.7×10^{-5}
PbI_2	9.8×10^{-9}
$PbCO_3$	1.5×10^{-13}
$PbCrO_4$	1.8×10^{-14}
$Pb(OH)_2$	1.4×10^{-20}
PbS*	9.0×10^{-29}
$PbSO_4$	1.8×10^{-8}
Sb_2S_3*	1.6×10^{-93}
SnS*	1.0×10^{-26}
$ZnCO_3$	1.2×10^{-10}
$Zn(OH)_2$	3.0×10^{-16}
$Zn_3(PO_4)_2$	9.1×10^{-33}
ZnS*	2.9×10^{-25}

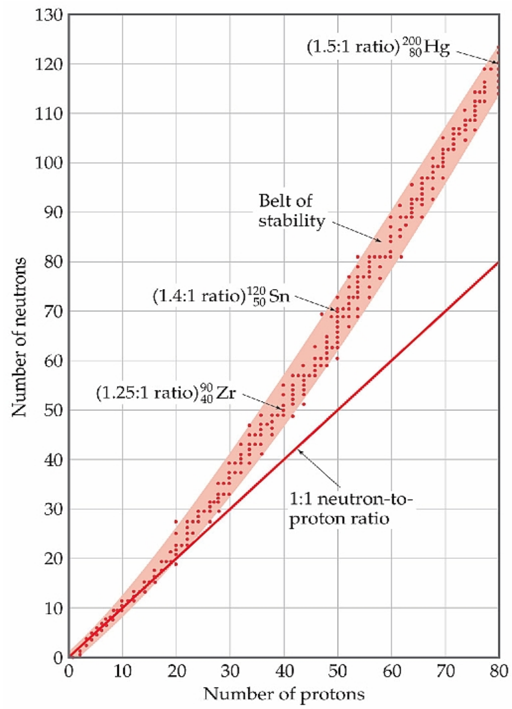
*For the reaction: M_nS_m (s) + m H_2O (l) $\rightleftharpoons$ n M^{m+} + m SH^- (aq) + m OH^- (aq)



Violet	400-430 nm
Blue	430-490 nm
Green	490-560 nm
Yellow	560-580 nm
Orange	580-650 nm
Red	650-750 nm

Spectrochemical series:

$Cl^- < F^- < H_2O < NH_3 < en < NO_2^-$ (N-bonded) $< CN^-$



Solubility Tables:

Water soluble compounds contain:	Exceptions:
Acetate	None
Nitrate	None
Iodide, Bromide, and Chloride	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
Sulfate	Compounds of Sr^{2+}, Ba^{2+},Hg_2^{2+}, and Pb^{2+}

Water insoluble compounds contain:	Exceptions:
Sulfide, Hydroxide	Compounds of the alkali metal cations, Ca^{2+}, Sr^{2+}, Ba^{2+}, and NH_4^+
Carbonate, Phosphate	Compounds of the alkali metal cations, and NH_4^+

Equilibrium constants for of complex-ion formation reactions. Cations that form complex ions with OH^- and NH_3 are given for: Ag, Al, Bi, Co, Cr, Cu, Fe, Ni, Zn.

Formation reaction	K_f
$Ag^+ + 2\,Cl^- \rightleftharpoons AgCl_2^-$	$1.8x10^5$
$Ag^+ + 2\,NH_3 \rightleftharpoons Ag(NH_3)_2^+$	$1.6x10^7$
$Pb^{2+} + 3\,Cl^- \rightleftharpoons PbCl_3^-$	$2.4x10^1$
$Co^{2+} + 6\,NH_3 \rightleftharpoons Co(NH_3)_6^{2+}$	$5.0x10^4$
$Co^{3+} + 6\,NH_3 \rightleftharpoons Co(NH_3)_6^{3+}$	$4.6x10^{33}$
$Cr^{3+} + 6\,NH_3 \rightleftharpoons Cr(NH_3)_6^{3+}$	$5.8x10^8$
$Cu^{2+} + 4\,NH_3 \rightleftharpoons Cu(NH_3)_4^{2+}$	$1.1x10^{13}$
$Ni^{2+} + 6\,NH_3 \rightleftharpoons Ni(NH_3)_6^{2+}$	$2.0x10^8$
$Zn^{2+} + 4\,NH_3 \rightleftharpoons Zn(NH_3)_4^{2+}$	$7.8x10^8$
$Cu^{2+} + 4\,OH^- \rightleftharpoons Cu(OH)_4^{2-}$	$1.3x10^{16}$
$Zn^{2+} + 4\,OH^- \rightleftharpoons Zn(OH)_4^{2-}$	$4.6x10^{17}$
$Pb^{2+} + 3\,OH^- \rightleftharpoons Pb(OH)_3^-$	$3.8\ x10^{14}$
$Al^{3+} + 4\,OH^- \rightleftharpoons Al(OH)_4^-$	$7.7x10^{33}$
$Cr^{3+} + 4\,OH^- \rightleftharpoons Cr(OH)_4^-$	$8x10^{29}$

hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
* *Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

1. Which statement about this redox reaction is correct?

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5O_2(g) + 8H_20(g)$$

(a) O_2 acts as the oxidizing agent
(b) H_2O_2 acts as a reducing agent
(c) H_2O_2 acts as an oxidizing agent
(d) Mn^2+ is oxidized
(e) Only oxidation takes place in this reaction

2. Which reaction will occur if each substance is in its standard state? Assume potentials are given in water at 25°C.

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ E°= +0.34 V
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ E°= +0.77 V
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ E°= –0.76 V

(a) Zn^{2+} will oxidize Cu(s) to give Cu^{2+}
(b) Fe^{2+} will reduce Cu^{2+} to give Cu(s)
(c) Cu(s) will oxidize Fe^{3+} to give Fe^{2+}
(d) Fe^{2+} will reduce Zn^{2+} to give Zn(s)
(e) Fe^{3+} will oxidize Cu(s) to give Cu^{2+}

3. Calculate the standard cell potential for this reaction.

$$2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+}(aq) + I_2(s)$$

(a) –1.31 V
(b) –0.23 V
(c) +0.23 V
(d) +1.00 V
(e) +1.31 V

For the next two questions, consider the following Voltaic Cell. A strip of Al(s) in a 0.010 M $Al(NO_3)_3$ solution is connected by a wire to another strip of Ag(s) in a solution containing 0.010 M $AgNO_3$. A porous gel of KCl connects the two solutions.

4. What is the e.m.f. of this cell?

(a) 2.38 V
(b) 2.46 V
(c) 2.54 V
(d) 4.06 V
(e) 4.14 V

5. Which of the following actions would decrease the e.m.f. of this Voltaic cell?

   (a) Increasing the [Al^{3+}]
   (b) Increasing the [Ag^{+}]
   (c) Decreasing the [Al^{3+}]
   (d) Decreasing the [Ag^{+}]
   (e) Both (a) and (d)

6. What is the minimum volume of 12.0 M HNO_3 required to completely dissolve 3.5 grams of Fe(s)?

   (a) 1.7 mL
   (b) 3.5 mL
   (c) 13.9 mL
   (d) 17.4 mL
   (e) 41.7 mL

7. 45.1 grams of chromium was plated in 853 minutes by running a current through a Cr^{3+} solution. What average current must be passed through this solution during this time interval?

   (a) 0.545 amps
   (b) 1.63 amps
   (c) 4.91 amps
   (d) 294 amps
   (e) 1.32×10^4 amps

8. Calculate the concentration of Ni^{2+} remaining in 546 mL of solution that was originally 0.480 M nickel nitrate after the passage of 7.83 amps for one hour.

   (a) 0.134 M
   (b) 0.212 M
   (c) 0.268 M
   (d) 0.346 M
   (e) 0.476 M

9. Several experiments were performed to analyze the behavior of the

   $$Cu(s)|Cu^{2+}(aq)||Cu^{2+}(aq)|Cu(s)$$

   concentration cell. Which of the following statements is/are true?
   i) Increasing the concentration of Cu^{2+} in the anode compartment will increase the cell potential.
   ii) Increasing the pH will increase the cell potential
   iii) Adding NH_3 to the cathode compartment will increase the cell potential
   iv) The standard cell potential is positive since Cu(s) is a good conductor of electricity.

   (a) i only
   (b) i and ii
   (c) ii and iii
   (d) i and iii
   (e) none of the above

10. For the following unbalanced reaction, find the equilibrium constant, K, at standard conditions:

$$MnO_4^- (aq) + Cr^{2+} (aq) \rightarrow Cr^{3+} (aq) + MnO_2 (s)$$

(a) 1.4×10^{9}
(b) 8.2×10^{16}
(c) 5.5×10^{50}
(d) 2.6×10^{97}
(e) 320

11. In the lab, you have 0.5 M solution of Zn^{2+} with a Zn(s) electrode available to use in creating a cell. You know Zn(s) is readily oxidized, so you have chosen Zn to be your anode. You are trying to create a cell which produces 0.657 V. The following cations and their respective electrodes are available to you in the lab. Assume the reaction occurs at 55°C. Which cathode will yield the desired e.m.f.?

(a) Ni^{2+} (aq)
(b) Mn^{2+} (aq)
(c) Co^{2+} (aq)
(d) Pb^{2+} (aq)
(e) Cd^{2+} (aq)

12. The K_{sp} of aluminum phosphate is 9.8×10^{-21}. Determine the value of the standard reduction potential for the following reaction:

$$AlPO_4(s) + 3e^- \rightarrow Al(s) + PO_4^{3-}(aq)$$

(a) −0.40 V
(b) −1.18 V
(c) −2.05 V
(d) −2.84 V
(e) More information is needed

13. The cell potential for the following electrochemical cell depends on the pH of the solution in the anode half cell:

$$Pt(s)|H_2(g, 1atm)|H^+(aq, ?\ M)||Cu^{2+}(aq, 0.5M)|Cu(s)$$

What is the pH of the solution if E_{cell} is 870 mV?

(a) -8.9
(b) 4.6
(c) 8.9
(d) 9.1
(e) 20.5

14. What is the ground state electron configuration for Co^{3+}?

    (a) [Ar] $4s^23d^7$
    (b) [Ar] $4s^13d^5$
    (c) [Ar] $4s^23d^4$
    (d) [Ar] $4s^03d^9$
    (e) [Ar] $4s^03d^6$

15. What is the oxidation state, geometry, and d electron count on the transition metal in the coordination complex listed below?

$$[NiCl_2(CO_3)_2]^{4-}$$

    (a) -4, tetrahedral, d^{10}
    (b) +2, tetrahedral,d^8
    (c) +2, square planar, d^8
    (d) +2, octahedral, d^8
    (e) 0, tetrahedral, d^{10}

16. The triethylenetetramine ligand is show below has the formula:

$$H_2N(CH_2)_2NH(CH_2)_2NH(CH_2)_2NH_2.$$

Based on your knowledge of coordination complexes, how many coordination sites would this ligand occupy on a transition metal center?

    (a) 1
    (b) 2
    (c) 4
    (d) 5
    (e) 6

17. How many different geometric <u>and</u> optical isomers does diamminedichloropalladium(II) have?
    (a) 0 isomers (only one molecule)
    (b) 2 isomers (two unique molecules)
    (c) 3 isomers (three unique molecules)
    (d) 4 isomers (four unique molecules)
    (e) 5 isomers (five unique molecules)

18. Which of the following statements about crystal field theory is/are true?

    i) In a square planer geometry, the dz^2 orbital is lower in energy than the dxy orbital.

    ii) The overlap with the ligands in a tetrahedron is weaker than an octahedron. As a consequence, the d electrons in a tetrahedral complex are most likely to populate the d orbitals in a low spin configuration.

    iii) In an octahedral geometry, the dx^2-y^2 orbital is doubly degenerate, and it is one of the higher energy orbitals.

    (a) ii only
    (b) i and ii
    (c) ii and iii
    (d) i and iii
    (e) i, ii, and iii

19. A chemist isolated a compound with general formula $VBr_2(OH)_2 \cdot 4H_2O$. Furthur testing indicates that the compound dissolves into 3 ions per formula unit. Addition of excess $AgNO_3$ precipitates two moles of AgBr(s) per formula unit. According to Werner's theory, what is the identity of the complex?

    (a) $[VBr_2(OH)_2] \cdot 4H_2O$
    (b) $[V(H_2O)_4(OH)_2]\ Br_2$
    (c) $[V(H_2O)_4Br_2]\ (OH)_2$
    (d) $[V(H_2O)_2(OH)_2Br_2] \cdot 2H_2O$
    (e) None of the above

20. The correct arrangement of the following complexes in terms of increasing crystal field splitting energy is:

    $[Co(NH_3)_4]^{2+}$ $[Co(H_2O)_6]^{2+}$ $[IrF_6]^{4-}$ $[Cr(CO)_6]^{3+}$

    (a) Smallest Δ $[Co(NH_3)_4]^{2+} < [Co(H_2O)_6]^{2+} < [IrF_6]^{4-} < [Cr(CO)_6]^{3+}$ Largest Δ
    (b) Smallest Δ $[Co(H_2O)_6]^{2+} < [Co(NH_3)_4]^{2+} < [Cr(CO)_6]^{3+} < [IrF_6]^{4-}$ Largest Δ
    (c) Smallest Δ $[IrF_6]^{4-} < [Co(H_2O)_6]^{2+} < [Co(NH_3)_4]^{2+} < [Cr(CO)_6]^{3+}$ Largest Δ
    (d) Smallest Δ $[Cr(CO)_6]^{3+} < [IrF_6]^{4-} < [Co(NH_3)_4]^{2+} < [Co(H_2O)_6]^{2+}$ Largest Δ
    (e) Smallest Δ $[IrF_6]^{4-} < [Co(H_2O)_6]^{2+} < [Co(NH_3)_4]^{2+} < [Cr(CO)_6]^{3+}$ Largest Δ

21. Which of the following complexes has the largest number of unpaired electrons?

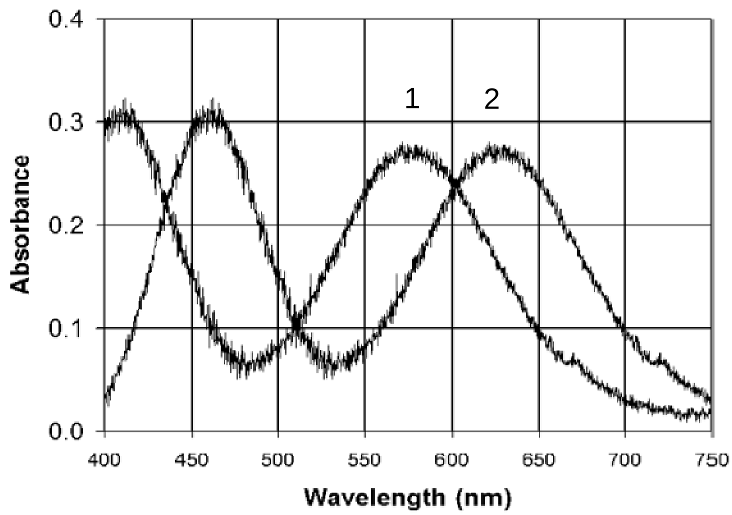
    (a) $[Co(H_2O)_6]^{2+}$
    (b) $[IrF_6]^{4-}$
    (c) $[PtCl_4]^{2-}$
    (d) $[Ni(H_2O)_6]^{2+}$
    (e) Both (a) and (b)

22. Assuming the formation of octahedral complexes, which of the following transition metal cations will not show a change of magnetism across the spectrochemical series?

i) W^{3+} ii) Mn^{2+} iii) Cu^{2+} iv) Zn^{2+}

(a) i only
(b) i and iii
(c) i and iv
(d) ii and iii
(e) i, iii, and iv

23. The absorption spectra for two unknown diamagnetic octahedral complexes are shown below:



What are the possible identities of (1) and (2)?
(a) (1) is FeF_6^{4-} (2) is $FeBr_6^{4-}$
(b) (1) is $Fe(CN)_6^{4-}$ (2) is $Ru(CN)_6^{4-}$
(c) (1) is $Fe(H_2O)_6^{2+}$ (2) is $Fe(en)_3$
(d) (1) is $Ru(CN)_6^{4-}$ (2) is $RuBr_6^{4-}$
(e) (1) is $Fe(CN)_6^{4-}$ (2) is $FeBr_6^{4-}$

24. A chemist prepared a solution of $Co(NO_3)_3$ and added concentrated KCN to produce the CN^- ligand in excess. The resulting aqueous solution most likely consists of:

(a) $Co(CN)_4^-$(aq) tetrahedra
(b) $Co(CN)_4^-$(aq) square planar
(c) $Co(CN)_6^{3-}$(aq) octahedra
(d) A mixture of $Co(CN)_4^-$(aq) tetrahedra and $Co(CN)_4^-$(aq) square planar
(e) A mixture of $Co(CN)_4^-$(aq) tetrahedra and $Co(CN)_6^{3-}$(aq) octahedral

25. List the following transition metal complexes in order of increasing number of unpaired electrons.

$Ni(H_2O)_6^{2+}$ $Ru(en)_3^{3+}$ $FeCl_5^{2-}$ $Cu(CN)_4^{2+}$

(a) $FeCl_5^{3+} < Ru(en)_3^{3+} < Ni(H_2O)_6^{2+} < Cu(CN)_4^{2+}$
(b) $Cu(CN)_4^{2+} < Ru(en)_3^{3+} < Ni(H_2O)_6^{2+} < FeCl_5^{3+}$
(c) $Cu(CN)_4^{2+} = Ru(en)_3^{3+} < Ni(H_2O)_6^{2+} < FeCl_5^{3+}$
(d) $Cu(CN)_4^{2+} < Ni(H_2O)_6^{2+} < Ru(en)_3^{3+} < FeCl_5^{3+}$
(e) $Cu(CN)_4^{2+} = FeCl_5^{3+} < Ni(H_2O)_6^{2+} < Ru(en)_3^{3+}$