I. Part 1. Laboratory questions 12 pts total)

1. (6 pts) Assume that you have just carried out a reaction between zinc and iodine in lab, adding solid zinc and iodine to acidified water (shaken, in a clean reaction tube). In this experiment, one of the reactants is in excess and one a limiting reagent. The appearance of the reaction mixture will tell you which is which. Describe what the reaction mixture looks like:

a) Observed, if zinc is the limiting reagent _____

b) Observed, if iodine is the limiting reagent _____

2. (6 pts) You have samples of the following 10 solutions, all 0.10 molar. (These are the compounds that made up the matrix of known solutions in the experiment "Reaction Types and Chemical Logic".)

$NH_3(aq)$	$BaCl_2(aq)$	$Cu(NO_3)_2(aq)$	$CoCl_2(aq)$	$CuSO_4(aq)$
$HCl(aq)$	$Na_2CO_3(aq)$	$NaCl(aq)$	$NaOH(aq)$	$H_2SO_4(aq)$

a) (2 pts) Two of these solutions are blue. Mixing one of the blue solutions with one of the colorless solutions gave a white precipitate. The solution remained blue in color. Write a balanced molecular equation for this reaction, including states (s, l, g, aq)

_____

b) (2 pts) From the 8 solutions that remain: select two that when mixed will react with evolution of a gas. What is the formula for the gas that is evolved? (Don't use reagents from parts a)

Gas formation: Reagents _____ and _____ Gas formed: _____

c) (2 pts) Select an acid and a base from this list and write a **net ionic equation** for the reaction of these reagents. (Don't use reagents from parts a and b)

Acid-base reaction: acid selected _____ base selected _____

Net Ionic equation _____

II. Part 2. Multiple choice (45 pts total) Put answers in the blank space preceding the question.

_____ 1. The enthalpy of formation of sodium chloride is the heat for which of the following reactions?

a) $Na^+(aq) + Cl^-(aq) \rightarrow NaCl(aq)$
b) $Na(s) + 1/2\ Cl_2(g) \rightarrow NaCl(s)$
c) $HCl(aq) + NaOH(aq) \rightarrow NaCl(s) + H_2O(l)$
d) $Na(s) + Cl(g) \rightarrow NaCl(s)$

_____ 2. When sulfuric acid dissolves in water, the temperature rises (a lot). What can we conclude about the enthalpy change when sulfuric acid dissolves in water?

a) This is an exothermic process and $\Delta H_{soln} < 0$
b) This is an exothermic process and $\Delta H_{soln} > 0$
c) This is an endothermic process and $\Delta H_{soln} > 0$
d) This is an endothermic process and $\Delta H_{soln} < 0$

_____ 3. Which of the following energy quantities are positive values? 1) heat of vaporization of water 2) heat of formation of water 3) ionization of H atoms 4) heat of reaction when hydrogen burns in air 5. electrolysis of water

a) 1 and 5
b) 3 and 4
c) 1, 3, and 5
d) 2 and 4

_____ 4. Which of the following is not a state function?

a) enthalpy b) work c) temperature d) internal energy

_____ 5. You are given enthalpies for three processes below. Which answer, (a, b, c, or d) will correctly give the standard enthalpy of formation ($\Delta H°_f$) of $C_3H_8(g)$?

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H°(1)$
$H_2(g) + 1/2\ O_2(g) \rightarrow H_2O(g)$ $\Delta H°(2)$
$C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$ $\Delta H°(3)$

a) $-3\ \Delta H°(1) - 4\ \Delta H°(2) + \Delta H°(3)$

b) $3\ \Delta H°(1) + 4\ \Delta H°(2) + \Delta H°(3)$

c) $3\ \Delta H°(1) + 2\ \Delta H°(2) - \Delta H°(3)$

d) $3\ \Delta H°(1) + 4\ \Delta H°(2) - \Delta H°(3)$

_____ 6. Which of the following lines in the atomic spectrum of hydrogen (identified by their wavelength) has the highest energy per photon?

a) 4.102×10^{-7} m b) 4.861×10^{-7} m
c) 4.341×10^{-7} m d) 6.563×10^{-7} m

_____ 7. Which transition in the hydrogen atom among those listed falls in the **visible region** of the spectrum (Bohr theory)?

a) $n = 7 \rightarrow n = 4$ b) $n = 4 \rightarrow n = 3$ c) $n = 3 \rightarrow n = 1$ d) $n = 5 \rightarrow n = 2$

_____ 8. Consider the wave mechanical picture of the potassium atom. Identify the lowest energy orbital that doesn't contain any electrons (assuming it is in the ground state).

a) 4s b) 4p c) 3d d) 5s

_____ 9. In a single atom, how many electrons can be accommodated in the 3rd shell?

a) 2 b) 8 c) 18 d) 32

_____ 10. How many electrons are in a single iron atom (Fe) are unpaired?

a) 0 b) 2 c) 4 d) 6

_____ 11. Which pair of ions, among those listed, are isoelectronic?
. (isoelectronic = same electron configuration.)

a) V^{2+} V^{3+} b) V^{2+} Cr^{3+} c) Cr^{2+} Cr^{3+} d) V^{3+} Cr^{2+}

_____ 12. Which of the following concerning atom/ion radii is **not** correct?

a) radius of K > radius of Na c) radius of S > radius of F

b) radius of Cl > radius of Cl^- d) radius of Na > radius of Na^+

_____ 13. Which of the following elements has the highest ionization potential?

a) Na b) K c) Rb d) Cs

_____ 14. Which ion among the following has the largest ionic radius?

a) O^{2-} b) F^- c) S^{2-} d) Cl^-

_____ 15. Which atom in the following list has the largest atomic radius?

a) F b) O c) S d) Cl

III. Part 3. Short questions and problems. (36 points total)

1. (8 pts) Give the ground state electron configurations for the following

Br _____

Fe^{3+} _____

2. (4 pts) Define: Ionization potential

3. (8 pts) The energies of the three lowest orbits in the Bohr description of H are given below.

n = 1 level: -2.18×10^{-18} J/atom
n = 2 level: -5.45×10^{-19} J/atom
n = 3 level: -2.42×10^{-19} J/atom

a) What is the energy per ~~photon~~ atom for the 4th Bohr level? _____

b) What is the energy per photon for a transition from n = 2 level to the n = 1 level? _____

4. (8 pts) The reaction between 5.00 g Mg and excess oxygen, $2\ Mg(s) + O_2(g) \rightarrow 2\ MgO(s)$, evolves 123.7 kJ. What is the heat of formation of MgO, ($\Delta H°_f$) in kJ/mol?

$\Delta H°_f$ = _____

5. (8 pts) Several standard enthalpies of formation (from Appendix L) are given below.

Species	$\Delta H°_f$ (kJ/mol)
Br(g)	111.9
$Br_2(l)$	0
$Br_2(g)$	30.9

Calculate:

a) The heat of vaporization of Br_2;

$\Delta H°_{vap}$ = _____

b) The energy required for the reaction $Br_2(g) \rightarrow 2\ Br(g)$.
(This is the Br-Br bond energy.)

$\Delta H°$ = _____

Part IV. One Problem (8 pts)

1. You have a insulated beaker that contains 22.0 g of ice and 150 g of liquid water, at 0 °C. A 48.2 g block of aluminum is heated to 100.0 °C, and added to this mixture. The SH of Al is 0.897 J/g deg, the SH of $H_2O(l)$ is 4.184 J/g deg, and the heat of fusion of ice is 333 J/g. Here is what we want to determine:

a) First, when thermal equilibrium is reached will all the ice have melted? Show your work on this problem (You won't get credit for a correct answer if work isn't shown. Guesses won't count!)

Did all the ice melt? Yes or No

b) Second: Two choices here: How much ice is left, if only part of the ice melted? Or: If all the ice melted what is the final temperature? WHICH question you answer will be determined by your answer in part a). Fill in your answer in one of the spaces at the bottom. You must show work to get credit for your answer.

If only part of the ice melted, how much ice is left? _____

If all the ice melted, what is the final temperature of the system? _____

STANDARD REDUCTION POTENTIALS

REDUCTION HALF-REACTION		STANDARD REDUCTION POTENTIAL (volts)
$Li^+ + e^-$	$\rightarrow Li$	- 3.05
$K^+ + e^-$	$\rightarrow K$	- 2.92
$Ca^{2+} + 2e^-$	$\rightarrow Ca$	- 2.76
$Na^+ + e^-$	$\rightarrow Na$	- 2.71
$Mg^{2+} + 2e^-$	$\rightarrow Mg$	- 2.37
$Al^3 + 3e^-$	$\rightarrow Al$	- 1.66
$2 H_2O + 2e^-$	$\rightarrow H_2 + 2OH^-$	- 0.83
$Zn^{2+} 2e^-$	$\rightarrow Zn$	- 0.76
$Cr^3 + 3e^-$	$\rightarrow Cr$	- 0.73
$Fe^{2+} + 2e^-$	$\rightarrow Fe$	- 0.44
$Cd^{2+} + 2e^-$	$\rightarrow Cd$	- 0.40
$PbSO_4 + 2e^-$	$\rightarrow Pb + SO_4^{2-}$	- 0.35
$Ni^{2+} + 2e^-$	$\rightarrow Ni$	- 0.23
$AgI + e^-$	$\rightarrow Ag + I^-$	- 0.15
$Sn^{2+} + 2e^-$	$\rightarrow Sn$	- 0.14
$Pb^{2+} 2e^-$	$\rightarrow Pb$	- 0.13
$Fe^{3+} + 3e^-$	$\rightarrow Fe$	- 0.04
$2 H^+ + 2e^-$	$\rightarrow H_2$	0.00
$Sn^{4+} + 2e^-$	$\rightarrow Sn^{2+}$	0.15
$Cu^{2+} + 2e^-$	$\rightarrow Cu^+$	0.16
$ClO_4 + H_2O + 2e^-$	$\rightarrow ClO_3^- + 2OH^-$	0.17
$AgCl + e^-$	$\rightarrow Ag + Cl^-$	0.22
$Cu^{2+} + 2e^-$	$\rightarrow Cu$	0.34
$ClO_3 + H_2O + 2e^-$	$\rightarrow ClO_2^- + 2OH^-$	0.35
$IO^- + H_2O + 2e^-$	$\rightarrow I^- + 2OH^-$	0.49
$Cu^+ + e^-$	$\rightarrow Cu$	0.52
$I_s(s) + 2e^-$	$\rightarrow 2I^-$	0.54
$ClO_2^- + H_2O + 2e^-$	$\rightarrow ClO^- + 2OH^-$	0.59
$Fe^{3+} + e^-$	$\rightarrow Fe^{2+}$	0.77
$Hg_2^{2+} + 2e^-$	$\rightarrow 2Hg$	0.80
$Ag^+ + e^-$	$\rightarrow Ag$	0.80
$Hg^{2+} + 2e^-$	$\rightarrow Hg$	0.85
$ClO^- + H_2O + 2e^-$	$\rightarrow Cl^- + 2OH^-$	0.90
$2Hg^2 + 2e^-$	$\rightarrow Hg_2^{2+}$	0.90
$NO_3 + 4H^+ + 3e^-$	$\rightarrow NO + 2H_2O$	0.96
$Br_2(\ell) + 2e^-$	$\rightarrow 2Br^-$	1.09
$MnO_2 + 4H + 2e^-$	$\rightarrow Mn^{2+} + 2H_2O$	1.21
$O_2 + 4H + 4e^-$	$\rightarrow 2H_2O$	1.23
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightarrow 2Cr^{3+} + 7H_2O$	1.33
$Cl_2(g) + 2e^-$	$\rightarrow 2Cl^-$	1.36
$MnO_4^- + 8H + 5e^-$	$\rightarrow Mn^{2+} + 4H_2O$	1.51
$PbO_2 + 4H^+ + SO_4^{2-} + 2e^-$	$\rightarrow PbSO_4 + 2H_2O$	1.69
$Ce^{4+} + e^-$	$\rightarrow Ce^{3+}$	1.70
$H_2O_2 + 2H+ + 2e^-$	$\rightarrow 2H_2O$	1.78
$Co^{3+} + e^-$	$\rightarrow Co^{2+}$	1.95
$O_3 + 2H^+ + 2e^-$	$\rightarrow O_2 + H_2O$	2.07
$F_2(g) + 2e^-$	$\rightarrow 2F^-$	2.87

CONVERSION FACTORS

1 inch = 2.54 cm
1 pound = 453.6 g
1 quart = 0.946 liter

1 calorie = 4.184 J
1 erg = 10^{-7} J
1 liter-atmosphere = 101.3 J

1 Angstrom = 10^{-8} cm

1 atmosphere = 760 torr (mmHg)
= 1.013×10^5 Pascal (N/m^2)
= 14.7 lb/in^2

1 electron volt = 1.602×10^{-19} J
= 96.48 kJ/mole
= 8066 cm^{-1}

1 amu = 1.66053×10^{-27} kg

1 atomic unit of energy, e^2/a°
= 4.360×10^{-18} J
= 2626 kJ/mole

MISCELLANEOUS RELATIONSHIPS:

$\ln x = 2.303 \log$

$\frac{RT}{F} = 0.257$ volt (at 298 K)

CONSTANTS

Avogardro's number	N_0	$6.02214155 \times 10^{23}$
Gas constant	R	0.0821 L-atm/mole-K
	R	62.3 l-torr/mole-K
	R	1.99 cal/mole-K
	R	8.314 J/mole-K
Absolute zero		-273.15°C
Planck constant	h	6.626×10^{-34} J-sec
Speed of light	c	3.00×10^8 m/sec
Mass of electron	m_e	9.1094×10^{-31} kg
Charge of electron	e	4.8033×10^{-10} esu
	e	1.602×10^{-19} coulomb
First Bohr radius	a_0	5.2918×10^{-11} m
Boltzman constant	k	1.3807×10^{-23} J/K
Faraday constant	F	96,485 coulomb/mole
	F	96.48 kJ/volt-mole

volt = 1 J/coulomb (1 V = 1 J/C)
1 ampere = 1 coulomb/sec (1 A = 1 c/s)