Name _____

TA's Name _____

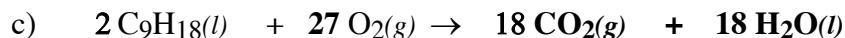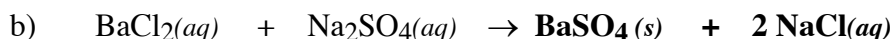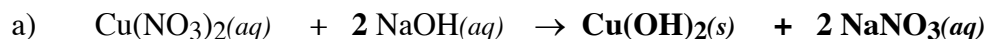Section _____

INSTRUCTIONS:

1. This examination consists of a total of 10 different pages. The last two pages include a periodic table, useful mathematical equations, and a solubility table. All work should be done in this booklet.

2. PRINT your name, TA's name and your lab section number now in the space at the top of this sheet. DO NOT SEPARATE THESE PAGES.

3. Answer all questions that you can and whenever called for, show your work clearly. Your method of solving problems should pattern the approach used in lecture. You do not have to show your work for the multiple choice or short answer questions.

4. No credit will be awarded if your work is not shown in 3, 4b(ii), 4c, 5a, 5b and 5c.

5. Point values are shown next to the problem number.

6. Budget your time for each of the questions. Some problems may have a low point value yet be very challenging. If you do not recognize the solution to a question quickly, skip it, and return to the question after completing the easier problems.

7. Look through the exam before beginning; plan your work; then begin.

8. **Relax** and do well.

|	Page 2	Page 3	Page 4	Page 5	MC	TOTAL
SCORES	_____	_____	_____	_____	_____	_____
	(23)	(17)	(28)	(11)	(24)	(103)

(9)   1.   Write the chemical formula(s) of the product(s) and balance the following reactions. Identify all products phases as either (g)as, (l)iquid, (s)olid or (aq)ueous.

   a) $Cu(NO_3)_2$(aq)   +   2 NaOH(aq)   →   **$Cu(OH)_2$(s)**   +   **2 $NaNO_3$(aq)**

   b) $BaCl_2$(aq)   + Na_2SO_4(aq)   →   **$BaSO_4$ (s)**   +   **2 NaCl(aq)**

   c)   2 C_9H_{18}(l)   +   **27** O_2(g)   →   **18 CO_2(g)**   +   **18 H_2O(l)**
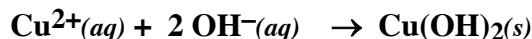
Grading Notes: +3 pts for correct products: possible deductions if the products are correct: -1 pt for incorrect or missing coefficients/balance, and -1 pt for incorrect or missing phase(s)

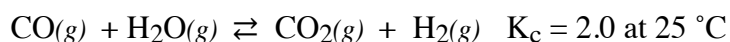(4)   2.   Write the ionic and net ionic chemical equations for reaction 1a.

   1a)   Ionic equation:

Cu^{2+}(aq) + 2 NO_3^-(aq) + 2 Na^+(aq) + 2 OH^-(aq)   → $Cu(OH)_2$(s) + 2 Na^+(aq) + 2 NO_3^-(aq)
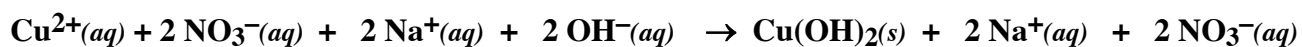
   1a)   Net Ionic equation:

   Cu^{2+}(aq) + 2 OH^-(aq)   → $Cu(OH)_2$(s)

Grading Notes: 2 points for the ionic equation and 2 points for the net ionic equations.

$$CO(g) + H_2O(g) \rightleftarrows CO_2(g) + H_2(g) \quad K_c = 2.0 \text{ at } 25 \text{ °C}$$

(10) 3. Calculate the concentration of all species at equilibrium when a 1.00 L container initially has 1.50 mol of CO(g) and 1.50 mol of H_2O(g). Assume no CO_2(g) or H_2(g) are present initially.

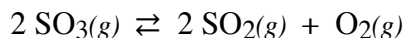|	CO(g)	+ H_2O(g)	$\rightleftarrows$	CO_2(g)	+ H_2(g)
Initial	1.50 M	1.50 M		0	0
Change	-x	-x		+x	+x
Equilibrium	1.50-x	1.50-x		+x	+x

$$K_c = \frac{[CO_2][H_2]}{[CO][H_2O]}$$

$$K_c = 2.0 = \frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{x \cdot x}{(1.50 - x) \cdot (1.50 - x)} = \frac{x^2}{(1.50 - x)^2}$$

   Taking the square root of both sides,

$$1.414 = \frac{x}{1.50 - x}$$

$$x = \frac{2.12}{2.414} = 0.878 \, M$$

$[CO] = [H_2O] = 1.50 \, M - 0.878 \, M = 0.621 \, M : [CO_2] = [H_2] = 0.878 \, M$

$$2\ SO_{3(g)} \rightleftarrows 2\ SO_{2(g)} + O_{2(g)}$$

(23) 4. A rigid container is filled with $SO_{3(g)}$ until the pressure of $SO_{3(g)}$ in the container is 0.83 atm at 298 K. The $SO_{3(g)}$ decomposes as the partial pressures of $SO_{3(g)}$, $SO_{2(g)}$, and $O_{2(g)}$ in the container are monitored over time, as shown in the graph below. A change is made to the system at time, t_1
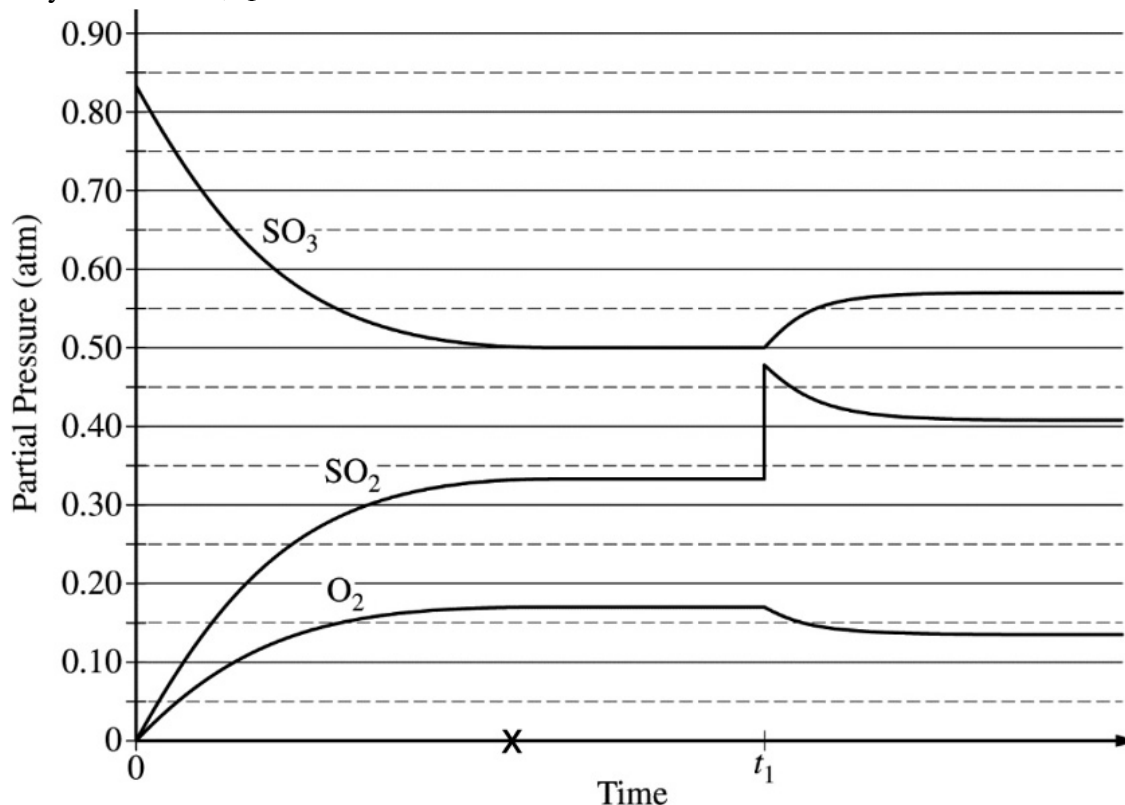
(a) Answer the following questions based on the graph.
    (i) Draw an X on the time axis to show when the system first reached equilibrium. (3)
    (ii) Describe the change that was made to the system at time t_1. (3)
    At time t_1 about 1.45 atm of $SO_{2(g)}$ was added to the reaction container.
    -2 pt if say PP of $SO_{2(g)}$ increases
    (iii) After the change was made at t_1, the partial pressure of $SO_{3(g)}$ increased while the partial pressure of $O_{2(g)}$ decreased. Explain this observation. (4)

    With the addition of $SO_{2(g)}$ the system was no longer in equilibrium. To re-establish equilibrium the reaction shifted from Right/products to Left/reactants resulting in the partial pressure of $SO_{3(g)}$ increasing and the partial pressure of $O_{2(g)}$ decreasing.

(b) Use the information above to answer the following.
    (i)   Write the expression for the equilibrium constant, K_p, for the reaction. (3)

$$K_p = \frac{P^2_{SO_2} \cdot P_{O_2}}{P^2_{SO_3}}$$

    (ii)   Determine the value of K_p for the reaction. (4)

$$K_p = \frac{(0.405)^2 \cdot (0.14)}{(0.57)^2} = 0.707 \ \text{or} \ K_p = \frac{(0.34)^2 \cdot (0.17)}{(0.50)^2} = 0.079$$

(c) Is the decomposition of $SO_{3(g)}$ to $SO_{2(g)}$ and $O_{2(g)}$ thermodynamically favored? Yes or **No**. Support your claim with a calculation of $\Delta G°$. (6)

$$\Delta G°_{rxn} = -RT \ln K$$

$$\Delta G°_{rxn} = -8.314 \frac{J}{mol\ K} \cdot 298\ K \ln 0.0707$$

$$\Delta G°_{rxn} = -8.314 \frac{J}{mol\ K} \cdot 298\ K \cdot -2.65$$

$$\Delta G°_{rxn} = 6.56 \times 10^3 \frac{J}{mol} = 6.56 \frac{kJ}{mol}$$

The reaction is not thermodynamically favored because $\Delta G°$ is positive.

(27) 5. Sodium bicarbonate, $NaHCO_3$, is soluble in water. An aqueous solution is 6.00% by weight sodium bicarbonate and has a density of 1.043 g mL^{-1}. Calculate

a) The molality of sodium bicarbonate in the solution; (7)

Assume 100 g of solution

$$94.0\ g\ of\ H_2O \left(\frac{1\ kg}{1000\ g}\right) = 0.0940\ kg$$

$$6.00\ g\ NaHCO_3 \left(\frac{1\ mol}{84.0\ g}\right) = 7.14 \times 10^{-2}\ mol\ NaHCO_3$$

$$\frac{7.14 \times 10^{-2}\ mol\ NaHCO_3}{0.0940\ kg} = 0.760\ molal\ NaHCO_3$$

b) the molarity of sodium bicarbonate in the solution; (7)

$$100\ g\ of\ solution \left(\frac{1\ mL\ solution}{1.043\ g\ solution}\right) = 95.88\ mL \left(\frac{1\ L}{1000\ mL}\right) = 0.09588\ L$$

$$\frac{7.14 \times 10^{-2}\ mol\ NaHCO_3}{0.09588\ L} = 0.745\ M\ NaHCO_3$$

c) The experimental freezing point of the sodium bicarbonate solution is –2.73 °C. Calculate the experimental 'i' value for sodium bicarbonate in this solution and indicate the formula(s), and charges where appropriate, for all of the particles in this solution. (NOTE: You do not have to include water as one of the particles.) (8)

$$\Delta T = ikm$$

$$i = \frac{\Delta T}{km} = \frac{2.73\ °C}{1.86 \frac{°C}{m} \cdot 0.760\ m\ \}} = 1.93$$

The ions in the solution are Na^+ and HCO_3^-

d) What do you think an ideal 'i' value would be for an aqueous solution of sodium bicarbonate? Provide an explanation for the difference in the experimental and ideal 'i' values. (5)

The ideal 'I' value for $NaHCO_3$ is a little complicated because I have not shared all of the details of the behavior of $NaHCO_3$. More about that in the Chapter on Acids and Bases. For the moment however, I was looking for a value of 2 for the ideal 'i' value. To understand why the experimental value of 'i' is 1.93 we say that at the concentration of the $NaHCO_3$ there are not enough water molecules to completely hydrate the $Na^+(aq)$ ions and the $HCO_3^-(aq)$ ions and as a result there is a small amount of ion-pairing.

e) Using equipment selected from below, describe how you would prepare 100.00 mL of 0.75 M NaHCO3 beginning with solid sodium bicarbonate and distilled water? (6)

Analytical balance   50 mL beaker   50 mL graduate cylinder   250.00 mL volumetric flask
Evaporating dish   25 mL pipet   100.00 mL volumetric flask   Eyedropper

$$0.100 \text{ L} \left(\frac{0.75 \text{ mol}}{1 \text{ L}}\right)\left(\frac{84.0 \text{ g}}{1 \text{ mol}}\right) = 6.30 \text{ g NaHCO}_3$$

1. mass 6.3 g of NaHCO3 using the analytical balance;

2. add the to the 100 mL volumetric flask and add some distilled water, about 50 mLs, to dissolve the NaHCO3;

3. shake the flask to dissolve the solid NaHCO3 and then add enough water to reach the etch on the neck of the flask.

Multiple Choice: (24 points)

Print the letter (A, B, C, D) which corresponds to the answer selected.

6. __C___   7. ___D___   8. ___D___   9. ___A___

10. ___A___   11. ___B___

ONLY THE ANSWERS IN THE AREA ABOVE WILL BE GRADED.   Select the most correct answer for each question. Each question is worth 4 points.

6. NaOH, an ionic solid, dissolves in water with an enthalpy of solution that is exothermic. Which of the following best describes the solution process for this system?

(A)   the lattice energy for the ionic solid is more positive than the absolute value of the hydration energy, and the change in entropy is positive.

(B)   the enthalpy of the solution process is negative and the entropy change of the solution process is negative.

(C)   the enthalpy of the solution process is negative and the entropy change of the solution process is positive.

(D)   more heat is required to separate both the solute and the solvent particles, compared to the heat released when the solute-solvent attractions are formed, and the entropy of the solution process is positive.