

Chemistry 2000 Spring 2002 Final Examination

Time: 3 hours

Marks: 100

Aids allowed: Calculator. No printed materials (e.g. periodic tables, calculator manuals) are allowed.

Formulas and data are given on page 4.

Instructions: Answer all questions in the booklets provided. Graphs should be drawn on the graph paper provided and inserted into your exam booklet prior to submission. Make sure to write your name, student number and the question number in the appropriate spaces on the graph paper. **Only** graphs may be submitted on separate pages. **All** other answers must be written in the exam booklets.

In sections 2 and 3, you have a choice of questions. **Do not** answer more than the required number of questions. Extra answers will not be marked.

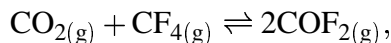
Clarity may be considered in evaluating your answers. If you are asked a direct question, give a direct answer. If you use advanced features of your calculator to carry out a nontrivial computation (e.g. solving a quadratic equation), say so. If you determined something from a graph, refer to the graph in explaining your answer.

1 Answer all questions in this section.

Value of this section: 70

1. There are at least three ways to determine by calculation whether or not a reaction is spontaneous. Name two. [2 marks]
2. In Eastern North America, acid rain due to industrial pollution is still a serious problem. Rain with a pH of 4.3 is still common in some areas despite significant improvements in recent years. What are the hydrogen and hydroxide ion concentrations in a solution with a pH of 4.3 at $25^{\circ}C$? [4 marks]
3. When $Bi(OH)_{3(s)}$ reacts with $SnO_{2(aq)}^{2-}$ in basic solution, the products are $SnO_{3(aq)}^{2-}$ and metallic bismuth. Balance the reaction. [5 marks]
4. The solubility product of BiI_3 is 8.1×10^{-19} at $25^{\circ}C$. What is the solubility of bismuth iodide? Express your answer in g/L. [8 marks]

5. For the reaction



$K = 0.50$ at 1000°C .

- (a) If a rigid flask is filled with 12 atm of CO_2 and 2 atm of CF_4 at 1000°C , what are the equilibrium pressures of the three gases at equilibrium? [9 marks]
- (b) Estimate the equilibrium constant for this reaction at 25°C . [10 marks]

6. Many processes with an underlying chemical basis obey the Arrhenius equation. In biology, molecular motors transport other molecules around a cell by “walking” along microtubules. The speed at which these motors move along microtubules can be measured. For a molecular motor known as Eg5, the following data have been obtained:

T ($^\circ\text{C}$)	13	17	24	26	30
speed ($\mu\text{m/s}$)	0.21	0.26	0.31	0.33	0.39

- (a) Determine the activation energy for this process. [8 marks]
Hint: The speed is proportional to the rate constant for the rate-determining step in the walking process.
- (b) Predict the temperature at which the speed would be $0.5 \mu\text{m/s}$. [4 marks]

7. 8.43 g of ammonium nitrate is dissolved in 88.43 g of water initially at 22.32°C . The temperature decreases to 15.23°C . What is the enthalpy of formation of solid ammonium nitrate? The specific heat capacity of water is $4.184 \text{ J K}^{-1} \text{ g}^{-1}$. [10 marks]

8. Many sugars crystallize as a hydrate. Depending on the storage conditions (esp. temperature and humidity), the hydration state can change with time. A sample of 14.30 g of glucose ($\text{C}_6\text{H}_{12}\text{O}_6 \cdot n\text{H}_2\text{O}$, where n is the unknown number of waters of hydration) is dissolved in 85.70 g of water. The freezing point of the solution is -1.3523°C . The freezing-point depression constant for water is $1.86 \text{ K kg mol}^{-1}$. How many waters of hydration (n) are there per glucose molecule? [10 marks]

2 Answer *one* question in this section.

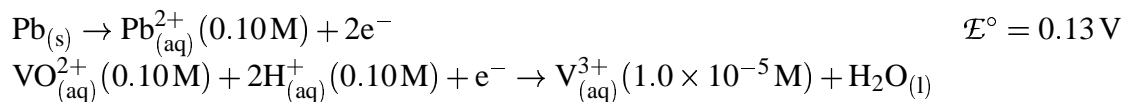
Value of this section: 10

1. Suppose that you want to make 2 L of a *pH* 10 buffer using the organic acid phenol (C_6H_5OH). You have a bottle of solid phenol as well as a standardized 1.8042 mol/L sodium hydroxide solution. The total concentration of phenol in the buffer should be approximately 0.5 mol/L. Describe the preparation of the buffer from these ingredients. Provide estimates of the quantities of chemicals required. [10 marks]
2. A hydrofluoric acid solution has a *pH* of 3.5 at 25°C. What is the formal (total dissociated + undissociated) concentration of hydrofluoric acid in this solution? [10 marks]

3 Answer any *two* questions in this section.

Value of this section: 20

1. Calculate the vapor pressure of mercury at 75°C. [10 marks]
2. If 20 mL of a 0.45 mol/L solution of sodium hydroxide is mixed with 15 mL of a 4.5×10^{-3} mol/L solution of calcium nitrate at 25°C, does a reaction occur? Either way, clearly identify any potential products and show detailed calculations supporting your conclusion. [10 marks]
3. An electrochemical cell is constructed which uses the following two half-reactions:



The cell produces 0.67 V at 25°C at the concentrations listed above. What is the standard reduction potential corresponding to the second half-reaction? [10 marks]

Data and formulas

$$k = k_{\infty} e^{-E_a/(RT)}$$

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta \bar{G} = \Delta \bar{G}^{\circ} + RT \ln Q$$

$$\Delta \bar{G}^{\circ} = -RT \ln K$$

$$\mathcal{E} = \mathcal{E}^{\circ} - \frac{RT}{n\mathcal{F}} \ln Q$$

$$K_w = 10^{-14} \text{ at } 25^{\circ}\text{C}.$$

$$R = 8.314472 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$\mathcal{F} = 9.6485309 \times 10^4 \text{ C/mol}$$

$$c^{\circ} = 1 \text{ mol/L}$$

$$P^{\circ} = 1 \text{ atm}$$

To convert degrees Celsius to Kelvin, add 273.15.

Acid dissociation constants at 25°C	
Acid	K_a
C ₆ H ₅ OH	1.3×10^{-10}
HF	7.2×10^{-4}

Standard thermodynamic properties at 25°C		
Species	$\Delta \bar{H}_f^{\circ}$ (kJ/mol)	$\Delta \bar{G}_f^{\circ}$ (kJ/mol)
CO _{2(g)}	-393.51	-394.37
COF _{2(g)}	-638.90	
CF _{4(g)}	-934.5	-879
Ca ²⁺ _(aq)	-541.3	-552.8
Ca(OH) _{2(s)}	-986.1	-898.6
Hg _(g)	61.38	31.88
NH ₄ ⁺ _(aq)	-133.3	-79.5
NO ₃ ⁻ _(aq)	-207.4	-111.5
Na ⁺ _(aq)	-240.30	-261.9
OH ⁻ _(aq)	-230.03	-157.34

