

Chem 322: Physical Chemistry II

Spring 2026 Exam 3
Professor Yuting Chen

Name: _____

This is an open note exam. You may use your prepared two-page cheat sheet and calculator, but no other external resources. No other electronics may be in your possession. The Hamilton College Honor Code applies to this exam.

By my signature below, I affirm on my honor the work represented in this exam is solely my own, and that I did not give or receive assistance on this exam. Violating the Honor Code will result in automatic failure of the course.

Signature: _____

Instructions

- Do not turn the page until instructed. You have 4 hours for the exam.
- Ensure you have all pages of the exam. The exam consists of one cover page and 5 pages of questions.
- Write your answers in the spaces indicated. Anything written on the backs of pages will not be graded. If you need more space, ask for scratch paper.
- Write legibly and show all of your work clearly and logically. Even if the final answer is correct, you may not receive credit if your work is incomplete, indecipherable, or unable to be followed.
- Grading is based on the consistency of your work. If you make an error in one step, you may still receive credit for later steps if your other steps are consistent, so it is in your best interest to attempt all parts of a problem.
- Include units for all of your answers. Report answers with a reasonable number of significant figures unless otherwise specified.

1. **A mix of everything**

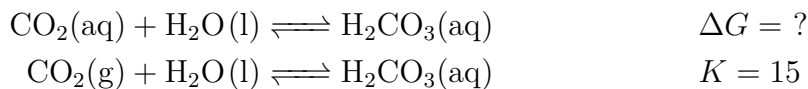
k_H of CO_2 in water is $3.4 \times 10^{-2} \frac{\text{mol}}{\text{L} \cdot \text{bar}}$ at 298 K.

(a) (4 points) Write the K expression for this equilibrium. What is the value of the equilibrium constant K at 298K?

(b) (2 points) Temperature is increased. What happens to K ?

K increase K decrease K remains constant Cannot be determined

(c) (8 points) Find ΔG° for the following equilibrium given the following information.



Consider the equilibrium: $\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{CO}_3(\text{aq})$.

The system is initially setup at equilibrium (EQ1). $\text{CO}_2(\text{g})$ is added to the system. **Immediately afterwards**, but before equilibrium is reestablished, answer the following.

(d) (2 points) How does Q compare to K ?

$Q > K$ $Q = K$ $Q < K$

After $\text{CO}_2(\text{g})$ is added, a second equilibrium (EQ2) is established. Fill in each blank with $>$, $<$, $=$, or X for cannot be determined.

(e) (2 points) K @ EQ1 _____ K @ EQ2

(f) (2 points) P_{CO_2} @ EQ1 _____ P_{CO_2} @ EQ2

(g) (2 points) $[\text{H}_2\text{CO}_3]$ @ EQ1 _____ $[\text{H}_2\text{CO}_3]$ @ EQ2

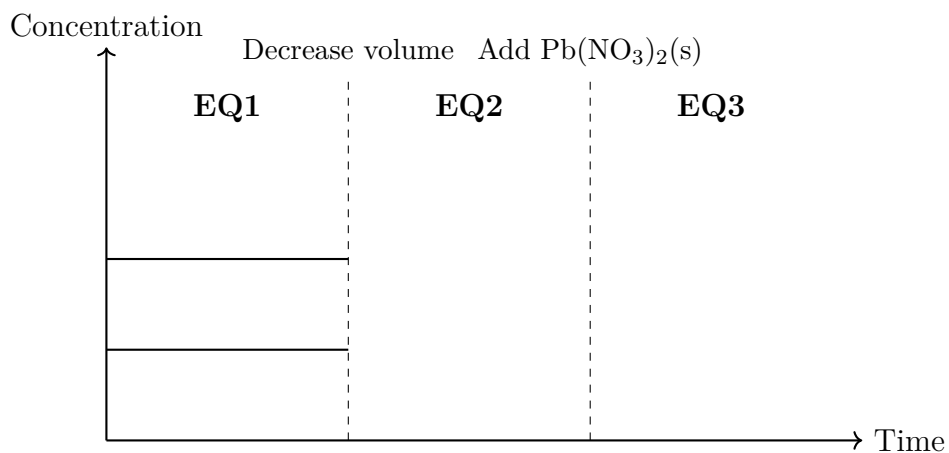
(h) (2 points) mol $\text{H}_2\text{O}(\text{l})$ @ EQ1 _____ mol $\text{H}_2\text{O}(\text{l})$ @ EQ2

2. Solution Chemistry

(a) (12 points) The solubility of PbF_2 is $m = 2.13 \times 10^{-3} \frac{\text{mol}}{\text{kg}}$ at 298 K. The density of a solution of PbF_2 is $1.2 \frac{\text{g}}{\text{mL}}$. Calculate K_{sp} of PbF_2 , stating any assumptions you make.

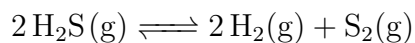
(b) (8 points) Calculate the molar solubility in $\frac{\text{mol}}{\text{L}}$ of PbF_2 in a solution of $0.10 \frac{\text{mol}}{\text{L}}$ NaF .

(c) (8 points) Fill in the concentration vs time graph below for the corresponding stressors for a saturated solution of PbF_2 . Be sure to label each line.



3. Equilibrium

2 mol of $\text{H}_2\text{S}(\text{g})$ is added to a flexible container at 298 K, initially occupying a volume of 4 L. The system is allowed to establish equilibrium under constant pressure and temperature conditions, and the volume of the container increases by 1 L.



(a) (10 points) Calculate K at 298 K for this equilibrium.

Hint: Think about the volume change and how it affects how you setup this problem.

(b) (6 points) It is reported that $K_{398} = 6.7$. Calculate $\Delta H_{\text{rxn}}^\circ$.

4. Maxwell Relations

- (a) (8 points) Starting from a cyclic triple product rule and using $C_V = T \left(\frac{\partial S}{\partial T} \right)_V$, show:

$$\left(\frac{\partial T}{\partial V} \right)_S = - \frac{T}{C_V} \left(\frac{\partial S}{\partial V} \right)_T$$

- (b) (10 points) Starting from a total differential of S , show the same result. You can use $C_V = T \left(\frac{\partial S}{\partial T} \right)_V$ again.

(c) (14 points) A gas has equation of state:

$$V = \frac{RT}{P} + aP + bT$$

where a, b are gas specific constants. Starting from $dU = T dS - P dV$, use Maxwell relations to determine constraints on a and b such that the gas behaves ideally, which is to say $\left(\frac{\partial U}{\partial P}\right)_T = 0$.