Equlibrium Practice Exam

Note: All problems included in this practice exam are drawn from problems used in previous semesters. Exams typically include 7 or 8 problems that are a mixture of qualitative problems calling for written explanations and quantitative problems that involve calculations and, in some cases, written explanations.

On the following pages are problems covering material in equilibrium chemistry. Read each question carefully and consider how you will approach it before you put pen or pencil to paper. If you are unsure how to answer a question, then move on to another question; working on a new question may suggest an approach to a question that is more troublesome. If a question requires a written response, be sure that you answer in complete sentences and that you directly and clearly address the question. No brain dumps allowed! Generous partial credit is available, but only if you include sufficient work for evaluation and that work is relevant to the question.

Problem	Points	Maximum	Problem	Points	Maximum
1		12	5		16
2		12	6		20
3		12	7		16
4		12	Total		100

A few constants are given here; other information is included within individual problems.

- density (d) of water is 1.00 g/mL
- specific heat (S) of water is 4.184 J/g $\bullet$ °C
- the gas constant (R) is 8.314 $\text{J/mol}_{\text{rxn}} \bullet \text{K}$
- Faraday's constant (F) is 96,485 J/V $\bullet$ mol e^-
- water's dissociation constant (K_w) is 1.00×10^{-14}

Problem 1. When you ingest a drug, it is absorbed into the bloodstream in either the stomach, the intestines, or both the stomach and the intestines. For a drug that is a weak acid or a weak base, absorption happens when the compound is in its neutral, unionized form. Quinidine, $C_{20}H_{24}N_2O_2$, is used to treat arrhythmia; it is a weak base with a K_b of 3.63×10^{-6} at body temperature. Knowing that the pH of stomach fluid is approximately 2 and that the pH of intestinal fluid is approximately 8, is quinidine absorbed in the stomach, in the intestines, or in both? Explain the reason for your decision in no more than three sentences.

Problem 2. To investigate an equilibrium reaction between the gases A, B, and C, you fill a 0.500-L flask with 0.800 mol A, 0.400 mol B, and 0.100 mol C and allow the system to reach equilibrium. Once equilibrium is reached, you find that the flask contains 0.500 mol A, 0.300 mol B, and 0.300 mol C. Using this information, determine (a) the reaction's stoichiometry and (b) the reaction's equilibrium constant.

Problem 3. The decomposition of ammonium chloride into ammonia and hydrogen chloride

$$\mathrm{NH_4Cl}(s) \rightleftharpoons \mathrm{NH_3}(g) + \mathrm{HCl}(g)$$

is endothermic with an equilibrium constant of 0.0167 at 500 K. Will the reaction's equilibrium constant increase, decrease, or remain the same if you increase the temperature to 1000 K? Explain your decision in no more than three sentences.

A 1.00–L flask is filled with 0.0500 mol each of NH_3*(g)*, HCl*(g)*, and NH_4Cl*(s)* and heated to 500 K. Will the moles of NH_4Cl in the flask increase, decrease, or remain the same? Explain the reason for your decision in no more than three sentences.

Problem 4. Adding a dilute solution of NaSCN to a suspension of the white solid AgCl produces an amber precipitate of AgSCN. Which of these two solids—AgCl or AgSCN—has the smallest K_{sp}? Explain your decision in no more than three sentences.

A saturated solution of $Fe(OH)_3$ has a lower pH than a saturated solution of $Al(OH)_3$. Which of these two solids—$Fe(OH)_3$ or $Al(OH)_3$—has the greater molar solubility? Explain your decision in no more than three sentences.

Problem 5. Many household bleaches are dilute solutions of sodium hypochlorite, NaOCl. For example, the bleach in my laundry room states that it contains 5.5 g NaOCl per 0.100 L. What is the pH of this solution? The K_a for HOCl is 3.0×10^{-8}.

Problem 6. A biochemist wishes to use X-ray diffraction to determine the structure of a crystalline protein. To isolate crystals of the protein, she needs a buffer with a pH of 5.20. How many grams of sodium acetate, CH_3COONa, does she need to add to 2.00-L of 0.500 M acetic acid, CH_3COOH, to prepare this buffer. The pK_a for acetic acid is 4.757.

Does this buffer have a greater capacity to neutralize strong acid or strong base? Explain your decision in no more than three sentences.

What is the pH if you add 5.00 mL of 6.00 M NaOH to one-half of this buffer?

How many mL of 6.00 M HCl can the other half of this buffer neutralize before the pH falls below 5.00?

Problem 7. Some progressive hair coloring products, such as Grecian Formula 16, contain soluble lead acetate, $Pb(CH_3CO_2)_2$. When rubbed into hair, Pb^{2+} reacts with the sulfur in hair proteins to form insoluble lead sulfide, PbS, which is black in color. A typical application of Grecian Formula 16 forms approximately 1.3 mg of PbS. At the pH of a typical shampoo, the solubility of PbS is controlled by the reaction

$$PbS(s) + 2H_3O^+(aq) \rightleftharpoons Pb^{2+}(aq) + H_2S(aq) + 2H_2O(l)$$

for which the equilibrium constant is 3.0×10^{-7}. Suppose someone who uses Grecian Formula 16 washes his or her hair using 12.0 L of water and shampoo at a constant pH of 5.5. How many mg of PbS are lost during this process?