Exam 2 Review

1. Reaction Rate

- Define rate of consumption of a reactant
- Write an expression for rate of production of a product
- Define the unique reaction rate in terms of any reactant or product

(a) How is the rate at which ozone disappears related to the rate at which oxygen appears in the reaction $2\,O_3(g) \longrightarrow 3\,O_2(g)$? If the rate at which O2 appears is 6.0×10^{-5} M/s at a particular instant, what is the rate of disappearance of O_3 at the same time?

(b) At a certain time in a reaction, substance A is disappearing at a rate of 4.0×10^{-1} M/s, substance B is appearing at a rate of 2.0×10^{-2} M/s and substance C is appearing at a rate of 6.0×10^{-2} M/s. What is the stoichiometry of the reaction? Write out the reaction with the proper coefficients.

(c) If the rate of decomposition of N_2O_5 in the reaction $2\,N_2O_5 \longrightarrow 4\,NO_2 + O_2$ at a particular instant is 4.2×10^{-7} M/s, what are the rates of appearance for NO_2 and O_2, and what is the rate of reaction?

2. Rate Laws

- Describe the difference between average and instantaneous rate
- Use the initial rate method to determine the experimental rate law
- Predict the changes in reaction rates with concentration based on the rate law

(a) Sketch on a graph of concentration vs time the difference between an average rate and an instantaneous rate. What is special about an initial rate?

(b) Use the data in the table below to determine the rate law for the reaction $A + B + C \longrightarrow$ products, the rate constant (with proper units), and the rate of reaction when all the reactants are at 0.100 M concentrations. (You will probably need the back of the page for this one.)

Run	$[A]_0$	$[B]_0$	$[C]_0$	Initial Rate (M/s)
1	0.151	0.213	0.398	0.480
2	0.251	0.105	0.325	0.356
3	0.151	0.213	0.525	1.102
4	0.151	0.250	0.480	0.988

(c) The decomposition of dimethyl ether at 510°C has a rate constant of 6.8×10^{-4}. If it has an initial pressure of 135 torr, what is its pressure after 1420 s, assuming it follows zero-order kinetics? What about first-order? Second-order?

(d) Calculate the rate constant for the decay of tritium given the fact that it follows first order kinetics and has a half-life of 12.32 years.

3. Equilibrium

- Describe the dynamic nature of a reaction at equilibrium
- Recognize that the ratio of product over reactant concentrations is a constant at equilibrium

(a) What is the defining characteristic of equilibrium?

(b) Write the equilibrium constant expression for the reactions $2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g)$, $2\,SO_2(s) + O_2(g) \rightleftharpoons 2\,SO_3(g)$, and $2\,SO_2(g) + O_2(l) \rightleftharpoons 2\,SO_3(g)$.

4. K vs Q

- Write an equation relating the equilibrium constant K_c and the concenrations of reactants and products for any reaction and determine its value based on known equilibrium concentrations
- Use the equilibrium constant for a given chemical reaction to find the equilibrium constant for a different, related reaction
- Assess how the concentrations of reactants or products will change to reach equilibrium based on the value of the reaction quotient, Q_c

(a) At 448° C, the equilibrium concentrations for the reaction $H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$ are $[H_2]$ = 0.20 M, $[I_2]$ = 0.10 M, and [HI] = 1.00 M. Calculate the equilibrium constant, K_c for this reaction. In which direction will the reaction proceed if we start with 2.0×10^{-2} moles of HI, 1.0×10^{-2} moles of H_2, and 3.0×10^{-2} moles of I_2 in a 2.00-L container?

(b) For the exothermic reaction $N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)$, known as the Haber process, use Le Chatelier's Principle to predict how the reaction will respond to

i. Increasing the temperature

ii. Removing some ammonia

iii. Adding more nitrogen

(c) Given the reactions $HF\,(aq) \rightleftharpoons H^+(aq) + F^-(aq)$ and $H_2C_2O_4(aq) \rightleftharpoons 2\,H^+(aq) + C_2O_4{}^{2-}$ and the respective equilibrium constants, $K_c = 6.8\times10^{-4}$ and $K_c = 3.8\times10^{-6}$, determine the value of $K_c$for the reaction $2\,HF\,(aq) + C_2O_4{}^{2-}\,(aq) \rightleftharpoons 2\,F^-\,(aq) + H_2C_2O_4(aq)$.

(d) At 800° C, the reaction $C\,(s) + H_2O\,(g) \rightleftharpoons CO\,(g) + H_2(g)$ has an equilibrium constant of 14.1. What are the equilibrium concentrations of H_2O, CO and H_2 if we start with 0.100 moles of water in a 1.00-L vessel? Also, what is the minimum amount of carbon needed to achieve equilibrium?

5. Acid Base

- Identify acid/base conugate pairs based on Bronsted-Lowry definition
- Write an appropriate acid-dissociation equilibrium constant K_a expression for any acid
- Describe what is meant by the terms "strong" and "weak" in reference to an acid
- Given the value of K_a, assess the relative strength of an acid

(a) When CH_3COOH is dissolved in water, it is called acetic acid. Write the equilibrium for its reaction with water and identify the conjugate acid-base pairs.

(b) Write the equilibrium for the dissociation of hydrochloric acid in liquid ammonia and identify the conjugate pairs.

(c) Write the acid-dissociation constant expressions for the previous two problems.

(d) The K_a for acetic acid is 1.8×10^{-5} and the K_b for formate is 5.6×10^{-11}. Is acetic or formic acid stronger?

6. Ionization

    - Use K_w to determine the relative amounts of hydroxide and hydronium ions in solution and assess whether the solution is acidic, basic, or neutral
    - Calculate the equilibrium concentrations and pH using any appropriate approximations
    - Define the relationship between K_a and K_b for a conjugate acid/base pair and assess the relative strength of an acid and its conjugate base
    - Determine the pH or pOH of a solution and identify the relationship between these two quantities
    - Carry out all kinds of pH calculations and calculations using pH to find other quantities

    (a) Hydrofluoric acid is a weak acid used in the builiding industry to etch patterns into glass for elegant windows. Because it dissolves glass, it is the only inorganic acid that must be stored in plastic containers. A 0.1 M solution of HF has a pH of 2.1. Calculate $[H_3O^+]$ and $[OH^-]$ for this solution.

    (b) The pH of a 0.129 M solution of a weak acid, HB, is 2.34. What is the K_a of the weak acid?

    (c) How many moles of HB must be dissolved in 1.00 liter of aqueous solution to produce a solution with a pH of 2.00?

    (d) Find the pH of a 0.115 M solution of ammonia, given the K_a of ammonium is 5.6×10^{-10}.

    (e) Morphine, an opiate derived from the opium poppy (genus *Papaver*), has the molecular formula $C_7H_{19}NO_3$. It is a weakly basic amine, with a K_b of 1.6×10^{-6}. What is the pH of a 0.0045 M solution of morphine?

7. BONUS: Sulfur dioxide can be generated by the reaction of sodium hydrogen sulfite ($NaHSO_3$) with hydrochloric acid. Write the balanced chemical equation for the reaction, given that the other products are sodium chloride and water. If 1.9 g of sodium hydrogen sulfite is reacted with excess HCl, what mass of SO_2 is produced? If the gas generated is in a 100 mL vessel at 25° C, and 0.05 mol of O_2 is introduced equilibrium between SO_2, O_2 and SO_3 will be established as shown by $SO_2 + \frac{1}{2} O_2 \rightleftharpoons SO_3$, with a K_c of 2.6×10^{12}. Calculate the equilibrium concentration of each species.