

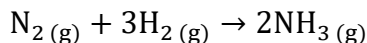
Spring 2024 CHM 2046 Exam 1 Review

The material covered in this review is from Chapters 16-19

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Chapter 16: Kinetics

1. Ammonia is generated on an industrial scale using the Haber-Bosch process. The reaction is shown below:



Find the rate law, individual, and overall reaction orders and the average value of k for the reaction.

| Experiment | Initial rate (mol/L*s) | Initial [N ₂] (mol/L) | Initial [H ₂] (mol/L) |
|------------|------------------------|-----------------------------------|-----------------------------------|
| 1 | 1.9×10^{-12} | 0.0113 | 0.0011 |
| 2 | 1.7×10^{-11} | 0.0220 | 0.0033 |
| 3 | 9.3×10^{-12} | 0.0550 | 0.0011 |
| 4 | 4.9×10^{-11} | 0.0220 | 0.0056 |

Rate Law: $\text{Rate} = k[\text{N}_2]^m[\text{H}_2]^n$

N₂ Order: 1st order

H₂ Order: 2nd order

Overall Reaction Order: 3rd order

Average Value of k: $1.39 \times 10^{-6} \text{ L/mol*s}$

$$\frac{\text{Rate 3}}{\text{Rate 1}} = \frac{k[\text{N}_2]_3^m [\text{H}_2]_3^n}{k[\text{N}_2]_1^m [\text{H}_2]_1^n} \rightarrow \frac{9.3 \times 10^{-12}}{1.9 \times 10^{-12}} = \left(\frac{0.0550 \text{ M}}{0.0113 \text{ M}} \right)^m$$

$$\hookrightarrow 4.9 = 4.9^m \rightarrow m = 1 \text{ 1st order N}_2$$

$$\frac{\text{Rate 4}}{\text{Rate 2}} = \frac{k[\text{N}_2]_4^m [\text{H}_2]_4^n}{k[\text{N}_2]_2^m [\text{H}_2]_2^n} \rightarrow \frac{4.9 \times 10^{-11}}{1.7 \times 10^{-11}} = \left(\frac{0.0056}{0.0033} \right)^n$$

$$\hookrightarrow 2.9 = (1.7)^n \rightarrow n = 2 \text{ 2nd order H}_2$$

$$\text{Rate} = k[\text{N}_2]^1[\text{H}_2]^2$$

$$k = \frac{\text{Rate}}{[\text{N}_2][\text{H}_2]^2} = \frac{1.9 \times 10^{-12}}{(0.0113 \text{ M})(0.0011)^2} = 1.39 \times 10^{-6} \frac{\text{L}}{\text{mol*s}}$$

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$$\ln \frac{[X]_0}{[X]_t} = kt$$

2. H_2O_2 decomposes into H_2 and O_2 in a first order reaction. If the initial concentration is 4.38 M, the final concentration is 2.91 M, and the decomposition takes place over 10 minutes, what is k ? Using the calculated k , how long will it take to decompose 25% of the initial amount?

- $k=0.035/\text{min}$; 7 minutes
- $k=0.041/\text{min}$; 7 minutes
- $k=0.035/\text{min}$; 10 minutes
- $k=0.041/\text{min}$; 10 minutes
- $k=0.059/\text{min}$; 7 minutes
- $k=0.059/\text{min}$; 10 minutes

$$\ln \left(\frac{4.38}{2.91} \right) = k(10 \text{ min}) \rightarrow k = 0.041/\text{min}$$

$$25\% \text{ decomposed} = 1 - .25 = 0.75$$

↳ 75% remains

$$\ln \frac{[\text{H}_2\text{O}_2]_0}{[\text{H}_2\text{O}_2]_t} = kt$$

$$\ln \left(\frac{1 \text{ M}}{0.75 \text{ M}} \right) = (0.041/\text{min})t \rightarrow t = 7 \text{ min}$$

3. Which of the following statements are true regarding exothermic reactions?

I. Heat is absorbed *Endothermic*

II. Heat is released *Exothermic*

III. Heat is a reactant *Endo*

IV. Heat is a product *Exo*

V. Heat and enthalpy will be on the same side of the equation *All*

VI. Heat and enthalpy will be on opposite sides of the equation *Wrong*

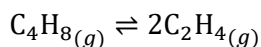
VII. The energy of the reactants is higher than the products *Exo*

VIII. The energy of the reactants is lower than the products *Endo*

- I, III, V, VII
- II, IV, V, VII
- I, II, III, IV
- V, VI, VII, VIII
- I, IV, V, VIII
- II, III, V, VII

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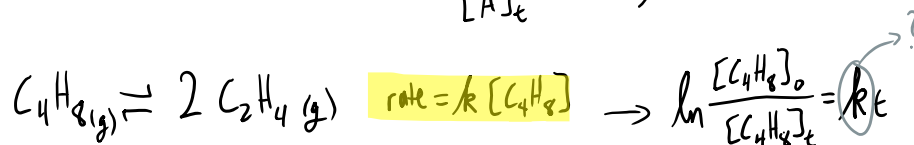
4. Cyclobutane decomposes in a first order reaction shown below.



Given that the initial concentration of C_4H_8 is 5M and the final concentration is 0.06M after 0.05 seconds, what is the rate constant and the expected rate law?

- 65 s^{-1} ; rate = $k[\text{C}_2\text{H}_4]^2$
- 88 s^{-1} ; rate = $k[\text{C}_4\text{H}_8]$
- 92 s^{-1} ; rate = $k[\text{C}_4\text{H}_8]$
- 88 s^{-1} ; rate = $k[\text{C}_2\text{H}_4]^2$
- 65 s^{-1} ; rate = $k[\text{C}_4\text{H}_8]$
- 92 s^{-1} ; rate = $k[\text{C}_2\text{H}_4]^2$

Integrated Rate Law: First Order $\rightarrow \ln \frac{[A]_0}{[A]_t} = kt$, rate = $k[A]$ k = rate constant



$$[A]_0 = [\text{C}_4\text{H}_8]_0 = 5\text{M} \quad t = 0.05\text{s}$$

$$[A]_t = [\text{C}_4\text{H}_8]_t = 0.06\text{M}$$

$$\ln \frac{[5\text{M}]}{[0.06\text{M}]} = k(0.05\text{s}) \quad \text{Question: What are the units of } k? \rightarrow \text{s}^{-1} \text{ (only 1st order } k)$$

$$\downarrow$$

$$k = 88\text{s}^{-1}$$

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5. Which of the following statements are true regarding catalysts?

I. Catalysts cause products to form slower

IV. Catalysts are not reformed

VII. Catalysts affect reaction rate; it increases

II. Catalysts cause products to form faster

V. Catalysts lower activation energy

VIII. Catalysts affect reaction rate; it decreases

III. Catalysts increase activation energy

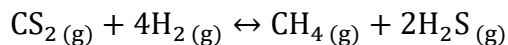
VI. Catalysts are reformed

IX. Catalysts don't affect reaction rate

- a. I, III, VI, IX
 b. II, III, VI, IX
 c. II, V, VI, VII
 d. I, IV, VI, VIII
 e. II, IV, VI, VII

Chapter 17: Equilibrium

$$K_p = K_c (RT)^{\Delta n_{\text{gas}}}$$

1. Given the following chemical reaction, calculate the K_p given that the K_c is 0.28 at 900°C .

- a. 7.5×10^{-5}
 b. 8.1×10^{-2}
 c. 3.6×10^{-3}
 d. 3.0×10^{-5}
 e. 2.9×10^{-4}

$$K_c = 0.28$$

$$T = 900^\circ\text{C} + 273.15\text{K}$$

$$R = 0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}$$

$$\Delta n_{\text{gas}} = 3 - 5 = -2$$

$$K_p = (0.28) \left((1173.15)(0.0821) \right)^{-2} = 3.0 \times 10^{-5}$$

2. Which of the following statements regarding Q and K are true?

I. If $K > Q$, then the reaction proceeds to the right

IV. If the reaction proceeds to the left, it will create more products

VI. If $K < Q$, then the reaction proceeds to the leftII. If $K = Q$, then the reaction is at equilibriumV. If $K > Q$, then the reaction proceeds to the leftVII. If $K = Q$, then the reaction proceeds to the right

III. If the reaction proceeds to the right, it will create more products

VIII. If $K < Q$, then the reaction is at equilibrium

- a. II, III, V, VIII
 b. I, II, III, VI
 c. IV, V, VI, VII
 d. VI, VII, VIII
 e. I, III, VI, VIII

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3. Fill in the table summarizing the effects of Le Chatelier's Principle.

| Change | Effect on Equilibrium (Left or Right) | Effect on the value of K (Equilibrium Constant) |
|-------------------------------|--|---|
| Increase [reactant] | Right (products) | None |
| Increase [product] | Left (reactants) | None |
| Decrease [reactant] | Left (reactants) | None |
| Decrease [product] | Right (products) | None |
| Increase pressure | Towards side with fewer moles of gas | None |
| Increase volume | Towards side with more moles of gas | None |
| Decrease pressure | Toward side with more moles of gas | None |
| Decrease volume | Towards side with fewer moles of gas | None |
| Increase pressure (inert gas) | No change in volume, no change; concentrations unchanged | None |
| Increase temperature | Towards absorption of heat (Endothermic shift right) (Exothermic shift left) | Endothermic, increases Exothermic, decreases |
| Decrease temperature | Towards release of heat (Endothermic shift left) (Exothermic shift right) | Endothermic, decreases Exothermic, increases |
| Add catalyst | None; forward and reverse rates increase equally | None |

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Chapter 18: Acid-Base Equilibria1. Which of the following statements regarding acids, bases, and K_a s is true?

- I. The stronger the acid, the larger the K_a , the larger the pK_a
- II. The stronger the acid, the larger the K_a , the smaller the pK_a
- III. The weaker the acid, the lower the concentration of H_3O^+ , the larger the pK_a
- IV. The larger the pK_a , the smaller the K_a
- V. A strong acid is a weak base
- VI. K_w , K_a , and K_b are related to each other in the equation $K_w = K_a * K_b$
- VII. The equilibrium of an acid base reaction goes from the stronger acid to the weaker acid
- VIII. The equilibrium of an acid base reaction goes from the weaker acid to the stronger acid
- IX. If the reaction proceeds to the right, $K_c > 1$.
- a. I, VIII
b. All but I, VIII
c. II, III, VII, VIII
d. IV, V, VII, VIII
e. I, III, IV, VII

2. Which of the following statements regarding pH is true?

- I. Acidic solutions have a higher concentration of OH^-
- II. Basic solutions have a higher concentration of OH^-
- III. A neutral solution has an equal concentration of H_3O^+ and OH^-
- IV. $K_w = \frac{[H_3O^+]}{[OH^-]}$
- V. $K_w = [H_3O^+] * [OH^-]$
- VI. $pH + pOH = 14$
- VII. $pH - pOH = 14$
- a. I, II, IV, VII
b. II, III, V, VI
c. III, IV, V, VII
d. II, IV, VI

3. If an unknown weak acid is 0.798% dissociated in a 2.15M solution. What is the K_a of the acid, the pK_a , and the identity of the acid?

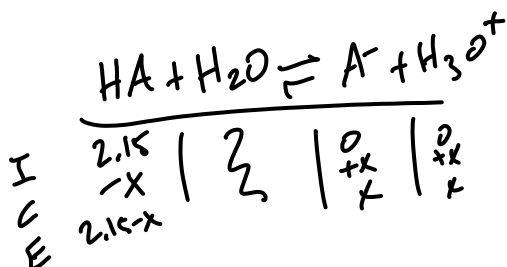
- a. $2.46 * 10^{-3}$, 10.5, Formic acid
b. $5.12 * 10^{-5}$, 3.14, Lactic acid
c. $1.38 * 10^{-4}$, 3.86, Lactic acid
d. $9.17 * 10^{-4}$, 4.68, Formic acid

$$0.798\% = \frac{x}{2.15M} \times 100\% \rightarrow x = 0.01715M$$

$$K_a = \frac{(x)(x)}{2.15-x} = \frac{x^2}{2.15-x} \rightarrow \frac{(0.01715)^2}{2.15-0.01715} = 1.38 \times 10^{-4}$$

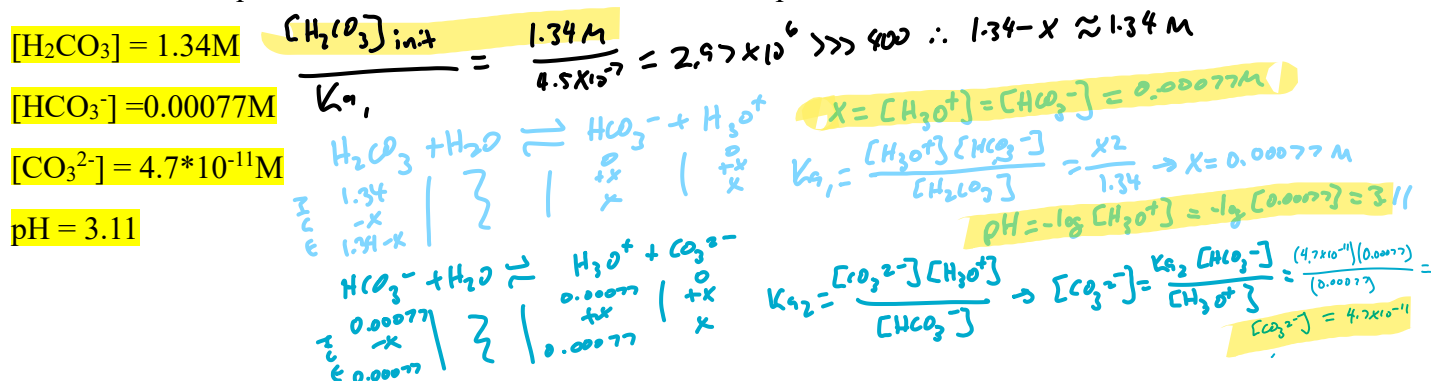
$$pK_a = -\log K_a = -\log(1.38 \times 10^{-4}) = 3.86$$

Lactic Acid



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4. What are the equilibrium values of carbonic acid and the pH of a 1.34M solution?



5. Which salts yield neutral solutions?

- a. NH_4Cl
 b. $CaCl_2$
 c. $LiNO_3$
 d. $Fe(NO_3)_3$
 e. B and C
 f. A and D
 g. None of the above

↳ Anions of strong hydrohalic acids: Cl^- , Br^- , I^-
 Strong oxoacid ions: NO_3^- , ClO_4^-
 Group 1 A ions
 Group 2 A ions: Ca^{2+} , Sr^{2+} , Ba^{2+}

6. Which of the following act as Lewis acids?

- a. Ba^{2+}
 b. $NH_3 \rightarrow$ Lewis Base $\text{:}N\text{H}_3$ electron pair acceptor
 c. $AlCl_3$
 d. $H_2O \rightarrow$ Lewis Base $H\ddot{O}H$
 e. A and C
 f. B and D

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Chapter 19: Ionic Equilibria in Aqueous Systems

1. What is the pH of a buffer of 0.83M $(\text{CH}_3)_2\text{NH}_2\text{Cl}$ and 1.2M $(\text{CH}_3)_2\text{NH}$ before and after adding 125mL of 0.75M HCl to 1 L of the buffer. (Info: $\text{p}K_b$ of $(\text{CH}_3)_2\text{NH}=3.23$).

- a. 9.776 \rightarrow 10.93 Before
- b. 2.726 \rightarrow 7.901
- c. **10.93 \rightarrow 10.85**
- d. 7.901 \rightarrow 2.726
- K_b $(\text{CH}_3)_2\text{NH} = 10^{-\text{p}K_b} = 10^{-3.23} = 5.9 \times 10^{-4}$
- $K_a = \frac{K_w}{K_b} = \frac{10^{-14}}{5.9 \times 10^{-4}} = 1.7 \times 10^{-11} = K_a$ of $(\text{CH}_3)_2\text{NH}_2^+$
- $\sum (\text{CH}_3)_2\text{NH}_2^+ = 0.83\text{M}$ $\sum (\text{CH}_3)_2\text{NH} = 1.2\text{M}$
- $[\text{H}_3\text{O}^+] = K_a \frac{[\text{Acid}]}{[\text{Base}]} = (1.7 \times 10^{-11}) \left(\frac{0.83}{1.2} \right) = 1.176 \times 10^{-11}$
- $\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log [1.176 \times 10^{-11}] = 10.93$
- After adding 125 mL of 0.75 M HCl to 1 L buffer
- $[\text{CH}_3)_2\text{NH}_2^+]_{\text{total}} = \frac{M_1 V_1}{M_{\text{total}}} = \frac{(0.83\text{M})(1\text{L})}{(1\text{L} + 0.125\text{L})} = 0.73777\text{M}$
- $[\text{CH}_3)_2\text{NH}] = \frac{(1.2\text{M})(1\text{L})}{(1.125\text{L})} = 1.0666\text{M}$
- $[\text{H}_3\text{O}^+]_{\text{added}} = \frac{(0.75\text{M})(0.125\text{L})}{(1.125\text{L})} = 0.0833\text{M}$
- $(\text{CH}_3)_2\text{NH} + \text{H}_3\text{O}^+ \rightleftharpoons (\text{CH}_3)_2\text{NH}_2^+ + \text{H}_2\text{O}$
- | | | | | |
|---|---------|---------|---------|---|
| I | 1.0666 | 0.0833 | 0.73777 | } |
| C | -0.0833 | -0.0833 | +0.0833 | |
| E | 0.9833 | 0 | 0.8211 | |
- $[\text{H}_3\text{O}^+] = K_a \frac{[\text{Acid}]}{[\text{Base}]} = (1.7 \times 10^{-11}) \left(\frac{0.8211\text{M}}{0.9833\text{M}} \right) = 1.42 \times 10^{-11}$
- $\text{pH} = -\log [\text{H}_3\text{O}^+] = 10.85$

2. Magnesium phosphate is an anticaking agent for silicone-containing cleaning agents and salt. Its K_{sp} is 1.04×10^{-24} . If $[\text{Mg}^{2+}] = [\text{PO}_4^{3-}] = 3.6 \times 10^{-10}\text{M}$, will magnesium phosphate precipitate?

- a. Yes, $Q_{sp} > K_{sp}$
- b. No, $Q_{sp} > K_{sp}$
- c. No, $Q_{sp} = K_{sp}$
- d. Yes, $Q_{sp} < K_{sp}$
- e. **No, $Q_{sp} < K_{sp}$**

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3. Does the addition of HNO_3 affect the solubility of calcium fluoride?

- a. Increases solubility
- b. Decreases solubility
- c. No effect on solubility

Strong acids increase solubility

4. What is the pH at the equivalence point of 912 mL of 10.67 M HBrO with 15.02 M NaOH ?

- a. 12.84
- b. 13.74
- c. 2.29
- d. 11.71
- e. 6.91

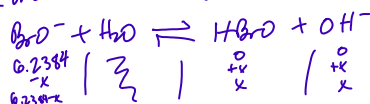
Initial $\text{HBrO} = (0.912 \text{ L}) \left(\frac{10.67 \text{ mol HBrO}}{1 \text{ L}} \right) = 9.73104 \text{ mol HBrO}$

Equivalence point \rightarrow Same mols of $\text{NaOH} \rightarrow 9.73104 \text{ mol NaOH}$

Volume (L) NaOH added

$$(9.73104 \text{ mol}) \left(\frac{1 \text{ L}}{15.02 \text{ mol NaOH}} \right) = 0.64787 \text{ L}$$

$$[\text{BrO}^-] = \frac{9.73104 \text{ mol}}{0.912 \text{ L} + 0.64787 \text{ L}} = 6.2384 \text{ M}$$



$$K_b = \frac{[\text{HBrO}][\text{OH}^-]}{[\text{BrO}^-]} = 4.3 \times 10^{-6} = \frac{x^2}{6.2384}$$

$$K_b \text{ BrO}^- = \frac{K_w}{K_a \text{ HBrO}} = \frac{1 \times 10^{-14}}{2.3 \times 10^{-9}} = 4.3 \times 10^{-6}$$

$$\begin{aligned} x = [\text{OH}^-] &= 0.00517 \text{ M} \\ \text{pOH} &= -\log[\text{OH}^-] = -\log[0.00517 \text{ M}] \\ \text{pOH} &= 2.2865 \\ \text{pH} &= 14 - \text{pOH} = 14 - 2.2865 = 11.71 \\ \text{pH} &= 11.71 \end{aligned}$$