Student name_____ TA name_____ Section_____

1. What is true if a forward reaction is spontaneous? (Chose all that apply)

   $K \ll 1$ $K \gg 1$ $Q > 1$ $Q < 1$ $Q < K$ $Q > K$ $Q = K$

   $\dfrac{Q}{K} > 1$ $\dfrac{Q}{K} = 1$ $\dfrac{Q}{K} < 1$ $\ln\dfrac{Q}{K} > 0$ $\ln\dfrac{Q}{K} < 0$ $\ln\dfrac{Q}{K} = 0$

2. If $K = 10^{-13}$ and $Q = 10^2$ what must be true? Circle all that apply.

   a. The reaction will be spontaneous
   b. The reaction will be nonspontaneous
   c. The reaction is at equilibrium
   d. Reactants are favored at equilibrium
   e. Products are favored at equilibrium

   f. Reactants and products are equally favored at equilibrium
   g. Currently, the reaction has more products than reactants
   h. Currently, the reaction has more reactants than products

3. The following reaction is at equilibrium and has an equilibrium constant K: $A_{(g)} + B_{(g)} \rightleftharpoons 2C_{(g)}$
   If we double the volume of the container, circle all that must be true immediately after the volume is changed below. *Hint: write an expression for K and Q and compare them.*

   a. K increases
   b. K decreases
   c. K will stay the same
   d. K will double

   e. Q increases
   f. Q decreases
   g. Q will stay the same

4. The following reaction is at equilibrium has an equilibrium constant K: $A_{(g)} \rightleftharpoons B_{(g)} + C_{(g)}$
   If we double the volume of the container, circle all that must be true immediately after the volume is changed below.

   a. K increases
   b. K decreases
   c. K will stay the same
   d. K will double

   e. Q will stay the same
   f. $Q = 2K$
   g. $Q = \dfrac{K}{2}$

5. The following reaction is at equilibrium has an equilibrium constant K: $A_{(g)} \rightleftharpoons B_{(aq)} + C_{(g)}$
   If we double the volume of the container, circle all that must be true immediately after the volume is changed below.

   a. K increases
   b. K decreases
   c. K will stay the same
   d. K will double
   e. Q increases

   f. Q decreases
   g. Q will stay the same
   h. $Q = 2K$
   i. $Q = \dfrac{K}{2}$

6. If an equilibrium constant of the reaction decreases with increasing temperature what must be true.

    a. Equilibrium constant always increases with temperature
    b. Equilibrium constant never changes
    c. Reaction is Endothermic
    d. Reaction is Exothermic
    e. Need more information

7. Consider the following reaction at equilibrium: $A_{(aq)} + 2B_{(aq)} \rightleftharpoons C_{(aq)}$ and $K = 3 \times 10^2$. For this reaction, $\Delta_r H° = -40.$ kJ/mol. In each of the following changes (a – d) circle the choice that indicates how the system will respond to return to equilibrium:

    a. Put a flame under the container: More products will form || More reactants will form || No change

    b. Adding 100 mL of water: More products will form || More reactants will form || No change

    c. The volume of the container is doubled: More products will form || More reactants will form || No change

    d. Remove 0.5 mol of A: More products will form || More reactants will form || No change

8. For the reaction $A_{(aq)} + 2B_{(aq)} \rightleftharpoons C_{(aq)}$, $K = 1 \times 10^{-13}$ at 25°C. 4 moles of A are added to 6 moles of C (at 25°C) in 1 L of water. Answer the following questions:

    a. Based on the equilibrium constant, are the reactants or product favorable?

    b. Calculate the Q for the initial conditions (Q_1).

    c. Based on the initial conditions which of the following will form:

           A   B   C

9. Consider the exothermic reaction: $2\,NH_{3(aq)} + H_2CO_{3(aq)} \rightleftharpoons (NH_2)_2CO_{(aq)} + 2\,H_2O_{(l)}$

    a. 1.0 moles of NH_3 and 3.0 moles of $(NH_2)_2CO$ are added to 1.0 L of water. Calculate the initial value of Q before any reaction takes place.

b. The equilibrium constant of this reaction (K) is $1 \cdot 10^3$. Which of the following must be true for the reaction mixture specified in part (a)? Circle all that apply.

- The reaction will be spontaneous
- The reaction will be nonspontaneous
- The reaction is at equilibrium
- Reactants will predominate at equilibrium

- Products will predominate at equilibrium
- Reactants and products are in equal proportion at equilibrium
- Before any reaction occurs, products predominate
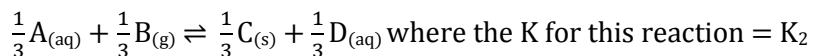- Before any reaction occurs, reactants predominate

c. A reaction mixture is prepared with the following concentrations: 1.00 M NH_3, 0.10 M H_2CO_3, and 0.10M $(NH_2)_2CO$. Which of the following will increase the value of the ratio $\frac{Q_{mixture}}{K}$? Circle all that apply.

- Add products
- Add reactants
- Heat the mixture
- Cool the mixture

- The reaction is already at equilibrium. Do nothing
- Add water

10. At a certain temperature, the equilibrium constant for $2H_{2(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)}$ is K= 2500

a. Calculate the numerical value of the equilibrium constant for $H_2O_{(g)} \rightleftharpoons H_{2(g)} + \frac{1}{2} O_{2(g)}$

b. Calculate the numerical value of the equilibrium constant for $2H_2O_{(g)} \rightleftharpoons 2H_{2(g)} + O_{2(g)}$

11. Given the two reactions below, find the relationships between K_1 and K_2

$A_{(aq)} + B_{(g)} \rightleftharpoons C_{(s)} + D_{(aq)}$ where the K for this reaction $= K_1$

$\frac{1}{3}A_{(aq)} + \frac{1}{3}B_{(g)} \rightleftharpoons \frac{1}{3}C_{(s)} + \frac{1}{3}D_{(aq)}$ where the K for this reaction $= K_2$
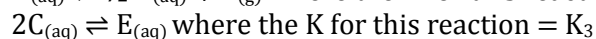
12. Given the two reactions below, find the relationships between K_1 and K_2

$A_{(aq)} + B_{(g)} \rightleftharpoons C_{(s)} + D_{(aq)}$ where the K for this reaction $= K_1$
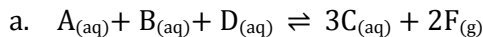
$C_{(s)} + D_{(aq)} \rightleftharpoons A_{(aq)} + B_{(g)}$ where the K for this reaction $= K_2$

13. Given the reactions below:

$A_{(aq)} + B_{(g)} \rightleftharpoons C_{(aq)} + D_{(aq)}$ where the K for this reaction = K_1
$D_{(aq)} \rightleftharpoons \frac{1}{2} E_{(aq)} + F_{(g)}$ where the K for this reaction = K_2
$2C_{(aq)} \rightleftharpoons E_{(aq)}$ where the K for this reaction = K_3
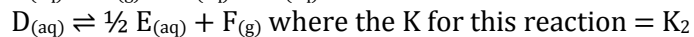
What is K in terms of K_1, K_2, and K_3 for the following reactions?

    a. $A_{(aq)} + B_{(aq)} + D_{(aq)} \rightleftharpoons 3C_{(aq)} + 2F_{(g)}$

    b. $D_{(aq)} + E_{(aq)} \rightleftharpoons A_{(aq)} + B_{(aq)} + C_{(aq)}$
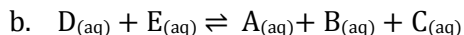
In preparation for next week discussion and lectures
Mahaffy, 2e chapter 14:

- Measure of the acidity of a solution
    - calculations of pH and $[H_3O^+]$: $pH = -\log[H_3O^+]$ $[H_3O^+] = 10^{-pH}$
- Measure of the basicity of a solution
    - calculations of pOH and $[OH^-]$: $pOH = -\log[OH^-]$ $[OH^-] = 10^{-pOH}$
- Water ionization constant: $K_w = [H_3O^+_{(aq)}][OH^-_{(aq)}]$
- For the reaction of acid and water, equilibrium constant is expressed as K_a
- For the reaction of base and water, equilibrium constant is expressed as K_b
- $K_w = K_a \cdot K_b$
- $pK_a = -\log K_a$ $pK_b = -\log K_b$ $pK_w = -\log K_w$
- Weak acids and weak bases: $K_w << K_b << 1$ $K_w << K_a << 1$

1. What are the relative concentrations of H_3O^+ and OH^- in a neutral solution?

2. For each of the quantities below, circle the correct relationship ($<$, $>$, or $=$). If you need more information in order to answer, circle nothing.

    a. What is true for an acidic solution?

        $[H_3O^+_{(aq)}]$ $<$ $>$ $=$ $[OH^-_{(aq)}]$ pH $<$ $>$ $=$ pOH

    b. What is true for a basic solution?

        $[H_3O^+_{(aq)}]$ $<$ $>$ $=$ $[OH^-_{(aq)}]$ pH $<$ $>$ $=$ pOH

3. If a solution has a pH < 7 but has equal concentrations of H_3O^+ and OH^- what must be true? (circle one)

<div align="center">
acidic   basic   neutral
</div>

4. The K_w for the autoionization of water is $1 \cdot 10^{-14}$ at 25°C and at 60°C, K_w is $1 \cdot 10^{-13}$. Circle all below that must be true:

    a. Pure water is acidic at 60 °C
    b. Autoionization is an endothermic process
    c. Autoionization is an exothermic process
    d. Pure water at 60°C has a pH = 7
    e. Pure water at 60°C has a pH < 7

5. You have a solution with the pH of 7.3 choose what applies:

    a. Solution is basic
    b. Solution is acidic
    c. I need more information
       ⇒ If you need more information, what information do you need?

6. Calculate the pHs of the following aqueous solutions assuming that all the following are strong acids and bases At 25°C.

    a. 0.50M H_2SO_4

       Reaction:

    b. 0.75 M $Ba(OH)_2$

       Reaction:

7. What is the concentration of a barium hydroxide solution if the pH is 11.48 at 25°C?

8. Write down an equilibrium reaction where equilibrium constant is K_a.

9. Write down an equilibrium reaction where equilibrium constant is K_b.

Unless told otherwise assume all reactions are run at room temperature (25°C). Do your calculations to the right number of significant figures. Review rules of significant figures for logarithms and antilogarithms from Packet 5.

10. A solution of 0.05 M of $HOClO_3$ in water has a pH=1.3 at room temperature.

    a. Based on the information given do you have a reaction of an acid with water or base with water? Why?

    b. Write the chemical equation for the acid-base reaction that occurs in this solution. What are the conjugate acid and base pairs in the solution?

c. Write the expression for equilibrium constant K. (Does your expression represent K_a or K_b?)

d. Using information given calculate equilibrium concentration of hydronium.

e. What percent of the acid reacted in solution? Is this a strong or weak acid?

f. Based on the information given will you expect the equilibrium constant to be: (choose one)

$$K_a << 1 \quad\quad \text{or} \quad\quad K_a >> 1$$

11. Calculate the pH of the following aqueous solutions assuming that all the following are strong acids and bases. *Remember log(1) = 0; log(10) = 1*

   a. 3.2M HCl

   b. 1.5M HCl

   c. 0.0024M HCl

   d. 0.039M HCl

   e. 0.0090 M NaOH *(hint: calculate pOH first and knowing pH + pOH =14 at room temperature)*

   f. 5.0M NaOH

12. What is the concentration of a sodium hydroxide solution if the pH is 11.48?

13. What is the concentration of a sodium hydroxide solution if the pH is 11.90?

14. What is the concentration of a sodium hydroxide solution if the pH is 14?

15. What is the concentration of HCl solution if the pH is 2.48?

16. What is the concentration of HCl solution if the pH is 3.40?

17. What is the concentration of HCl solution if the pH is 5.16?

18. What is the concentration of HCl solution if the pH is 1.04?

Answers

1. $Q < K$, $\ln\left(\frac{Q}{K}\right) < 0$, $\frac{Q}{K} < 1$
2. B, D, G
3. C, G
4. C, G
5. C, G
6. D
7.
   a. more reactants will form
   b. more reactants will form
   c. no change
   d. more reactants will form
8.
   a. $Q = \infty$
   b. A, B
9.
   a. $Q = \infty$
   b. ii, v, vii
   c. i, iii, vi
10.
   a. $K_{new} = 0.020$
   b. $K_{new} = 0.00040$
11. $K_2 = (K_1)^{1/3}$
12. $K_2 = (K_1)^{-1}$
13.
   a. $K = \frac{K_1 \cdot (K_2)^2}{K_3}$
   b. $K = \frac{1}{K_1 \cdot K_3}$

Answers in preparation for Chapter 14

1. $[OH^-] = [H_3O^+]$
2.
   a. $[H_3O^+] > [OH^-]$ and $pH < pOH$
   b. $[H_3O^+] < [OH^-]$ and $pH > pOH$
3. neutral
4. b, e
5. c; need to know temp
6. H_2SO_4 pH = 0.3, $Ba(OH)_2$ pH = 14.18
7. $1.5 \times 10^{-3} M$
8. $HA_{(aq)} + H_2O_{(l)} \rightleftharpoons A^-_{(aq)} + H_3O^+_{(aq)}$;
   $K_a = \frac{[H_3O^+] \cdot [A^-]}{[HA]}$
9. $A^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HA_{(aq)} + OH^-_{(aq)}$;
   $K_b = \frac{[OH^-] \cdot [HA]}{[A^-]}$
10.
   a. pH < 7; acid + water
   b. $HClO_{4(aq)} + H_2O_{(l)} \rightleftharpoons ClO_4^-_{(aq)} + H_3O^+_{(aq)}$;
      acid   base   conj. base conj. acid

   c. $K_a = \frac{[H_3O^+][ClO_4^-]}{[HClO_4]}$
   d. 0.05 M
   e. 100%; strong
   f. $K_a \gg 1$
11.
   a. -0.5
   b. -0.2
   c. 2.62
   d. 1.41
   e. 11.95
   f. 14.7
12. 0.0030 M
13. 0.0079 M
14. 1 M
15. 0.0033 M
16. 3.98 x 10⁻⁴ M
17. 6.9 x 10⁻⁶ M
18. 9.1·10⁻²

Exam 1 answers

1.
    a. 4
    b. 18
    c. 8/3
    d. 0
    e. 0
2.
    a. 2 or 4
    b. 0
3.
    a. 4060kPa
    b. 2.77×10^3 kPa
4. 29g/mol
5. 538g/mol
6. 59.2kPa
7. 0.31Pa
8. $C_3H_8 > C_2H_6 > CH_4$
9. A>d>b>s
10. 281K or 282K
11. PA=PB=PC
12.
    a. 430m/s
    b. Ar
    c. N_2
13. $3K^+ (g) + PO_4^{3-}(g) \rightarrow 3K^+ (aq) + PO_4^{3-}(aq)$
14. $(NH_4)_2CO_3(s) \rightarrow 2 NH_4^+(aq) + CO_3^{2-} (aq)$
15. 4.08bar