BCI SCIENCE

SCH 4U

Name:

Equilibrium Review Exemplar

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Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question. (25 marks)

1. **Which of these is NOT an example of heterogeneous equilibrium?**
   a. $H_2O(l) \Leftrightarrow H_2O(g)$
   b. $C(s) + CO_2(g) \Leftrightarrow CO_2(g)$
   c. $N_2O_4(g) \Leftrightarrow 2NO_2(g)$
   d. $C_2H_5OH(l) \Leftrightarrow C_2H_5OH(g)$

2. **What does it mean if $K_{eq} < 1$, at equilibrium?**
   a. The concentration of reactants is greater than the concentration of products.
   b. The concentration of products is greater than the concentration of reactants.
   c. The rate of the forward reaction is greater than the rate of the reverse reaction.
   d. The rate of the reverse reaction is greater than the rate of the forward reaction.

3. **Which of these affects the equilibrium constant, K_{eq}.**
   a. concentration
   b. pressure
   c. volume
   d. temperature

4. **Which change does NOT shift equilibrium toward reactant formation?**
   a. increasing product concentration
   b. decreasing reactant concentration
   c. decreasing product concentration
   d. a and b

5. **Which is NOT true of a reaction quotient?**
   a. the system cannot reach equilibrium
   b. the formula is the same as the equilibrium constant
   c. it has a numerical value
   d. it can predict the direction in which the reaction shifts to reach equilibrium

6. **If $Q_{eq} > K_{eq}$, then _____.**
   a. the system is at equilibrium
   b. the ratio of products to reactants is less than K_{eq}
   c. the ratio of products to reactants is greater than K_{eq}
   d. the reaction shifts toward product formation

7. **If temperature of the system is increased of the reaction below,**

   Nitrogen and oxygen can react as follows:

   $$N_2(g) + O_2(g) \underset{\text{Exothermic}}{\overset{\text{Endothermic}}{\rightleftharpoons}} 2NO(g)$$

   $$\Delta H = +180 \text{ kJ}$$

   a. more of NO(g) will be formed
   b. more of N_2(g) and O_2 (g) will be formed
   c. there will be no effect on the concentration of N_2(g), O_2(g) or NO(g)
   d. the reaction will not occur at all

8. **If the equation in question 7 has the pressure increased, what will happen to the equilibrium?**
   a. The concentration of N_2 will increase.
   b. The concentration of O_2 will decrease.
   c. The concentration of NO will increase.
   d. There will be no change to the equilibrium system.

9. **In which of the following reactions does NH_3 act as Bronsted acid?**
   a. $NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$
   b. $NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$
   c. $NH_3(aq) + Na(s) \rightarrow NaNH_2(aq) + \frac{1}{2}H_2(g)$
   d. $NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq$

10. **The ionization constant for diethylamine is $(C_2H_5)_2NH(aq)$:**

    a. $K_b = \frac{[(C_2H_5)_2NH_2^+][OH^-]}{[(C_2H_5)_2NH]}$

    b. $K_b = \frac{[(C_2H_5)_2NH_2^+][OH^-]}{[(C_2H_5)_2NH_2]}$

    c. $K_b = \frac{[(C_2H_5)_2NH_2^+][OH^-]}{[(C_2H_5)_2NH]}$

    d. $K_b = \frac{[(C_2H_5)_2NH^+][OH^-]}{[(C_2H_5)_2NH]}$

11. **Which of the following substances is not a Brønsted acid?**
    a. HF(aq)
    b. H_2SO_3(aq)
    c. NO_3^-(aq)
    d. NH_4^+(aq)

12. **A student prepares a CH_3COOH–CH_3COONa buffer system. The buffer solution used in this process is**
    a. ethanoic acid–sodium acetate
    b. formic acid–sodium formate
    c. carbonic acid–bicarbonate
    d. ammonium hydroxide–ammonium chloride

13. **A solution of hydrochloric acid, HCl(aq), is prepared by dissolving 3.7 g of HCl(g) in enough water to make 1.0 L of solution. The pH of the solution is**
a. 0.10
b. 0.99
c. 1.02
d. 1.09

14. **A soft drink is found to have pH 2.40. The hydroxide ion concentration in the bottle is**
a. 3.9×10^{-3} mol/L
b. 4.9×10^{-3} mol/L
c. 2.5×10^{-12} mol/L
d. 3.1×10^{-3} mol/L

15. **At a point, during the reaction of two soluble ionic compounds, calculations revealed that a precipitate will form until the solution is saturated. Which is true of these calculations?**
a. $Q_{sp} > K_{sp}$
b. $Q_{sp} < K_{sp}$
c. $Q_{sp} = K_{sp}$
d. $Q_{eq} > K_{sp}$

16. **The characteristics of a titration curve is based on which of these?**
a. the strength of the acid only
b. the strength of the base only
c. the strength of both the acid and the base
d. the pH at equivalence point

17. **The value of equilibrium constant K_{eq}, for the reaction, $SO_2(g) + Cl_2(g) \Leftrightarrow SO_2Cl_2(g)$, is**

Compound	$SO_2(g)$	$Cl_2(g)$	$SO_2Cl_2(g)$
Equilibrium Concentration	1.78 mol/L	0.90 mol/L	1.20 mol/L

a. 0.72
b. 0.75
c. 0.80
d. 0.82

K = 0.80

18. **If the equilibrium constant is very small, which assumption can be made?**
a. concentration of reactant at equilibrium is the same as the initial concentration
b. concentration of reactant at equilibrium is greater than the initial concentration
c. concentration of reactant at equilibrium is less than the initial concentration
d. concentration of reactant at equilibrium is the same as concentration of the product

19. **When is chemical equilibrium achieved?**
a. when both the forward and reverse reactions stop
b. when all of the reactants are used up
c. when the concentration of products and reactants become equal
d. when the rates of the forward and reverse reactions are equal

20. **The pH of a solution is 2.3. Using the ionic product constant for water, the value of $[OH^-]$ is**
a. 3×10^{-5} mol/L
b. 2×10^{-12} mol/L
c. 1×10^{-10} mol/L
d. 2×10^{-15} mol/L

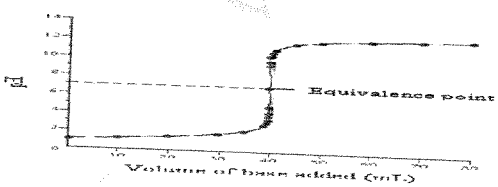
$[H_3O^+] = 10^{-pH}$

$[OH^-] = \frac{K_w}{[H_3O^+]}$

21. **A buffer is prepared containing equal volumes of 1.00 molar ammonia and 1.00 molar ammonium chloride. What is its pOH? K_b for ammonia is 1.77×10^{-5}**
a. 4.752
b. 1.00
c. 9.248
d. 1.77×10^{-5}

$pOH = pK_b + \log\frac{[NH_4^+]}{[NH_3]}$

22. **While performing a titration in the laboratory, a student plotted the following graph of:**



a. $HClO_4$ (aq) with NaOH (aq)
b. CH_3COOH (aq) with NaOH (aq)
c. HCN (aq) with NaOH(aq)
d. H_2S (aq) with NaOH(aq)

23. **9.54×10^{-4} mol/L is the solubility of lead(II) iodide in water at 0°C. What is the solubility product constant for lead(II) iodide at the same temperature?**
a. 9.54×10^{-4}
b. 1.82×10^{-6}
c. 9.10×10^{-7}
d. 3.48×10^{-9}

$K_{sp} = [9.54 \times 10^{-4}][9.54 \times 10^{-4}]$

24. **The solubility product constant for lithium carbonate is 1.7×10^{-3} at 25°C. What is the molar solubility of lithium carbonate at this temperature?**
a. 0.0017 mol/L
b. 0.041 mol/L
c. 0.075 mol/L
d. 0.095 mol/L

$K_{sp} = 0.041$

25. **A drop (0.050 mL) of 6.0 mol/L silver nitrate is added to 1.0 L of 0.10 mol/L sodium chloride. What is the Q_{sp}?**
a. 0.10
b. 0.001
c. 3.0×10^{-5}
d. 0.006

$Q_{sp} =$

Short Answer and Calculations: *Choose a COMBINATION of questions that ADDS to 40. Answer the questions you can do the best on! Only work on the* ***Foolscap*** will be marked. *For each question, show* ***ALL*** *your work if you want part marks.*

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26. Complete the following table, based on the following equilibrium system.
$CH_{4(g)} + 2H_2S_{(g)} \Leftrightarrow CS_{2(g)} + 4H_{2(g)}$ $\Delta H = -43$ kJ (5)

Stress	Equilibrium shift (left/right)
decrease in volume	left
addition of inert gas at constant pressure	no shift
removal of $H_2S_{(g)}$	left
increase in temperature	right
decrease in pressure	right

27. At 500 K, the partial pressures of this system at equilibrium werer found to be as follows:

$P_{HBr(g)} = 1.74$ atm $P_{Cl2(g)} = 1.06$ atm $P_{HCl(g)} = 2.48$ atm $P_{Br2(g)} = 1.95$ atm

a) Calculate the Kp for the reaction when hydrogen bromide gas reacts with chlorine gas to produce Hydrogen chloride gas and bromine gas: (3)

$HBr_{(g)} + Cl_{2(g)} \leftrightarrow HCl_{(g)} + Br_{2(g)}$

$$K_p = \frac{P_{HCl(g)} P_{Br_2(g)}}{P_{HBr(g)} P_{Cl_2(g)}}$$

$$= \frac{(2.48\text{ atm})(1.95\text{ atm})}{(1.74\text{ atm})(1.06\text{ atm})}$$

$$= 2.62$$

b) Based on the concentrations of reactants and products at eq'm is the Keq suitable? (2)

Since Kp is in the one's column, the relative concentrations of reactants and products should be the same.

28. When nitrogen gas reacts with oxygen gas, nitrogen monoxide gas forms. Initially, 0.30 mol of each reactant is placed into a 2.0 L container and equilibrium is established. If K_{eq} = 52.1, what are the equilibrium concentrations of all reactants and products? (10)

Concentration	$N_2(g)$ +	$O_2(g)$ ⇔	$2NO(g)$
Initial (mol/L)	0.15	0.15	0
Change	−x	−x	+2x
Equilibrium (mol/L)	0.15 − x	0.15 − x	2x

$C = \frac{n}{V}$

$= \frac{0.30}{2}$

$= 0.15\,M$

$K_{eq} = \frac{[NO_{(g)}]^2}{[N_{2(g)}][O_{2(g)}]}$

$52.1 = \frac{[0.15][0.15]}{[2x]}$

$104.2x = 0.0225$

$x = 2.159 \times 10^{-4}\,M$

$[N_2] = 0.15 - x$

$= 0.1498\,M$

$[O_2] = 0.1498\,M$

$[NO] = 2x$

$= 2(2.159 \times 10^{-4})$

$= 4.318 \times 10^{-4}\,M$

29. Carbon monoxide and water vapour react to form carbon dioxide and hydrogen. The equilibrium constant for this reaction is 5.12. At equilibrium, it is determined that a 4.00 L container contains 0.65 mol of hydrogen. If equal amounts of carbon monoxide and water were added to the container, how much of each was added in moles? (10)

Concentration				
Initial (mol/L)				
Change				
Equilibrium (mol/L)				

30. a) Codeine, $C_8H_{21}NO_{3(s)}$, a weak base, is added to some cough medicines. When a 0.020 mol/L aqueous solution of codeine was prepared, the pH of the solution was determined to be 10.26. Calculate the K_b for codeine. (8)

Concentration	$C_8H_{21}NO_{3(aq)}$	$+ H_2O_{(l)} \rightleftharpoons$	$C_8H_{22}NO_3^+{}_{(aq)}$	$+ OH^-{}_{(aq)}$
Initial (mol/L)	0.020	—	0	0
Change	$-x$	—	$+x$	$+x$
Equilibrium (mol/L)	$0.020 - x$	—	x	x

$[OH^-] = 10^{-10.26}$
$\doteq 5.495 \times 10^{-11} M$

$K_b = \frac{[C_8H_{22}NO_3^+{}_{(aq)}][OH^-{}_{(aq)}]}{[C_8H_{21}NO_{3(aq)}]}$
$= \frac{[5.495 \times 10^{-11}][5.495 \times 10^{-11}]}{[0.020]}$
$\doteq 1.5 \times 10^{-19}$

b) Calculate the percent ionization of codeine. (2)

% ionization $= \frac{[OH^-]}{C_8H_{21}NO_3} \times 100$
$= \frac{5.495 \times 10^{-11}}{0.020} \times 100$
$= 2.75 \times 10^{-7}\%$

31. Determine the pH at the equivalence point when 0.104 g of sodium acetate, $NaC_2H_3O_{2(s)}$, $K_b = 5.6 \times 10^{-10}$, is added to enough water to make 25.00 mL of solution and is titrated with 0.100 M $HCl_{(aq)}$. (10)

Concentration				
Initial (mol/L)				
Change				
Equilibrium (mol/L)				

32. The K_{sp} value for lead(II)bromide is 6.6×10^{-6}. What is the solubility of this solid, in g/L? (10)

Concentration			
Initial (mol/L)			
Change			
Equilibrium (mol/L)			

33. K_{sp} for barium fluoride is 1.7×10^{-6}. Calculate the molar solubility of barium fluoride in 0.10 mol/L sodium fluoride. (10)

approx

$\frac{[F^-(aq)]}{K_{sp}} \geq 500$ $\quad \frac{[0.10]}{1.7 \times 10^{-6}} = 58823$

Concentration	$BaF_2(s)$ ⇔	$Ba^{+2}(aq)$ +	$2F^-(aq)$
Initial (mol/L)	—	0	0.10
Change	—	+x	+x
Equilibrium (mol/L)	—	x	0.10 + x ≃ 0.10

$$K_{sp} = [Ba^{+2}(aq)][F^-(aq)]^2$$
$$= [x][0.10]^2$$
$$x = 1.7 \times 10^{-4}\ M$$

$$\frac{1\ mol\ Ba^{+2}}{1.7 \times 10^{-4}} = \frac{1\ mol\ BaF_2(s)}{x}$$

$$x = 1.7 \times 10^{-4}\ M$$

∴ $[BaF_2(s)]$ is $1.7 \times 10^{-4}\ M$