

Name:

/60

**Multiple Choice**

Identify the letter of the choice that best completes the statement or answers the question. (20 marks)

1. **Equilibrium happens when \_\_\_\_\_.**
  - a. opposing forces balance
  - b. opposing forces are unbalanced
  - c. the forward and reverse reactions occur at different rates
  - d. the forward and reverse reactions are unbalanced
  
2. **Which is a macroscopic property?**
  - a. colour
  - b. temperature
  - c. concentration
  - d. pH
  
3. **A system reaches equilibrium. Which must be true of the system?**
  - a. it is open
  - b. it is closed
  - c. it is either open or closed
  - d. it is open and has pressure
  
4. **Ice cubes are melting in a glass of water with a lid on it. Why does this situation not represent an equilibrium system?**
  - a. It is not closed system.
  - b. The equilibrium cannot be approached from the opposite direction.
  - c. The temperature is not constant.
  - d. The rates of opposing changes are not equal.
  
5. **Which of these is NOT an example of heterogeneous equilibrium?**
  - a.  $\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{O}(\text{g})$
  - b.  $\text{C}(\text{s}) + \text{CO}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g})$
  - c.  $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$
  - d.  $\text{C}_2\text{H}_5\text{OH}(\text{l}) \rightleftharpoons \text{C}_2\text{H}_5\text{OH}(\text{g})$
  
6. **In the equilibrium constant expression below, what do the exponents represent?**

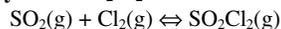
$$K_{\text{eq}} = \frac{[\text{C}]^c [\text{D}]^d}{[\text{A}]^a [\text{B}]^b}$$
  - a. the concentrations of reactants and products
  - b. the equilibrium constant
  - c. the rates of the forward and reverse reactions
  - d. the stoichiometric coefficients from the balanced equation
  
7. **Which is true of the numerical value of the equilibrium constant,  $K_{\text{eq}}$ ?**
  - a. It represents the relative concentration of products compared with reactants.
  - b. It represents the ratio of reactants to products.
  - c. It is measured in the SI unit, mole.
  - d. Both a and c are true.
  
8. **What does it mean if  $K_{\text{eq}} < 1$ , 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.
  
9. **When the equilibrium constant is very small, the approximate concentration of reactant at equilibrium is \_\_\_\_\_ the initial concentration.**
  - a. greater than
  - b. less than
  - c. the same as
  - d. exactly 100 times
  
10. **If  $Q_{\text{eq}} > K_{\text{eq}}$ , then \_\_\_\_\_.**
  - a. the system is at equilibrium
  - b. the ratio of products to reactants is less than  $K_{\text{eq}}$
  - c. the ratio of products to reactants is greater than  $K_{\text{eq}}$
  - d. the reaction shifts toward product formation
  
11. **Use the following information to answer the next question.**

The following reaction is an example of homogeneous equilibrium:  
 $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$

**If the pressure is halved, by doubling the volume and the temperature remains constant, the equilibrium will**

  - a. shift forward.
  - b. shift backward
  - c. not be affected
  - d. will not reach equilibrium
  
12. **Which condition is NOT a condition for an equilibrium system?**
  - a. equal rates for opposing changes
  - b. a closed system
  - c. reactants in the same phase
  - d. constant temperature

13. Sulfur dioxide is a colourless gas, which smells like burnt matches. When sulfur dioxide and chlorine react with each other, they form  $\text{SO}_2\text{Cl}_2$  as



At equilibrium, the concentration values of compounds are:

Compound	$\text{SO}_2(\text{g})$	$\text{Cl}_2(\text{g})$	$\text{SO}_2\text{Cl}_2(\text{g})$
Equilibrium Concentration	1.78 mol/L	0.90 mol/L	1.20 mol/L

The value of equilibrium constant  $K_{\text{eq}}$  for the above reaction is

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

14. Use the following information to answer the next question.

The equilibrium constant has been determined in several reactions as follows:

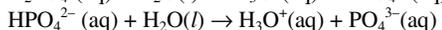
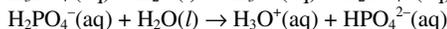
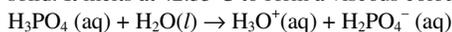
- |  |                                       |
|--|---------------------------------------|
| 1. $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g})$                               | $K_{\text{eq}} = 4.8 \times 10^{-31}$ |
| 2. $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{HCl}(\text{g})$                             | $K_{\text{eq}} = 4.0 \times 10^{31}$  |
| 3. $2\text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{CO}_2(\text{g})$                             | $K_{\text{eq}} = 2.3 \times 10^{22}$  |
| 4. $\text{Cu}(\text{s}) + 2\text{Ag}^+(\text{aq}) \rightleftharpoons \text{Cu}^{2+}(\text{aq}) + 2\text{Ag}(\text{s})$ | $K_{\text{eq}} = 2.0 \times 10^{15}$  |

The correct arrangement of the above reactions, in decreasing order of their ability to form products, is

- \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.  
a. 1, 2, 4, 3  
b. 1, 4, 3, 2  
c. 2, 1, 3, 4  
d. 2, 3, 4, 1

15. Use the following information to answer the next question.

Hydrogen phosphate,  $\text{H}_3\text{PO}_4(\text{s})$ , is a chemical substance, which, in pure anhydrous form, exists as white solid. It melts at  $42.35^\circ\text{C}$  to form a viscous colourless liquid. In aqueous solution, it ionizes as follows:



The concentration of the following substances involved in the reaction are:

$$[\text{H}_3\text{O}^+(\text{aq})] = x \text{ mol/L}$$

$$[\text{PO}_4^{3-}(\text{aq})] = y \text{ mol/L}$$

$$[\text{H}_3\text{PO}_4(\text{aq})] = z \text{ mol/L}$$

The equilibrium constant for the overall reaction is:

- a.  $x^3yz$   
b.  $\frac{x^2y}{z}$   
c.  $x^2yz$   
d.  $\frac{x^3y}{z}$

16. Which of the following species is neither an acid or a base as defined by Bronsted-Lowry?

- a.  $\text{HPO}_4^{2-}$   
b.  $\text{AlCl}_3$   
c.  $\text{NH}_3$   
d.  $\text{CO}_3^{2-}$

17. Use the following information to answer the next question.

Diethylamine,  $(\text{C}_2\text{H}_5)_2\text{NH}(\text{aq})$ , is a base that partially ionizes in water.

The ionization constant for diethylamine is:

- a.  $K_b = \frac{[(\text{C}_2\text{H}_5)_2\text{NH}_2^+][\text{OH}^-]}{[(\text{C}_2\text{H}_5)_2\text{NH}]}$   
b.  $K_b = \frac{[(\text{C}_2\text{H}_5)_2\text{NH}_2^+][\text{OH}^-]}{[(\text{C}_2\text{H}_5)_2\text{NH}_2]}$   
c.  $K_b = \frac{[(\text{C}_2\text{H}_5)_2\text{NH}_2^+][\text{OH}^-]}{[(\text{C}_2\text{H}_5)_2\text{NH}]}$   
d.  $K_b = \frac{[(\text{C}_2\text{H}_5)_2\text{NH}_2^+][\text{OH}^-]}{[(\text{C}_2\text{H}_5)_2\text{NH}]}$

18. Which of the following combinations will not result in the formation of a buffer solution?

- a. Ethanoic acid–sodium acetate  
b. Formic acid–sodium formate  
c. Ethanoic acid–hydrochloric acid  
d. Boric acid–sodium borate

19. A soft drink is found to have pH 2.40. The hydroxide ion concentration in the bottle is

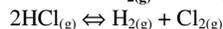
- a.  $3.9 \times 10^{-3} \text{ mol/L}$   
b.  $4.9 \times 10^{-3} \text{ mol/L}$   
c.  $2.5 \times 10^{-12} \text{ mol/L}$   
d.  $3.1 \times 10^{-3} \text{ mol/L}$

20. 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.  $Q_{\text{sp}} > K_{\text{sp}}$   
b.  $Q_{\text{sp}} < K_{\text{sp}}$   
c.  $Q_{\text{sp}} = K_{\text{sp}}$   
d.  $Q_{\text{eq}} > K_{\text{sp}}$

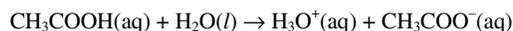
**Short Answer and Calculations:** For the following questions, show all your work if you want part marks. (40 marks). Choose FIVE of the six questions!

21. The following equilibrium system has an equilibrium constant of  $3.2 \times 10^{-34}$  at 25 °C. Find the equilibrium concentrations of  $\text{H}_{2(\text{g})}$  and  $\text{Cl}_{2(\text{g})}$  if 3.00 mol/L of  $\text{HCl}_{(\text{g})}$  is allowed to come to equilibrium. [ /8]



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

22. Ethanoic acid is also called acetic acid and has the chemical formula  $\text{CH}_3\text{COOH}(l)$ . It is a colourless liquid. It is used in the production of vinyl acetate monomer, acetic anhydride, and ester. It exhibits the following equilibrium in water:



The value of  $K_a$  for the above acid is  $1.8 \times 10^{-5}$ . The concentration of hydronium ions in a 0.020 mol/L solution of ethanoic acid is \_\_\_\_\_  $\times 10^{-4}$  mol/L. [ /8]

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

23. A 35.0 mL sample of (monoprotic) lactic acid,  $\text{C}_3\text{H}_6\text{O}_3$ , is titrated with 20.0 mL of a  $4.0 \times 10^{-4}$  mol/L sodium hydroxide solution. What is the pH of the resulting solution at the equivalence point, if  $K_a$  for lactic acid is  $1.4 \times 10^{-4}$ ? [ /12]

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

24.  $K_b$  for caffeine,  $\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$ , is  $4.1 \times 10^{-4}$ . If the equilibrium concentration of caffeine is 0.0250 mol/L, what was the initial concentration of caffeine? [ /6]

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

25. Calculate the concentrations of iron ions and hydroxide ions in a solution of iron(II) hydroxide ( $K_{sp} = 1.8 \times 10^{-15}$ ). [ /8]

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

26. A buffer solution is made by mixing 400.0 mL of 0.15 mol/L acetic acid with 325 mL of 0.20 mol/L sodium acetate. What is the pH of the buffer solution? [ /12]

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