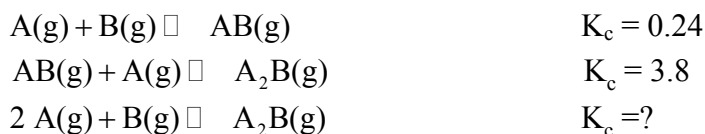


1) Which of the following statements is FALSE?

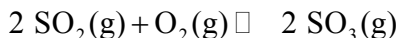
- A) When  $K \gg 1$ , the forward reaction is favored and essentially goes to completion.
- B) When  $K \ll 1$ , the reverse reaction is favored and the forward reaction does not proceed to a great extent.
- C) When  $K \approx 1$ , neither the forward or reverse reaction is strongly favored, and about the same amount of reactants and products exist at equilibrium.
- D)  $K \gg 1$  implies that the reaction is very fast at producing products.
- E) All of the above statements are true.

2) The equilibrium constant is given for two of the reactions below. Determine the value of the missing equilibrium constant.



- A) 4.0
- B) 0.91
- C) 3.6
- D) 16
- E) 0.63

3) The reaction below has a  $K_c$  value of  $1.0 \times 10^{12}$ . What is the value of  $K_p$  for this reaction at 500 K?



- A)  $4.2 \times 10^{-11}$
- B)  $1.0 \times 10^{12}$
- C)  $2.4 \times 10^{-12}$
- D)  $4.1 \times 10^{13}$
- E)  $2.4 \times 10^{10}$

4) Express the equilibrium constant for the following reaction.



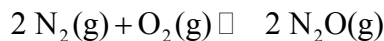
- A)  $K = \frac{[\text{P}_4][\text{O}_2]^5}{[\text{P}_4\text{O}_{10}]}$
- B)  $K = \frac{[\text{P}_4\text{O}_{10}]}{[\text{P}_4][\text{O}_2]^5}$

C)  $K = [\text{O}_2]^{-5}$

D)  $K = [\text{O}_2]^5$

E)  $K = \frac{[\text{P}_4\text{O}_{10}]}{[\text{P}_4][\text{O}_2]^{1/5}}$

5) Determine the value of  $K_c$  for the following reaction if the equilibrium concentrations are as follows:  $[\text{N}_2]_{\text{eq}} = 3.6 \text{ M}$ ,  $[\text{O}_2]_{\text{eq}} = 4.1 \text{ M}$ ,  $[\text{N}_2\text{O}]_{\text{eq}} = 3.3 \times 10^{-18} \text{ M}$



A)  $2.2 \times 10^{-19}$

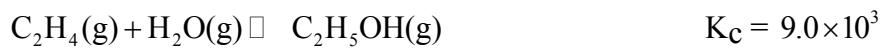
B)  $4.5 \times 10^{18}$

C)  $2.0 \times 10^{-37}$

D)  $5.0 \times 10^{36}$

E)  $4.9 \times 10^{-17}$

6) Consider the following reaction, equilibrium concentrations, and equilibrium constant at a particular temperature. Determine the equilibrium concentration of  $\text{H}_2\text{O}(\text{g})$ .



$$[\text{C}_2\text{H}_4]_{\text{eq}} = 0.015 \text{ M}$$

$$[\text{C}_2\text{H}_5\text{OH}]_{\text{eq}} = 1.69 \text{ M}$$

A)  $9.9 \times 10^{-7} \text{ M}$

B)  $80. \text{ M}$

C)  $1.0 \text{ M}$

D)  $1.68 \text{ M}$

E)  $0.013 \text{ M}$

7) Consider the following reaction:



A reaction mixture initially contains  $0.50 \text{ M CH}_4$  and  $0.75 \text{ M H}_2\text{S}$ . If the equilibrium concentration of  $\text{H}_2$  is  $0.44 \text{ M}$ , find the equilibrium constant ( $K_c$ ) for the reaction.

A)  $0.23$

B)  $0.038$

C)  $2.9$

D)  $10.$

E)  $0.34$

8. A reaction mixture contains 0.39 M  $\text{SO}_2$ , 0.14 M  $\text{NO}_2$ , 0.11 M  $\text{SO}_3$  and 0.14 M  $\text{NO}$ . Which of the following statements is TRUE concerning this system?

- A) The reaction will shift in the direction of reactants.
- B) The equilibrium constant will decrease.
- C) The reaction will shift in the direction of products.
- D) The reaction quotient will decrease.
- E) The system is at equilibrium.

9) Which of the following statements is TRUE?

- A) If  $Q < K$ , it means the reverse reaction will proceed to form more reactants.
- B) If  $Q > K$ , it means the forward reaction will proceed to form more products.
- C) If  $Q = K$ , it means the reaction is at equilibrium.
- D) All of the above are true.
- E) None of the above are true.

10) Consider the following reaction at equilibrium. What effect will adding more  $\text{SO}_3$  have on the system?



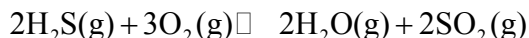
- A) The reaction will shift in the direction of products.
- B) The reaction will shift to decrease the pressure.
- C) No change will occur since  $\text{SO}_3$  is not included in the equilibrium expression.
- D) The reaction will shift in the direction of reactants.
- E) The equilibrium constant will decrease.

11) Consider the following reaction at equilibrium. What effect will reducing the volume of the reaction mixture have on the system?



- A) The equilibrium constant will decrease.
- B) No effect will be observed.
- C) The reaction will shift to the right in the direction of products.
- D) The equilibrium constant will increase.
- E) The reaction will shift to the left in the direction of reactants.

12) Consider the following reaction at equilibrium. What effect will adding 1 atm of Ar to the reaction mixture have on the system?



- A) The reaction will shift to the right in the direction of products.

- B) No effect will be observed.
- C) The reaction will shift to the left in the direction of reactants.
- D) The equilibrium constant will decrease.
- E) The equilibrium constant will increase.

13) Consider the following reaction at equilibrium. What effect will increasing the temperature have on the system?



- A) The reaction will shift to the left in the direction of reactants.
- B) The equilibrium constant will increase.
- C) The equilibrium constant will decrease.
- D) No effect will be observed.
- E) The reaction will shift to the right in the direction of products.

14) How is the reaction quotient (Q) different from an equilibrium constant (K<sub>c</sub>) for a given reaction?

15) What is the conjugate acid of  $\text{HCO}_3^-$  ?

- A)  $\text{H}_3\text{O}^+$
- B)  $\text{H}_2\text{O}$
- C)  $\text{CO}_3^{2-}$
- D)  $\text{OH}^-$
- E)  $\text{H}_2\text{CO}_3$

16) Which of the following is a STRONG base?

- A)  $\text{Cl}^-$
- B)  $\text{NH}_3$
- C)  $\text{CH}_3\text{OH}$
- D)  $\text{NO}_3^-$
- E)  $\text{KOH}$

17) Which of the following statements is TRUE?

- A) A strong acid is composed of a proton and an anion that have a very strong attraction for one another.
- B) A weak base is composed of a cation and an anion with a very weak attraction between them.
- C) A strong acid has a strong conjugate base.
- D) The conjugate base of a very weak acid is stronger than the conjugate base of a strong acid.

E) None of the above statements are true.

18) Which of the following acids is the STRONGEST? The acid is followed by its  $K_a$  value.

- A) HF,  $3.5 \times 10^{-4}$
- B) HCN,  $4.9 \times 10^{-10}$
- C) HNO<sub>2</sub>,  $4.6 \times 10^{-4}$
- D) HCHO<sub>2</sub>,  $1.8 \times 10^{-4}$
- E) HClO<sub>2</sub>,  $1.1 \times 10^{-2}$

19) Determine the  $K_b$  for  $CN^-$ . The  $K_a$  for HCN is  $4.9 \times 10^{-10}$ .

- A)  $4.9 \times 10^{-14}$
- B)  $2.3 \times 10^{-9}$
- C)  $1.4 \times 10^{-5}$
- D)  $2.0 \times 10^{-5}$
- E)  $3.7 \times 10^{-7}$

20) Calculate the concentration of  $OH^-$  in a solution that contains  $3.9 \times 10^{-4}$  M  $H_3O^+$  at 25°C. Identify the solution as acidic, basic or neutral.

- A)  $2.6 \times 10^{-11}$  M, acidic
- B)  $2.6 \times 10^{-11}$  M, basic
- C)  $3.9 \times 10^{-4}$  M, neutral
- D)  $2.7 \times 10^{-2}$  M, basic
- E)  $2.7 \times 10^{-2}$  M, acidic

21) Determine the pH of a 0.023 M HNO<sub>3</sub> solution.

- A) 12.36
- B) 3.68
- C) 1.64
- D) 2.30
- E) 2.49

22) Determine the  $[H_3O^+]$  in a 0.265 M HClO solution. The  $K_a$  of HClO is  $2.9 \times 10^{-8}$ .

- A)  $1.1 \times 10^{-10}$  M
- B)  $7.7 \times 10^{-9}$  M
- C)  $1.3 \times 10^{-6}$  M
- D)  $4.9 \times 10^{-4}$  M

E)  $8.8 \times 10^{-5} \text{ M}$

23) Determine the  $K_a$  of an acid whose 0.294 M solution has a pH of 2.80.

A)  $1.2 \times 10^{-5}$

B)  $8.6 \times 10^{-6}$

C) 2.7

D)  $4.9 \times 10^{-7}$

E)  $5.4 \times 10^{-3}$

24) Determine the pH of a solution that is 0.15 M  $\text{HClO}_2$  ( $K_a = 1.1 \times 10^{-2}$ ) and 0.15 M  $\text{HClO}$  ( $K_a = 2.9 \times 10^{-8}$ ).

A) 4.18

B) 9.82

C) 12.55

D) 1.45

E) 3.55

25) Determine the  $[\text{OH}^-]$  concentration in a 0.235 M NaOH solution.

A)  $4.25 \times 10^{-14} \text{ M}$

B) 0.470 M

C)  $2.13 \times 10^{-14} \text{ M}$

D) 0.198 M

E) 0.235 M

26) Determine the pH of a 0.188 M  $\text{NH}_3$  solution. The  $K_b$  of  $\text{NH}_3$  is  $1.76 \times 10^{-5}$ .

A) 5.480

B) 2.740

C) 8.520

D) 11.260

E) 12.656

27) Which of the following is a Lewis base?

A)  $\text{AlF}_3$

B)  $\text{H}_2\text{O}$

C)  $\text{SiF}_4$

D)  $\text{C}_5\text{H}_{12}$

E) None of the above are Lewis bases.

28) Place the following in order of increasing acid strength.



- A) HBrO<sub>2</sub> < HBrO<sub>4</sub> < HBrO < HBrO<sub>3</sub>
- B) HBrO < HBrO<sub>2</sub> < HBrO<sub>3</sub> < HBrO<sub>4</sub>
- C) HBrO<sub>2</sub> < HBrO<sub>3</sub> < HBrO<sub>4</sub> < HBrO
- D) HBrO<sub>4</sub> < HBrO<sub>2</sub> < HBrO<sub>3</sub> < HBrO
- E) HBrO < HBrO<sub>4</sub> < HBrO<sub>3</sub> < HBrO<sub>2</sub>

**28. MATCHING. Choose the item in column 2 that best matches each item in column 1.**

60) Arrhenius acid	A) proton acceptor
61) Arrhenius base	B) produces hydroxide ions in aqueous solution
62) Bronsted-Lowry base	C) electron pair donator
63) Lewis acid	D) electron pair acceptor
64) Lewis base	E) produces protons in aqueous solution

29. For the reaction system,  $\text{H}_2(\text{g}) + \text{X}_2(\text{g}) \rightleftharpoons 2 \text{HX}(\text{g})$ ,  $K_c = 24.4$  at 300 K. A system made up from these components which is at equilibrium contains 0.200 moles of  $\text{X}_2$  and 0.600 moles of HX in a 4.00 liter container. Calculate the number of moles of  $\text{H}_2(\text{g})$  present at equilibrium.

- a. 0.059 mol
- b. 0.074 mol
- c. 0.123 mol
- d. 0.148 mol
- e. 0.295 mol

30. A study of the system,  $4 \text{NH}_3(\text{g}) + 7 \text{O}_2(\text{g}) \rightleftharpoons 2 \text{N}_2\text{O}_4(\text{g}) + 6 \text{H}_2\text{O}(\text{g})$ , was carried out. A system was prepared with  $[\text{NH}_3] = [\text{O}_2] = 3.60 \text{ M}$  as the only components initially. At equilibrium,  $[\text{N}_2\text{O}_4]$  is 0.60 M. Calculate the equilibrium concentration of  $\text{NH}_3$ .

- a. 3.00 M
- b. 2.10 M
- c. 3.30 M
- d. 1.80 M
- e. 2.40 M