

**MULTIPLE CHOICE**

- 1) Which of the following is true about a system at equilibrium?
- A) The concentration(s) of the reactant(s) is equal to the concentration(s) of the product(s).
  - B) No new product molecules are formed.
  - C) The concentration(s) of reactant(s) is constant over time.
  - D) The rate of the reverse reaction is equal to the rate of the forward reaction and both rates are equal to zero.
  - E) None of the above (A-D) is true.
- 2) Which of the following is true about chemical equilibrium?
- A) It is microscopically and macroscopically static.
  - B) It is microscopically and macroscopically dynamic.
  - C) It is microscopically static and macroscopically dynamic.
  - D) It is microscopically dynamic and macroscopically static.
  - E) None of these are true about chemical equilibrium.
- 3) Equilibrium is reached in chemical reactions when:
- A) The rates of the forward and reverse reactions become equal.
  - B) The concentrations of reactants and products become equal.
  - C) The temperature shows a sharp rise.
  - D) All chemical reactions stop.
  - E) The forward reaction stops.
- 4) For the reaction given below, 2.00 moles of A and 3.00 moles of B are placed in a 6.00-L container.
- $$A(g) + 2B(g) \rightleftharpoons C(g)$$
- At equilibrium, the concentration of A is 0.246 mol/L. What is the concentration of B at equilibrium?
- A) 0.246 mol/L
  - B) 0.325 mol/L
  - C) 0.500 mol/L
  - D) 0.492 mol/L
  - E) none of these
- 5) If the equilibrium constant for  $A + B \rightleftharpoons C$  is 0.208, then the equilibrium constant for  $2C \rightleftharpoons 2A + 2B$  is
- A) 0.584
  - B) 4.81
  - C) 0.416
  - D) 23.1
  - E) 0.208

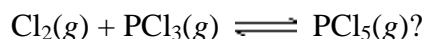
6) Apply the law of mass action to determine the equilibrium expression for  $2\text{NO}_2\text{Cl}(aq) \rightleftharpoons 2\text{NO}_2(aq) + \text{Cl}_2(aq)$ .

- A)  $K = 2[\text{NO}_2][\text{Cl}_2]/2[\text{NO}_2\text{Cl}]$
- B)  $K = 2[\text{NO}_2\text{Cl}]/2[\text{NO}_2][\text{Cl}_2]$
- C)  $K = [\text{NO}_2\text{Cl}]^2/[\text{NO}_2]^2[\text{Cl}_2]$
- D)  $K = [\text{NO}_2]^2[\text{Cl}_2]/[\text{NO}_2\text{Cl}]^2$
- E)  $K = [\text{NO}_2\text{Cl}]^2/[\text{NO}_2]^2[\text{Cl}_2]$

7) At a given temperature,  $K = 0.017$  for the equilibrium:



What is  $K$  for:



- A) 0.017
- B) 59
- C) 0.00029
- D) 17
- E) 3500

8) Which expression correctly describes the equilibrium constant for the following reaction?



- A)  $K = (4[\text{NH}_3] + 5[\text{O}_2]) / (4[\text{NO}] + 6[\text{H}_2\text{O}])$
- B)  $K = (4[\text{NO}] + 6[\text{H}_2\text{O}]) / (4[\text{NH}_3] + 5[\text{O}_2])$
- C)  $K = ([\text{NO}][\text{H}_2\text{O}]) / ([\text{NH}_3][\text{O}_2])$
- D)  $K = ([\text{NO}]^4[\text{H}_2\text{O}]^6) / ([\text{NH}_3]^4[\text{O}_2]^5)$
- E)  $K = ([\text{NH}_3]^4[\text{O}_2]^5) / ([\text{NO}]^4[\text{H}_2\text{O}]^6)$

(Use for #9 and #10) Consider the chemical system  $\text{CO} + \text{Cl}_2 \rightleftharpoons \text{COCl}_2$ ;  $K = 4.6 \times 10^9$  L/mol.

9) How do the equilibrium concentrations of the reactants compare to the equilibrium concentration of the product?

- A) They are much smaller.
- B) They are much bigger.
- C) They are about the same.
- D) They have to be exactly equal.
- E) You can't tell from the information given.

10) If the concentration of the product were to double, what would happen to the equilibrium constant?

- A) It would double its value.
- B) It would become half its current value.
- C) It would quadruple its value.
- D) It would not change its value.
- E) It would depend on the initial conditions of the product.

11) Determine the equilibrium constant for the system  $\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$  at  $25^\circ\text{C}$ . The concentrations are shown here:  $[\text{N}_2\text{O}_4] = 2.32 \times 10^{-2} \text{ M}$ ,  $[\text{NO}_2] = 1.41 \times 10^{-2} \text{ M}$ .

- A) 0.608
- B) 1.65
- C)  $1.17 \times 10^2$
- D) 0.369
- E)  $8.57 \times 10^{-3}$

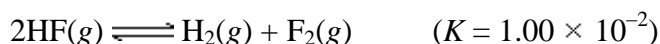
12) If  $K = 0.144$  for  $\text{A}_2 + 2\text{B} \rightleftharpoons 2\text{AB}$ , then for  $4\text{AB} \rightleftharpoons 2\text{A}_2 + 4\text{B}$ ,  $K$  would equal:

- A) 0.288
- B) 0.144
- C)  $-0.144$
- D) 3.47
- E) 48.2

13) For the reaction  $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{HCl}(\text{g})$ ,  $K_c = 1.22 \times 10^{33}$  at a temperature of 301 K. What is  $K_p$  at this temperature?

- A)  $1.22 \times 10^{33}$
- B)  $3.01 \times 10^{34}$
- C)  $4.93 \times 10^{31}$
- D)  $7.43 \times 10^{35}$
- E)  $2.00 \times 10^{30}$

14) Consider the following reaction:



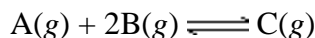
Given 1.00 mole of  $\text{HF}(\text{g})$ , 0.362 mole of  $\text{H}_2(\text{g})$ , and 0.750 mole of  $\text{F}_2(\text{g})$  are mixed in a 5.00 L flask, determine the reaction quotient,  $Q$ .

- A)  $Q = 0.0543$
- B)  $Q = 0.272$
- C)  $Q = 0.0679$
- D)  $Q = 2.11$
- E) none of these

15) Consider the following equilibrated system:  $2\text{NO}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) + \text{O}_2(\text{g})$ . If the  $K_p$  value is 0.604, find the equilibrium pressure of the  $\text{O}_2$  gas if the  $\text{NO}_2$  gas pressure is 0.520 atm and the  $P_{\text{NO}}$  is 0.300 atm at equilibrium.

- A) 1.05 atm
- B) 24.8 atm
- C) 0.348 atm
- D) 0.201 atm
- E) 1.81 atm

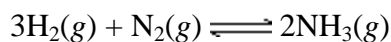
16) For the reaction given below, 2.00 moles of A and 3.00 moles of B are placed in a 6.00-L container.



At equilibrium, the concentration of A is 0.213 mol/L. What is the value of  $K$ ?

- A) 2.18
- B) 1.79
- C) 0.213
- D) 8.40
- E) 0.565

17) Initially 2.0 moles of  $N_2(g)$  and 4.0 moles of  $H_2(g)$  were added to a 1.0-liter container and the following reaction then occurred:



The equilibrium concentration of  $NH_3(g) = 0.55$  moles/liter at  $700.^{\circ}C$ . The value for  $K$  at  $700.^{\circ}C$  for the formation of ammonia is:

- A)  $1.0 \times 10^{-1}$
- B)  $5.5 \times 10^{-2}$
- C)  $5.5 \times 10^{-3}$
- D)  $3.0 \times 10^{-1}$
- E) none of these

18) The following reaction is investigated (assume an ideal gas mixture):



Initially there are 0.10 moles of  $N_2O$  and 0.25 moles of  $N_2H_4$ , in a 10.0-L container. If there are 0.048 moles of  $N_2O$  at equilibrium, how many moles of  $N_2$  are present at equilibrium?

- A)  $2.6 \times 10^{-2}$
- B)  $5.2 \times 10^{-2}$
- C)  $7.8 \times 10^{-2}$
- D)  $1.6 \times 10^{-1}$
- E) none of these

(Use for #19-21) Given the equation  $2A(g) \rightleftharpoons 2B(g) + C(g)$ . At a particular temperature,  $K = 1.6 \times 10^4$ .

19) If you mixed 5.0 mol B, 0.10 mol C, and 0.0010 mol A in a one-liter container, which direction would the reaction initially proceed?

- A) To the left.
- B) To the right.
- C) The above mixture is the equilibrium mixture.
- D) Cannot tell from the information given.
- E) None of these (A-D).

- 20) Addition of chemical B to an equilibrium mixture of the above will
- A) cause [A] to increase
  - B) cause [C] to increase
  - C) have no effect
  - D) cannot be determined
  - E) none of the above
- 21) Raising the pressure by lowering the volume of the container will
- A) cause [A] to increase
  - B) cause [B] to increase
  - C) have no effect
  - D) cannot be determined
  - E) none of the above
- 22) Which of the following statements concerning equilibrium is *not* true?
- A) A system that is disturbed from an equilibrium condition responds in a manner to restore equilibrium.
  - B) Equilibrium in molecular systems is dynamic, with two opposing processes balancing one another.
  - C) The value of the equilibrium constant for a given reaction mixture is the same regardless of the direction from which equilibrium is attained.
  - D) A system moves spontaneously toward a state of equilibrium.
  - E) The equilibrium constant is independent of temperature.
- 23) For a certain reaction at 25.0°C, the value of  $K$  is  $1.2 \times 10^{-3}$ . At 50.0°C the value of  $K$  is  $3.4 \times 10^{-1}$ . This means that the reaction is
- A) exothermic
  - B) endothermic
  - C) never favorable
  - D) more information needed
  - E) none of these (A-D)
- 24) Consider the following equilibrium:  $2\text{H}_2(\text{g}) + \text{X}_2(\text{g}) \rightleftharpoons 2\text{H}_2\text{X}(\text{g}) + \text{energy}$
- Addition of  $\text{X}_2$  to a system described by the above equilibrium
- A) will cause  $[\text{H}_2]$  to decrease
  - B) will cause  $[\text{X}_2]$  to decrease
  - C) will cause  $[\text{H}_2\text{X}]$  to decrease
  - D) will have no effect
  - E) cannot possibly be carried out

25) Consider the following system at equilibrium:  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) + 92.94 \text{ kJ}$

Which of the following changes will shift the equilibrium to the right?

- I. increasing the temperature
- II. decreasing the temperature
- III. increasing the volume
- IV. decreasing the volume
- V. removing some  $\text{NH}_3$
- VI. adding some  $\text{NH}_3$
- VII. removing some  $\text{N}_2$
- VIII. adding some  $\text{N}_2$

- A) I, IV, V, VIII
- B) II, III, V, VIII
- C) I, VI, VIII
- D) I, III, V, VII
- E) II, IV, V, VIII

26) Consider the combustion of methane (as represented by the following equation). This is the reaction that occurs for a Bunsen burner, which is a source of heat for chemical reactions in the laboratory.



For the system at chemical equilibrium, which of the following explains what happens if the temperature is raised?

- A) The equilibrium position is shifted to the right and the value for  $K$  increases.
- B) The equilibrium position is shifted to the right and the value for  $K$  decreases.
- C) The equilibrium position is shifted to the left and the value for  $K$  decreases.
- D) The equilibrium position is shifted to the left and the value for  $K$  increases.
- E) The equilibrium position is shifted but the value for  $K$  stays constant.

27) For the gaseous reaction,  $2 \text{H}_2 + 2 \text{NO} \rightleftharpoons 2 \text{H}_2\text{O} + \text{N}_2$ ,  $K_p$  at  $120^\circ\text{C} = 2.42$ . At a given moment, it is found that the partial pressures of  $\text{H}_2$ ,  $\text{NO}$ ,  $\text{H}_2\text{O}$  and  $\text{N}_2$  are 1.1, 1.3, 0.78 and 2.2 atm, respectively. Which of the following statements describes the situation?

- A)  $Q_p = 1.2$  so the reaction goes to the right
- B)  $Q_p = 1.2$  so the reaction goes to the left
- C)  $Q_p = 0.65$  so the reaction goes to the right
- D)  $Q_p = 0.65$  so the reaction goes to the left
- E) The reaction is at equilibrium

28) What effect does a) increasing the total pressure and b) increasing the temperature have on the equilibrium  $\text{H}_2(\text{g}) + \text{CO}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}(\text{g}) + \text{CO}(\text{g})$ ,  $\Delta H^\circ = 41.2 \text{ kJ/mol}$ .

- A) a) equilibrium shifts towards products, b) equilibrium shifts towards products.
- B) a) equilibrium shifts towards reactants, b) equilibrium shifts towards products.
- C) a) equilibrium shifts towards products, b) equilibrium shifts towards reactants.
- D) a) no change in the equilibrium, b) equilibrium shifts towards products.
- E) a) no change in the equilibrium, b) equilibrium shifts towards reactants.

29) Consider the reaction, which is exothermic as written,  $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$ . Which of the following changes would result in the production of MORE  $\text{Cl}_2(\text{g})$ ?

- I. adding  $\text{PCl}_3(\text{g})$
- II. removing  $\text{PCl}_3(\text{g})$
- III. reducing the volume of the container
- IV. removing  $\text{PCl}_5(\text{g})$
- V. increasing the temperature
- VI. increasing the volume of the container
- VII. adding  $\text{PCl}_5(\text{g})$
- VIII. reducing the temperature
- IX. adding a suitable catalyst

- A) I, IV, V, VI
- B) II, VI, VII, VIII
- C) II, III, VII, VIII
- D) II, V, VI, VII
- E) II, VI, VII, VIII, IX

30) Consider a 1 gallon jug of water stored for Y2K emergency use. Assume the water level in the jug has not changed visibly over the 17 years of shelf life. Inside the jug:

- I) there is zero evaporation or condensation taking place
- II) the evaporation and condensation are taking place at equal rates
- III) equilibrium has been reached
- IV) evaporation and condensation are occurring but one will always be faster than the other

- A) I
- B) II, III
- C) II, IV
- D) I, III
- E) I, II, III, IV

**Go Vikings!!**