

CHEMICAL EQUILIBRIUM

1. What is the difference between the homogeneous equilibrium and heterogeneous equilibrium? Indicate which ones of the following equilibrium reactions are homogeneous and which are heterogeneous

- A. $\text{H}_{2(g)} + \text{I}_{2(g)} \leftrightarrow 2\text{HI}_{(g)}$
- B. $2\text{CO}_{2(g)} \leftrightarrow 2\text{CO}_{(g)} + \text{O}_{2(g)}$
- C. $\text{Ag}^+_{(aq)} + 2\text{NH}_{3(aq)} \leftrightarrow \text{Ag}(\text{NH}_3)_2^+_{(aq)}$
- D. $\text{ZnSO}_{3(s)} \leftrightarrow \text{ZnO}_{(s)} + \text{SO}_{2(g)}$
- E. $6\text{CO}_{2(g)} + 6\text{H}_2\text{O}_{(l)} \leftrightarrow \text{C}_6\text{H}_{12}\text{O}_{6(s)} + 6\text{O}_{2(g)}$

2. Write K_c expression for each of the following reactions.

- A. $\text{H}_{2(g)} \leftrightarrow 2\text{H}_{(g)}$
- B. $\text{N}_{2(g)} + \text{O}_{2(g)} \leftrightarrow 2\text{NO}_{(g)}$
- C. $2\text{N}_2\text{O}_{5(g)} \leftrightarrow 4\text{NO}_{2(g)} + \text{O}_{2(g)}$
- D. $\text{H}_2\text{O}_{(g)} \leftrightarrow \text{H}_{2(g)} + \text{O}_{2(g)}$
- E. $\text{N}_2\text{H}_4(g) + 6\text{H}_2\text{O}_{2(g)} \leftrightarrow 2\text{NO}_{2(g)} + 8\text{H}_2\text{O}_{(g)}$

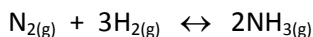
3. Write K_c expressions for each of the following reactions involving pure solids and pure liquids .

- A. $\text{MgCO}_{3(s)} \leftrightarrow \text{MgO}_{(s)} + \text{CO}_{2(g)}$
- B. $\text{H}_{2(g)} + \text{S}_{(l)} \leftrightarrow \text{H}_2\text{S}_{(g)}$
- C. $\text{H}_{2(g)} + \text{S}_{(s)} \leftrightarrow \text{H}_2\text{S}_{(l)}$
- D. $5\text{Fe}^{+2}_{(aq)} + \text{MnO}_4^-_{(aq)} + 8\text{H}^+_{(aq)} \leftrightarrow 5\text{Fe}^{+3}_{(aq)} + \text{Mn}^{+2}_{(aq)} + 4\text{H}_2\text{O}_{(l)}$

4. The rate of the reaction

$\text{X}_{2(g)} + \text{Y}_{2(g)} \leftrightarrow 2\text{XY}_{(g)}$ at 25°C is given by $\text{Rate} = 4 \times 10^{-3} [\text{X}^2][\text{Y}^2]$, rate of the reaction $2\text{XY}_{(g)} \leftrightarrow \text{X}_{2(g)} + \text{Y}_{2(g)}$ at 25°C is given by $\text{Rate} = 2 \times 10^{-4} [\text{XY}]^2$. What is the equilibrium constant for the formation of XY from the gaseous X₂ and Y₂?

5. For the reaction:



The equilibrium concentrations in mol/L found at 257°C are $[\text{H}_2] = 0.5$, $[\text{N}_2] = 0.2$, $[\text{NH}_3] = 2$.

- A. Calculate K_c for this equilibrium reaction.
- B. What would be the value of K_c for the reverse reaction?

6. 0.5 mol of CO₂ and 0.2 mol of H₂ are put into a 5-L vessel at a certain temperature. When the reaction



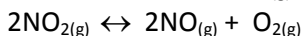
is reached equilibrium, the vessel contains 0.1 mol of CO. Calculate the equilibrium constant, K_c, for the reaction at given temperature.

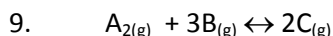
7. At a certain temperature a mixture of A(g) and B(g) was prepared by placing 1 mol of A and 2.5 mol of B into a 2-L flask. After a period of time the equilibrium



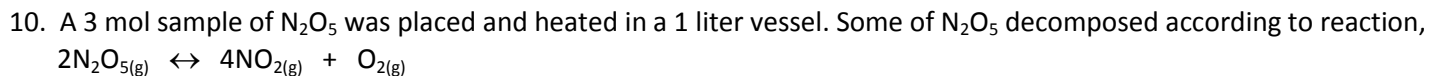
was established. It was determined that the concentration of C was 0.5 mol/L at equilibrium. Calculate the value of K_c for this reaction at this temperature.

8. 0.6 mol of NO_{2(g)} is placed into a sealed 4-L container, and heated to a certain temperature. At equilibrium it is found that 0.2 mol of NO_{2(g)} remained unreacted. Calculate for the reaction K_c of the reaction.





The reaction was started with 2 mol of A_2 and 4 mol of B in a 1-L container. When the reaction reached equilibrium, 1 mol of B remained behind. Calculate the K_c .



At equilibrium the total number of moles of gases was found to be 3.75. Calculate the value of K_c for this reaction.

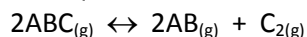
11. At a certain temperature K_c for the equilibrium $2A_{(g)} + B_{(g)} \leftrightarrow 3C_{(g)}$ is 4. If the equilibrium concentrations of A and C are 0.2 M each, what is the equilibrium concentration of B?

12. At a certain temperature the K_c for the reaction $PCl_{5(g)} \leftrightarrow PCl_{3(g)} + Cl_{2(g)}$ is 4×10^{-2} . How many grams of PCl_5 must be put into a 2-L container to obtain 7.1 g of Cl_2 at equilibrium? (PCl_5 : 208.5, Cl_2 : 71)

13. The equilibrium constant, K_c for the reaction:

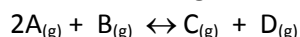
$FeO_{(s)} + CO_{(g)} \leftrightarrow Fe_{(s)} + CO_{2(g)}$ at a certain temperature is 1. Find the equilibrium concentrations of the CO and CO_2 if the reaction is started with a mixture of 14 g of CO and 54 g of FeO dust in a 5-L vessel. (CO: 28, FeO: 72)

14. The equilibrium constant, K_c , is 0.2 at $100^\circ C$ for the reaction:



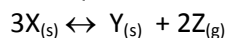
An equilibrium mixture in 1-L flask at $100^\circ C$ contains 0.1 mol of AB, 0.2 mol of ABC and 28.4 g of C_2 . What is the atomic mass of C?

15. At a certain temperature equilibrium mixture in 1-L vessel has the following composition: 0.2 mol of A, 0.3 mol of B, 0.3 mol of C and 64g of D for the reaction:



When 0.9 mol B and 2.4 mol of D are added to the vessel at the same temperature, the system remains at equilibrium. Calculate the formula mass of D.

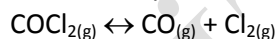
16. The equilibrium constant, K_c is 0.16 at a certain temperature for the reaction:



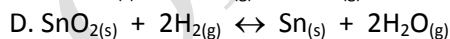
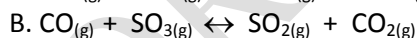
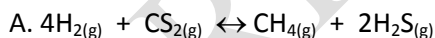
At least how many moles of X must be placed in a 5-L flask to establish the equilibrium at the given temperature?

17. What is K_p ? How is it related to K_c ? In what conditions are they equal?

18. Prove that $K_p = K_c RT$ for the reaction



19. Write relationship between K_p and K_c for each of the following reactions. Indicate the unit of K_p in atm in each case.

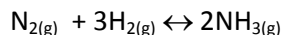


20. In the reaction



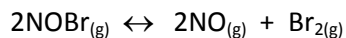
At $27^\circ C$ the partial pressures of the gases at equilibrium is as follows: $P(PCl_5) = 1.8 \times 10^{-2}$ atm, $P(PCl_3) = P(Cl_2) = 6 \times 10^{-3}$ atm. What is the equilibrium constant, K_p for the reaction at $27^\circ C$?

21. An equilibrium mixture contains 2 mol of NH_3 , 2 mol of N_2 and 1 mol of H_2 at 227°C in a 2-L container. For the reaction:



Calculate K_c and K_p .

22. Nitrosyl bromide, dissociates on heating:



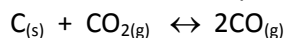
When 44 g of NOBr is placed in a 4-L container and heated to 127°C , the equilibrium pressure is 4.1 atm. Calculate

A. the partial pressure of each gas at equilibrium.

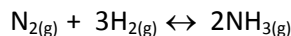
B. the value of K_p and K_c

C. the degree of dissociation of NOBr.

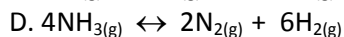
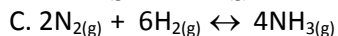
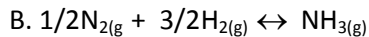
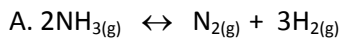
23. A container at a certain temperature contains CO_2 at a pressure of 0.5 atm, solid graphite is added to the container and some of the carbon dioxide is converted to carbon monoxide. At equilibrium the total pressure of gases in the container is 0.75 atm. Calculate K_p for the reaction:



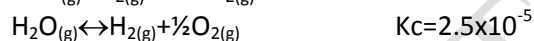
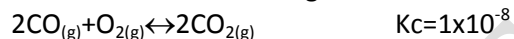
24. The equilibrium constant, K_c , for the following reaction is 0.64 at 600 K.



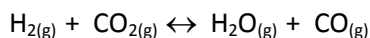
What are the K_c values for the following reactions?



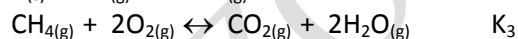
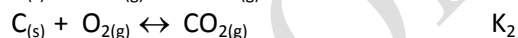
25. At 200 K the values of K_c are given for the reactions.



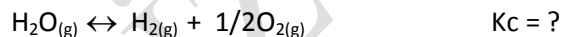
Find the value of K_c at 200 K for the reaction,



26. From the values of K_c given,



Determine the value of K_c in terms of K_1 , K_2 and K_3 for the reaction,



27. Consider the reaction:



In several experiments the gases were mixed as indicated below. In each case decide whether a net reaction will occur, and so in what direction? Calculate the final equilibrium concentration of each component.

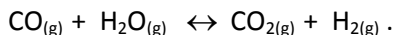
A. 0.1 mol of N_2 , 0.1 mol of O_2 , and 0.02 mol of NO in 1-L box.

B. 0.1 mol of N_2 , 0.1 mol of O_2 , and 0.02 mol of NO in 10-L box.

C. 0.1 mol of N_2 , 0.01 mol of O_2 , and 0.01 mol of NO in 50-L box.

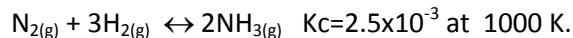
D. 0.2 mol of N_2 , 0.2 mol of O_2 , and 0.02 mol of NO in 100-L box.

28. Can a mixture of 2 mol of H_2O , 2 mol of CO , 3 mol of H_2 and 3 mol of CO_2 exist in equilibrium in a 5-L flask at 600 K at which $K_c = 36$ for the reaction



If not, in which direction will a reaction take place? Calculate the concentration of each component in the final equilibrium.

29. For the reaction ,

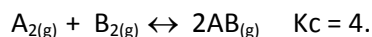


A. Will a mixture of 1 mol of each N_2 , H_2 , and NH_3 produce a net reaction in a 2-L flask?

B. If not, will NH_3 be produced or consumed?

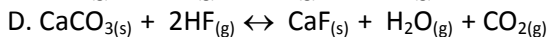
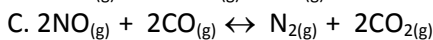
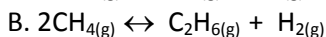
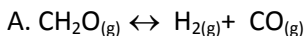
C. What must be the volume of the flask if the mixture described in part (a) to be at equilibrium?

30. For the reaction:

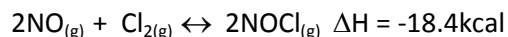


Initially 1 mol of A_2 , 1 mol of B_2 and 3 mol of AB are placed into 5-L container. What will be the molarity of each substance at equilibrium?

31. Which of the following equilibrium reactions will not be affected by a change in volume or pressure?



32. Consider the reaction:



How will be the equilibrium be affected by

A. The addition of NOCl

B. The removal of NO

C. A decrease in the volume of the container

D. An increase in the temperature

E. The injection of the catalyst

33. Given the reaction:



Which direction does the reaction shift when the following changes are applied to the reaction?

A. The addition of O_2

B. The removal of CH_4

C. The removal of CO_2

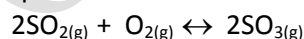
D. An increase in the temperature

E. A decrease in the volume

F. A decrease in the pressure

G. The addition of a catalyst

34. An equilibrium mixture in a 1-L container for the reaction,

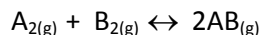


has the following composition. $[\text{SO}_2] = 0.2 \text{ M}$, $[\text{O}_2] = 0.2 \text{ M}$, $[\text{SO}_3] = 0.4 \text{ M}$.

A. How many moles of SO_3 must be added to increase the equilibrium concentration of SO_2 to 0.4 M?

B. How many moles of SO_3 must be removed from the original equilibrium mixture to decrease the equilibrium concentration of O_2 to 0.15 M?

35. If 4 mol of AB are placed in a 1-L vessel, the equilibrium reaction,



will take place. If the equilibrium concentration of B₂ is 1 M,

A. Calculate the Kc.

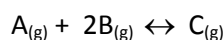
B. To decrease the equilibrium concentration of A₂ to 0.1 M, how many moles of AB must be removed from the container?

36. Given the equilibrium reaction:



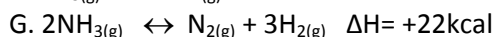
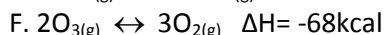
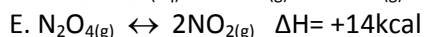
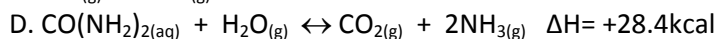
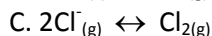
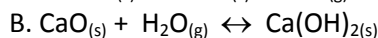
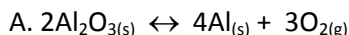
When the reaction is at equilibrium at a certain temperature, the concentrations are found to be [PCl₃]=[Cl₂]=0.3 M and [PCl₅]=2.25 M in 0.5-L vessel. If the volume of the container in which the reaction is at equilibrium is suddenly doubled at constant temperature, what will be the new equilibrium concentrations be?

37. 3 mol of A and 2 mol of B are introduced into a container at a certain temperature. When the equilibrium is



was established, 12.5% of the mixture by moles found to be C. What is the percentage by moles of B equilibrium?

38. For each of the following reactions, decide to which direction the maximum entropy and the minimum energy will be



MULTIPLE CHOICES

1. In an equilibrium reaction which of the following will change the equilibrium constant itself

A. a change in the temperature

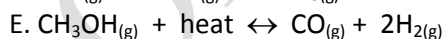
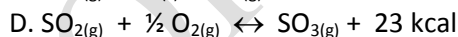
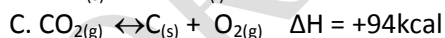
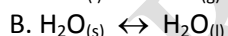
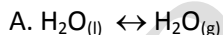
B. a change in the pressure

C. a change in the catalyst used

D. a change in the molar concentration of the reactants

E. a change in the molar concentration of the products.

2. In which one of the following reactions, the equilibrium will not shift in the direction of products with the increase in temperature?



3. For the reaction, $H_{2(g)} + CO_{2(g)} \leftrightarrow H_2O_{(g)} + CO_{(g)}$

Kc = 1.6 at 986°C. When equilibrium is established at 986°C, [CO₂] = 0.5M, [H₂] = 1.0M, [CO] = 2.0 M.

What is [H₂O] at equilibrium?

A. 0.1M

B. 0.4M

C. 0.5M

D. 1.0M

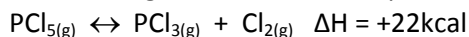
E. 2.0M

4. For the equilibrium $A_{(g)} + B_{(g)} \leftrightarrow 2C_{(g)}$

The rates constant for the forward and reverse reactions are 3.16×10^{-2} and 0.79 respectively. What is the numerical value of the equilibrium constant?

- A. 0.0158 B. 0.025 C. 0.02 D. 0.04 E. 1.0

5. Which of the following will increase the equilibrium concentration of Cl_2 for the reaction.



- A. decreasing the temperature
B. increasing the concentration of PCl_3
C. increasing the pressure
D. increasing the concentration of PCl_5
E. adding catalyst

6. If K is small, it indicates that equilibrium occurs

- A. at a low product concentration
B. at a high product concentration
C. after considerable time
D. with the help of a catalyst
E. with no forward reaction

7. For the reaction, $2\text{A}_{(g)} + \text{B}_{(g)} \leftrightarrow 2\text{C}_{(g)}$ $\Delta H = -Q$ kcal.

Which of the following pairs shift the equilibrium in the direction of the production of more C?

- A. increasing the temperature and pressure
B. decreasing the pressure and adding catalyst
C. decreasing the temperature and pressure
D. increasing temperature and decreasing pressure
E. decreasing the temperature and increasing the pressure

8. Given;



What is the numerical value of K for the following reaction at the same temperature?



- A. 3 B. 9 C. 9×27 D. 27×81 E. $27/81$

9. If K_p for the reaction $\text{A}_{2(g)} + \text{B}_{2(g)} \leftrightarrow 2\text{AB}_{(g)}$ was equal to 1.5 at 25°C , what would be the numerical value of K in terms of molar concentrations?

- A. $1/1.5$ B. $1.5 \times 0.082 \times 298$ C. 1.5×0.082 D. 1.5 E. 1.5×25

10. What occurs when a reaction is at equilibrium and more reactants is added to the container?

- A. The equilibrium remains unchanged.
B. The forward reaction rate increases.
C. The reverse reaction rate increases.
D. The forward reaction rate decreases.
E. The reverse reaction rate decreases.

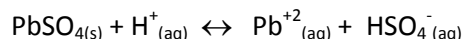
11. In which one of the following reactions, tendency toward minimum energy favors the formation of reactants?

- A. $\text{H}_{2(g)} + \text{Cl}_{2(g)} \leftrightarrow 2\text{HCl}_{(g)}$ $\Delta H = -44$ kcal
B. $\text{CO}_{(g)} + \frac{1}{2} \text{O}_{2(g)} \leftrightarrow \text{CO}_{2(g)} + \text{heat}$
C. $\text{H}_2\text{O}_{(g)} \leftrightarrow \text{H}_2\text{O}_{(l)}$
D. $\text{SO}_{2(g)} + \frac{1}{2} \text{O}_{2(g)} \leftrightarrow \text{SO}_{3(g)} + 23$ kcal
E. $\text{I}_{2(g)} + 1.6$ kcal $\leftrightarrow \text{I}_{2(\text{in alcohol})}$

12. Which one of the following reactions cannot be an equilibrium reaction?

- A. $\text{C}_2\text{H}_5\text{OH}_{(l)} \leftrightarrow \text{C}_2\text{H}_5\text{OH}_{(aq)} + \text{heat}$
- B. $2\text{NH}_{3(g)} \leftrightarrow \text{N}_{2(g)} + 3\text{H}_{2(g)} \quad \Delta H = +44 \text{ kcal}$
- C. $\text{I}_{2(s)} \leftrightarrow \text{I}_{2(g)}$
- D. $\text{C}_{(s)} + \text{H}_2\text{O}_{(g)} \leftrightarrow \text{H}_{2(g)} + \text{CO}_{(g)} \quad \Delta H = +31.4 \text{ kcal}$
- E. $\text{CaCO}_{3(s)} + \text{heat} \leftrightarrow \text{CaO}_{(s)} + \text{CO}_{2(g)}$

13. In the reaction



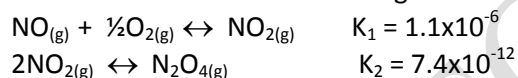
Which of the following will not occur by the addition of Pb^{+2} to the system at equilibrium?

- A. the amount of PbSO_4
- B. $[\text{H}^+]$ increases
- C. $[\text{HSO}_4^-]$ increases
- D. $[\text{Pb}^{+2}]$ increases
- E. equilibrium shifts to left

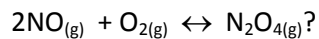
14. Which of the following statements concerning catalysts is not correct?

- A. Catalysts do not affect the position of equilibrium
- B. Catalysts affect the speed at which equilibrium is reached
- C. Catalysts increase the rate of forward reaction
- D. Catalysts increase the rate of reverse reaction
- E. Le Chatelier's principle is useful in predicting the effect of catalysts upon a system at equilibrium

15. The equilibrium constants of the following reactions are given

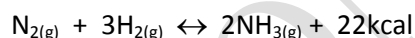


what is the value of K at the same temperature for



- A. 8.8×10^{-24}
- B. 8.6×10^{-14}
- C. 9.8×10^{-12}
- D. 6.2×10^{-12}
- E. 6.17

16. In the reaction



Which of the following will not increase the amount of NH_3 at equilibrium?

- A. Increasing the concentration of N_2
- B. Increasing the concentration of H_2
- C. Removal of NH_3 as rapidly as it is formed.
- D. Increasing the pressure at constant temperature
- E. Increasing the temperature

17. Which one of the following does not occur with the increase in temperature, after the equilibrium



- A. The quantity of CO at equilibrium increases
- B. The quantity of O_2 at equilibrium increases
- C. The quantity of CO_2 at equilibrium increases
- D. The total pressure increases.
- E. The value of the equilibrium constant does not change.