CHEMICAL EQUILIBRIUM REVIEW

INSTRUCTIONS: For each question, select the **BEST** answer and record your choice on the answer sheet provided. Using an **HB** pencil, completely fill in the circle that has the letter corresponding to your answer.

1. At equilibrium, which of the following are equal?

   A. Moles of reactants and products.
   B. Rates of forward and reverse reactions.
   C. Concentrations of reactants and products.
   D. Potential energies of reactants and products.

2. Which equation has the largest value of K_{eq}:

   A. $N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)} \quad \Delta H = 21kJ$

   B. $C_2H_{6(g)} \rightleftarrows 2C_{(g)} + 3H_{2(g)} \quad \Delta H = 83kJ$

   C. $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightleftarrows H_2O_{(g)} \quad \Delta H = -240kJ$

   D. $Ca_{(s)} + 2H_2O_{(l)} \rightleftarrows Ca(OH)_{2(aq)} + H_{2(g)} \quad \Delta H = -240kJ$

3. Consider the following equilibrium:

$$PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)}$$

When 0.40 mol of PCl_3 and 0.40 mol of Cl_2 are placed in a 1.00 L container and allowed to reach equilibrium, 0.244 mol of PCl_5 are present.

From this information, the value of K_{eq} is

   A. 0.10
   B. 0.30
   C. 3.3
   D. 10

4. 0.300 mol of S_2 and 0.310 mol of C are placed in a 1.00 L flask and allowed to reach equilibrium according to this reaction:

$$S_{2(g)} + C_{(s)} \rightleftarrows CS_{2(g)}$$

At equilibrium, 0.271 mol of CS_2 is present. The value of K_{eq} for the reaction is

   A. 0.91
   B. 2.9
   C. 9.3
   D. 240

5. Consider the following equilibria:

$$\text{I. } PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

$$\text{II. } 2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)}$$

$$\text{III. } NO_{(g)} + O_{3(g)} \rightleftarrows NO_{2(g)} + O_{2(g)}$$

An increase in pressure alone will cause the value of K_{eq} to decrease in

A. reaction I.
B. reaction II.
C. reaction III.
D. none of the reactions.

6. Which is the equilibrium constant expression for the following reaction?

$$H_{2(g)} + \frac{1}{2}O_{2(g)} \rightleftarrows H_2O_{(g)}$$

A. $K_{eq} = [H_2][O_2]^{\frac{1}{2}}$

B. $K_{eq} = \dfrac{1}{[H_2][O_2]^{\frac{1}{2}}}$

C. $K_{eq} = \dfrac{[H_2]^2[O_2]}{[H_2O]^2}$

D. $K_{eq} = \dfrac{[H_2O]}{[H_2][O_2]^{\frac{1}{2}}}$

7. Consider the equilibrium below:

$$2NO_{2(g)} \rightleftarrows N_2O_{4(g)}$$

After 2.0 moles of NO_2 are introduced into an empty 10.0 L container, product concentrations

A. increase and reactant concentrations increase.
B. increase and reactant concentrations decrease.
C. decrease and reactant concentrations increase.
D. decrease and reactant concentrations decrease.

8. Equilibrium is attained when there is a balance between the tendencies to

A. minimum enthalpy and minimum entropy.
B. minimum enthalpy and maximum entropy.
C. maximum enthalpy and minimum entropy.
D. maximum enthalpy and maximum entropy.

9. Which statement describes the concentrations of reactants and products in every chemical system at equilibrium?

A. Reactant concentrations are less than product concentrations.
B. Reactant concentrations and product concentrations are equal.
C. Reactant concentrations are greater than product concentrations.
D. Reactant concentrations and product concentrations are constant.

10. Equilibrium is achieved in a chemical system as it attempts to proceed towards

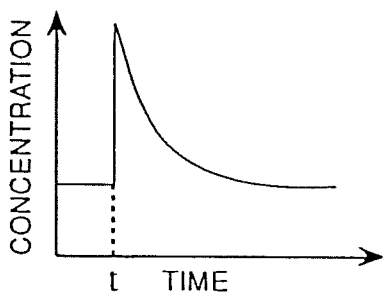
A. minimum enthalpy and minimum entropy.
B. minimum enthalpy and maximum entropy.
C. maximum enthalpy and minimum entropy.
D. maximum enthalpy and maximum entropy.

11. Consider the following equilibrium:

$$I_{2(g)} + Cl_{2(g)} \rightleftarrows 2ICl_{(g)}$$

Which graph below best illustrates the change in the concentration of I_2 when some more I_2 is added at time t?

A.



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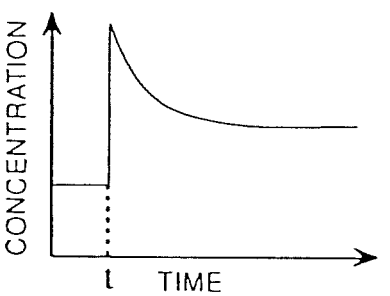
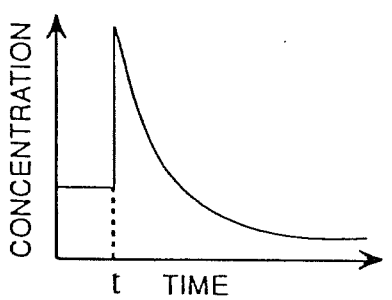
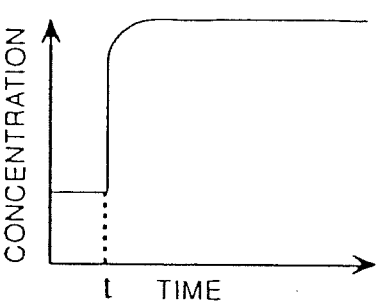


C.



D.



12. Addition of a catalyst to a reaction system causes

A. equilibrium to be reached faster.
B. the equilibrium to shift to the right.
C. the rate of the reverse reaction to decrease.
D. more products to be present at equilibrium.

13. Methanol, CH_3OH, can be manufactured using the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} + \text{energy}$$

The equilibrium will shift to the right when

A. a catalyst is added.
B. the [CO] is increased.
C. the [CH_3OH] is increased.
D. the temperature is increased.

14. To increase the yield of product in the following equilibrium:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)} ; \quad \Delta H = -92 \text{ kJ}$$

A. increase the pressure and temperature.
B. decrease the pressure and temperature.
C. increase the pressure and decrease the temperature.
D. decrease the pressure and increase the temperature.

15. Which of the following systems most favours products at equilibrium?

A. $2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 1.55 \times 10^{-6}$

B. $H_{2(g)} + Cl_{2(g)} \rightleftarrows 2HCl_{(g)} \qquad K_{eq} = 1.80 \times 10^{8}$

C. $CO_{(g)} + Cl_{2(g)} \rightleftarrows COCl_{2(g)} \qquad K_{eq} = 8.20 \times 10^{-1}$

D. $2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)} \qquad K_{eq} = 2.61 \times 10^{2}$

16. When air is drawn into a car's engine, the following endothermic reaction occurs:

$$N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)}$$

At room temperature the K_{eq} for this reaction is 4.8×10^{-31}. At the high temperatures found in a car's engine the

A. [NO] increases and the K_{eq} increases.
B. [NO] increases and the K_{eq} decreases.
C. [NO] decreases and the K_{eq} increases.
D. [NO] decreases and the K_{eq} decreases.

17. Consider the following equilibrium system:

$$FeO_{(s)} + H_{2(g)} \rightleftarrows Fe_{(s)} + H_2O_{(g)}$$

Which one of the following statements describes the effect that a decrease in volume would have on the position of equilibrium and the $[H_2]$ in the above system?

A. No shift, $[H_2]$ increases.
B. Shift right, $[H_2]$ increases.
C. Shift right, $[H_2]$ decreases.
D. No shift, $[H_2]$ remains constant.

18. Tooth enamel, $Ca_5(PO_4)_3OH$ establishes the following equilibrium:

$$Ca_5(PO_4)_3OH_{(s)} \rightleftarrows 5Ca^{2+}_{(aq)} + 3PO^{3-}_{4(aq)} + OH^-_{(aq)}$$

Which one of the following, when added to the above equilibrium system, would result in a shift to the right?

A. $H^+_{(aq)}$
B. $OH^-_{(aq)}$
C. $Ca^{2+}_{(aq)}$
D. $Ca_5(PO_4)_3OH_{(s)}$

19. Consider the following equilibrium system:

$$SnO_{2(s)} + 2CO_{(g)} \rightleftarrows Sn_{(s)} + 2CO_{2(g)}$$

The equilibrium constant expression for the above system is

A. $K_{eq} = \dfrac{[CO_2]^2}{[CO]^2}$

B. $K_{eq} = \dfrac{[2CO_2]^2}{[2CO]^2}$

C. $K_{eq} = \dfrac{[CO_2]^2\ [Sn]}{[CO]^2\,[SnO_2]}$

D. $K_{eq} = \dfrac{[2CO_2]^2\ [Sn]}{[2CO]^2\,[SnO_2]}$

20. Consider the following system:

$$Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightleftarrows FeSCN^{2+}_{(aq)}$$

A solution of $Fe(NO_3)_3$ is added to a solution of KSCN. As equilibrium is being established, the

A. $[Fe^{3+}]$ increases and the $[FeSCN^{2+}]$ increases.
B. $[Fe^{3+}]$ decreases and the $[FeSCN^{2+}]$ increases.
C. $[Fe^{3+}]$ increases and the $[FeSCN^{2+}]$ decreases.
D. $[Fe^{3+}]$ decreases and the $[FeSCN^{2+}]$ decreases.

21. A system has reached equilibrium when

A. maximum entropy has been achieved.
B. minimum enthalpy has been achieved.
C. the rate of the forward and reverse reactions is zero.
D. the concentration of reactants and products has stopped changing.

22. Entropy is a measure of

A. disorder.
B. kinetic energy.
C. potential energy.
D. change in potential energy.

23. Consider the following system at equilibrium:

$$CH_{4(g)} + H_2O_{(l)} \rightleftarrows CO_{(g)} + 3H_{2(g)}$$

Which of the following chemicals, when added to the above equilibrium, would result in a decrease in $[H_{2(g)}]$?

A. H_2
B. CO
C. CH_4
D. H_2O

24. Consider the following reaction:

$$2H_{2(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)}$$

A container at 0°C is filled with a mixture of oxygen and hydrogen. The fastest way to establish an equilibrium is to

A. add more H_2.
B. increase the temperature.
C. increase the surface area.
D. do nothing, equilibrium will occur.

25. Consider the following equilibrium:

$$NH_2COONH_{4(s)} \rightleftarrows 2NH_{3(g)} + CO_{2(g)}$$

The K_{eq} expression for this reaction is:

A. $[NH_3]^2[CO_2]$

B. $[2NH_3][CO_2]$

C. $\dfrac{[NH_3]^2[CO_2]}{[NH_2COONH_4]}$

D. $\dfrac{[2NH_3][CO_2]}{[NH_2COONH_4]}$

26. In which of the following equilibrium reactions will the products be favoured the most?

A. $N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$ $K_{eq} = 0.20$

B. $PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$ $K_{eq} = 1.8$

C. $S_{2(g)} + C_{(s)} \rightleftarrows CS_{2(g)}$ $K_{eq} = 9.4$

D. $H_{2(g)} + Cl_{2(g)} \rightleftarrows 2HCl_{(g)}$ $K_{eq} = 2.5 \times 10^4$

27. Consider the following equilibrium:

$$CH_{4(g)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + 3H_{2(g)} \qquad K_{eq} = 26$$

The value of K_{eq} can be changed by

A. adding a catalyst.
B. increasing the temperature.
C. increasing the concentration of CH_4.
D. increasing the pressure in the system.

28. Consider the following equilibrium system:

$$CO_{2(g)} + H_{2(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)}$$

At equilibrium, $[CO_2] = 0.648$ mol/L, $[H_2] = 0.148$ mol/L, $[CO] = 0.352$ mol/L and $[H_2O] = 0.352$ mol/L. From these data, the K_{eq} value for the above system is

A. 0.774
B. 1.29
C. 3.07
D. 3.67

29. Given the following equilibrium system:

$$C_{(s)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + H_{2(g)}$$

The equilibrium constant expression for the above system is

A. $K_{eq} = [CO][H_2]$

B. $K_{eq} = \dfrac{[CO][H_2]}{[H_2O]}$

C. $K_{eq} = \dfrac{[CO][H_2]}{[H_2O][C]}$

D. $K_{eq} = \dfrac{[H_2O]}{[CO][H_2]}$

30. Given the following system:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)}$$

Which of the following would alter the numerical value of K_{eq} for the above system?

A. Change in pressure.
B. Addition of a catalyst.
C. Change in temperature.
D. Change in concentration of N_2.

31. Consider the following equilibrium system:

$$2HI_{(g)} \rightleftarrows H_{2(g)} + I_{2(g)}$$

An analysis of the above equilibrium system shows that the [reactants] are much larger than the [products]. Which of the following equilibrium constant values would be consistent with these data?

A. −0.040
B. 0.0030
C. 1.0
D. 25

32. Consider the following equilibrium:

$$N_{2(g)} + 2O_{2(g)} \rightleftarrows N_2O_{4(g)}$$

The K_{eq} expression for this reaction is:

A. $\dfrac{[N_2O_4]}{[N_2][O_2]}$

B. $\dfrac{[N_2O_4]}{[N_2][O_2]^2}$

C. $\dfrac{[N_2O_4]}{[N_2][2O_2]}$

D. $\dfrac{[N_2O_4]}{[N_2][2O_2]^2}$

33. Which of the following reactions will come closest to completion?

A. $2HCl_{(g)} \rightleftarrows H_{2(g)} + Cl_{2(g)}$ $\quad K_{eq} = 5.5 \times 10^{-34}$

B. $2NO_{2(g)} \rightleftarrows N_2O_{4(g)}$ $\quad K_{eq} = 1.2$

C. $CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)}$ $\quad K_{eq} = 10$

D. $C_{(s)} + 2H_{2(g)} \rightleftarrows CH_{4(g)}$ $\quad K_{eq} = 8.1 \times 10^{8}$

34. Consider the following equilibrium:

$$PCl_{5(s)} + H_2O_{(l)} \rightleftarrows 2HCl_{(g)} + POCl_{3(g)} \qquad \Delta H = -120 \text{ kJ}$$

As the temperature is increased, the equilibrium

A. shifts to the left and the value of K_{eq} increases.

B. shifts to the left and the value of K_{eq} decreases.

C. shifts to the right and the value of K_{eq} increases.

D. shifts to the right and the value of K_{eq} decreases.

35. Equilibrium is considered to be a "dynamic" process because

A. it occurs in a closed system.
B. equilibrium can be achieved from either direction.
C. the forward and reverse reactions continue to occur.
D. the concentrations of reactants and products are constant.

36. An equal number of moles of $I_{2(g)}$ and $Br_{2(g)}$ are placed into a closed container and allowed to establish the following equilibrium:

$$I_{2(g)} + Br_{2(g)} \rightleftarrows 2IBr_{(g)} \qquad K_{eq} = 280$$

Which one of the following relates [IBr] to $[I_2]$ at equilibrium?

A. $[I_2] = [IBr]$
B. $[I_2] < [IBr]$
C. $[I_2] = 2[IBr]$
D. $[I_2] = 280[IBr]$

37. Consider the following equilibrium system:

$$2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 65$$

At equilibrium, the [NO] = 0.600 M and the $[O_2]$ = 0.300 M. Using this data, the equilibrium $[NO_2]$ is

A. 7.0 M
B. 3.4 M
C. 2.6 M
D. 0.60 M

38. Consider the following equilibrium system:

$$CO_{2(g)} + H_{2(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)}$$

1.00 mole of CO_2 and 2.00 moles of $H_{2(g)}$ are placed into a 2.00 litre container. At equilibrium, the [CO] = 0.31 mol/L. Based on this data, the equilibrium $[CO_2]$ is

A. 0.19 M
B. 0.31 M
C. 0.38 M
D. 0.69 M

39. In which of the following reactions will entropy favour the reactants while enthalpy favours the products?

A. $Cl_{2(g)} \rightleftarrows Cl_{2(aq)} + 25\ kJ$

B. $P_{4(s)} + 6H_{2(g)} + 37\ kJ \rightleftarrows 4PH_{3(g)}$

C. $PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$; $\Delta H = +92.5\ kJ$

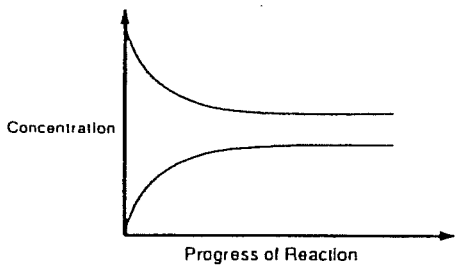
D. $NO_{2(g)} \rightleftarrows \frac{1}{2}N_{2(g)} + O_{2(g)}$; $\Delta H = -33.8\ kJ$

40. Reactants are mixed and allowed to react according to this reaction:

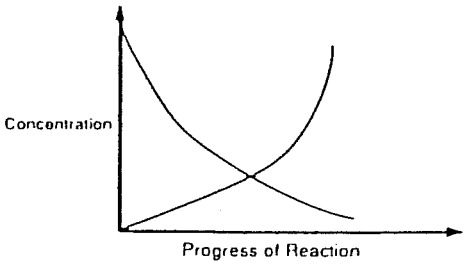
$$CO_{2(g)} + H_{2(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)}$$

Which diagram below represents the changing concentrations of CO_2 and H_2O as equilibrium is established?

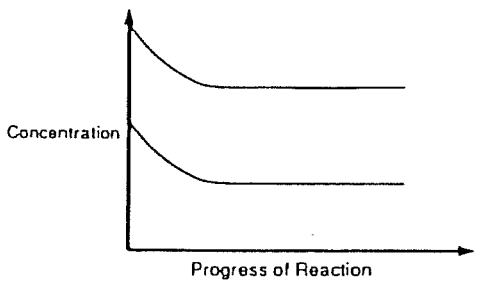
A.



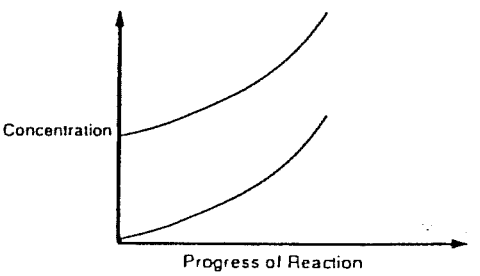
B.



C.



D.



41. Consider the following equilibrium:

$$H_{2(g)} + Br_{2(g)} \rightleftarrows 2HBr_{(g)} \qquad K_{eq} = 1.02$$

Equal moles of H_2 and Br_2 were placed in a flask and at equilibrium the [HBr] was 0.500 mol/L. The equilibrium concentration of $H_{2(g)}$ was

A. 0.123 mol/L
B. 0.245 mol/L
C. 0.495 mol/L
D. 0.700 mol/L

42. Consider the following equilibrium:

$$2O_{3(g)} \rightleftarrows 3O_{2(g)} \qquad K_{eq} = 55$$

If 0.060 mol of O_3 and 0.70 mol of O_2 are introduced into a 1.0 L vessel, the

A. $K_{trial} > K_{eq}$ and the $[O_2]$ increases.
B. $K_{trial} < K_{eq}$ and the $[O_2]$ increases.
C. $K_{trial} > K_{eq}$ and the $[O_2]$ decreases.
D. $K_{trial} < K_{eq}$ and the $[O_2]$ decreases.

43. Consider the following equilibrium system:

$$N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)} \qquad \Delta H = +182 \text{ kJ}$$

Which one of the following changes would cause the K_{eq} value to increase?

A. Remove $O_{2(g)}$.
B. Add more $NO_{(g)}$.
C. Decrease volume.
D. Increase temperature.

44. Consider the following equilibrium system:

$$2\ ICl_{(g)} \rightleftarrows I_{2(g)} + Cl_{2(g)} \qquad K_{eq} = 0.11$$

At equilibrium, the $[ICl] = 0.40$ mol/L and the $[I_2] = 0.10$ mol/L. The equilibrium $[Cl_2]$ is

A. 0.44 mol/L
B. 0.20 mol/L
C. 0.10 mol/L
D. 0.18 mol/L

45. Consider the following equilibrium system:

$$S_{2(g)} + C_{(s)} \rightleftarrows CS_{2(g)} \qquad K_{eq} = 9.0 \text{ at } 627°C$$

In trial one of an experiment, S_2 and C were placed into a 1.0 L container. In trial two, CS_2 was placed into a different 1.0 L container. Both containers were then heated to 627°C. After 5 minutes at this temperature, the following data was recorded for each trial:

Trial	mol S_2	mol C	mol CS_2
one	0.020	0.300	0.180
two	0.050	0.050	0.270

Based on the above data, equilibrium was established in

A. both trial one and trial two.
B. trial one but not in trial two.
C. trial two but not in trial one.
D. neither trial one nor trial two.

46. Identify the equilibrium system that **least** favours the formation of products.

A. $2HgO_{(s)} \rightleftarrows 2Hg_{(l)} + O_{2(g)}$ $K_{eq} = 1.2 \times 10^{-22}$

B. $CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + CH_3COO^-_{(aq)}$ $K_{eq} = 1.8 \times 10^{-5}$

C. $2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)}$ $K_{eq} = 6.5 \times 10^{5}$

D. $H_{2(g)} + Cl_{2(g)} \rightleftarrows 2HCl_{(g)}$ $K_{eq} = 1.8 \times 10^{33}$

47. Consider the following equilibrium:

$$2H_2S_{(g)} + 20kJ \rightleftarrows 2H_{2(g)} + 2S_{(s)}$$

Which of the following would cause the concentration of the H_2 to increase?

A. Removal of some S.
B. Decrease in pressure.
C. Addition of a catalyst.
D. Increase in temperature.

48. Given this reaction at equilibrium:

$$2CrO^{2-}_{4(aq)} + 2H^+_{(aq)} \rightleftarrows Cr_2O^{2-}_{7(aq)} + H_2O_{(l)}$$

An increase in the concentration of CrO_4^{2-} will

A. shift the equilibrium to the left.

B. increase the concentration of H^+.

C. increase the concentration of $Cr_2O_7^{2-}$.

D. cause no change in the position of equilibrium.

49. In which of the following systems would the tendencies toward minimum enthalpy and maximum entropy be in opposition to each other?

A. $Br_{2(l)} + \text{heat} \rightarrow Br_{2(g)}$

B. $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)} + \text{heat}$

C. $2C_{(g)} + 2H_{2(g)} \rightarrow C_2H_{4(g)}$ ΔH is positive

D. $K_{(s)} + H_2O_{(l)} \rightarrow K^+_{(aq)} + OH^-_{(aq)} + \frac{1}{2}H_{2(g)}$ ΔH is negative

30. Consider the following equilibrium:

$$2H_2S_{(g)} \rightleftarrows 2H_{2(g)} + S_{2(g)} \qquad K_{eq} = 4.2 \times 10^{-4}$$

If 0.050 mol of H_2S, 0.020 mol of H_2 and 0.015 mol of S_2 are placed in a 1.00 L flask, then the trial K_{eq} is

A. less than K_{eq} and the reaction proceeds to the left.

B. less than K_{eq} and the reaction proceeds to the right.

C. greater than K_{eq} and the reaction proceeds to the left.

D. greater than K_{eq} and the reaction proceeds to the right.

CHEMICAL EQUILIBRIUM REVIEW

1. State Le Chatelier's Principle. **(2 marks)**

2. 0.400 mol of H_2 and 0.200 mol of I_2 were placed in a 2.00 L flask and allowed to reach equilibrium according to the reaction:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

At equilibrium the concentration of HI was 0.160 mol/L. Calculate the equilibrium constant value. **(4 marks)**

3. Define the term 'closed system'. **(1 mark)**

4. At equilibrium, the macroscopic properties of a system are constant. Give an example of a macroscopic property and explain why it is constant at equilibrium. **(2 marks)**

5. Consider the following equilibrium:

$$SO_{3(g)} + NO_{(g)} \rightleftarrows NO_{2(g)} + SO_{2(g)} \qquad K_{eq} = 0.500$$

Exactly 0.100 mol SO_3 and 0.100 mol NO were placed in a 1.00 L flask and allowed to react. Calculate the concentration of SO_2 at equilibrium. **(4 marks)**

6. Consider the following equilibrium system:

$$C_{(s)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + H_{2(g)} \qquad K_{eq} = 0.80$$

In an experiment, a student places 0.10 mol of C, 0.15 mol of H_2O, 0.25 mol of CO, and 0.20 mol of H_2 into a 1.0 L flask. The student predicts that the [CO] will decrease as equilibrium becomes established. (3 marks)

a) Would you agree or disagree with the student? _____

b) Justify your answer, including appropriate calculations.

7. The production of ammonia by the Haber process involves the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + \text{heat}$$

The table below indicates the percentage of ammonia in equilibrium mixtures at various temperatures.

Temperature °C	Percentage of Ammonia in Equilibrium
200	98
350	80
500	51

a) Explain why the lower temperature results in a higher percentage of ammonia in the equilibrium mixture. (1 mark)

_____

_____

b) Explain why a temperature of 500°C is used in the Haber process rather than a lower temperature. (1 mark)

_____

_____

8. Consider the equilibrium below:

$$\underset{\text{pink}}{Co(H_2O)_{6(aq)}^{2+}} + 2Cl_{(aq)}^{-} \rightleftarrows \underset{\text{blue}}{Co(H_2O)_4Cl_{2(aq)}} + 2H_2O_{(l)}$$

The colour of this equilibrium mixture is pink at 5°C, and blue at 60°C. Is the forward reaction endothermic or exothermic? Explain. **(2 marks)**

9. Consider the following equilibrium:

$$2POCl_{3(g)} \rightleftarrows 2PCl_{3(g)} + O_{2(g)}$$

2.0 mol $POCl_3$ are placed in a 2.00 L container and allowed to establish equilibrium. At equilibrium, $[O_2] = 0.16$ M. Calculate the value of K_{eq}. **(3 marks)**