Year 11 Pre12 Homework 7
Equilibrium Part I

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Homework Lecture 7

Equilibrium Part I

Textbook Questions

Heinemann Chemistry 2 - 5th Edition

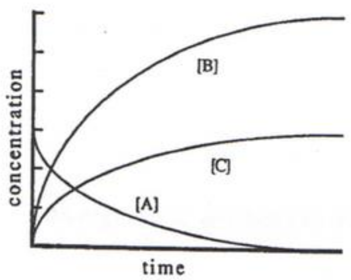
Chapter 8 – Equilibrium

Content

- The distinction between reversible and irreversible reactions, and between rate and extent of a reaction
- Homogenous equilibria involving aqueous solutions or gases with reference to collision theory and representation by balanced chemical or thermochemical equations (including states) and by concentration–time graphs
- Calculations involving equilibrium expressions and equilibrium constants (K_C only) for a closed homogeneous equilibrium system including dependence of value of equilibrium constant, and its units, on the equation used to represent the reaction and on the temperature

Question 1

The following diagram shows the changes in concentration for a reaction that goes to completion:



The equation for this reaction is:

A. $A + B \longrightarrow C$

B. $A + C \longrightarrow 2B$

C. $A \longrightarrow B + 2C$

D. $A \longrightarrow 2B + C$

Question 2

A system is in a state of equilibrium when:

A. all reaction stops

B. the rate of reaction is negligible

C. the rate of the reverse reaction is insignificant compared to that of the forward reaction

D. the rate of the forward and reverse reactions are equal

Question 3

The equilibrium expression for the formation of iron (III) thiocyanate is

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

Iron (III) thiocyanate has a reddish-brown colour while Fe^{3+} and SCN^{-} are colourless in solution.

If the equilibrium constant of the reverse reaction; $K_{reverse} = 2.03 \times 10^{-8}$ at room temperature, how would the solution appear at equilibrium?

A. Reddish-brown

B. Colourless

C. Slightly reddish brown

D. It is impossible to tell

Question 4

The correct expression for the equilibrium constant *K* for the equation below is:

$$2CI_2(g) + 2H_2O(g) \rightleftarrows 4HCI(g) + O_2(g)$$

A. $\dfrac{[H_2O]\,[CI_2]}{[HCI]\,[O_2]}$

B. $\dfrac{[HCI]^4[O_2]}{[CI_2]^2}$

C. $\dfrac{2[H_2O]\,2[CI_2]}{4[HCI]\,[O_2]}$

D. $\dfrac{[HCI]^4[O_2]}{[CI_2]^2[H_2O]^2}$

Question 5

Dinitrogen tetroxide, N_2O_4, forms an equilibrium with nitrogen dioxide, NO_2.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

The value of *K* at 25°C for this reaction is 0.0055 M. Which of the following reactions will have a numerical value for *K* of 0.074?

A. $2N_2O_4(g) \rightleftharpoons 4NO_2(g)$

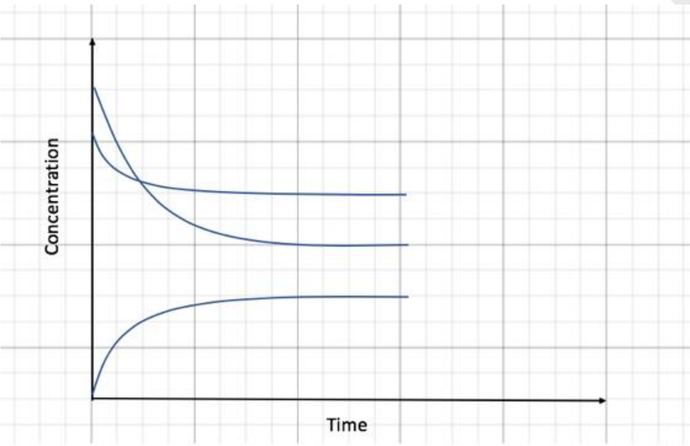
B. $\frac{1}{2}N_2O_4(g) \rightleftharpoons NO_2(g)$

C. $2NO_2(g) \rightleftharpoons N_2O_4(g)$

D. $NO_2(g) \rightleftharpoons \frac{1}{2}N_2O_4(g)$

Question 6

Gaseous reactants are added to an empty reactor and allowed to come to equilibrium. The concentrations of each species present are shown on the graph below.



The reaction taking place could be

A. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

B. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

C. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

D. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

Question 7

Consider the following equilibrium expression

$$K_c = \frac{[L][M]^4}{[J]^6[K]}$$

The equation for the backward reaction for this equilibrium is

A. $6J + K \rightleftarrows L + 4M$

B. $L + M_4 \rightleftarrows J_6 + K$

C. $J_6 + K \rightleftarrows L + M_4$

D. $L + 4M \rightleftarrows 6J + K$

Question 8

Determine the units for the equilibrium constant of the following reaction equation:

$$N_2O_4(g) \rightleftarrows 2NO_2(g)$$

A. M

B. M^{-2}

C. M^2

D. No unit

Question 9

The reaction $X(g) + Y(g) \rightleftarrows XY(g)$ has an equilibrium constant of $2.1 ´\ 10^8\ M^{-1}$. This reaction is favoured

A. very strongly in the forward reaction.

B. very strongly in the reverse reaction.

C. slightly in the forward reaction.

D. slightly in the reverse reaction.

Question 10

Which of the following affects equilibrium constant?

A. Adding catalysts

B. Increase in pressure

C. Decrease in volume

D. Change in temperature

Question 11

What does ‘extent of reaction’ and ‘rate of reaction’ measure respectively when a system reaches equilibrium?

Question 12

Find the value of the equilibrium constant for $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ given equilibrium concentrations:

$$[H_2] = 1.2 \times 10^{-3} M \quad [I_2] = 3.4 \times 10^{-3} M \quad [HI] = 4.0 \times 10^{-8} M$$

Question 13

Find the value of the equilibrium constant for $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ given equilibrium concentrations:

$$[H_2] = 0.1 \text{ M} \quad [N_2] = 0.06 \text{ M} \quad [NH_3] = 6.0 \text{ M}$$

Question 14

Find the equilibrium value of $[CO]$ if $Kc = 14.5$ given the equation $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ and equilibrium concentrations of:

$$[H_2] = 0.322\ M \quad [CH_3OH] = 1.56\ M$$

Question 15

Consider this reaction:

$$2A(g) + B(g) \rightleftharpoons 2C(g)$$

The equilibrium constant of this reaction is equal to $4.0\ M^{-1}$ at a particular temperature. 2.0 mol of A, B and C are introduced into a 1.0 L flask.

(a) Write an expression for the equilibrium constant

(b) Give the unit in which the equilibrium constant is expressed

(c) Determine whether the mixture is at equilibrium

(d) Determine the volume of the container for this particular mixture to be at equilibrium

Question 16

Gaseous $X_2(g)$ and $Y_2(g)$ react reversibly giving $XY(g)$. In a particular experiment, 1.0 mol of $X_2(g)$ and 1.0 mol of $Y_2(g)$ are mixed in a 1.0 L closed vessel of and a state of equilibrium is reached. Analysis indicates the presence of 1.0 mol of $XY(g)$. Calculate the value of the equilibrium constant for the reactions:

(a) $X_2(g) + Y_2(g) \rightleftarrows 2XY(g)$

(b) $\frac{1}{2}X_2(g) + \frac{1}{2}Y_2(g) \rightleftarrows XY(g)$

Question 17

Consider the following reaction

$$CH_4\,(g) + H_2O\,(g) \rightleftharpoons CO\,(g) + 3H_2\,(g)$$

(a) Write an equilibrium expression for the steam reforming reaction, including units.

(b) At 1500°C the concentrations of the gases in a particular equilibrium mixture were found to be: $[CH_4]$ = 0.350 M, [CO] = 0.250 M, $[H_2O]$ = 0.058 M, $[H_2]$ = 0.609 M. K_c = 5.67 M^2 at 1500°C for the reaction. Is the system in equilibrium? If not, which way would the equilibrium shift?

Question 18

Consider the following reversible reaction

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$$

0.300 mole of ammonia gas was mixed with 0.400 mol of oxygen gas in a sealed 2.00 L container at a particular temperature. 0.200 mol of nitrogen oxide gas was present in the equilibrium mixture. Calculate the value of the equilibrium constant.

Question 19

Consider the following equilibrium reaction:

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

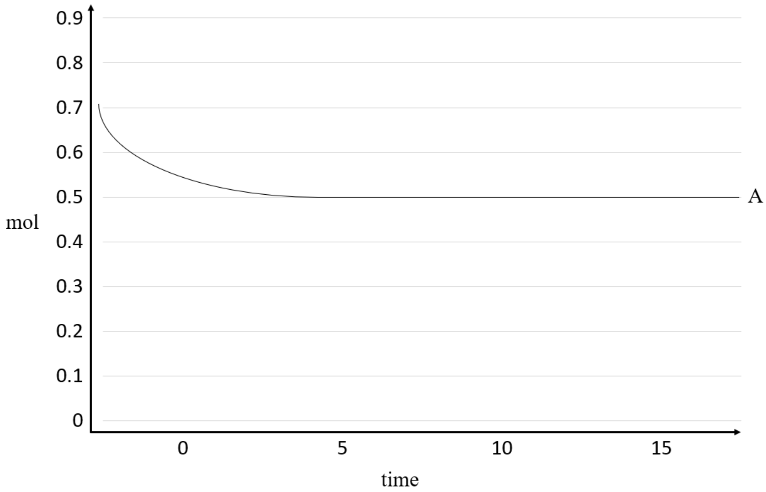
0.736 mol of ethene and 0.985 mol of steam were introduced into a sealed 5.00 L container at a set temperature. When equilibrium was established at the set temperature, the concentration of ethanol was found to be 0.130 M. Calculate the concentration of ethene in the equilibrium mixture.

Question 20

An equilibrium reaction involving A, B and AB_3 can be represented by the following reaction:

$$A(g) + 3B(g) \rightleftharpoons AB_3(g)$$

A student used the equation above in one of their experiments. The experiment involved a 6.0 L and was conducted at $200.0°C$. The graph below shows the number of mol of A during the experiment.



(a) If 0.90 mol of B and 0.20 mol of AB_3 were initially added into the vessel, draw the expected curve for both of them on the graph above.

(b) Write an expression for the equilibrium constant of this reaction, assuming that A is a reactant. Include the units with your expression.

(c) Calculate the value of the equilibrium constant at $200.0°C$.

Question 21

A sample containing only 4.00 mol of NOBr (nitrosyl bromide) was injected into an evacuated 4.00 L vessel. At equilibrium the concentration of NOBr was found to be 0.150 M. The reaction can be expressed with the following equation:

$$2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g)$$

Calculate the equilibrium constant for the reverse reaction shown in the equation above.

Answer

Question 1

D

Question 2

D

Question 3

A

Question 4

D

Question 5

B

Question 6

C

Question 7

D

Question 8

A

Question 9

A

Question 10

D

Question 11

The extent of reaction indicates how much product is formed at equilibrium whereas the rate of reaction is a measure of the change in concentration of the reactants and products with time.

Question 12

3.9×10^{-10}

(<u>NOTE</u>: no unit)

Question 13

$6.0 \times 10^{5}\ \mathrm{M}^{-2}$

Question 14

1.04 M

Question 15

(a) $K_c = \dfrac{[\mathrm{C}]^2}{[\mathrm{B}][\mathrm{A}]^2}$

(b) M^{-1}

(c) Not at equilibrium as $\dfrac{1}{2}\mathrm{M}^{-1} \neq 4.0\ \mathrm{M}^{-1}$

(d) 8 L

Question 16

(a) 4

(b) 2

Question 17

(a) $K_c = \dfrac{[CO][H_2]^3}{[CH_4][H_2O]}$ M^2

(b) Not at equilibrium as $K_c > Q_c$ so the system would shift to favour the right side.

Question 18

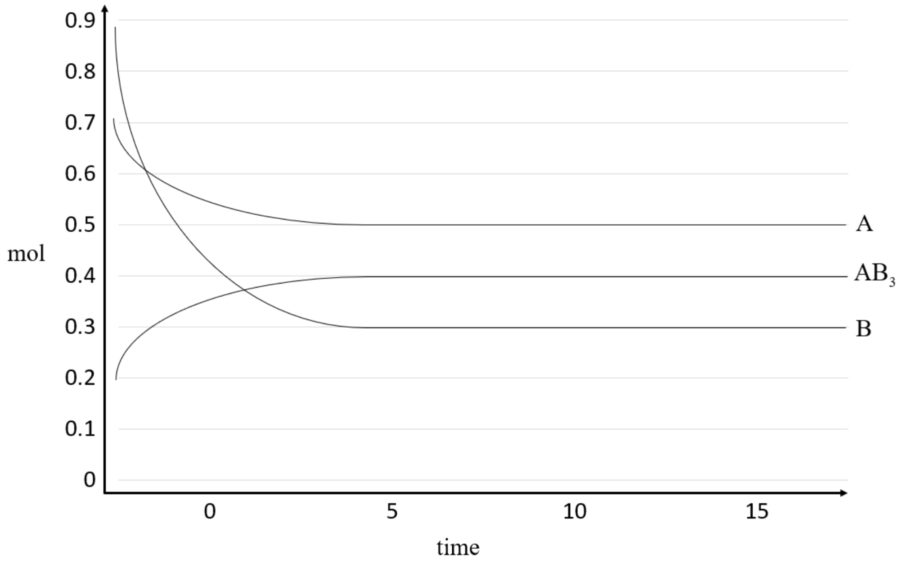
$K_c = \dfrac{0.100^4 \times 0.150^6}{0.050^4 \times 0.0750^5}$ =76.8 M

Question 19

0.0172 M

Question 20

(a)



(b) $K_c = \dfrac{[AB_3]}{[A][B]^3}$ M^{-3}

(c) 6.4×10^3 M^{-3}

Question 21

13.6 M

Worked Solutions

Question 1

D

The concentration of B moves twice as much as C and A, while C and A move equally as much. That means the coefficient of A and C are the same, while the coefficient of B must be twice as much.

Question 2

D

Equilibrium occurs when the concentrations of the reactants and constants don't change. This is when the rate of the forward reaction is the same as the rate of the reverse reaction.

Question 3

A

As the equilibrium constant is less than 10^{-4}, it favours the reverse reaction over the forward reaction. However, remember that this equilibrium constant is for the reaction, meaning the solution will mainly have iron (III) thiocyanate. This will make it appear reddish-brown.

Question 4

D

Recall that for the reaction:

$$aA + bB + cC \rightleftharpoons zZ + yY + xX$$

The equilibrium constant is equal to:

$$K_c \frac{[\mathrm{Z}]^z[\mathrm{Y}]^y[\mathrm{X}]^x}{[\mathrm{A}]^a[\mathrm{B}]^b[\mathrm{C}]^c}$$

Question 5

B

$$0.0055\text{ M} = \frac{[NO_2]^2}{[N_2O_4]}$$

Through trial and error:

$$\left(\frac{[NO_2]^2}{[N_2O_4]}\right)^{\frac{1}{2}} = \frac{[NO_2]}{[N_2O_4]^{\frac{1}{2}}} = 0.0055^{\frac{1}{2}} = 0.074$$

Question 6

C

Looking at how much the concentration moves, we can conclude that one of the reactants has a coefficient that is 3 times as much as the other. Th only answer that can fit in this category is C.

Question 7

D

Recall that the concentration of the products are at the top, while the concentration of the reactants are at the bottom.

Forward reaction: $6J + K \rightleftarrows L + 4M$

Reverse reaction: $L + 4M \rightleftarrows 6J + K$

Question 8

A

The power of the unit is the same as the sum of the coefficients of the products minus the sum of the coefficients of the reactants.

$$M^{2-1} = M$$

Question 9

A

As the equilibrium constant is greater than 10^4, the forward reaction is favoured.

Question 10

D

Only temperature affects the equilibrium constant.

Question 11

The extent of reaction indicates how much product is formed at equilibrium whereas the rate of reaction is a measure of the change in concentration of the reactants and products with time.

Question 12

3.9×10^{-10}

$$\begin{aligned} K_c &= \frac{[\mathrm{HI}]^2}{[\mathrm{H_2}][\mathrm{I_2}]} \\ &= \frac{(4.0\times10^{-8})^2}{1.2\times10^{-3}\times3.4\times10^{-3}} \\ &= 3.9\times10^{-10} \end{aligned}$$

(<u>NOTE</u>: no unit)

Question 13

$6.0\times 10^{5}\ \mathrm{M}^{-2}$

$$\begin{aligned} K_c &= \frac{[\mathrm{NH_3}]^2}{[\mathrm{N_2}][\mathrm{H_2}]^3} \\ &= \frac{6^2}{0.06\times0.1^3} \\ &= 6.0\times10^{5}\ \mathrm{M}^{-2} \end{aligned}$$

Question 14

1.04 M

$$K_c = \frac{[CH_3OH]}{[CO][H_2]^2}$$
$$14.5 = \frac{1.56}{x \times 0.322^2}$$
$$x = \frac{1.56}{14.5 \times 0.322^2}$$
$$= 1.04 \text{ M}$$

Question 15

(a) $K_c = \frac{[\text{C}]^2}{[\text{B}][\text{A}]^2}$

(b) M^{-1}

The power of the unit is the same as the sum of the coefficients of the products minus the sum of the coefficients of the reactants.

$$\text{M}^{2-3} = \text{M}^{-1}$$

(c) Not at equilibrium as $\frac{1}{2}\text{M}^{-1} \neq 4.0 \text{ M}^{-1}$

$$Q_c = \frac{2^2}{2 \times 2^2} = \frac{1}{2} \text{ M}^{-1}$$

As $Q_c \neq K_c$, the mixture is not at equilibrium.

(d) Let volume be x:

$$K_c = \frac{\left[\frac{2}{x}\right]^2}{\left[\frac{2}{x}\right] \times \left[\frac{2}{x}\right]^2}$$
$$4 = \frac{1}{\left[\frac{2}{x}\right]}$$
$$= \frac{x}{2}$$
$$x = 8 \text{ L}$$

Question 16

(a) 4

	$X_2(g)$	$Y_2(g)$	$2XY(g)$
I	1.0	1.0	0
C	-0.5	-0.5	+1.0
E	0.5	0.5	1.0

$$K_c = \frac{1^2}{0.5 \times 0.5} = 4$$

(b) 2

$$K_c = \frac{1}{0.5^{\frac{1}{2}} \times 0.5^{\frac{1}{2}}} = 2$$

Question 17

(a) $K_c = \dfrac{[CO][H_2]^3}{[CH_4][H_2O]}\ M^2$

(b) Not at equilibrium as $K_c > Q_c$ so the system would shift to favour the right side.

$$K_c = \frac{[CO][H_2]^3}{[CH_4][H_2O]}$$
$$= \frac{0.250 \times 0.609^3}{0.350 \times 0.058}$$
$$= 2.78\ M^2$$

Question 18

	$4NH_3(g)$	$5O_2(g)$	$4NO(g)$	$6H_2O(g)$
I	0.300	0.400	0	0
C	-0.200	$-\frac{5}{4} \times 0.200$	+0.200	+0.300
E	0.100	0.150	0.200	0.300

$$K_c = \frac{0.100^4 \times 0.150^6}{0.050^4 \times 0.0750^5} = 76.8\ M$$

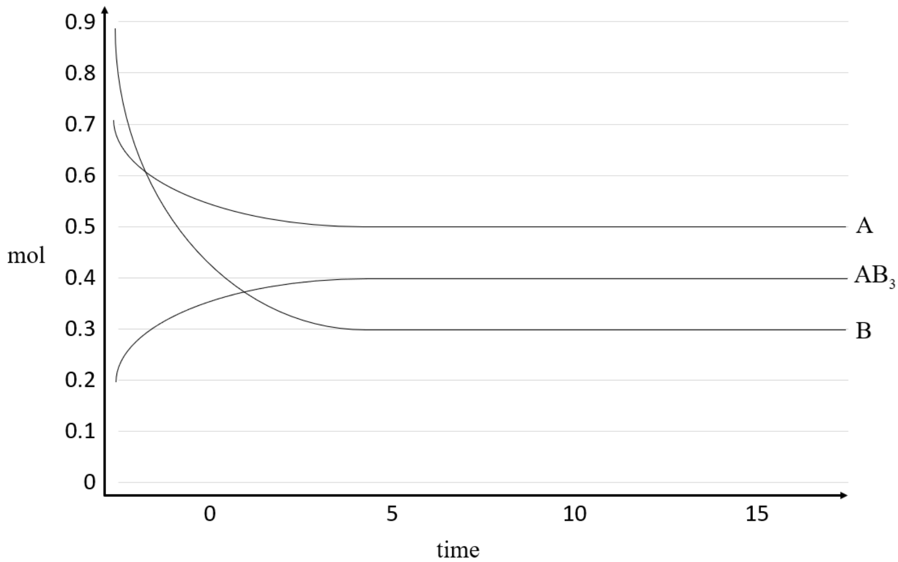
Question 19

	$C_2H_4(g)$	$H_2O(g)$	$C_2H_5OH(g)$
I	0.736	0.985	0
C	-0.650	-0.650	+0.650
E	0.086	0.335	0.650 (0.130 x 5.00)

$$c = \frac{0.086}{5.00} = 0.0172 \text{ M}$$

Question 20

(a)



(b) $K_c = \dfrac{[AB_3]}{[A][B]^3} \text{ M}^{-3}$

(c)

$$[AB_3] = \frac{n}{v} = \frac{0.4}{6} = 0.0667 \text{ M}$$

$$[A] = \frac{n}{v} = \frac{0.5}{6} = 0.0833 \text{ M}$$

$$[B] = \frac{n}{v} = \frac{0.3}{6} = 0.05 \text{ M}$$

$$K_c = \frac{0.0667}{0.0833 \times 0.05^3} = 6.4 \times 10^3 \text{ M}^{-3}$$

Question 21

	$2NOBr(g)$	$2NO(g)$	$Br_2(g)$
I	4	0	0
C	-3.4	+3.4	+1.7
E	$0.15 \times 4 = 0.6$	3.4	1.7
Concentration	0.15 M	$\frac{3.4}{4} = 0.85$ M	$\frac{1.7}{4} = 0.425$ M

$$K_c = \frac{[NO]^2[Br_2]}{[NOBr]^2}$$
$$= \frac{0.85^2 \times 0.425}{0.15^2}$$
$$= 13.6 \text{ M}$$