

23 April 2018

H.W

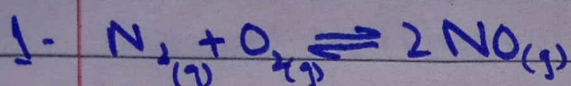
Tuesday

Chapter: 9

"Chemical Equilibrium"

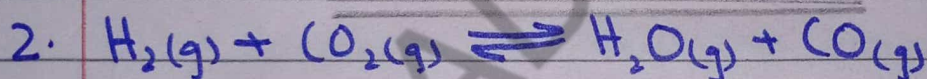
Self-Assessment Exercise: 9.3

Q. Determine the units of equilibrium constants for the following reactions.



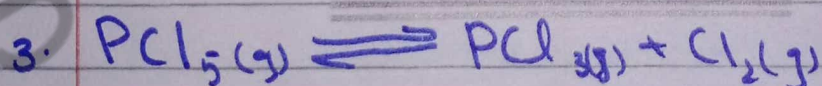
$$K_c = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]}$$
$$= \frac{[\text{mol} \cdot \text{dm}^{-3}]^2}{[\text{mol} \cdot \text{dm}^{-3}][\text{mol} \cdot \text{dm}^{-3}]}$$

$$K_c = \text{no units}$$



$$K_c = \frac{[\text{H}_2\text{O}][\text{CO}]}{[\text{H}_2][\text{CO}_2]}$$
$$= \frac{[\text{mol} \cdot \text{dm}^{-3}][\text{mol} \cdot \text{dm}^{-3}]}{[\text{mol} \cdot \text{dm}^{-3}][\text{mol} \cdot \text{dm}^{-3}]}$$

$$K_c = \text{no units.}$$

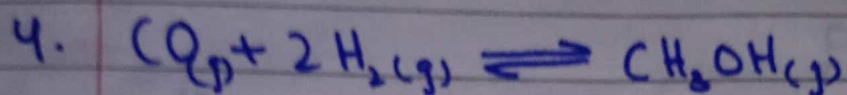


$$K_c = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]}$$
$$= \frac{[\text{mol} \cdot \text{dm}^{-3}][\text{mol} \cdot \text{dm}^{-3}]}{[\text{mol} \cdot \text{dm}^{-3}]}$$

$$K_c = [\text{mol} \cdot \text{dm}^{-3}].$$

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$$K_c = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}] \cdot [\text{H}_2]^2}$$

$$K_c = \frac{[\text{mol} \cdot \text{dm}^{-3}]}{[\text{mol} \cdot \text{dm}^{-3}] [\text{mol} \cdot \text{dm}^{-3}]^2}$$

$$K_c = \frac{1}{(\text{mol} \cdot \text{dm}^{-3})^2}$$

$$= \text{mol}^{-2} \cdot \text{dm}^6$$

$$= \text{dm}^6 \cdot \text{mol}^{-2}$$

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Chapter: 9

"Chemical Equilibrium"

Review Exercise:

Q2: Give short answers:

- (i) Differentiate between forward and reverse reactions.

Forward Reaction

Reverse Reaction

Direction of Reaction

Forward reaction

Reverse reaction always

always proceeds from left to right.

proceeds from right to left.

Resultant Species

In forward reaction reactants react to produce products.

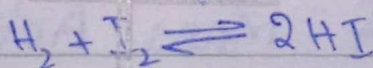
In reverse reaction reaction products react to produce reactants.

Rate of Reaction

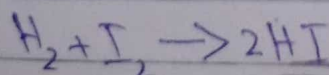
Rate is fastest in the beginning and gradually slows down.

Its rate is zero in the beginning and gradually speeds up.

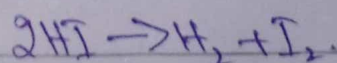
Example



In this reaction Hydrogen (H_2) and Iodine (I_2) react to produce hydrogen iodide and produces product, it is forward reaction i.e.



In this reaction hydrogen iodide decompose to produce hydrogen and iodine and it moves from right to left. i.e.



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(ii) What is chemical equilibrium?

Chemical Equilibrium:

Definition:

"A state of a chemical reaction in which forward and reverse reactions take place at the same rate is called chemical equilibrium."

Explanation:

Chemical equilibrium is a dynamic equilibrium. This is because reactions do not stop when they come to equilibrium state. The individual molecules keep on reacting continuously. But there is no change in the actual amounts of reactants and products. This means concentration of reactants and products become constant at equilibrium stage.

(iii) State the law of Mass Action.

Law of Mass Action:

Statement:

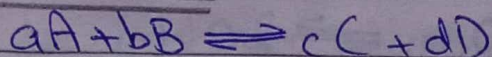
"It states that the rate at which a substance reacts is directly proportional to its active mass and the rate at which the reaction proceeds

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is directly proportional to the product of the active masses of the reactants."

Explanation:



According to law of mass action:

Rate of forward reaction $\propto [A]^a [B]^b$

$$R_f = k_f [A]^a [B]^b$$

Rate of reverse reaction $\propto [C]^c [D]^d$

$$R_r = k_r [C]^c [D]^d$$

(iv) State conditions for equilibrium.

Conditions for Equilibrium:

Equilibrium is reached whether pure reactants, pure products or a mixture of reactants and products is initially placed in a closed container. In any of these cases, a condition will eventually be reached in the container such that the forward and reverse reaction occur at exactly the same rate. This leads to situation where the concentration of reactants and products remain the same indefinitely, as long as the following conditions are observed:

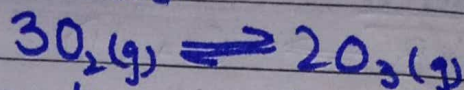
Concentration of none of the reactant or product is changed.

Temperature of the system is kept constant.

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Pressure or Volume of the system is kept constant.

Q3: Following reaction can occur during lightning storms.



For this reaction write:

(i) Equilibrium Constant Expression.

According to the law of mass actions:

Forward Reaction:

Rate of Forward reaction $\propto [\text{O}_2]^3$

$$R_f = k_f [\text{O}_2]^3$$

Reverse Reaction:

Rate of reverse reaction $\propto [\text{O}_3]^2$

$$R_r = k_r [\text{O}_3]^2$$

At Equilibrium state:

Rate of forward reaction = Rate of reverse reaction

$$R_f = R_r$$

$$k_f [\text{O}_2]^3 = k_r [\text{O}_3]^2$$

$$k_f = \frac{[\text{O}_3]^2}{[\text{O}_2]^3}$$

$$k_r$$

This is the equilibrium expression.

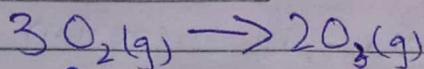
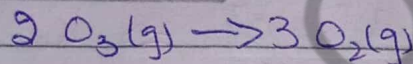
(ii) Determine the units of equilibrium constant:

$$K_c = \frac{[\text{O}_3]^2}{[\text{O}_2]^3}$$

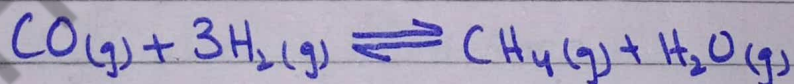
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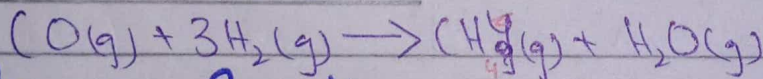
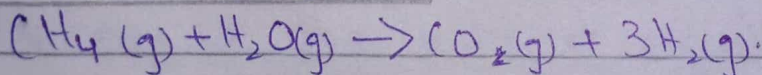
$$\begin{aligned}
 K_c &= \frac{[\text{mol} \cdot \text{dm}^{-3}] [\text{mol} \cdot \text{dm}^{-3}]}{[\text{mol} \cdot \text{dm}^{-3}] [\text{mol} \cdot \text{dm}^{-3}] [\text{mol} \cdot \text{dm}^{-3}]} \\
 &= \frac{1}{[\text{mol} \cdot \text{dm}^{-3}]} \\
 &= [\text{mol}^{-1} \cdot \text{dm}^3] \\
 K_c &= \text{dm}^3 \cdot \text{mol}^{-1}.
 \end{aligned}$$

(iii) Forward and reverse reactions.Forward Reaction:Reverse Reaction:

Q4: Coal reacts with hot steam to form CO and H₂. These substances react further in the presence of catalyst to give methane and water vapour.



(i) Write forward and reverse reactions for it.

Forward Reaction:Reverse Reaction:(ii) Derive K_c expression for the reaction.

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According to law of mass action:

Forward Reaction:Rate of forward reaction $\propto [\text{CO}][\text{H}_2]^3$

$$R_f = k_f [\text{CO}][\text{H}_2]^3$$

Reverse Reaction:Rate of reverse reaction $\propto [\text{CH}_4][\text{H}_2\text{O}]$

$$R_r = k_r [\text{CH}_4][\text{H}_2\text{O}]$$

In Equilibrium State:

Rate of forward reaction = Rate of Reverse reaction

$$k_f [\text{CO}][\text{H}_2]^3 = k_r [\text{CH}_4][\text{H}_2\text{O}]$$

$$\frac{k_f}{k_r} = \frac{[\text{CH}_4][\text{H}_2\text{O}]}{[\text{CO}][\text{H}_2]^3} \Rightarrow K_c = \frac{[\text{CH}_4][\text{H}_2\text{O}]}{[\text{CO}][\text{H}_2]^3}$$

^{Ans} This is $\frac{k_f}{k_r} = K_c$ required equilibrium expression.

(iii) Determine units for K_c .

$$K_c = \frac{[\text{CH}_4][\text{H}_2\text{O}]}{[\text{CO}][\text{H}_2]^3}$$

$$= \frac{[\text{mol} \cdot \text{dm}^{-3}][\text{mol} \cdot \text{dm}^{-3}]}{[\text{mol} \cdot \text{dm}^{-3}][\text{mol} \cdot \text{dm}^{-3}]^3}$$

$$= \frac{1}{[\text{mol} \cdot \text{dm}^{-3}]^2}$$

$$= [\text{mol} \cdot \text{dm}^{-3}]^{-2}$$

$$= [\text{mol}^{-2} \cdot \text{dm}^6]$$

$$= \text{dm}^6 \cdot \text{mol}^{-2}$$

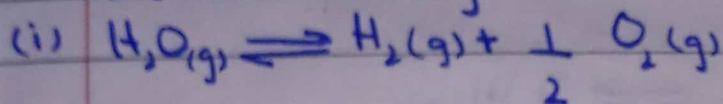
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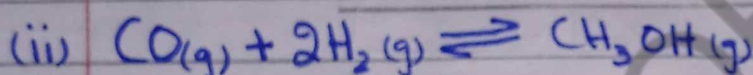
Chapter: 9 "Chemical Equilibrium"

Review Exercise:

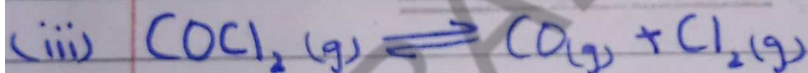
Q5: Write equilibrium constant expression for each of following reactions.



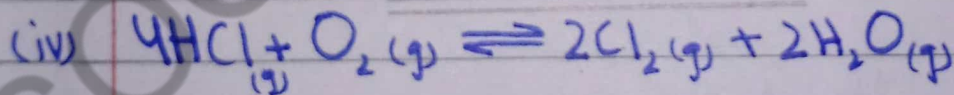
$$K_c = \frac{[\text{H}_2][\text{O}_2]^{1/2}}{[\text{H}_2\text{O}]}$$



$$K_c = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2}$$



$$K_c = \frac{[\text{CO}][\text{Cl}_2]}{[\text{COCl}_2]}$$



$$K_c = \frac{[\text{Cl}_2]^2 [\text{H}_2\text{O}]^2}{[\text{HCl}]^4 [\text{O}_2]}$$

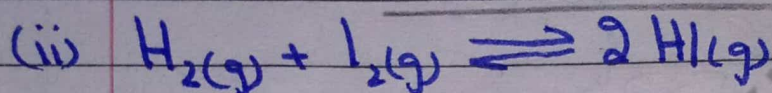
Q6: Determine the units of equilibrium constants for following reactions.



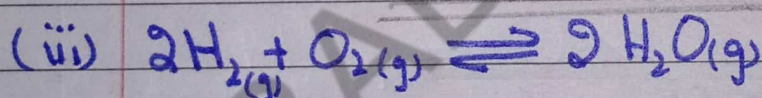
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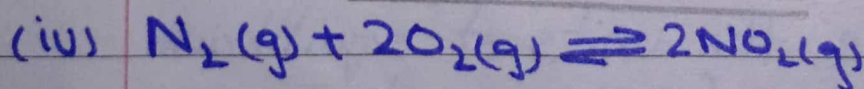
$$\begin{aligned}
 K_c &= \frac{[CO][Cl_2]}{[COCl_2]} \\
 &= \frac{[\text{mol} \cdot \text{dm}^{-3}][\text{mol} \cdot \text{dm}^{-3}]}{[\text{mol} \cdot \text{dm}^{-3}]} \\
 &= \text{mol} \cdot \text{dm}^{-3}
 \end{aligned}$$



$$\begin{aligned}
 K_c &= \frac{[HI]^2}{[H_2][I_2]} \\
 &= \frac{[\text{mol} \cdot \text{dm}^{-3}][\text{mol} \cdot \text{dm}^{-3}]}{[\text{mol} \cdot \text{dm}^{-3}][\text{mol} \cdot \text{dm}^{-3}]} \\
 &= \text{no units}
 \end{aligned}$$



$$\begin{aligned}
 K_c &= \frac{[H_2O]^2}{[H_2]^2[O_2]} \\
 &= \frac{[\text{mol} \cdot \text{dm}^{-3}][\text{mol} \cdot \text{dm}^{-3}]}{[\text{mol} \cdot \text{dm}^{-3}]^2[\text{mol} \cdot \text{dm}^{-3}]} \\
 &= \frac{1}{[\text{mol} \cdot \text{dm}^{-3}]} \\
 &= \text{mol}^{-1} \cdot \text{dm}^3 \\
 &= \text{dm}^3 \cdot \text{mol}^{-1}
 \end{aligned}$$



$$K_c = \frac{[NO_2]^2}{[N_2][O_2]^2}$$

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$$\begin{aligned}
 K_c &= \frac{[\text{mol} \cdot \text{dm}^{-3}] [\text{mol} \cdot \text{dm}^{-3}]}{[\text{mol} \cdot \text{dm}^{-3}] [\text{mol} \cdot \text{dm}^{-3}]^2} \\
 &= \frac{1}{[\text{mol} \cdot \text{dm}^{-3}]} \\
 &= \text{mol}^{-1} \cdot \text{dm}^3 \\
 &= \text{dm}^3 \cdot \text{mol}^{-1}
 \end{aligned}$$

Q1: State the ways that equilibrium can be recognized.

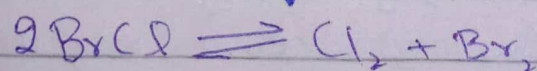
Ways to Recognize Equilibrium:

Equilibrium state of chemical reaction can be determined by determining concentration of reactants and products at regular intervals. When constant concentration of products and reactants is observed, the reaction is equilibrium. This can be done by physical methods as well as chemical methods such as titration, spectroscopy etc.

"Think-Tank"

Q1. Bromine chloride (BrCl) decomposes to form chlorine and bromine. For this reaction write.

(i) Chemical Equation.



(ii) K_c expression.

$$K_c = \frac{[\text{Cl}_2][\text{Br}_2]}{[\text{BrCl}]^2}$$

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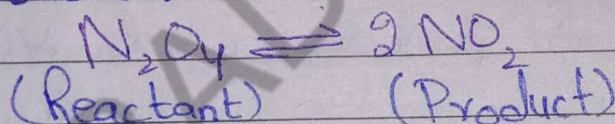
(iii) Units of K_c .

$$\begin{aligned}
 K_c &= \frac{[Cl_2][Br_2]}{[BrCl]^2} \\
 &= \frac{[\text{mol dm}^{-3}][\text{mol dm}^{-3}]}{[\text{mol dm}^{-3}]^2} \\
 &= \text{no units.}
 \end{aligned}$$

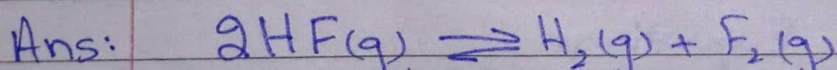
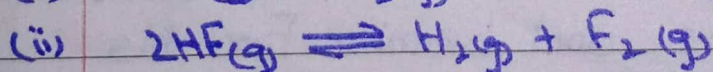
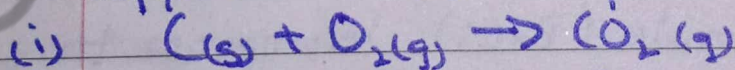
Q2: K_c expression for reaction is given below:

$$K_c = \frac{[NO_2]^2}{[NO]_4}$$

Choose reactant and product and derive the units of K_c for this reaction.



Q3: For which of following reactions are both reactants and products likely to be found when the reaction appears to be complete. Justify



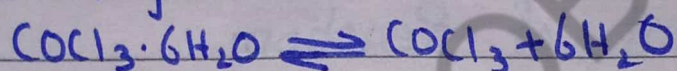
As equilibrium established only in reversible reaction and when the reaction is in equilibrium it contains both products and reactants. So the

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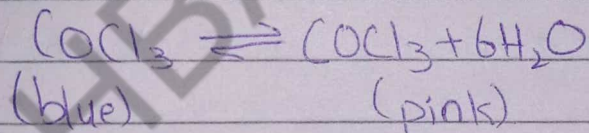
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reaction in which hydrogen fluoride decompose to give hydrogen and fluorine, both reactants and products likely to be found when the reaction appears to complete.

Cobalt chloride forms pink crystals ($\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$). When they are heated water is evolved and they turn blue (CoCl_2). Can you use cobalt chloride as test for water. Argue.



Cobalt chloride is used as a test for water. To check if the colourless liquid is water, test with piece of cobalt chloride paper. Water turns blue paper pink.



"Review Exercise"

Q2(v) What is the importance of equilibrium constant for a chemical reaction?

Direction of Reaction:

$$\text{As } K_c = \frac{[\text{Product}]}{[\text{Reactant}]}$$

The direction of chemical reaction at any particular time can be predicted by means of $[\text{Product}]/[\text{Reactant}]$ ratio leads by to one of the following three possibilities:

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- (a) The ratio is less than K_c . This implies that more of the product is required to attain equilibrium, therefore the reaction will proceed in the forward direction.
- (b) The ratio is greater than K_c . This means that ~~the~~ reverse reaction will occur to attain the equilibrium.
- (c) When the ratio is equal to K_c , the reaction is at equilibrium.

Extent of Reaction:

- (a) If the equilibrium constant is very large, this indicates that the reaction is almost complete.
- (b) If the value of K_c is very small, it reflects that the reaction does not proceed appreciably in the forward direction.
- (c) If the value of K_c is moderate this shows very little forward reaction.

The Effect of External Conditions on the position of Equilibrium:

When a system reaches equilibrium it will remain in the same state indefinitely, if the conditions do not change. However, equilibrium state of a system is disturbed, if external conditions are

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changed e.g. change of pressure, temperature, concentration of reactant and product will alter the position of equilibrium.

Whenever the equilibrium is disturbed by changes in the conditions, the system will always tend to restore equilibrium.

Concentration:

It can be used to determine the equilibrium concentration of equilibrium mixture knowing the initial concentration of reactants.

Good
Neat Work
for