Le Chatelier's Principle
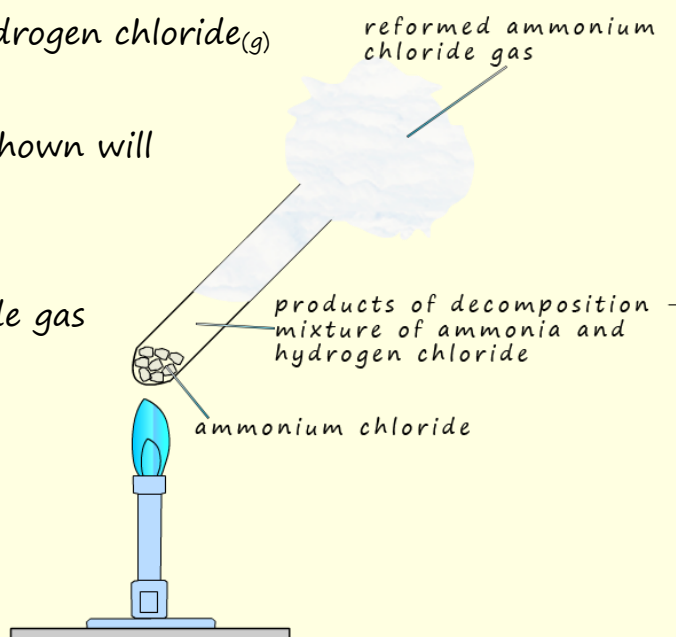
Answer all the questions below as fully as you can then check your answers
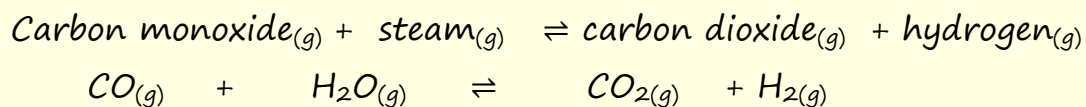
1. What does the "$\rightleftharpoons$" symbol mean when you see it in an equation?

2. In may chemical reactions you hear chemists talking about "the system" and the surroundings, what do they mean by the phrases "the system" and the "surroundings"?

a. What is the difference between a reaction in a closed and open system?

4. What do we mean when we say the system has achieved dynamic equilibrium?

5. Ammonium chloride is a colourless solid that when heated in a boiling tube over a Bunsen burner undergoes thermal decomposition according to the equation:

Ammonium chloride $_{(s)}$ $\rightleftharpoons$ ammonia$_{(g)}$ + hydrogen chloride$_{(g)}$
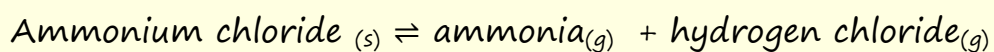
a. Explain why this reversible reaction as shown will never achieve equilibrium.

b. How is the reformed ammonium chloride gas being made?

reformed ammonium chloride gas

products of decomposition - mixture of ammonia and hydrogen chloride
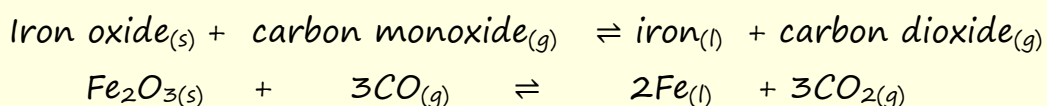
ammonium chloride

6. The reaction between carbon monoxide and steam is often called the water-gas reaction. It is a common reaction in industry, it is used as an method of producing large amounts of hydrogen gas. The reaction can be shown as:

$$\text{Carbon monoxide}_{(g)} + \text{steam}_{(g)} \rightleftharpoons \text{carbon dioxide}_{(g)} + \text{hydrogen}_{(g)}$$
$$CO_{(g)} + H_2O_{(g)} \rightleftharpoons CO_{2(g)} + H_{2(g)}$$

a. Use your knowledge of Le Chatelier's principle to explain how the equilibrium will change when:

i. more carbon monoxide is added.

ii hydrogen gas is removed

iii carbon dioxide gas is removed.

b. The forward reaction is exothermic.

i. What will happen to the amount of hydrogen gas in the equilibrium mixture if the temperature of the system is raised? What will happen to the value of K_c for this reaction?

c. What effect will increasing the pressure have on the concentration of gases at equilibrium?

7. In the blast furnace used to produce iron the following reaction happens:
$$\text{Iron oxide}_{(s)} + \text{carbon monoxide}_{(g)} \rightleftharpoons \text{iron}_{(l)} + \text{carbon dioxide}_{(g)}$$
$$Fe_2O_{3(s)} + 3CO_{(g)} \rightleftharpoons 2Fe_{(l)} + 3CO_{2(g)}$$

a. Use your knowledge of Le Chatelier's principle to explain how the equilibrium will change when:

I. The CO_2 is removed.   ii. More solid iron oxide is added

Answers

1. What does the "$\rightleftharpoons$" symbol mean when you see it in an equation?

   Reaction is reversible

2. In may chemical reactions you hear chemists talking about "the system" and "the surroundings", what do they mean by the phrase "the system" and "the surroundings"?

   The system is the reacting chemicals

   The surroundings are the boiling tubes, beakers, classroom, lab, everything else – the universe!

a. What is the difference between a reaction in a closed and open system?

   In a closed system nothing enters or escapes – mostly means no gases are given off, or reactions take place in sealed vessels, in an open system substances can leave and enter the reaction.

4. What do we mean when we say the system has achieved dynamic equilibrium?

   Rate of the forward and reverse reactions in a reversible reaction are the same. The concentrations/amounts of reactants and products do not change with time.

5. Ammonium chloride is a colourless solid that when heated in a boiling tube over a Bunsen burner undergoes thermal decomposition according to the equation:
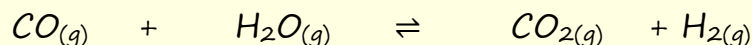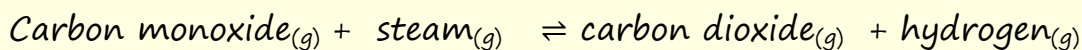
   Ammonium chloride (s) $\rightleftharpoons$ ammonia(g) + hydrogen chloride(g)
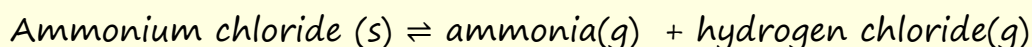
a. Explain why this reversible reaction as shown will never achieve equilibrium. It is taking place in an open system– substances are leaving the boiling tube, can only achieve equilibrium in a closed system

reformed ammonium chloride gas

products of decomposition – mixture of ammonia and hydrogen chloride
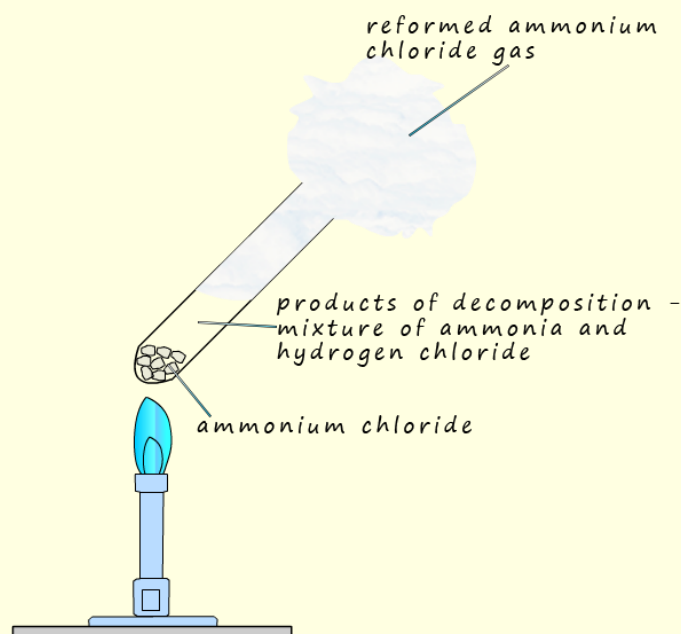
ammonium chloride

b. How is the reformed ammonium chloride gas being made? Products are basic (ammonia gas) and acidic hydrogen chloride), they react and turn back in reactant, solid ammonium chloride

6. The reaction between carbon monoxide and steam is often called the water-gas reaction. It is a common reaction in industry, it is used as an method of producing large amounts of hydrogen gas. The reaction can be shown as:

Carbon monoxide$_{(g)}$ + steam$_{(g)}$ ⇌ carbon dioxide$_{(g)}$ + hydrogen$_{(g)}$

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

a. Use your knowledge of Le Chatelier's principle to explain how the equilibrium will change when:

i. more carbon monoxide is added. Equilibrium position shift to the right hand side, more CO_2 and hydrogen are produced.

ii hydrogen gas is removed –equilibrium position shifts to the right hand side to replace removed hydrogen.
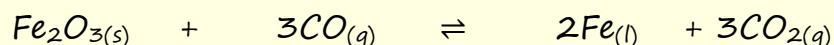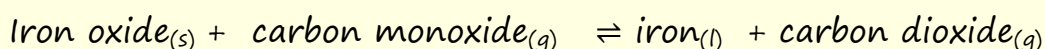
iii carbon dioxide gas is removed. Equilibrium position shifts to the right hand side to replace removed carbon dioxide.

b. The forward reaction is exothermic.

I What will happen to the amount of hydrogen gas in the equilibrium mixture if the temperature of the system is raised? More reactants are made, equilibrium position   shifts to the left hand side, less hydrogen in equilibrium mixture of gases, the endothermic reaction removes heat introduced.

c. What effect will increasing the pressure have on the concentration of gases at equilibrium? None, equal number of moles of gas on reactant and product side of the equation.

7. In the blast furnace used to produce iron the following reaction happens:

Iron oxide$_{(s)}$ + carbon monoxide$_{(g)}$ ⇌ iron$_{(l)}$ + carbon dioxide$_{(g)}$

$$Fe_2O_{3(s)} + 3CO_{(g)} \rightleftharpoons 2Fe_{(l)} + 3CO_{2(g)}$$

a. Use your knowledge of Le Chatelier's principle to explain how the equilibrium will change when:

I. The CO_2 is removed. More products, reaction equilibrium position shifts to right hand side to replace removed carbon dioxide gas.

ii. More solid iron oxide is added, no change in equilibrium position, because the iron oxide is a solid adding more does not change the "concentration" of the solid present.

The following questions involve equilibrium constant which you may or not have done yet!

6. Write out expression for K_c for each of the following reactions and give the units for K_c in each case.
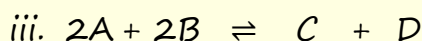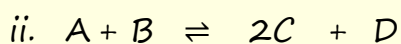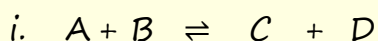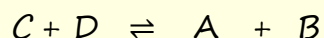
i. $A + B \rightleftharpoons C + D$

ii. $A + B \rightleftharpoons 2C + D$

iii. $2A + 2B \rightleftharpoons C + D$

7. If one reaction had an equilibrium constant of 10^{10} and another reaction had an equilibrium constant of 10^{-10}, how would these reaction differ from each other?

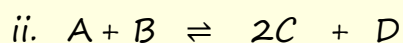8. If the equilibrium constant k_c for the reaction below is 10.

$A + B \rightleftharpoons C + D$
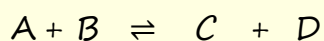
What is the equilibrium constant for the following reaction?

$C + D \rightleftharpoons A + B$

$$K_c = \frac{[C]\,[D]}{[A]\,[B]} = \frac{(mol\ dm^{-3})\,(mol\ dm^{-3})}{(mol\ dm^{-3})\,(mol\ dm^{-3})}$$

K_c has no units

ii. $A + B \rightleftharpoons 2C + D$

$$K_c = \frac{[C]^2 \, [D]}{[A] \, [B]} = \frac{(mol \; dm^{-3}) \, (mol \; dm^{-3}) \, (mol \; dm^{-3})}{(mol \; dm^{-3}) \, (mol \; dm^{-3})}$$

K_c has units of $mol \; dm^{-3}$

iii. $2A + 2B \rightleftharpoons C + D$
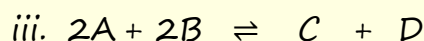
$$K_c = \frac{[C]^2 \, [D]}{[A]^2 \, [B]^2} = \frac{(mol \; dm^{-3}) \, (mol \; dm^{-3})}{(mol^2 \; dm^{-6}) \, (mol^2 \; dm^{-6})}$$

K_c has units of $mol^{-2} \; dm^6$

7. If one reaction had an equilibrium constant of 10^{10} and another reaction had an equilibrium constant of 10^{-10}, how would these reaction differ from each other?
    If k_c is very large then the reaction can be considered to essentially go to completion. If K_c is very small then the reaction essentially fails to start, it is almost entirely made up of reactants and no products.

8. If the equilibrium constant k_c for the reaction below is 10.
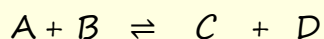
    $A + B \rightleftharpoons C + D$

    What is the equilibrium constant for the following reaction?

    $C + D \rightleftharpoons A + B$
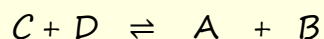
The equilibrium constant for the reverse reaction is simply $1/k_c$, so in this case it is 1/10 or 0.1