Heat changes Associated with Chemical Reactions

Chemistry

08

Recall again about the evidences you have learnt in grade 10 to ensure that a reaction has taken place. Do the following activity to study further about it.

Activity 8.1

Materials required ; - Two small beakers about 100 cm^3 , A thermometer, a glass rod, solid sodium hydroxide (NaOH), solid ammonium chloride (NH_4Cl)

Method; - Add about half full of water to a beaker, measure its temperature and note it down. Add a little amount of solid sodium hydroxide to the same beaker, stir with the glass rod and again measure and record the temperature. State your observations.

Fill half of a beaker with water and record its temperature. Add a little amount of solid ammonium chloride to this beaker. Stir with the glass rod and record the temperature again. State your observations.

It can be observed that when solid sodium hydroxide dissolves in water the temperature rises whereas when solid ammonium chloride dissolves in water, the temperature falls. The reason for the temperature changes happening in the above two instances is the heat changes accompanying them.

What is the reason for the increase in temperature when solid sodium hydroxide dissolves in water? The temperature increases because of the loss of heat.

Why did the temperature decrease when solid ammonium chloride was dissolved in water?

In this case, temperature decreased because of the absorption of heat.

The temperature change can be considered as a measure of the amount of heat either evolved or absorbed.

In order to explore further about the heat changes occuring in a chemical reation, let us conduct the following activity.

Activity 8.2

Materials required; - A small beaker, a piece of magnesium strip, dilute hydrochloric acid, a thermometer

Method; - Add about 10 cm^3 of dilute hydrochloric acid to a small beaker and measure its temperature. Add a piece of magnesium ribbon about 2 cm long into it. Measure the temperature at the end of the reaction again. Record your observations.

When magnesium metal reacts with hydrochloric acid, the temperature has increased. That means, when this reaction happens heat is lost. **The chemical reactions happening with the evolution of heat are called exothermic reactions. Exothermic reactions can be represented simply as follows.**

$$\text{Reactants} \longrightarrow \text{Products} + \text{Heat}$$

The exothermic reaction studied in activity 8.2 can be represented by the following equation.

$$Mg\,(s) + HCl\,(aq) \longrightarrow MgCl_2\,(aq) + H_2\,(g) + \text{Heat}$$

The reason for the evolution of heat in an exothermic reaction is that the energy contained in the products is less than the energy content of the reactants.
An exothermic reaction can be illustrated by an energy level diagram as follows.

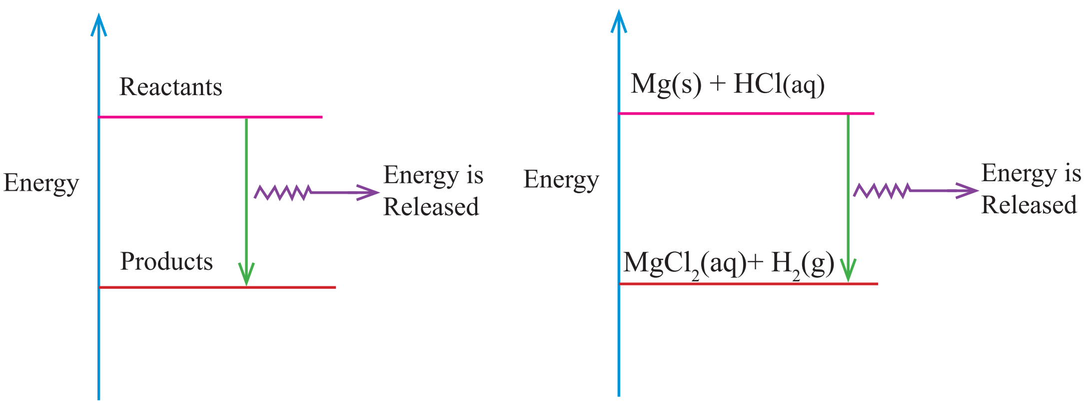


Figure 8.1 Energy level diagram for an exothermic reaction

Activity 8.3

Materials required ; - A small beaker, a solution of citric acid, a solution of sodium bicarbonate

Method ; - Add about 10 cm^3 of the citric acid solution to a small beaker and record its temperature. Record the temperature of the sodium bicarbonate solution also. Add about 10 cm^3 of the sodium bicarbonate solution to the beaker containing citric acid, stir and note the temperature. State your observations.

When the reaction between citric acid and sodium bicarbonate occurs, the temperature decreases. The reason for this decrease in temperature is the absorption of heat during the reaction. **The reactions taking place with the absorption of heat are known as endothermic reactions.**
An endothermic reaction can be simply represented as follows.

$$\text{Reactants} + \text{Heat} \longrightarrow \text{Products}$$

The reason for the absorption of heat during an endothermic reaction is the fact that the energy in the products is greater than the energy in the reactants.
An endothermic reaction can be represented by an energy level diagram as follows.

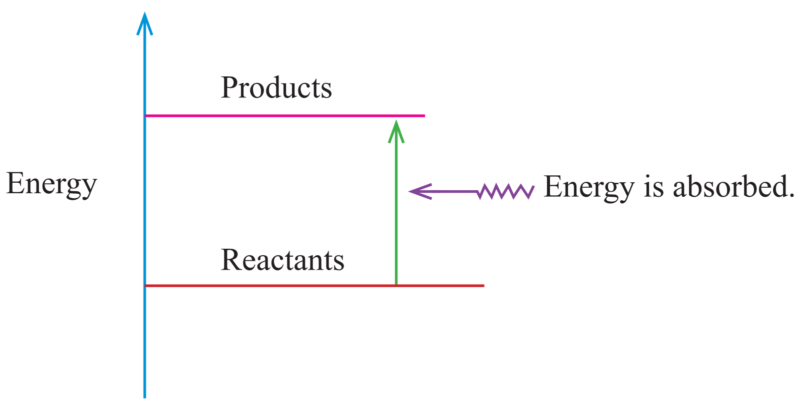


Figure 8.2 Energy level diagram for an endothermicmic reaction

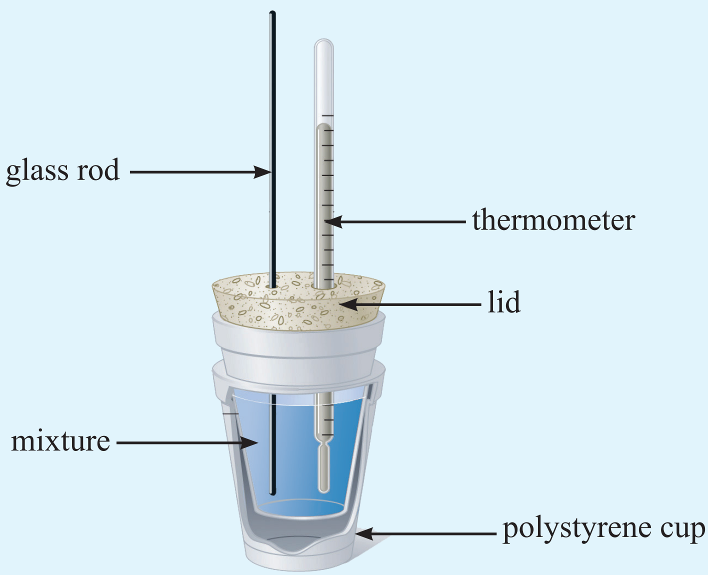
Let's do the following activity to find the energy change of a chemical reaction quantitatively.

Activity 8.4

Experimental determination of the heat change of the reaction between sodium hydroxide (NaOH) and hydrochloric acid (HCl)

Materials required ; - 50 cm^3 of 2 mol dm^{-3} sodium hydroxide solution, 50 cm^3 of 2 mol dm^{-3} hydrochloric acid solution, two 100 cm^3 beakers, a thermometer of range 0-100 ^0C, a polystyrene cup, a glass rod

Method ; -



To two beakers, measure 50 cm^3 of the sodium hydroxide solution and 50 cm^3 of the hydrochloric acid solution separately using the measuring cylinder. With the thermometer, measure the initial temperatures of the two solutions.

(After measuring the temperature of the solution of the base, wash the thermometer before measuring the temperature of the acid solution . Mix these two solutions in a polystyrene cup, stir with the glass rod and record the maximum temperature.

The heat change associated with the reaction can be calculated using the following equation.

$$Q = m c \theta$$

m = Mass of the substance accompanying the exchange of heat

c = Specific heat capacity of the substance related to the heat change

θ = Temperature change in the mixture (maximum temperature - initial temperature)

If the temperatures of the solutions of the base and acid are different, their mean should be taken as the initial temperature.

This calculation is based on the assumption that the entire quantity of heat of the reaction between sodium hydroxide and hydrochloric acid is used to raise the temperature of 100 cm^3 of the solution. Since dilute solutions were used for mixing, it is also assumed that the specific heat capacity of the solution is equal to that of water and the density of the solution is equal to that of water.

Specific heat capacity of water = 4200 J kg^{-1} $^0C^{-1}$

Density of water = 1 g cm^{-3}

Mass of 100 cm^3 of water = 100 g

Let us assume that the observed temperature change in the experiment is 10 ^0C

$$Q = m c \theta$$

$$= \frac{100}{1000} \text{ kg} \times 4200 \text{ J kg}^{-1} \, {}^0\text{C}^{-1} \times 10 \, {}^0\text{C}$$

$$= 4200 \text{ J}$$

The experiment gives the heat change that results when 50 cm^3 of the 2 mol dm^{-3} sodium hydroxide solution reacts with 50 cm^3 of 2 mol dm^{-3} hydrochloric acid solution.

Extra knowledge

This experiment gives the quantity of heat evolved when the amount of moles of sodium hydroxide in 50 cm^3 of the solution reacts with the amount of moles of hydrochloric acid in 50 cm^3 of the solution used.

Amount of moles of NaOH in 50 cm^3 of the 2 mol dm^{-3} NaOH solution $= \frac{2}{1000} \times 50$ mol

$= 0.1$ mol

Amount of moles of HCl in 50 cm^3 of the 2 mol dm^{-3} HCl solution $= \frac{2}{1000} \times 50$ mol

$= 0.1$ mol

Referring to this, the quantity of heat that evolves when 1 mol of sodium hydroxide reacts with 1 mol of hydrochloric acid can be calculated.

The quantity of heat released when 0.1 mol of NaOH reacts with 0.1 mol of HCl $= 4.2$ kJ

Quantity of heat released when 1.0 mol of NaOH reacts with 1.0 mol of HCl $= \frac{4.2 \text{ kJ}}{0.1 \text{ mol}}$

$= 42 \text{ kJ mol}^{-1}$

This is the heat of reaction of the reaction between sodium hydroxide and hydrochloric acid.(This is an experimental value).

When conducting this experiment loss of heat to the surroundings and absorption of heat by the container occur. Neglecting these leads to an error in the calculation. To minimize it, a thermally insulating polystyrene cup is used. To keep the temperature uniform throughout the mixture, the mixture should be stirred well with a stirrer or a glass rod.

In the above experiment, we determined the heat change associated with the reaction between aqueous sodium hydroxide and aqueous hydrochloric acid.

$$HCl\,(aq) + NaOH(s) \longrightarrow NaCl\,(aq) + H_2O\,(l)$$

The above experiment can be carried out using solid sodium hydroxide (NaOH (s)) too. But the heat change here is different from the previous value.

Therefore, when expressing the heat change accompanying a reaction, the physical state of the reactants and the products should be indicated (Solid, liquid, gas, aqueous)

Exothermic and endothermic reactions are important in various activities in day to day life. We meet our energy requirements by burning fuels. Coal, bio gas (methane), and petrol (a mixture of hydrocarbons) are few examples. The energy liberated during the combustion of these fuels are used for various tasks such as running vehicles and operating machinery in factories. Combustion of fuels is an exothermic reaction. The neutralisation reactions taking place between acids and bases are also exothermic reaction. Cellular respiration taking place in live bodies are also exothermic reactions.

In the production of slaked lime, water is added to quicklime. During this process, lot of heat is liberated. This is also an exothermic reaction.

$$CaO\,(s) + H_2O\,(l) \longrightarrow Ca(OH)_2\,(s)$$

Next, let us consider about endothermic processes. You have studied the photosynthesis happening in green plants. In this, simple sugars are produced by absorbing solar energy. It is an endothermic process.

$$6CO_2\,(g) + 6H_2O\,(l) \xrightarrow[\text{chlorophyll}]{\text{solar energy}} C_6H_{12}O_6\,(s) + 6O_2\,(g)$$

Thermal decomposition of many chemical compounds is also an endothermic process. Consider the production of quicklime by burning limestone. This reaction also absorbs heat.

$$CaCO_3\,(s) \longrightarrow CaO\,(s) + CO_2\,(g)$$

Summary

- During every chemical reaction, a heat change also occurs.
- Reactions during which heat is released to the surroundings are called exothermic reactions.
- Reactions in which heat is absorbed from the surroundings are called endothermic reactions.
- The amount of heat released or absobed during a reaction can be calculated using the equation $Q = mc\theta$

Exercises

01. (a) What do you mean by an exothermic reaction and an endothermic reaction

(b) Are the following reactions exothermic or endothermic?

1. Burning of a candle
2. Putting a piece of sodium into water
3. Dissolving the fertilizer urea in water
4. Adding glucose to water
5. Adding water to quicklime

(c) The quantity of heat evolved during the following reaction is 822 kJ mol^{-1}

$$2\,Na\,(s) + Cl_2\,(g) \longrightarrow 2\,NaCl(s)$$

Represent this using an energy level diagram.

02. 40 cm^3 of a vinegar (dilute acetic acid) solution was mixed with 60 cm^3 of a very dilute solution of lime water. (calcium hydroxide)Then, the temperature of the mixture increased by 10 ^0C

i) Calculate the heat change occurred during the above reaction

ii) What were the assumptions you made in (i) above? Is this reaction exothermic or endothermic?

Density of water = 1000 kg m^{-3}

Specific heat capacity of water = 4200 J $kg^{-1}\,{}^0C^{-1}$

Glossary

exothermic reaction	-	තාපදායක ප්‍රතික්‍රියාව	-	புறவெப்பத்தாக்கம்
endothermic reaction	-	තාප අවශෝෂක ප්‍රතික්‍රියාව	-	அகவெப்பத்தாக்கம்