CHAPTER-10

CHEMICAL ENERGETICS

You will learn in this chapter about :

* Exothermic and Endothermic reaction.
* Heat of Reactions.
* Measurement of heat of reactions.
* Heat of Neutralization.

INTRODUCTION

The chemical reactions during which material changes are accompained with change in heat energy are called thermochemical reactions. The branch of chemistry which deals with the study of heat changes in chemical reactions is called thermochemistry. There are two types of thermochemical reactions i.e. exothermic and endothermic chemical reactions.

10.1 EXOTHERMIC AND ENDOTHERMIC REACTIONS

10.1.1 Exothermic Reaction:

It is Greek word and composed of EXO means out of or to evolve + THERME means heat. An Exothermic Reaction is the chemical change during which heat is given out or released. The change of heat is represented by ΔH and it is shown by negative sign.

Examples:

(i) The combustion of coal in air is the example of exothermic reaction. 393.7 Kilo joules of heat energy is released when 1 mole of coal is burnt in 1 mole of O_2 to produce 1 mole of CO_2.

$$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H = -393.7 \text{ K.J/mol}$$

(ii) Burning of methane in presence of oxygen is another example of exothermic reaction. When 1 mole of methane is burnt in 2 moles of O_2 then 1mole of CO_2 and 2 moles of water are formed. During this reaction 890 Kilo joules per mole of heat energy is released.

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l) \quad \Delta H = -890 \text{ K.J/mol.}$$

(iii) The formation of water from hydrogen and oxygen is also example of exothermic reaction. 286 Kilo joules per mole of heat energy is released, when 1mole of H_2 reacts with $\frac{1}{2}$ moles of O_2 to form 1 mole of H_2O.

$$H_2(g) + \frac{1}{2} O_2(g) \longrightarrow H_2O(l) \qquad \Delta H = -286 \text{ K.J/mol.}$$

Generally in exothermic reactions, heat flows from the system to surroundings and container becomes hot, this is only possible, when total energy of the reactants is greater than total energy of products. The difference in the energies is the heat supplied by the system to surroundings.

Using Exothermic Reactions to Warm Food:

In modern army, food rations can be warmed without benefit of stove or camfire. The pouch that contains the food is attached to flameless radiation heater. The heater contains chemicals that react with water to produce heat. When the pouch is placed in a bag and water added, temperature of the food reaches to 60^0C in about 15 minutes.

$$Mg(s) + 2H_2O(l) \longrightarrow Mg(OH)_2(s) + H_2(g) \quad \Delta H = -3.53 \text{KJ/mol}$$

The reaction of (Mg) with water is slow, because of the formation of film oxide (MgO). The reaction of Mg with water is highly accelerated in the presence of iron (Fe) and ordinary salt (NaCl). Thus, the flameless radiation heater contains a mixture of Mg, Fe and NaCl.

(a)

(b)

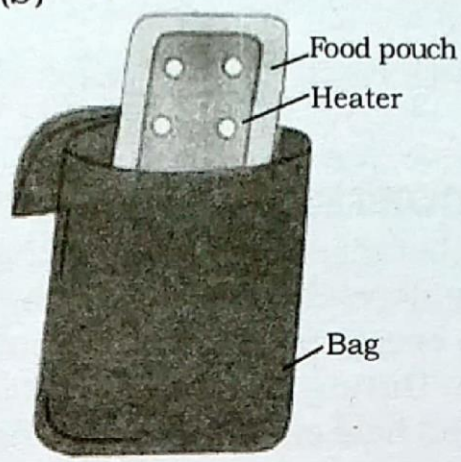

Fig. 10.1(a) A soldier adding water to the bag containing pouch
Fig. 10.1(b) The food pouch is attached with chemical heater containing Mg, Fe and NaCl.

10.1.2 Endothermic Reactions:

It is Greek word and composed of ENDO mean into or to absorb and THERME means heat. Endothermic reaction is the chemical change during which heat is absorbed or taken in. The change of heat energy is represented by ΔH and sign of ΔH is positive ($+\Delta H$= Absorbs heat). During the endothermic reaction heat is absorbed from the surroundings, it means heat flows from surroundings to the system and container becomes cold. This is because the total energy of the products is greater than the total energy of reactants. Here, the difference in the energies is the heat supplied to the system by the surroundings.

Examples:

(i) The decomposition of water into hydrogen and oxygen is example of endothermic reaction. During decomposition of 1mole of water to 1 mole of hydrogen and half mole of oxygen 286 Kilo joules per mole of heat energy is absorbed.

$$H_2O(l) \longrightarrow H_2(g) + \frac{1}{2} O_2(g) \quad \Delta H = +286 \text{ KJ/mol}$$

(ii) 1 mole of nitric oxide (NO) is formed by combination of $\frac{1}{2}$ mole of N_2

and $\frac{1}{2}$ mole of O_2. This is the example of endothermic reaction and heat absorbed is about 90.25 Kilo joules per mole.

$$\frac{1}{2} N_2(g) + \frac{1}{2} O_2(g) \longrightarrow NO(g) \quad \Delta H = + 90.25 \text{ KJ/mol}$$

10.2 HEAT CONTENTS OF REACTION

Every substance possesses a characteristic internal energy and internal energy depends upon the structure and physical state of that substance. The energy possessed by a substance is called heat contents of that substance. During a chemical reaction, the reactants are converted into products and heat energy is either absorbed or evolved. This is because the heat contents of these respective substances are different. The heat evolved or absorbed at constant pressure is called as enthalpy of the reaction.

The heat content (enthalpy) of a substance is represented by "H" and the change in heat content during a chemical reaction is then represented by ΔH. Here Greek letter Δ (delta) signifying the change in the property. It means the change in heat content during chemical reaction is the difference between the heat content of products and reactants of that reaction.

It is difficult to measure the enthalpy of a reaction, but we can measure the change in enthalpy which is denoted by (ΔH). It is obtained by subtracting the enthalpy of reactant (H_1) from enthalpy of products (H_2).

$$\underset{\text{Change of Enthalpy}}{\Delta H} = \underset{\text{Heat content of product}}{(H_2} - \underset{\text{Heat content of reactants}}{H_1)}$$

If enthalpy of products is greater than the enthalpy of reactants, then the sign of ΔH will be positive and over all reaction is endothermic and heat is absorbed.

$$\frac{1}{2} N_2(g) + \frac{1}{2} O_2(g) \longrightarrow NO(g) \qquad \Delta H = + 90.25 \text{ KJ/mol.}$$

$$C(s) + H_2O(l) \longrightarrow CO(g) + H_2(g) \qquad \Delta H = + 118 \text{ KJ/mol.}$$

$$H_2O(l) \longrightarrow H_2(g) + \frac{1}{2} O_2(g) \qquad \Delta H = + 286 \text{ KJ/mol.}$$

If enthalpy of product is smaller than the reactants, then the sign of ΔH will be negative and overall reaction is exothermic and heat is evolved.

The examples of exothermic reactions are following:

$$H_2(g) + \frac{1}{2} O_2(g) \longrightarrow H_2O(l) \qquad \Delta H = -286 \text{ KJ/mol.}$$

$$S(g) + O_2(g) \longrightarrow SO_2(g) \qquad \Delta H = -296.8 \text{ KJ/mol.}$$

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H = -890.4 \text{ KJ/mol.}$$

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g) \qquad \Delta H = -92.0 \text{ KJ/mol.}$$

10.3 MEASUREMENT OF HEAT OF REACTION

The heat absorbed or evolved during thermochemical reaction is called heat of reaction. Exothermic and endothermic reactions can easily be detected by touching the vessel before and after chemical reaction. The increase in temperature indicate that reaction is exothermic and decrease in temperature indicates that the reaction is endothermic. The accurate values of ΔH can be determined by using calorimeter. The simple type of calorimeter is an insulated container fitted with thermometer and a stirrer. Known amounts of reactants are placed in calorimeter, when reaction proceeds the heat energy evolved or absorbed will either cool or warm the system. ΔH for reaction may be calculated by determining the difference in temperature, mass of reactants and specific heat of reaction mixture.

Heat of Neutralization:

The reaction between an acid and base to form a salt and water is called neutralization reaction. Neutralization reaction is an example of exothermic reaction. The amount of heat released during a neutralization reaction in which 1 mole of water is formed is called as the heat of neutralization or the amount of heat released when 1 mole of hydrogen ions (H^+) from an acid reacts with 1 mole of hydroxide ions (OH^-) from base to form salt and one mole of water is called heat of neutralization.

Procedure:

Take 50 cm^3 of molar NaOH solution and note its temperature (t_1) and 50 cm^3 of molar HCl solution and note its temperature (t_2). The two temperatures will be usually same, but they need not. Pour the HCl solution in 250 mls beaker (Calorimeter) and then add quickly NaOH solution the solution being stirred all the time, and note down the highest temperature

reached during the reaction. At the end weigh the calorimeter with salt solution. Heat of neutralization is calculated by the following formula.

$$\Delta H = m \times S \times (t_2 - t_1)$$

or $$\Delta H = m \times S \times \Delta t$$

Observation and Calculations

1. Mass of calorimeter along with stirrer $= w_1 = 50g$
2. Mass of calorimeter along with stirrer + salt sol. $= w_2 = 150g$
3. Mass of salt solution $(w_2 - w_1)$ $= m = 100g$
4. Specific heat of salt solution $= s = 4.25J/g/^0C$
5. Initial temperature of reactants $t_1 = t_2$ $= t^0C = 20^0C$
6. Final highest temperature $= t_3{}^0C = 26.8^0C$
7. Increase in temperature i.e. $t_3{}^0C - t^0C$ $= \Delta t = 6.8^0C$

Then

Heat of neutralization is given by $\Delta H = ms\ \Delta t$

$$\Delta H = 100g \times \frac{4.25J}{1g \times 1^0C} \times 6.8^0C = 2856J$$

The value obtained i.e 2856J is for 50 mls of solution, it must be multiplied by 20 to give the amount of heat evolved, when 1 mole of NaOH is neutralized by HCl

$$\therefore \quad 2856\ J \times 20 = 57120\ J = 57.12\ K.J/mol$$

Result: The heat of neutralization of NaOH by HCl is $\Delta H = -57.12$ KJ/mol.

Note: The heat of neutralizaiton for any strong acid with strong base is approximately same.

For example:

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l) \qquad \Delta H = -57.3\ KJ/mol.$$

$$KOH(aq) + HNO_3(aq) \longrightarrow KNO_3(aq) + H_2O(l) \qquad \Delta H = -57.3\ KJ/mol.$$

$$2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l) \quad \Delta H = -(2 \times 57.3)KJ/mol.$$

SUMMARY

1. Heat energy is given out in exothermic reaction.
2. Heat energy is absorbed in endothermic reaction.
3. In chemical reactions, the material change is accompained with the change of heat energy.
4. There are two types of thermochemical reactions i.e. exothermic and endothermic reaction.
5. All combustion reactions are the examples of exothermic reactions.
6. The enthalpy is represented by "H" and change of enthalpy is represented by "ΔH".
7. The energy given out or absorbed at constant pressure is called enthalpy of the reaction.
8. Another name for heat content of a reaction is enthalpy of the reaction.
9. In neutralization reactions, the heat is evolved, which is called as heat of neutralization.
10. The change in heat contents during a chemical reaction is the difference between the heat content of products and reactants.
11. When enthalpy of products is greater than the enthalpy of reactants than the reaction will be endothermic.
12. The sign of ΔH for exothermic reactions is negative (-ve)
13. The sign ΔH for endothermic reaction is positive. (+ve)

EXERCISE

1. Fill in the blanks:

(i) The heat given out in a chemical reaction is called ..... reaction.

(ii) In ..... reaction, heat is taken in.

(iii) Heat evolved or absorbed during chemical reaction at constant pressure is called .....

(iv) Acid base reaction is called ..... reaction.

(v) $C(s) + O_2(g) \longrightarrow CO_2(g)\ \Delta H$ = ------ KJ/mol.

(vi) $H_2(g) + \frac{1}{2} O_2(g) \longrightarrow H_2O(l)\ \Delta H$ = ------ KJ/mol.

2. Tick the correct answers:

(i) In an exothermic reaction.

(a) Heat energy is lost. (b) Heat energy is gained.

(c) Heat energy is lost as well as gained.

(d) None of them.

(ii) In an exothermic reaction.
(a) Container becomes hot.
(b) Container becomes cold.
(c) The temperature of container remains the same.
(d) None of them.

(iii) During an endothermic reaction.
(a) Container used becomes cold.
(b) Container used becomes hot.
(c) The temperature of container used remains same.
(d) Total energy of reactants increases.

(iv) The heat evolved during the formation of 1 mole of water from H_2 and O_2 is
(a) 286 Kilo joules/mol (b) 186 Kilo joules/mol
(c) 300 Kilo joules/mol (d) 200 Kilo joules/mol

(v) The formation of water form H_2 and O_2 is example of,
(a) Exothermic reaction. (b) Endothermic reaction.
(c) Neutralization reaction. (d) None of them.

3. Write answer of the following questions:

(i) Define the following terms:
(a) Thermo chemistry. (b) Exothermic reaction.
(c) Endothermic reaction

(ii) Give atleast two examples of exothermic reactions and two examples of endothermic reactions.

(iii) Which of the following are exothermic or endothermic processes?
(a) The decomposition of mercuric oxide (HgO).
(b) The electrolysis of water.
(c) The reaction of (Na) with water.
(d) The burning of methane CH_4.
(e) The decomposition of $KClO_3$.
(f) A match burn.

(iv) Define the following terms:
(a) Enthalpy. (b) Enthalpy of reaction.

(v) Define heat of neutralization. What would be the value of heat of neutralization, when strong acid reacts with strong base?