Suva Sangam College
Year: 13 Chemistry Lesson notes
Strand: 3 (Physical Chemistry)
Sub strand: Thermochemistry Lesson notes

Week 1- 5th – 9th July, 2021

Achievement Indicators: Students should be able to:

1) Define system and surrounding
2) Describe the three types of systems associated with thermochemistry.
3) Define heat of reactions and describe the two types of reactions.

System and Surrounding

System is the part of the universe (everything) we want to study.

Surrounding is everything in the universe apart from the system.

Types of System

Open system – is a system where the energy and the matter can be transferred in and out of the system. E.g. boiling water in an open pot.

Closed system – is a system where only energy can be transferred out of the system. E.g. boiling water in a pot covered with lid.

Isolated system - is a system where neither energy nor matter can be transferred. E.g. A bomb calorimeter.

Heat of Reactions

Heat of reaction is the energy absorbed or released in chemical reactions. There are **two** types of reactions: exothermic and endothermic reactions.

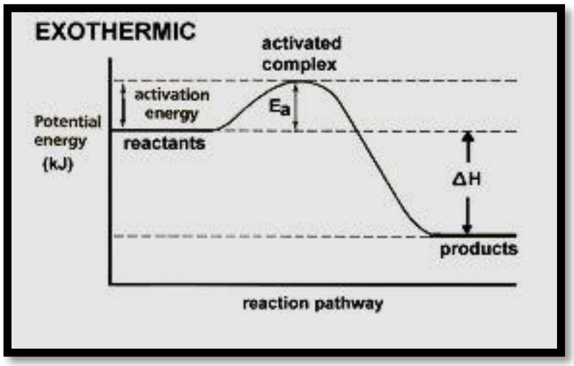
Exothermic

- Reaction in which **energy is released** into the surrounding, therefore the temperature of the system decreases.
- Since heat is released, the products have less energy than the reactants.
- The surrounding becomes warmer because the energy flows from the system to the surrounding.
- Has a negative value for change in enthalpy.

Eg. 1 a hot cup of tea cooling down

Eg.2 Adding NaOH to water (beaker gets warm)

Eg.3 heating any material is exothermic.

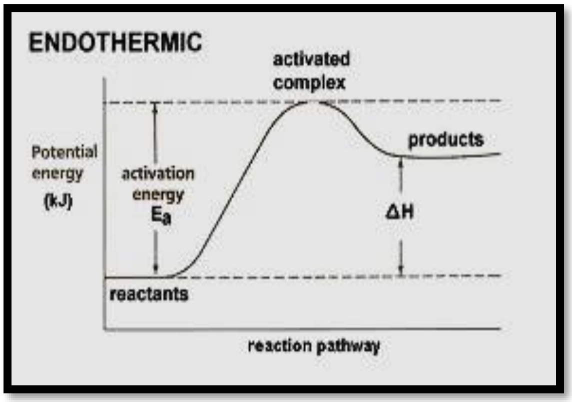


Endothermic

- Reaction in which energy is absorbed from the surrounding, therefore, the temperature of the system increases.
- Since heat is absorbed, the heat energy of the products is higher than the heat of the reactants.
- The surrounding becomes cooler because the energy flows from the surrounding to the system.
- Has positive value for change in enthalpy.

Eg.1 melting ice (heat from surrounding goes to the system)

Eg.2 adding $AgNO_3$ to water (beaker gets cooler)



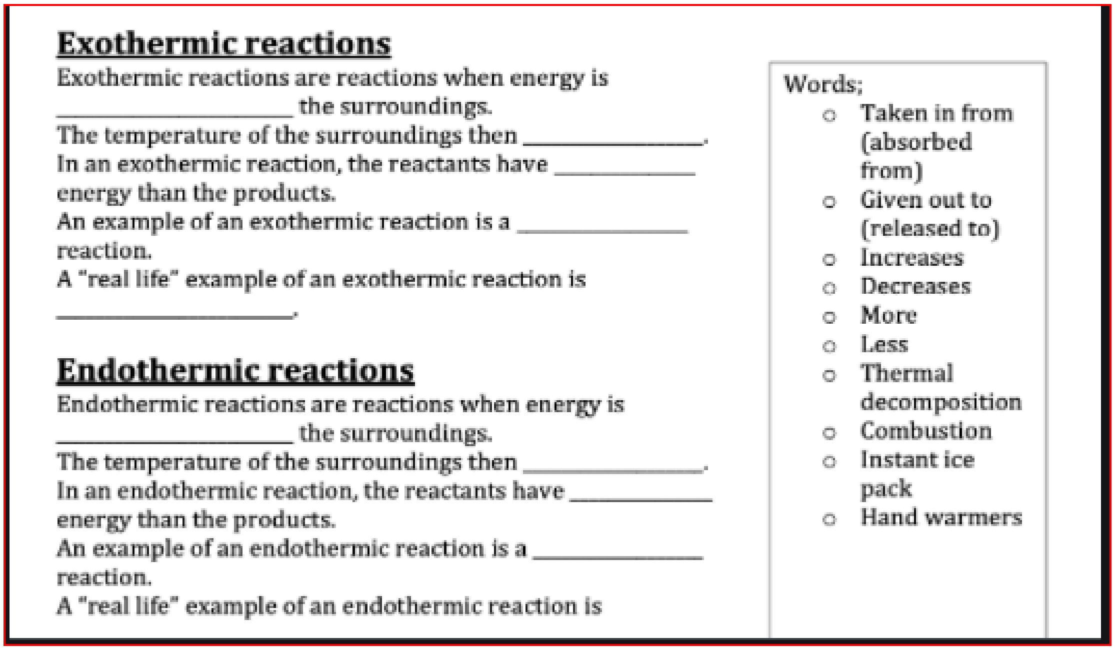
Activities

1.

Identify the system and the surrounding in the table given below

Cases	system	surrounding
Student is observing aqueous solution of sodium hydroxide in a test – tube	Aqueous solution of sodium hydroxide solution	Space outside of the test – tube
Mixing of aqueous solution of silver nitrate and hydrochloric acid		

2. Fill in the Blanks



Exothermic reactions

Exothermic reactions are reactions when energy is ____________________ the surroundings.
The temperature of the surroundings then _______________.
In an exothermic reaction, the reactants have ____________ energy than the products.
An example of an exothermic reaction is a ______________ reaction.
A "real life" example of an exothermic reaction is ____________________.

Endothermic reactions

Endothermic reactions are reactions when energy is ____________________ the surroundings.
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An example of an endothermic reaction is a ______________ reaction.
A "real life" example of an endothermic reaction is

Words;
- Taken in from (absorbed from)
- Given out to (released to)
- Increases
- Decreases
- More
- Less
- Thermal decomposition
- Combustion
- Instant ice pack
- Hand warmers

3. List the **three** types of system.

Week 2 – 12th – 16th July, 2021

Achievement Indicators: Students should be able to:

- Define enthalpy change and perform calculations on enthalpy change related to it.

Enthalpy

Enthalpy is a measurement of energy in a thermodynamic system which is equivalent to the total heat content of a system.

Enthalpy Change (ΔH)

Enthalpy change is the heat change under constant pressure. It is also known as heat of reaction.

$$\Delta H = H_{\text{Products}} - H_{\text{Reactants}}$$

OR

$$\Delta H = H_f - H_i$$

Where:

H_f = heat of products

H_i = heat of reactants

Heat Capacity (C)

Heat capacity of an object is the amount of heat that will change the temperature of the object by 1 °C. It is also known as thermal capacity. It has units as joules per degrees Celsius (J/°C) or joules per kelvin (J/K).

$$\textbf{Heat Capacity} = \frac{\text{Heat absorbed or released}}{\text{Change in temperature}}$$

$$C = \frac{H}{\Delta T}$$

Units = J/°C or J/K

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Specific Heat Capacity (c)

Specific heat capacity of an object is the amount of heat that will change the temperature of 1 gram of the object by 1 °C.

$$\textbf{Specific Heat Capacity} = \frac{\text{Heat capacity}}{\text{Mass}}$$

$$c = \frac{C}{m}$$

Units = J/°C.g or J/K.g

Heat capacity (C) = specific heat capacity (c) x mass (g)

Rearranging:

$C = c \times m$

$H/ \Delta T = c \times m$

$\mathbf{H = m\, c\, \Delta T}$

For examples, please refer to the text book Chemistry for Year 13 page 129 – 130, Examples 1 and 2.

EXERCISE

1. When 2500 J of energy is supplied to 120 g of C2H5OH, the temperature increases from 13.5 °C to 23.5 °C. What is the specific heat capacity of C2H5OH in J/g.°C?

2. How much thermal energy needs to be added to change a 250 g block of polythene from 25 °C to 80 °C if the specific heat of polyethene is 2.3 kJ/g.°C?

3. The temperature of 200.0 g of water was lowered from 25.0 °C to 15.0 °C. Calculate the amount of heat lost during the process. (Specific capacity: Water = 4.18 J/g.°C)

For more exercises please refer to the textbook page : 131

Week 3 – 19th – 23rd July, 2021

Achievement Indicators: Students should be able to:

- Define calorimetry and identify the two types of calorimeter.

Calorimetry

Calorimetry is the science of measuring the quantities of heat that are involved in chemical or physical changes. Calorimeter is a device used to measure the enthalpy change of a chemical reaction. There are two types of calorimeter, coffee-cup calorimeter and bomb calorimeter.

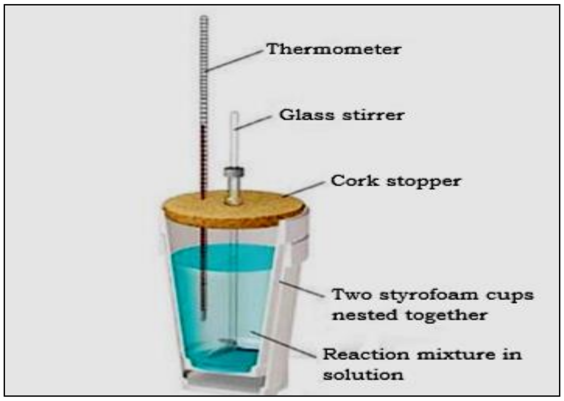
1. Coffee-cup Calorimeter

- It is one of the simplest type of calorimeter.
- It is used to determine the heat of solution.

Heat of solution is the energy released or absorbed when the solute dissolves in the solvent.

Heat of solution = mass$_{water}$ × specific heat capacity × change in temperature

$$= m_{water} \times c \times \Delta T$$



- It consists of a capped cup made of Styrofoam.
- Reaction occurs at constant pressure.
- Two solutions of known volume containing the reactants at the same temperature are mixed in the calorimeter.
- From the heat capacity of the contents in the calorimeter and the change in temperature (either increase or decrease), heat of reaction can be calculated.

Components of a Coffee-Cup Calorimeter

1. Styrofoam cup – prevents heat being lost to the surrounding and contains either pure solvent or solution.
2. Glass stirrer – ensures thorough mixing so that the temperature of the solution, as measured by the thermometer, is the same for all locations within the calorimeter.

EXAMPLE:

When 5.00 g of CaCl2 is dissolved in 100 g of water in a coffee-cup calorimeter, the temperature changes from 22.3 °C to 30.2 °C. Calculate the heat of solution in kJ. Assume that the specific heat of water is 4.18 J/g.°C and that no heat is transferred to the surrounding or to the calorimeter.

Solution:

Heat of solution = mass × specific heat capacity × change in temperature

$$= m \times c \times \Delta T$$

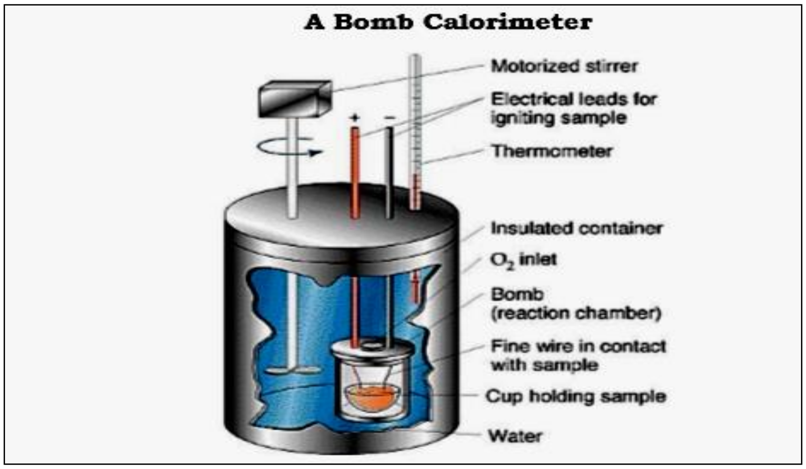
$$= 100g \times 4.18\ J/g^0C \times (30.2 - 22.3)^0\ C$$

$$= 3.30 \times 10^3\ J$$

$$\mathbf{= 3.30\ kJ}$$

Bomb Calorimeter

- It is used to determine the enthalpy of combustion.
- Reaction occurs at constant volume.
- Some weighed amount of reactants are placed inside a rigid stainless steel container called a bomb.
- The bomb is sealed, filled with oxygen and is placed in a large insulated container of water.
- Reactants in the bomb are ignited by passing an electric spark that will heat up the surrounding air initiating the combustion reaction and the heat released due to combustion increases the temperature of the insulated container.

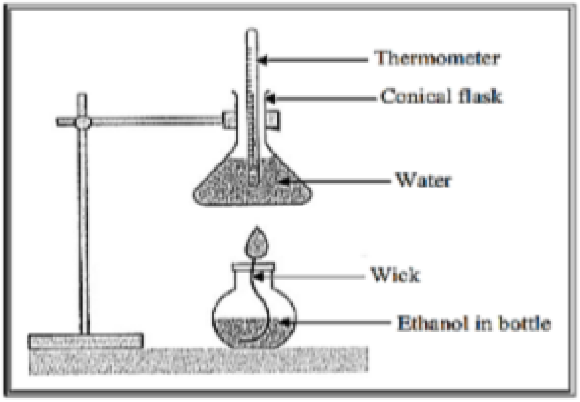


Components of Bomb Calorimeter

1. The bomb – is the inner steel container in which the sample will be combusted rapidly and completely using oxygen gas.
2. An electrical heater – it is inside the 'bomb' which is used to ignite the sample.
3. Stirrer – it circulates the water to ensure that the temperature of the water in different places within the container will be the same.
4. Thermometer – is used to record the initial temperature which is the temperature before the combustion reaction and the final temperature which is the maximum temperature reached after the combustion reaction.

ACTIVITY

3. A group of students measured the heat of combustion of ethanol using the equipment shown below.



The correct value for the heat of combustion of ethanol is 1.367 kJ mol^{-1}. The students' results show a heat of combustion of 0.254 kJ mol^{-1}.

a. Provide a reason for the difference in the value.

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b. Suggest one way of improving the set up for a more accurate result.

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Week 4 – 26th – 30th July, 2021

Achievement Indicators: Students should be able to:

- Define standard heat of reaction, standard heat of formation and standard heat of combustion.

STANDARD ENTHALPY OF REACTION ($\triangle H^0$)

This is the change in enthalpy during a chemical reaction.

$$\boxed{\Delta H^\circ_{(reaction)} = \sum \Delta H^\circ_{f\,(products)} - \sum \Delta H^\circ_{f\,(reactants)}}$$

H^0 refers to standard conditions which are:
Pressure of 101.3 kPa or 1 atm , A temperature of 298K
Eg1 .The following reaction,
$C_2H_4 + H_2O \rightarrow C_2H_5OH \qquad \triangle H^0 = -44kJ / mol$

can be read as :*When **1 mol** (/ mol) of **C_2H_4** reacts with **1 mole of water** to form **1 mole of C_2H_5OH** under **standard conditions** (H^0) , 44kJ of energy is **released** (-).*
For example please refer page 136 of the textbook

STANDARD ENTHALPY OF FORMATION ($\Delta H^0{}_f$)

This is the energy absorbed or released when:
- One mole of product is formed from its elements
- All measurements are under standard conditions

Eg 1 the following equation,
$\frac{1}{2} N2 + 1\frac{1}{2} Cl_2 \rightarrow NCl_3 \qquad (\Delta H^0{}_f) = + 230kJ /mol$

can be read as : when 1 mole of NCl_3 is formed from its elements (N_2 & Cl_2) in their standard states, 230kJ of energy is absorbed.
For example please refer to the example 1 and 2 on page 137 of the textbook

STANDARD ENTHALPY OF COMBUSTION ($\Delta H^0{}_c$)

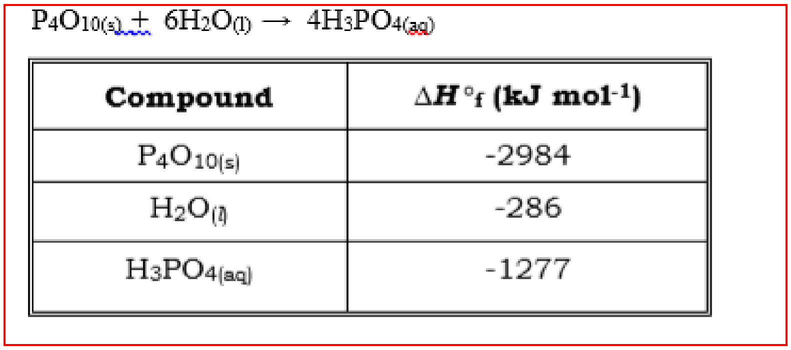
This is the energy released when:
- One mole of a substance is completely burnt in oxygen
- All measurements are made under standard conditions

Eg.The following reaction,
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \qquad (\Delta H^0 c) = -890kJ /mol$

Can be read as:
1 mole of methane under standard conditions is completely burnt in air to form products, releasing 890kJ of energy.

ACTIVITY

1.0 Calculate standard heat for the reaction of $P_4O_{10(s)}$ with water to form phosphoric acid using the standard heat of formation given below.

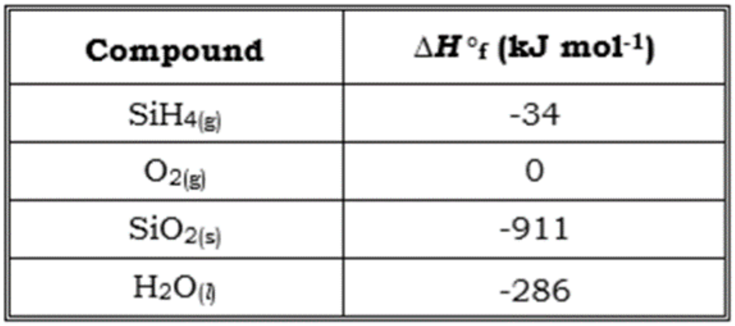


$P_4O_{10(s)} + 6H_2O_{(l)} \rightarrow 4H_3PO_{4(aq)}$

Compound	ΔH°_f (kJ mol^{-1})
$P_4O_{10(s)}$	-2984
$H_2O_{(l)}$	-286
$H_3PO_{4(aq)}$	-1277

2.0 Silane burns in air to produce silicon dioxide and water.

$SiH_{4(g)} + 2O_{2(g)} \rightarrow SiO_{2(s)} + 2H_2O_{(l)}$



Compound	ΔH°_f (kJ mol^{-1})
$SiH_{4(g)}$	-34
$O_{2(g)}$	0
$SiO_{2(s)}$	-911
$H_2O_{(l)}$	-286

3.0 Consider the following enthalpy data:

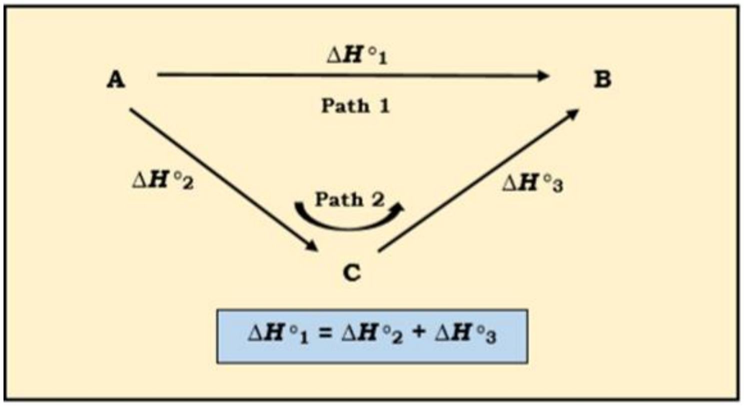
ΔH^0 c $(H_{2(g)})$ = -282 $kJmol^{-1}$
ΔH^0 f $(H_2O_{(g)})$ = -282 kJmol-1

i) Explain what is meant by : ΔH^0 c $(H_{2(g)})$ = -282 $kJmol^{-1}$

ii) Account for the fact that the two values of ΔH^0 c $(H_{2(g)})$ = -282 kJmol-1 ΔH^0 f $(H_2O_{(g)})$ = -282 kJmol-1 are equal

Week 5 – 2nd – 6th August, 2021
Achievement Indicators: Students should be able to:
Explain Hess's Law

Hess's Law states that in going from a particular set of reactants to a particular set of products, the enthalpy change is the same whether the reaction takes place in one step or a number of steps.
According to Hess's Law, we can add thermochemical equations, including their ΔH^0 values, to obtain a desired chemical equation and its $\Delta H^{0.}$



NOTE :

a. When thermochemical equation is reversed, the sign of $\triangle H^0$ must be reversed.
b. If all the coefficients of an equation are multiplied or divided by a factor, the value of $\triangle H^0$ must be multiplied or divided by the same factor.

Eg.1 Given the following standard heats of reaction, calculate the heat of formation of CO.

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -393kJ/mol$

$CO_{(g)} + \frac{1}{2}O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -282kJ/mol$

$C + \frac{1}{2}O_2 \rightarrow CO$ $\Delta H_f(CO) = ?$

Manipulate equations so that the equations add up to give the required equation.

- **Leave equation 1**

  $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -393kJ/mol$

- **Reverse equation 2**

$CO_2(g \rightarrow CO(g) + \frac{1}{2}O_2(g))$ $\Delta H = 282kJ/mol$

- **Add the equations**

  $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -393kJ/mol$

  $CO_{2(g} \rightarrow CO_{(g)} + \frac{1}{2}O_{2(g))}$ $\Delta H = 282kJ/mol$

$C + \frac{1}{2}O_2 \rightarrow CO$ $\Delta H = -111 kJ/mol$

ACTIVITY

1.0 From the following data, calculate the heat of reaction for the water gas reaction:

$C_{(s)} + H_2O_{(g)} \rightarrow CO_{(g)} + H_{2(g)}$ Given that :

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -394$ kJ/mol

$H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(g)}$ $\Delta H = -242$ kJ/mol

$CO_{(g)} + \frac{1}{2}O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -282$ kJ/mol

2.0

2. The powerful rocket fuel, hydrazine(N_2H_4) reacts with the oxidizing agent, dinitrogentetraoxide, according to the equation:

$2N_2H_4 + N_2O_4 \rightarrow 3N_2 + 4H_2O$

Calculate the enthalpy change for the reaction above, given the following data for standard molar enthalpies of formation.

$\Delta H_f^0{}_{(N2H4)} = 50$ kJ/mol

$\Delta H_f^0{}_{(N2O4)} = -20$kJ/mol

$\Delta H_f^0{}_{(H2O)} = -242$kJ/mol

3.0 Define Hess's Law