3055 BA SANGAM COLLEGE

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WORKSHEET 21

School: Ba Sangam College **Year:** 13

Subject: Chemistry **Name:**

Strand	**3- Reactions**
Sub strand	**3.2- Thermo chemistry**
Content Learning Outcome	**-Define a system and a surrounding** **-Describe the three types of 'system' associated with thermo-chemistry** **-Define enthalpy change and perform calculations on enthalpy change related to it.**

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

1. **Open system** – is a system where the energy and the matter can be transferred in and out of the system. Example,burning rubbish.
2. **Closed system** – is a system where only energy can be transferred out of the system. Example, cooking curry.
3. **Isolated system** - is a system where neither energy nor matter can be transferred. Example, a bomb calorimeter.

Note:

A system is defined in terms of properties or functions like pressure, temperature, volume, heat, enthalpy and entropy.

Heat of Reactions

Heat of reaction is the change in the enthalpy of a chemical reaction that occurs at a constant pressure.

Types of Reactions

1. Exothermic Reaction

-Reaction in which energy is released into the surrounding, therefore the temperature of the system decreases.

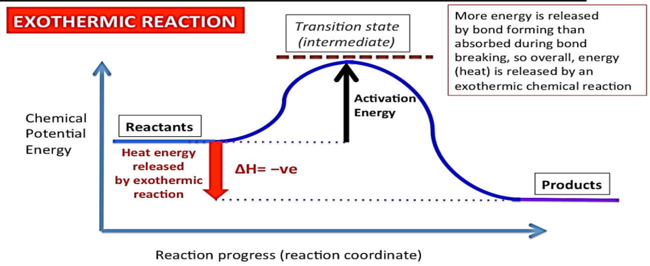
-Since heat is released, the products have less energy than the reactants.

-Energy flows from the system to the surrounding, thus surrounding becomes warmer.

-Has a negative value for change in enthalpy.

In an exothermic reaction, energy is released into the surrounding as heat. As a result, the temperature of the surrounding increases.

Reaction Profile of an Exothermic Reaction



2. Endothermic Reaction

-Reaction in which energy is absorbed from the surrounding, therefore the temperature of the system increases.

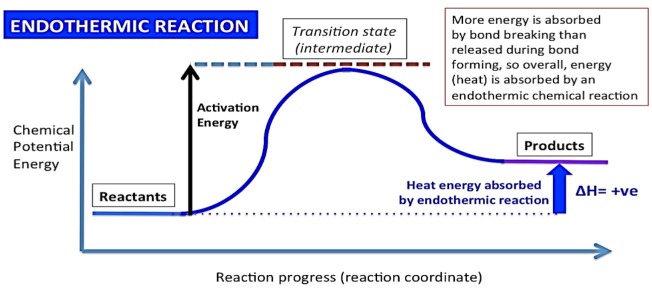
-Since heat is absorbed, the heat energy of the products is higher than the heat of the reactants.

-Energy flows from the surrounding to the system, therefore the surrounding becomes cooler.

-Has positive value for change in enthalpy.

In an endothermic reaction, energy is absorbed from the surrounding. As a result, the temperature of the surrounding decreases.

Reaction Profile of an Endothermic Reaction



Summary

Endothermic Reaction	Exothermic Reaction
✓ Products have higher potential energy than the reactants.	✓ Products have lower potential energy than the reactants.
✓ ΔH is positive.	✓ ΔH is negative.
✓ Heat is absorbed from the surrounding.	✓ Heat is released to the surrounding.
✓ Temperature of surrounding decreases.	✓ Temperature of surrounding increases.
✓ Reaction container becomes cool.	✓ Reaction container becomes warm.

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.

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

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 ℃. It

is also known as thermal capacity. It has units as joules per degrees Celsius (J/℃) or joules per kelvin

(J/K).

$$C = \frac{\text{Heat absorbed or released}}{\text{Change in temperaature}}$$

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

Units = J/℃ or J/K

Specific Heat Capacity (c)

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

$$c = \frac{\text{Heat capacity}}{\text{Mass}}$$

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

Units = J/℃.g or J/K.g

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

Rearranging:

$$C = c \times m$$

$$\frac{H}{\Delta T} = c \times m$$

$$H = m\,c\,\Delta T$$

Example: Reference 2019

1. Bond energy values can be used to determine the **enthalpy change** (ΔH°) for a reaction. Consider the reaction equation and the bond energy values given below to answer the questions that follow.

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)} \quad \Delta H^\circ = ?$$

Bond	H–H	O=O	O–H
Energy (kJ mol^{-1})	436	498	463

(i) Calculate the **enthalpy change** (ΔH°) for the above reaction using the bond energy values from the table. **(2 marks)**

(ii) State whether the above reaction is **endothermic** or **exothermic** with reference to the enthalpy change (ΔH°) value calculated in part (i) above. **(1 mark)**

Answer:

(i) ΔH° = (Total energy required to break reactants bond) - (Total energy released in product bond formation)

$= (\Delta H^\circ_{BE(H-H)} + (\Delta H^\circ_{BE(O=O)}) - (\Delta H^\circ_{BE(O-H)})$

$= [2(436) + 498] – [4(463)]$

$= 1370 - 1852$

$= -482$ kJ mol^{-1}

(ii) Exothermic

Reference: 2018

c) Use the table on bond energy values below to answer the questions that follow.

Bond	C=C	C–C	C–H	H–H
Energy (kJ mol^{-1})	614	346	413	436

(i) State why the bond energy value for each of the bonds is positive. **(1 mark)**

Answer

✓ **Energy is absorbed when bonds are broken**. (1 mark) **OR**;

✓ **Bond energy values measure the amount of energy required/absorbed during breakdown of a chemical bond**. (1 mark)

(ii) Calculate the **enthalpy change** (ΔH°) for the reaction given below using the bond energy values from the table. **(2 marks)**

$$H_2C{=}CH_{2(g)} + H_{2(g)} \longrightarrow H_3C{-}CH_{3(g)}$$

Answer

ΔH° = **(Total energy required to break reactants bond) - (Total energy released in product bond formation)**

$= (\Delta H^\circ_{BE(C=C)} + \Delta H^\circ_{BE(H-H)}) - (\Delta H^\circ_{BE(C-C)} + \Delta H^\circ_{BE(C-H)})$

$= (614 + 436) - (346 + 2 \times 413)$

• 1 mark for any two steps.

$= 1050 - 1172$

$= \underline{-122 \text{ kJ}}$ (1 mark for final answer; -½ mark if negative sign missing)

OR;

ΔH° = **(Total energy in reactants bond) - (Total energy in products bond)**

$= (\Delta H^\circ_{BE(C=C)} + \Delta H^\circ_{BE(C-H)} + \Delta H^\circ_{BE(H-H)}) - (\Delta H^\circ_{BE(C-C)} + \Delta H^\circ_{BE(C-H)})$

$= (614 + 4 \times 413 + 436) - (346 + 6 \times 413)$

• 1 mark for any two steps.

$= 2702 - 2824$

$= \underline{-122 \text{ kJ}}$ (1 mark for final answer; -½ mark if negative sign is missing)

2, 1½, 1, ½ or 0

- Students should realise that the enthalpy change (ΔH°) for a reaction is obtained by:

  ΔH° = Energy absorbed - Energy released ;

- **Energy is absorbed in breaking of reactants bonds and energy is released by products during bond formation.**

Reference: 2017

Consider the reaction given below.

$$H_{2(g)} + F_{2(g)} \longrightarrow 2HF_{(g)}$$

Calculate the **enthalpy change** (ΔH°) for the above reaction using the following bond energy values.

Bond	H – H	F – F	H – F
Energy (kJ mol^{-1})	432	154	565

2 marks

Answer and Additional Notes

ΔH° = (Total energy required to break reactants bond) – (Total energy released in product bond formation)

= $(\Delta H^\circ_{BE(H-H)} + \Delta H^\circ_{BE(F-F)}) - (\Delta H^\circ_{BE(H-F)})$

= (432 + 154) – (2 x 565) (1 mark)

= 586 - 1130

= -544 kJ (1 mark)

- To answer this question students need to use the bond energy values to :
  - Add the energy for bonds broken (reactants bonds are broken: H_2 and F_2)
  - Add the energy for bonds formed (products bonds are formed: 2HF)
  - Use the equation to get the final energy value.

Reference: 2016

In thermochemical reactions, heat energy either flows from the reaction mixture to the surrounding or from the surrounding into the reaction mixture.

Name the type of thermochemical reaction where heat energy flows from the reaction mixture to the surrounding and indicate the sign of ΔH.

Answer

✓ Name - **Exothermic Reaction** (½ mark)
✓ Sign - **Negative OR** (-) (½ mark)

Reference: 2015

When a 13.9 g sample of solid sodium hydroxide dissolves in 250.0 g of water in a coffee-cup calorimeter, the temperature increases from 23.0 °C to 37.0 °C. Calculate the amount of heat released in this process. Assume that the solution has the same specific heat as liquid water, i.e., 4.18 J g^{-1} °C^{-1}. **(2 marks)**

Answer

Heat released by the solution = mcΔT (½ mark)

= 263.9 g × 4.18 J g^{-1} °C^{-1} × (37.0 – 23.0) °C (1 mark)

= 15443.43 J OR 15.44 × 10^3 J OR 15.44 kJ (½ mark)

Exercise

1. 88.2 J of heat raises temperature of 45.8 g lead by 15 ℃. Calculate the specific heat capacity of lead?

2. The following results were obtained for combustion of ethanol in the laboratory:

Volume of water in the calorimeter = 400 mL
Initial temperature of water = 33 °c
Final temperature of water = 44 °c
Mass of ethanol burnt = 1.95 g
Specific heat capacity of water = 4.2 J/g.K
***M* of ethanol = 46 g/mol**

Calculate the heat required to raise the temperature of water from 33℃ to 44 ℃.

3. 89.3 J of heat is required to raise the temperature of 10 g of copper by 100 ℃.

   Calculate the heat capacity of copper?

4. A gold ring with a mass of 5.5 g changes in Temperature from 25.0 ℃ to 28.0 ℃. How much energy in joules has it absorbed? (Specific heat capacity = 0.129 J/g.℃)

5. The temperature of 250 g of water is changed from 25 ℃ to 30 ℃. How much energy (kJ) was transferred into the water? (Specific heat capacity of water = 4.2 J/g.℃)

6. How much energy (in joules) is needed to increase the temperature of 15.0 g of Fe from 20.0 ℃ to 40.0 ℃?

   (Specific heat capacity of Fe = 0.45 J/g.℃)

7. A sample of copper was heated to 120 ℃ and then thrust into 200 g of water at 25.00 ℃. The temperature of the mixture became 26.50 ℃.

(Specific capacity: Water = 4.2 J/g.℃ ;

Copper = 0.387 J/g.℃)

a. How much heat in joules was absorbed by the water?

b. How much heat in joules is lost by the copper sample?

c. What was the mass in grams of the copper sample?

Calorimetry

Is the science of measuring the amount of heat.
Is the science of using calorimeters and obtaining heats of reaction.

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

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

Components of a Coffee-Cup Calorimeter

- **Styrofoam cup** – prevents heat being lost to the surrounding and contains either pure solvent or solution.
- **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.

Note:

It is assumed that the heat absorbed by the styrofoam is negligible.

Example

When 5.00 g of $CaCl_2$ 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.K and that no heat is transferred to the surroundings or to the calorimeter.

Solution

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

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

$= (100)\ \cancel{g} \times 4.18\ J/\cancel{g}.\cancel{°C} \times (30.2 - 22.3)\ \cancel{°C}$

$= 3.30 \times 10^3$ J

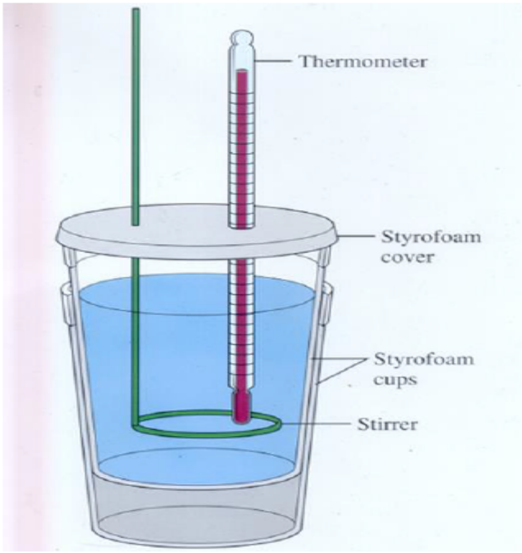
= 3.30 kJ

When 5.00 g of $CaCl_2$ is dissolved, 3.30 kJ of heat is released.

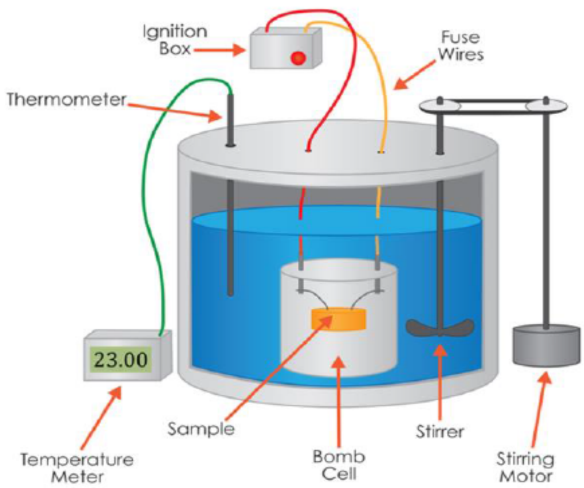
2. Bomb Calorimeter

- 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.

Coffee-cup calorimeter



Bomb calorimeter



Components of Bomb Calorimeter

- **The bomb** – is the inner steel container in which the sample will be combusted rapidly and completely using oxygen gas.
- **An electrical heater** – it is inside the 'bomb' which is used to ignite the sample.
- **Stirrer** – it circulates the water to ensure that the temperature of the water in different places within the container will be the same.
- **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.