Theme: ***Thermochemistry***

Topic 18: ENERGY CHANGES DURING CHEMICAL REACTIONS

Energy changes normally occur every time chemical changes take place.

Energy is neither created nor destroyed but is can be transformed from one form to another.

For example

1. In electrochemical cells, chemical energy is transformed to electrical energy

2. Fuel like coal store chemical energy which is transformed into heat energy when the fuel is burnt.

3. The chemical energy is food is transformed into heat energy during metabolism to facilitate body processes.

The most common form of energy change in chemical reactions is the ***heat changes***.

All chemical substances possess chemical energy stored in bonds that connect atoms in a compound.

The energy content (heat content) of a substance which is stored in its bonds is referred to as **Enthalpy**

Also, energy has to be supplied if bonds are to be broken.

The enthalpy of a substance is denoted by **H**.

Changes in enthalpy are denoted by **ΔH**

Enthalpy changes occur in a reaction when some old bonds in the reactants are broken and new bonds are formed in the products

ACTIVITY

You are provided with the following chemicals and apparatus

- *Dilute hydrochloric acid (2M HCl)*
- *Zinc granules*
- *Calcium oxide*
- *Ammonium chloride crystals*
- *Sodium hydroxide pellets*
- *Distilled water*
- *Thermometer*
- *4 Beakers labeled A, B, C and D*
- *Spatula*
- *4 test tubes*

Procedure

- Put ***dilute hydrochloric acid*** in a beaker labeled **A**.
- Put ***distilled water*** in a beaker labeled **B**
- Read and record the ***initial temperatures*** of both solutions
- In beaker **A**, put ***zinc granules*** using a spatula
- In beaker **B**, put ***calcium oxide*** using a spatula.
- Read and Record the ***final temperatures*** of both solutions
- Put $100cm^3$ of ***distilled water*** in beaker labeled **C**.
- Put $100cm^3$ of ***distilled water*** in beaker labeled **D**.
- In beaker **C**, put one spatula endful of ***ammonium chloride crystals***
- In beakers **D**, put one spatula endful of ***sodium hydroxide pellets*** and stir
- Read and record the ***final temperatures*** of both solutions.
- Record your results in the table below.

Substance	*Initial temperature (^oC)*	*Final temperature (^oC)*
A		
B		
C		
D		

TASKS:

1. Which reactions produced heat?

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2. Which reactions absorbed heat?

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3. List two uses of heat in everyday life.

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Reactions are categorized into two depending on whether *there is release of heat to the surrounding* or *absorption of heat from the surrounding.*

The reaction during which heat is liberated to the surrounding is called ***exothermic reaction.***

The reaction during which heat is absorbed from the surrounding is called ***Endothermic reaction***.

EXOTHERMIC REACTIONS

An exothermic reaction is one during which heat is liberated to the surrounding.

During exothermic reaction, *heat is given out* and therefore, the temperature of the products rises above room temperature, but with time, it drops to room temperature as heat is lost to the surrounding

At the end of the reaction, ***the heat content of the products is less than that of the reactants.***

Therefore, the enthalpy (heat) change of an exothermic reaction is *negative*

ΔH = *Heat content of products – Heat content of reactants.*

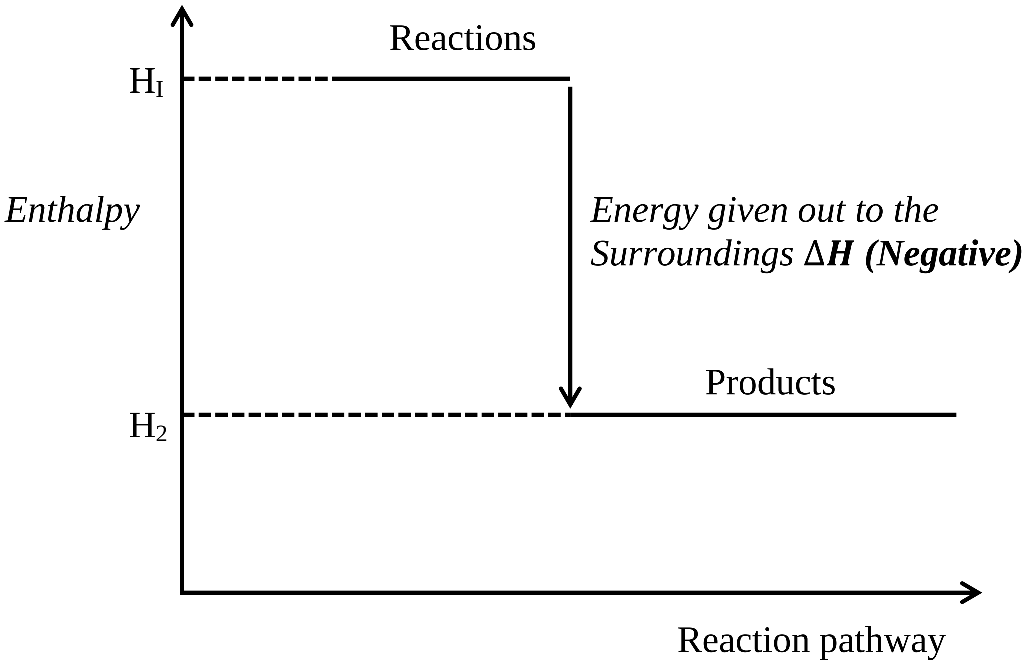
If: H_1 = Is the heat content of reactants

H_2 = Is the heat content of products

Then; $\Delta H = H_1 - H_2$

Since the heat content of products (H_2) is less than the heat content of reactants (H_1), that is to say $\mathbf{H_2 < H_1}$, then it means that Δ***H is negative.***

This can be represented on an energy level diagram.

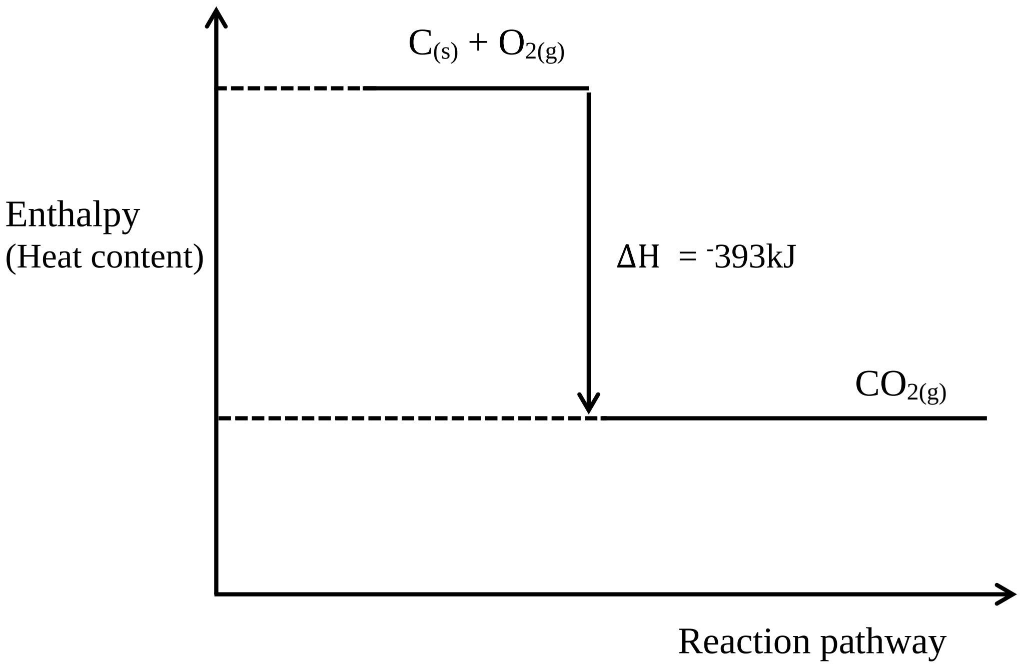


An example of exothermic reaction is when carbon reacts with oxygen. In such a reaction, heat is evolved

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \qquad \Delta H = {}^{-}393kJ$$

The chemical energy in carbon and oxygen is partly transferred to chemical energy in carbon dioxide and partly evolved as heat. This means that carbon dioxide has less energy than the starting material that is carbon and oxygen; thus the value of enthalpy change is negative.

Energy level diagram to represent the reaction.



NOTE:
Bond making involves the ***liberation of heat to the surroundings*** implying that it is an ***exothermic process***.

Examples of Exothermic Reactions or Processes In Everyday Life.

1) Cellular respiration

This is a vital exothermic reaction that occurs in living cells of the body. This process provides energy to the body cells to maintain the other vital processes of the body. During this process, glucose molecules are broken down in the body living cells into carbon dioxide, water molecules and energy is released.

$$C_6H_{12}O_{6(aq)} + 6O_{2(g)} \longrightarrow 6CO_{2(g)} + 6H_2O_{(l)} + energy$$

The energy released during the break down of sugar is used in the synthesis of Adenosine triphosphate (ATP) which is the energy carrier molecule of the cells.

2) *Rusting of iron*

In the process, heat is released when ***iron*** comes into contact with ***oxygen*** and ***water*** to form Hydrated iron(Ⅲ) oxide.

3) *Fermentation*

Fermentation is the process by which sugars (for example ***glucose***) are decomposed by enzymes (for example ***zymase***) produced by microorganism (for example ***yeast***) forming ***ethanol***, ***carbon dioxide*** and ***energy***.
Fermentation can also mean incomplete oxidation of glucose in the absence of oxygen.
Fermentation is an exothermic reaction, meaning that the process releases energy in form of heat.

4) *Making an ice cube*

This is the process of a liquid changing its state to a solid. Changing water into ice cube is an exothermic reaction, since the water slowly loses heat and starts to cool down to form ice cubes.

5) *Combustion*

This refers to a chemical reaction in which a substance reacts with oxygen
In this kind of reaction, heat energy is released to the surrounding. For example, when wood is burnt in oxygen, large amount of heat energy is produced.

6) *Snow formation of clouds*

Clouds cone into existence from the condensation of water vapour. This process is an exothermic reaction.

7) *Burning of candle*

The candle is a hydrocarbon which burns in oxygen to form carbon dioxide and water. This process evolves heat to the surrounding.

Other examples of exothermic reactions include:-

- Laundry detergent
- Decomposition of vegetables
- Neutralization reaction
- Nuclear fission
- Cold packs to heal an injury
- Reaction of water and calcium chloride
- Dissolving a strong acid in water.

ENDOTHEMRIC REACTIONS

Endothermic reaction is one during which heat is absorbed from the surroundings.

When an endothermic reaction occurs, the heat required for the reaction is taken from the reacting materials and the temperature of the products falls below the initial temperature.

Eventually, the temperature of the products raises to room temperature again as heat is absorbed form the surrounding.

In this case, the heat content of the product is greater than that of the reactants and the enthalpy change is ***positive.***

ΔH = Heat content of products – Heat content of reactants.

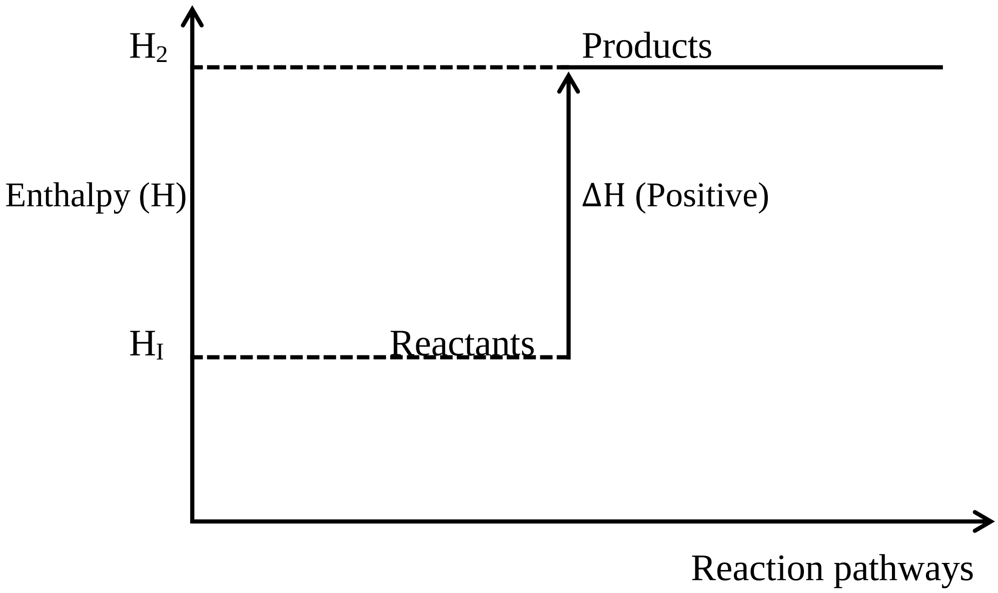
If: H_1 = Is the heat content of reactants

H_2 = Is the heat content of products

Then; $\Delta H = H_1 - H_2$

Since the heat content of products (H_2) is greater than the heat content of reactants (H_1), that is to say $H_2 > H_1$ then the ***ΔH is positive***

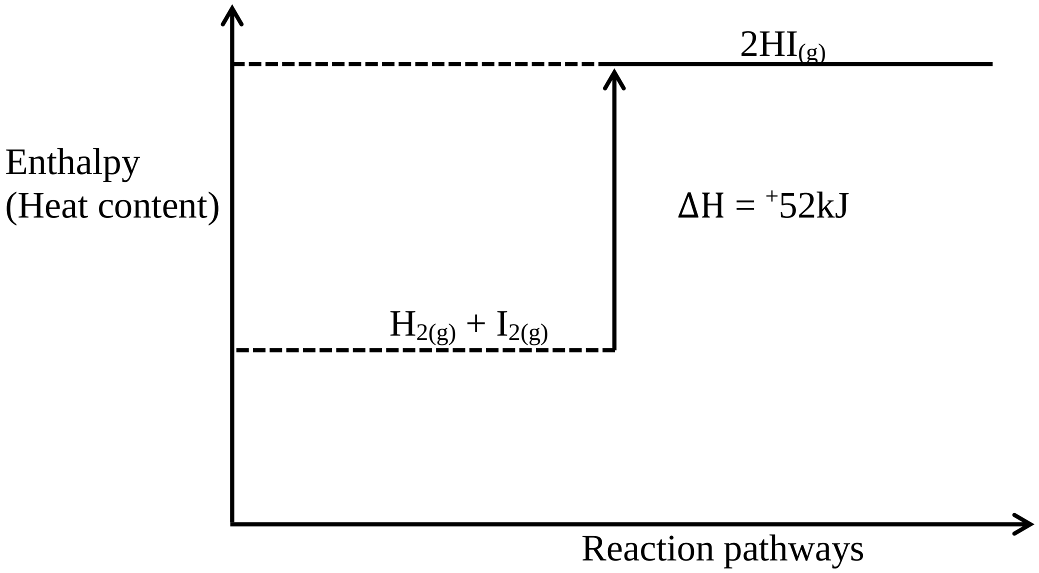
This can be represented on an energy level diagram



For example, when hydrogen reacts with iodine, heat is absorbed from the surroundings.

$H_{2(g)} + I_{2(g)} \longrightarrow 2HI_{(g)} \qquad \Delta H = +52kJ$

Hydrogen iodide has more energy than the starting materials, Hydrogen and iodine. Therefore the value of enthalpy change is positive.



NOTE:
Bond breaking requires the ***absorption of heat from the surroundings*** implying that it is an ***endothermic process***.

Examples of Endothermic Reactions or Processes in Everyday Life

1) Melting of ice

Heat is absorbed to convert ice into liquid water

$H_2O_{(s)} \longrightarrow H_2O_{(l)}$

2) Dissolving ammonium nitrate in water.

This dissolution process absorbs heat from the surrounding.

$NH_4NO_{3(s)} + {}_{(aq)} \longrightarrow NH_4^{+}{}_{(aq)} + NO_3^{-}{}_{(aq)}$

3) Photosynthesis

This is an endothermic process because it requires energy from sunlight.

$6CO_{2(g)} + 6H_2O_{(l)} \xrightarrow[\text{chlorophyll}]{\text{Sunlight}} C_6H_{12}O_{6(aq)} + 6O_{2(g)}$

4) Thermal decomposition of calcium carbonate.

Heat is needed to break down calcium carbonate into calcium oxide and carbon dioxide

$CaCO_{3(s)} \xrightarrow{\text{Heat}} CaO_{(s)} + CO_{2(g)}$

5. Dissolving ammonium chloride in water.

This process absorbs heat from the surrounding, thus it is an endothermic process.

$NH_4Cl_{(s)} \quad + \quad _{(aq)} \longrightarrow NH_4^+{}_{(aq)} \quad + \quad Cl^-{}_{(aq)}$

6. Electrolysis of water

This process requires an input of electrical energy, making it an endothermic process.

$2H_2O_{(l)} \longrightarrow 2H_{2(g)} \quad + \quad O_{2(g)}$

7. Sublimation of dry ice (Solid carbon dioxide).

Dry ice sublimates at a temperature below room temperature, absorbing heat.

$CO_{2(s)} \longrightarrow CO_{2(g)}$

8. Thermal decomposition of hydrogen peroxide.

Breaking down hydrogen peroxide into water and oxygen requires intake of heat

$2H_2O_{2(l)} \longrightarrow 2H_2O_{(l)} \quad + \quad O_{2(g)}$

9. Dissolving sodium chloride (common salt) in water.

This dissolution process absorbs heat energy from the surrounding, resulting into temperature fall.

$NaCl_{(s)} \quad + \quad (aq) \longrightarrow Na^+{}_{(aq)} \quad + \quad Cl^-{}_{(aq)}$

10. Cooking an egg

The process of cooking is an endothermic reaction.

For example, during the process of frying eggs, heat energy from the hot frying pan is absorbing by the raw eggs, hence making the process to be endothermic.

Other examples of endothermic processes include:-

- Reacting ethanoic acid and sodium carbonate.
- Reacting baking soda (sodium bicarbonate) and vinegar (acetic acid)
- Melting of ice to water

Differences between Endothermic and exothermic Reactions

Endothermic reactions	***Exothermic reactions***
These are reactions during which heat is absorbed from the surroundings	These are reactions during which heat is liberated to the surroundings
Enthalpy changes of endothermic reactions are positive	Enthalpy changes of exothermic reactions are negative
Endothermic reactions result from bond breaking	Exothermic reactions results from bond making

Activity One

Exploring the reactions or processes in which energy is given out or absorbed.

a) Complete the table below by stating whether the reaction given is endothermic or exothermic.

Reaction	***Is energy absorbed?***	***Endothermic/ Exothermic?***
Fermentation		
Respiration		
Cooking an egg		
Burning salt in water		
Melting ice cubes		
Neutralization		
Decomposition		

b) State any other five reactions in which energy is

i) absorbed	***ii) given out***

Activity two

Exploring changes in temperature as different substances dissolve in water.

What you are required to do:

i) Label small plastic cups with
- ✓ *Potassium chloride*
- ✓ *Calcium chloride*
- ✓ *Sodium carbonate*
- ✓ *Sodium hydrogen carbonate*
- ✓ *Ammonium nitrate*
- ✓ *Sodium hydroxide*

ii) Add **150cm^3** of water into the cup labeled '***potassium chloride***" and measure its temperature using a thermometer. Record the temperature in the table as ***initial temperature* (T_o)**

iii) Weigh **2g** of potassium chloride and add it to the cup in step (ii) above. Stir the mixture until the temperature stops changing and record the ***final temperature*** **(T_f)** in the table.

iv) Repeat steps (ii) to (iii) using the cups labeled '*calcium chloride*' '*sodium carbonate*' '*sodium hydrogencarbonate*' '*ammonium nitrate* and '*sodium hydroxide*'. Weigh and add the solutes to their corresponding cups.

Table: Temperature changes in some chemical reactions

Experiment	***Solid***	**T_o (°C)**	**T_f (°C)**
1	Potassium chloride		
2	Calcium chloride		
3	Sodium carbonate		
4	Sodium hydrogen carbonate		
5	Ammonium nitrate		
6	Sodium hydroxide		

Observation and Analysis

1. Which solutes dissolved endothermically?

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2. Which solutes dissolved exothermically?

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3. Which solute dissolved most exothermically?

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4. Which solute dissolved most endothermically?

Importance of Endothermic Reactions in Everyday Life

The significance of endothermic reactions in our everyday life stretch from *household applications* to *industrial processes* and *medical treatments.*

Endothermic reactions have significant importances in our everyday life, and these include the following:

1) Cooling systems:

Refrigeration and air conditioning rely on endothermic reactions to absorb heat and cool the surroundings

2) Food preparation:

Cooking and baking involve endothermic reactions to break down ingredients and create desired textures and flavors.

3) Energy storage:

Batteries and fuel cells use endothermic reactions to store energy for later use.

4) Medical applications:

Some medical treatments, for example cancer therapy, utilize endothermic reactions to target and destroy cancer cells.

5) Environmental remediation:

Endothermic reactions can help to clean pollutants from soil and water.

6) Material synthesis

Endothermic reactions are used to create materials like cement, glass and steel.

7) Water treatments

Endothermic reactions help to purify water by removing impurities and contaminants.

8) Pharmaceuticals:

Endothermic reactions are involved in the productions of some mediation.

9) *Food preservation:*

Endothermic reactions help to preserve food by inactivating enzymes and microorganisms.

10) *Scientific research;*

Endothermic reactions are essential in various scientific experiments and investigations.

Importances of Exothermic Reactions in Everyday Life

The significance of exothermic reactions in our everyday life, stretch from *energy production* and *industrial processes* to *cooking* and *transportation*.

Exothermic reactions have significant importance in our everyday life, and these include the following;

1) *Energy production*

Combustion reactions, for example burning fossil fuels, provide energy for transportation, heating and electricity generation.

2) *Cooking and heating*

Exothermic reactions are used in cooking, heating of water and space heating

3) *Industrial process:*

Exothermic reactions are used in cement production, steel manufacturing and chemical synthesis.

4) *Transportation:*

Combustion reactions power internal combustion engines in cars, trucks and airplanes causing them to move.

5) *Food preparation:*

Exothermic reactions are used in baking, grilling and frying.

6) *Water treatments*

Exothermic reactions are used to disinfect water and break down organic matter.

7) *Medicine:*

Exothermic reactions are used in some medical treatments, like cancer therapy.

8) Welding and cutting

Exothermic reactions are used in welding and cutting of metals.

9) Catalytic converters

Exothermic reactions reduce emissions in the vehicle exhaust systems

10) Fuel cells:

Exothermic reactions generate electricity in fuel cells

ENERGY TRANSFORMATIONS

These are processes that convert energy from one form into another.

First law of thermodynamics (law of conservation of energy)

Energy is neither created nor destroyed but it can be transformed from one form to another.

Every useful process transforms energy from one form to another.

Examples of everyday energy transformations include the following:

1. Electricity to light:

Electric lamps transform electrical energy into light and heat energy.

2. Chemical energy to kinetic energy:

Gasoline is transformed into motion (kinetic) energy in cars.

3. Thermal energy to kinetic energy:

Heat from a stove is transformed into motion energy to cook food.

4. Kinetic energy to thermal energy

Brakes on a bike transform motion energy into heat energy.

5. Electrical energy to sound energy:

Speakers transform electrical energy into sound waves.

6. Chemical energy to thermal energy:

Food is transformed into energy for body use through digestion.

7. Solar energy to electrical energy:

Solar panels transform sunlight energy into electrical energy.

8. Kinetic energy to electrical energy

Generators transform motion energy into electrical energy.

9. Thermal energy to electrical energy;

Power plants transform heat energy into electrical energy

10.Mechanical energy to thermal energy:

Friction transforms motion energy into heat energy

ENERGY TRANSFORMATIONS IN BURNING ETHANOL

Ethanol is a ***fuel*** that has chemical energy stored in carbon – carbon (C-C) bonds, carbon – hydrogen (C-H) bonds and oxygen – hydrogen bonds (O–H)

Ethanol being a combustible fuel, it releases heat energy during combustion.

The *chemical energy* in ethanol is converted into *heat energy* when burnt and this is an example of an exothermic reaction.

Burning of ethanol releases heat energy and the enthalpy change (ΔH) value of this reaction is negative.

The chemical energy in ethanol is also transformed into *light energy* during combustion.

ENERGY TRANSFORMATION IN BURNING PARAFFIN

Paraffin is a group of alkanes. It is a mixture of different types of hydrocarbons with the general formula C_nH_{2n+2}.

Paraffin is a *by- product* of crude oil, which is a fossil fuel.

In fossil fuels, energy is stored in form of chemical energy, which is converted into heat and light energies when burnt.

ENERGY TRANSFROMATIONS IN BURNING WOOD

The chemical energy in wood is released as heat and light because of the chemical reaction between chemicals in wood (for example cellulose) and oxygen in air. This type of chemical reaction is called ***combustion*** and it requires oxygen.

Combustion converts the stored chemical energy in wood into heat and light energy.

THE FLOW OF ENERGY THROUGH AN ACOSYSTEM

Energy flow in an ecosystem involves reactions which are endothermic (photosynthesis) and those which are exothermic (respiration)

Endothermic reactions occur during photosynthesis, while exothermic reactions occur during consumption and decomposition. Energy flows from one trophic level to another, with some energy lost as heat at each level.

For example;

1) Producers (Endothermic):

Plants absorb light energy from the sun and convert it into chemical energy through photosynthesis (endothermic reaction).This energy is stored in organic compounds like glucose.

2) Herbivores (Exothermic)

Herbivores consume plants and breakdown the organic compounds into simpler molecules, releasing energy (exothermic reaction). The energy released is used for growth, maintenance, and reproduction.

3) Carnivores (Exothermic)

Carnivores consume herbivores and break down their organic compound, releasing energy (exothermic reaction). This energy is used for growth, maintenance, and reproduction.

4) Decomposers (Exothermic)

Decomposers break down dead organic matter, releasing energy (exothermic reaction). This energy is used by other organism in the ecosystem.

5) Energy loss (Exothermic):

Energy is lost as heat at each tropic level due to metabolic processes (Exothermic reactions)

6) Energy input (Endothermic)

The ecosystem receives energy input from the sun through photosynthesis (endothermic reaction), which supports the entire food web.

NOTE:

An ecosystem is a community of organisms and their physical environment interacting together to form a self-sustaining unit.

ENERGY FLOW DIAGRAM

Sun

↓

Plants (Producers)

↓ *Photosynthesis*

Glucose (Chemical energy)

↓ *Herbivory*

Herbivores (Primary consumers)

↓ *Consumption*

Carnivores (Secondary consumers)

↓ *Consumption*

Decomposers (Detritivores)

↓ *Decomposition.*

Nutrients (Energy released)

↓ *Energy loss*

Heat (Energy dissipated)

An Investigation to Compare the Heat Given Out When Different Fuels Burn

(For example: *Peanuts*, *Oils*, *paper* and *Wood*)

Title:	***Comparative Investigation of Heat released from Burning Peanuts, oils, paper and Wood.***	
Aim:	To determine and compare the heat released when peanuts, oils, paper and wood are burnt	
Hypothesis:	Wood releases the most heat per unit mass, compared to peanuts, oils and paper.	
Variables:	Dependent variable:	*Temperature*
	Control variable:	*Mass of fuel materials*
Materials:	✓ Peanuts ✓ vegetable oil ✓ paper (Newspaper) ✓ Wood ✓ Thermometer ✓ Heat – resistant container or crucible ✓ Weighing balance ✓ Stop watch or timer	
Procedure	**1.** The initial temperature **(T_o)** of the thermometer is recorded. **2.** A fixed mass (for example: 10g) of each fuel material (Peanuts, oil, paper and wood) is weighed. **3.** Each material is placed in the heat – resistant crucible. **4.** Each material is ignited and its temperature is measured using a thermometer **5.** The maximum temperature **(T_f)** reached and the time taken to reach it are measured and recorded. **6.** Steps (3) to (5) for each fuel materials are repeated. **7.** The heat released per unit mass is calculated using the formula below ***8. Heat released = Mass (m) x Specific heat Capacity (C) x change in temperature*** **9**. Per unit mass $Q = MC\Delta\theta$	
Risks:	✓ Working with open flames and combustible materials increase the risk of fires and burns. ✓ Handling hot materials and equipment can cause heat - related injuries. ✓ Burning materials can release harmful chemicals, such as volatile organic compounds which can be harmful if inhaled ✓ Inhaling fumes from burning materials can cause respiratory problems. ✓ Exposure to smoke, heat or chemicals can cause eye and skin irritation ✓ Improper use of equipment such as thermometers can lead to damage or breakage ✓ Measure errors or equipment malfunctions can lead to inaccurate data, which can affect the validity of the conclusions of the investigation.	

Mitigations	✓ Follow proper laboratory guidelines ✓ Wear appropriate persona; protective equipment (PPE) such as gloves, goggles and lab coats ✓ Ensure proper ventilation and exhaust systems are in place ✓ Use equipment correctly and follow manufacturer's instructions. ✓ Monitor temperature and heat output carefully ✓ Keep a fire extinguisher nearby ✓ Supervision of students during the investigation ✓ Proper disposal of fuel materials

Data presentation

Table of results. ***(These are assumed values)***

Material	T_o (ºC)	T_f (ºC)	Time (s)	C (Jg^{-1} ℃$^{-1}$)	Heat released
Peanut	25.0	450.0	120	0.59	2500
Vegetable oil	25.0	380.0	90	0.51	1800
Paper	25.0	320.0	60	0.41	1200
Wood	25.0	500.0	150	0.65	3100

Data interpretation

- ✓ Wood released the most heat per unit mass followed by peanuts, oil and paper
- ✓ The release of heat by fuel materials is in the order of wood >Peanuts > Oil>paper
- ✓ The high heat released from wood is due to its high carbon content and combustion efficiency.
- ✓ Peanuts have a higher heat release than oil and paper due to their high protein and fat content, which burn more efficiently.
- ✓ Paper has the lowest heat release due to its low carbon content and higher water content, which reduces combustion.

Conclusion

- ✓ The investigation compared the heat released when peanuts, oils, paper and wood are burnt.
- ✓ The results show that wood releases the most heat per unit mass, followed by peanuts, oil and paper.

INVESTIGATION OF EXOTHERMIC REACTION

(Using the Scientific Method of Dissolving Substances)

(For example: Sodium hydroxide dissolved in water)

Title:	Investigation of Exothermic reactions that occur when Sodium Hydroxide Dissolves in water.
Aim:	To investigate an exothermic reaction that occurs when sodium hydroxide dissolves in water
Hypothesis:	Dissolving sodium hydroxide pellets in water will result in an exothermic reaction, causing a temperature increase, and increasing the mass of sodium hydroxide will increase the temperature change.
Variables:	*Dependent variable:* Temperature change of the mixture *Independent variable:* Mass of sodium hydroxide pellets. *Control variable:* Initial temperature of water
Materials:	✓ Sodium hydroxide pellets. ✓ Distilled water ✓ Thermometer ✓ Stirring rod ✓ Containers (beakers or cups) ✓ Weighing balance
Procedure**:**	**1.** The initial temperature **(T_i)** of the water in a plastic beaker is measured and recorded. **2.** A fixed mass **(m)** of sodium hydroxide (for example 1g) is weighed and recorded. **3.** The sodium hydroxide is slowly added to water while stirring **4.** Stirring is continued until the sodium hydroxide is fully dissolved. **5.** The final temperature **(T_f)** of the mixture is measured and recorded. **6.** Steps (2) to (5) are repeated with different masses of sodium hydroxide (for example **2g**, **3g**, **4g** and **5g**) **7.** The temperature change (ΔT) is calculated using the formula: $\Delta T = T_f - T_i$ **8.** A graph of temperature change (ΔT) against mass of NaOH is plotted.

Risks:	✓ Splashes of sodium hydroxide solution cause skin and eye irritation ✓ Sodium hydroxide solution formed in the investigation can burn if not handled carefully. ✓ Inhaling sodium hydroxide dust can cause respiratory problems for example bronchitis ✓ The exothermic reactions can generate heat, potentially causing burns ✓ Improper use of equipment such as thermometers can lead to breakage. ✓ Measurement errors can lead to inaccurate data, affecting the validity of the investigation.
Mitigations:	✓ Wear appropriate personal protective equipment (PPE) including gloves, goggles and a lab coat ✓ Handle sodium hydroxide solution formed with care, to avoid splashes and spills ✓ Ensure proper ventilation and exhaust systems are in place ✓ Use equipment correctly and follow the instructions of the manufacturer ✓ Monitor temperature and heat output carefully ✓ Keep a fire extinguisher nearby ✓ Dispose the materials properly

Data presentation, Data analysis and Interpretation

Data presentation

Table of results ***(These are assumed values)***

m(g)	T_i(°C)	T_f °C)	ΔT (°C)
1.0	20.0	35.0	15.0
2.0	20.0	40.0	20.0
3.0	20.0	45.0	25.0
4.0	20.0	50.0	30.0
5.0	20.0	55.0	35.0

Data analysis

Plot a graph of ΔT against m.

Data Interpretation

The results show a consistent temperature increase with increasing mass of sodium hydroxide, indicating an exothermic reaction.

The temperature change (ΔT) is directly proportional to the mass of sodium of sodium hydroxide

The graph shows a linear relationship between ΔT and concentration of sodium hydroxide, allowing for predictions of temperature changes at different concentrations.

Conclusion:

This investigation demonstrates the exothermic reaction between sodium hydroxide and water, with a clear dependence on the mass of sodium hydroxide.

The results support the hypothesis and provide a quantitative understanding of the temperature change.

INVESTIGATION OF ENDOTHERMIC REACTION

(Using the Scientific Method Of Dissolving Substances)

(For example: Sodium hydrogen carbonate dissolved in water)

Title:	Investigation of Endothermic reaction that occur when *sodium Hydrogencarbonate* dissolves in water.
Aim:	To investigate an endothermic reaction that occurs when *sodium hydrogencarbonate* dissolves in water
Hypothesis:	Dissolving *sodium hydrogencarbonate* in water will result in an endothermic reaction, causing a temperature decrease, and increasing the mass of sodium hydrogen carbonate will increase the temperature decrease.
Variables:	*Dependent variable:* Temperature change of the mixture *Independent variable:* Mass of *sodiumhydrogen carbonate* *Control variable:* Initial temperature of water
Materials:	✓ Sodium hydrogen carbonate powder ✓ Distilled water ✓ Thermometer ✓ Stirring rod ✓ Containers (beakers or cups) ✓ Weighing balance
Procedure:	**1.** The initial temperature of water **(T_i)** in a beaker is measured and recorded **2.** A fixed mass **(m)** of *sodium hydrogencarbonate* (for example: 1g) is weighed and recorded. **3.** $NaHCO_3$ is slowly added to the water while stirring **4.** Stirring is continued until the *sodium hydrogencarbonate* is fully dissolved **5.** The final temperature **(T_f)** of the mixture is measured and recorded **6.** Steps (2) to (5) are repeated with different masses of *sodium hydrogencarbonate* (for example: **2g**, **3g**, **4g** and **5g**) **7.** The temperature change (ΔT) is calculated using the formula: $\Delta T = T_f - T_i$ **8.** A graph of temperature change (ΔT) against mass of $NaHCO_3$ is plotted.

Risks:	✓ *Sodium hydrogencarbonate* is a mild irritant whose splashes can cause skin and eye irritation if not handled carefully. ✓ Inhaling *sodium hydrogencarbonate* dust can cause respiratory problems such as coughing ✓ Direct contact of the skin with *sodium hydrogencarbonate* can cause irritation and discomfort ✓ Improper use of equipments such as thermometers can lead to inaccurate data, affecting the validity of the investigation ✓ Some individuals may be allergic to $NaHCO_3$, which can cause an allergic reaction.
Mitigations:	✓ Wear appropriate personal protective equipment (PPE) including gloves, goggles and a lab coat ✓ Handle *sodium hydrogencarbonate* with care, to avoid splashes and spills ✓ Ensure proper ventilation and exhaust systems are in place ✓ Use equipment correctly following instructions of the manufacturer ✓ Monitor temperature and heat output carefully ✓ Keep a first aid kit nearby ✓ Dispose off the materials properly ✓ Be aware of any allergies or sensitivities

Data presentation, Data analysis and Interpretation

Data presentation

Table of results ***(These are assumed values)***

m(g)	T_i(°C)	T_f °C)	ΔT (°C)
1.0	20.0	18.0	-2.0
2.0	20.0	16.0	- 4.0
3.0	20.0	14.0	- 6.0
4.0	20.0	12.0	- 8.0
5.0	20.0	10.0	- 10.0

Data analysis

Plot a graph of ΔT against M

Data interpretation

The results show a consistent temperature decrease with increasing mass of $NaHCO_3$, indicating an endothermic reactions.

The temperature change (ΔT) is directly proportional to the mass of $NaHCO_3$, supporting the hypothesis.

The graph shows a linear relationship between (ΔT) and the mass of $NaHCO_3$, allowing for predictions of temperature changes at different concentrations.

Conclusion:

This investigation demonstrates the endothermic reaction between *sodium hydrogencarbonate* and water, with a clear dependence on $NaHCO_3$ concentration

The results support the hypothesis and provide a quantitative understanding of the temperature change

OBTAINING USEFUL ENERGY FROM BURNING FUELS

Energy can be released in chemical reactions in various forms for example light and sound energy, although it is usually released as heat energy.

AMOUNT OF ENRGY RELEASED FROM BURNING FUELS

Amount of energy released from a burning fuel (for example ethanol) is got from the expression below.

Energy released (Q) = Mass(m) x specific heat capacity (c) x change in temperature

$$Q = MC\Delta\theta \quad \text{———} \quad \textbf{(eqn i)}$$

Change in temperature ($\Delta\theta$) = Final temperature (θ_f) – Initial temperature (θ_i)

$$\Delta\theta = \theta_f - \theta_i \quad \text{———} \quad \textbf{eqn(ii)}$$

Putting equation (ii) into equation (i)

$$\boxed{Q = MC(\theta_f - \theta_i)}$$

Where Q	-	Is the energy released by the fuel.
M	-	Is the mass of the liquid heated
C	-	Specific heat capacity of the liquid heated
θ_f	-	Final temperature
θ_i	-	Initial Temperature

Example

1. 3.5g of a fuel is burned to heat 50cm^3 of water. The temperature of water increased from 22^{o}C to 71^{o}C. Calculate the:-

i) Energy released by the fuel

ii) Energy released per gram of the fuel

Solution (i)

Heat released = Mass of water X specific heat capacity X change in temperature

From density = $\frac{\text{mass}}{\text{volume}}$

Density of water = 1gcm^{-3}

Volume of water = 50cm^3

Mass of water = Density X volume

= 1gcm^{-3} x 50cm^3

Mass of water = 50g

Heat released by the fuel = 50 x 4.2 x (71 – 22)

= 50 x 4.2 x 49

Heat released by the fuel = **10,290Joules**

Solution (ii)

Energy released per gram of the fuel = $\frac{\text{Energy released by the furl}}{\text{mass of the fuel}}$

= $\frac{\text{10,290Joules}}{\text{3.5g}}$

Energy released per gram of the fuel = **2,940Joules per gram**

INTERPRETATION OF CHEMICAL EQUATIONS FOR EXOTHERMIC REACTIONS

Consider the equation below

$H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} \quad \Delta H = {}^-286kJmol^{-1}$

<u>*Interpretation of the equation*</u>

When ***one mole of hydrogen*** is ***completely burnt in oxygen***, ***it evolves*** or produces ***286kJ of heat***

Consider the equation below

$C_{(s)} \quad + \quad O_{2(g)} \longrightarrow CO_{2(g)} \qquad \Delta H \quad = {}^{-}406kJmol^{-1}$

<u>*Interpretation of the equation:*</u>

When ***one mole of carbon*** is ***completely burnt in oxygen***, it produces ***406kilo joules of heat.***

Note: *The negative sign on the value of ΔH means that heat is produced or evolved or liberated to the surrounding implying that is an exothermic reaction*

INTERPRETATION OF CHEMICAL EQUATIONS FOR ENDOTHEMRIC REACTIONS

Consider the equation below

$C_{(s)} \quad + \quad 2S_{(s)} \longrightarrow CS_{2(i)} \; \Delta H = +117kJmol^{-1}$

<u>*Interpretation of the equation*</u>

When ***one mole of carbon*** reacts with ***2moles of sulphur***, ***117 kilo joules of heat*** are ***absorbed*** form the surrounding.

Note: *The positive sign on the value of ΔH means that heat is absorbed form the surrounding, implying that it is an endothermic reaction.*

TYPES OF HEAT CHANGES

Heat of combustion (Enthalpy of combustion)

Heat of combustion is the <u>heat change</u> that occurs when <u>one mole of a substance</u> is <u>completely burnt in excess oxygen</u>.

Heat (enthalpy) of combustion is usually ***negative***; that is to say ΔH is negative

This implies that heat combustion is an ***exothermic process*** or reaction, which ***evolves heat to the surrounding***.

Heat of neutralization.

This is the <u>heat change</u> that occurs when <u>one mole of hydrogen ions</u> from <u>an acid</u> react with <u>one mole of hydroxyl ions</u> form <u>an alkali</u> to form <u>one mole of water.</u>

Ionic equation:

$H^{+}_{(aq)} \quad + \quad \bar{O}H_{(aq)} \longrightarrow H_2O_{(i)}$

Heat of neutralization is usually ***negative***, that is to say ΔH is negative

This implies that heat neutralization is an ***exothermic process*** or reaction, which liberates heat to the surrounding.

INTERPRETATION ENERGY PROFILES OF CHEMICAL REACTIONS

There is transfer of energy during a chemical reaction as reactants are converted into products. The idea of transfer of energy during a chemical reaction is illustrated using energy profile diagram.

ENERGY PROFILE DIAGRAM

An energy profile diagram show the theoretical energy pathway of the reaction as it progresses from reactants to products.

The energy profile diagram compares the energy of the reactants to that of the products

The difference between the energy of reactants and that of products represents the amount of energy transferred to the surroundings or absorbed from the surroundings.

Potential energy

This is the energy stored in the bonds of a compound or substance.

Activation energy

This is the minimum energy needed for the reaction to proceed.

Note: The difference in the energy of products and that of the reactants is called *enthalpy change* or *heat change* and it is donated by **ΔH**

Heat change (ΔH) = Energy of products - Energy of reactants

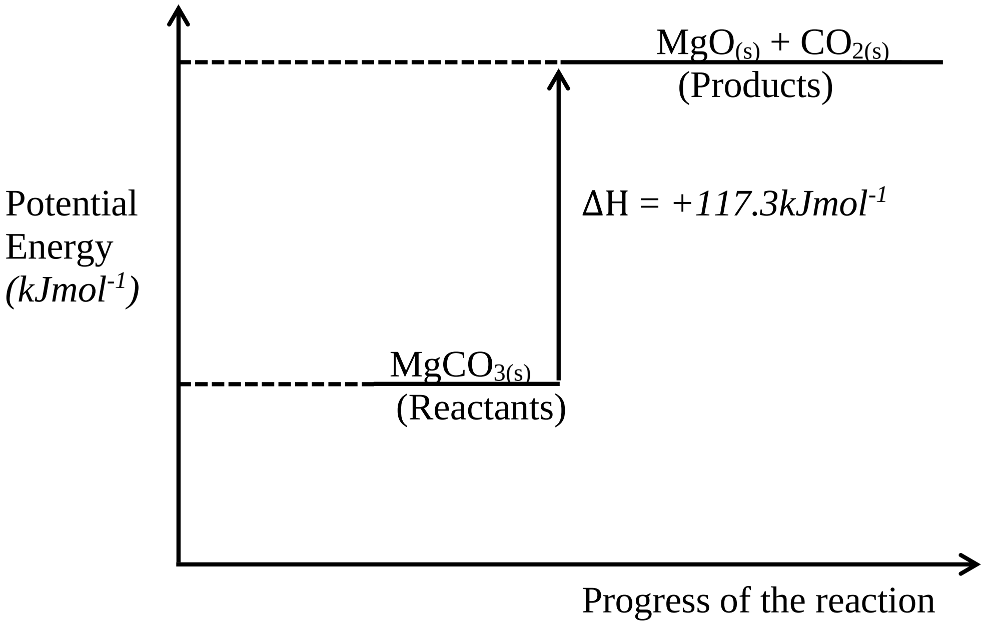
Energy level diagrams are simplified illustrations that only show the initial and final energies of substances during the reaction.

ENERGY LEVEL DIAGRAM FOR THE DECOMPSOITION OF MAGNESIUM CARBONATE

The thermal decomposition of magnesium carbonate is an endothermic reaction, requiring 117.3kJmol^{-1} of heat.

Equation:

$$MgCO_{3(s)} \longrightarrow MgO_{(s)} + CO_{2(g)} \qquad \Delta H = +117.3kJmol^{-1}$$



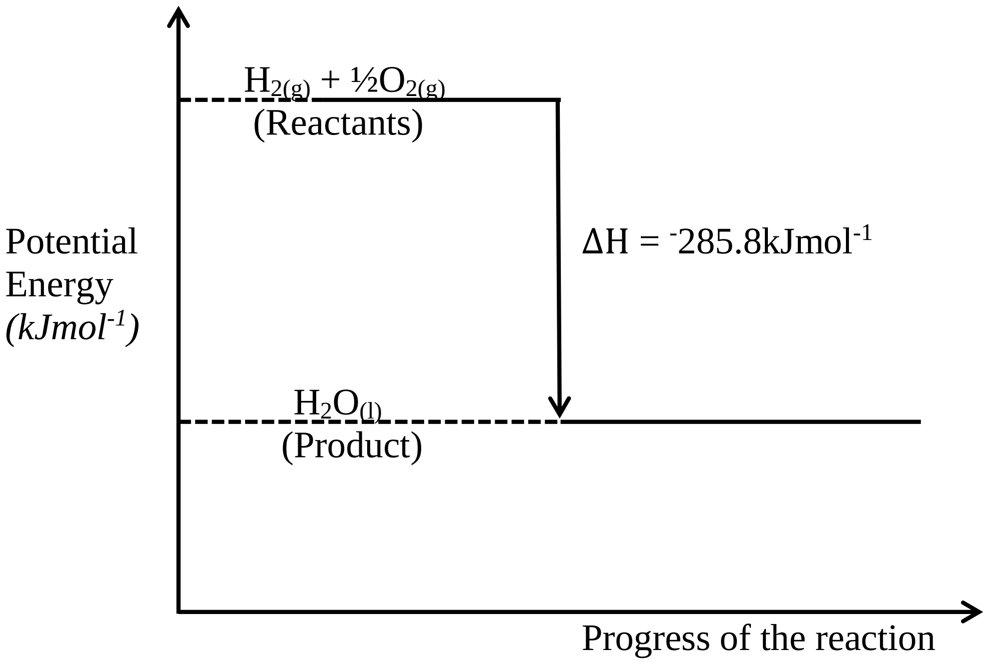
From the equation and energy level diagram, we can conclude that during the reaction, energy is transferred from the surrounding to the system, so the heat energy of the products is greater than the heat energy of the reactants, thus, the enthalpy change (ΔH) is positive.

ENERGY LEVEL DIAGRAM FOR THE FORMATION OF A WATER MOLECULE FROM HYDROGEN AND OXYGEN

The reaction of hydrogen gas with oxygen gas to produce water is an exothermic reaction, producing $285.8kJmol^{-1}$

Equation

$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} \qquad \Delta H = {}^{-}285.8kJmol^{-1}$$



Form the equation and energy level (profile) diagram, we can conclude that during the reaction, energy is transferred from the system to the surroundings, so the enthalpy of the products is lower than the enthalpy of the reactants, thus, the enthalpy change (ΔH) is ***negative*** implying that is an ***exothermic reaction***.

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