Energy Changes in Chemical Reactions

Energy changes are central to chemical reactions. During a reaction, bonds in reactants break, and new bonds form in products, involving either the absorption or release of energy. These energy changes govern the feasibility and applications of reactions in real-world processes.

Enthalpy Changes and Energy Profiles

Enthalpy (H)

Enthalpy is the total heat energy of a system under constant pressure.

It cannot be measured directly but changes in enthalpy (\Delta H) can be observed.

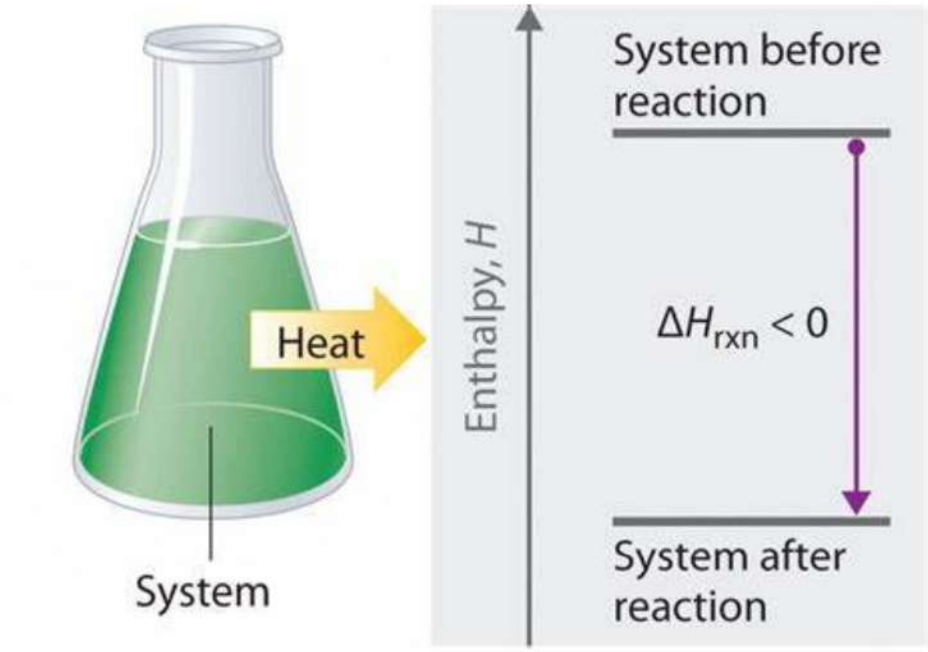
Types of Enthalpy Changes

1.Exothermic Reactions

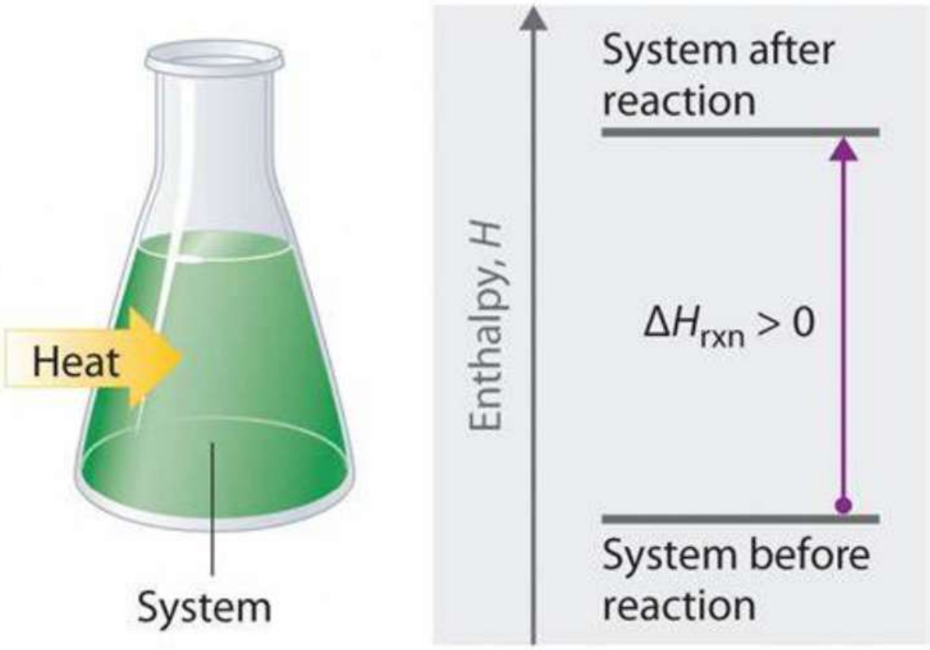
•Energy is released.

•Products have lower energy than reactants.

•Example: Combustion of methane:



(a) Exothermic reaction



(b) Endothermic reaction

2.Endothermic Reactions

•Energy is absorbed.

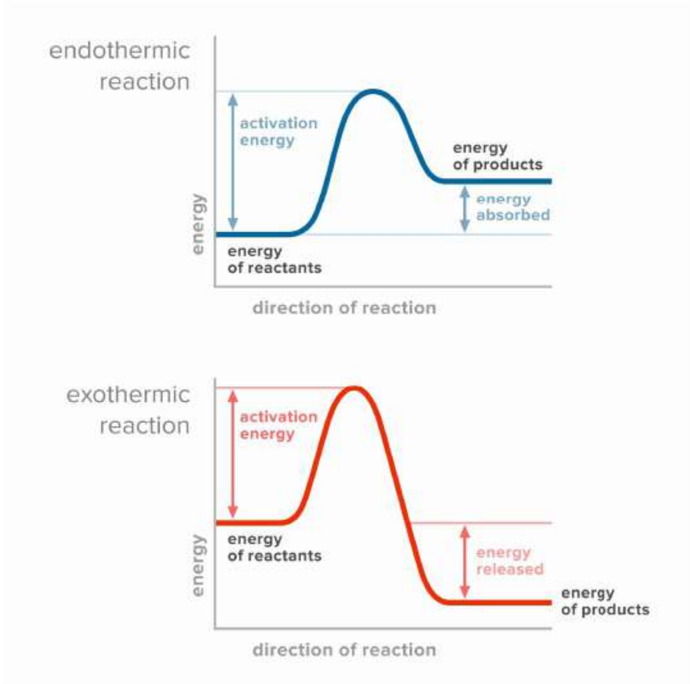
•Products have higher energy than reactants.

•Example: Photosynthesis

Type of Enthalpy	Concept	Example
Formation	Heat involved in production of 1 mole of product starting from element.	Formation of propane: $3 C (s) + 4 H_2 (g) \rightarrow C_3H_8 (g)$
Combustion Burning	Heat involved in production of carbon dioxide and water by combination of organic compounds with oxygen. compound + $O_2(g) \rightarrow CO_2 (g) + H_2O (l)$ In most cases enthalpy-change is negative and reaction is exothermic.	Combustion of methane: $CH_4 (g) + 2 O_2 (g) \rightarrow CO_2 (g) + 2 H_2O (l)$ ΔH=-890 kJ/mol
Bond	Heat absorbed [always positive, endothermic] in the breaking of 1 mole of bonds.	Bond-enthalpy of H-H: $H_2 (g) \rightarrow 2 H (g)$ ΔH=+436 kJ/mol
Atomization	Heat needed to produce 1 mole of gaseous atoms from the element in its standard state	Enthalpy of atomization of hydrogen: ½ $H_2 (g) \rightarrow H (g)$ ΔH=+218 kJ/mol
Vaporization	Heat needed to convert one mole of substance from liquid to gas [$\Delta H>0$; endothermic]	Heat of vaporization of water: $H_2O (l) \rightarrow H_2O (g)$ ΔH=+41 kJ/mol

Energy Profiles

Energy profiles are graphical representations of energy changes during a reaction.



1.Exothermic Profile:

•Energy level of reactants is higher than products.

•Activation energy is required to start the reaction.

2.Endothermic Profile:

•Energy level of reactants is lower than products.

•Requires a continuous energy supply.

Bond Breaking and Bond Forming

Breaking and Forming of Bonds

•Breaking bonds in reactants absorbs energy (endothermic).

•Forming bonds in products releases energy (exothermic).

$$CH_3CH_2-Br + H-OH \longrightarrow CH_3CH_2-OH + H-Br$$

Bonds broken   Bonds formed

Bond Energy

•Bond energy is the amount of energy needed to break a bond.

•Stronger bonds have higher bond energies.

Overall Energy Change

Examples

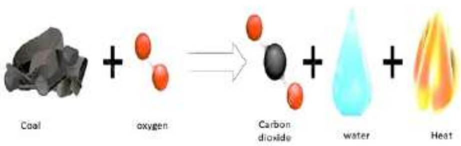
1.Exothermic Reaction:

Combustion of methane.

•Bond-breaking: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$.

•Energy released > Energy absorbed.

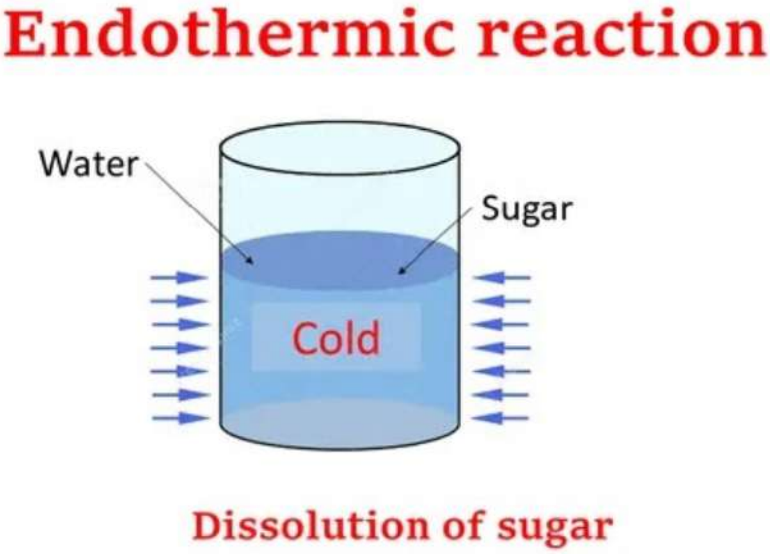
Exothermic reaction



2.Endothermic Reaction:

Decomposition of calcium carbonate.

•Bond-breaking requires more energy than bond-forming.



Fuels and Energy Resources

Fuels

•Substances that release energy during combustion or other chemical reactions.

•Examples: Coal, oil, natural gas, and biofuels.

Characteristics of Fuels

•High energy content.

•Easy to store and transport.

•Combustible in air to release heat energy.

Renewable Energy Resources

Sources that are replenished naturally over time:

•Solar Energy.

•Wind Energy.

•Hydropower.

•Biomass.

Non-Renewable Energy Resources

Fossil fuels that take millions of years to form:

•Coal: Used in power plants for electricity generation.

•Oil: Refined into petrol, diesel, and kerosene.

•Natural Gas: Methane-rich fuel used for heating and cooking.

Advantages and Disadvantages of Fuels

•Fossil fuels are energy-dense but contribute to pollution and global warming.

•Renewable resources are cleaner but may be less efficient and costly to implement.

Fuel Cells

•Devices that convert chemical energy directly into electrical energy.

•Example: Hydrogen fuel cells combine hydrogen and oxygen to produce electricity and water.

Conservation of Energy in Reactions

Law of Conservation of Energy

•Energy cannot be created or destroyed but only transformed from one form to another.

•The total energy before and after a reaction remains constant.

Energy Flow in Reactions

1.Exothermic Reactions

•Chemical energy in bonds is converted to thermal energy.

•Example: Combustion reactions power engines and generate heat.

2.Endothermic Reactions

•Thermal energy is absorbed to form chemical bonds.

•Example: Photosynthesis stores solar energy in glucose molecules.

Practical Applications

1.Calorimetry:

•Measures energy changes during a reaction.

•Useful for determining fuel efficiency.

2.Energy Efficiency:

•Improving insulation, reducing energy waste in industrial processes.

Examples of Energy Changes in Everyday Life

1.Cooking:

•Endothermic process of heating food.

2.Combustion of Fuels:

•Powers vehicles and generates electricity.

3.Battery Operation:

•Conversion of chemical energy to electrical energy.

Conclusion

Energy changes in chemical reactions are essential for understanding natural processes and industrial applications. From bond breaking and forming to harnessing fuels and conserving energy, these concepts highlight the significance of chemical energy transformations. By focusing on sustainability and innovation, society can meet energy demands while protecting the environment.