5 CHAPTER ENERGETICS

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Student Learning Outcomes

After studying this chapter, students will be able to:

- Explain the idea of a chemical system and its connection with-its surroundings influences energy transfer, during a chemical reaction.
- Differentiate between exothermic and endothermic reactions by giving examples. State that thermal energy is called enthalpy change and recognize its sign as negative for exothermic and positive for endothermic reactions
- Define activation energy as the minimum energy that colliding particles must have for a successful collision.
- Explain that activation energy depends on reaction pathway which can be changed using catalysts or enzyme (detailed pathways not required).
- Draw, label and interpret reaction pathway diagram for exothermic and endothermic reaction which includes enthalpy' change; activation energy (uncatalyzed and catalyzed), reactants and products.
- Recognize-that bond breaking and bond making is exothermic processes.
- Explain that enthalpy change-is sum of energies absorbed and' released bond breaking and bond forming.
- Calculate enthalpy change of à reaction given bond energy values
- Explain how respiration (aerobic and anaerobic), an. exothermic process, provides energy for biological systems and lipids as reserve stores of energy.

INTRODUCTION
SHORT QUESTIONS

Q.9 Define chemical energetics. What are different forms of energy? ***(K.B)***

Ans:

CHEMICAL ENERGETICS

Definition

The study of energy changes during a chemical reaction or physical processes is called chemical energetics.

In energetics we study the energy changes that take place during a chemical reaction. These changes are caused by the making and breaking of bonds during a reaction. It results in gain or loss of energy.

Forms of Energy

Energy exists in different forms which are often interconvertible. In chemical energetics we are mainly concerned with two forms of energy.

1. **Chemical Energy**
   This energy is stored in a molecule in which atoms are bonded to each other.
2. **Heat Energy**
   This form of energy is released when a bond is formed and absorbed when it is broken.

Q.10 Define Thermochemical reactions. What are the types of thermochemical reactions? ***(K.B)***

Ans:

THERMOCHEMICAL REACTIONS

Definition:

The chemical reaction in which heat energy is either released or absorbed is called thermochemical reaction.

Scope

In energetics we not only encounter heat which comes out of a chemical reaction but also another quantity which is called enthalpy.

Types of Thermochemical Reactions

1. **Exothermic Reactions**
   The chemical reaction in which heat energy is released is called exothermic reaction.
   Examples
   - Combustion reactions
   - Neutralization reactions
   - Respiration
   - Breakage of chemical bond
2. **Endothermic Reactions**
   The chemical reaction in which heat energy is absorbed is called exothermic reaction.
   Examples
   - Photosynthesis
   - Decomposition reactions
   - Formation of chemical bond

How to determine whether a reaction is exothermic or endothermic?

In energetics we study the energy changes that take place during a chemical reaction. These changes are caused by the making and breaking of bonds during a reaction. In most of the reactions the weak bonds of reactants break while in products new strong bonds are formed.

Since energy is needed to break a bond while energy is evolved when a bond is formed, such reactions take place always with the evolution of heat.

- If a reaction is accompanied with the evolution of heat it is called an exothermic reaction.
- If heat is absorbed during a reaction it is called an endothermic reaction.

Q.3 Define Enthalpy or heat content. How enthalpy of a system increases or decreases? ***(K.B)***

Ans: **ENTHALPY OR HEAT CONTENT**

Definition

Enthalpy (H) or heat content, is defined as the total amount of thermal energy stored in a compound.

Unit of Measurement

The unit of its measurement is KJ/mol^{-1}.

Enthalpy Change

When the energy is absorbed during a reaction, the total enthalpy of the system increases. When energy is evolved during a reaction, the total enthalpy of the system decreases.

Q.4 Differentiate between energetics and thermodynamics. ***(K.B)***

Ans: **DIFFERENTIATION**

ENTHALPY	HEAT
Definition	
In energetics we study the flow of energy in a chemical reaction.	*Thermodynamics deals with how the energy changes during chemical reaction affect the properties of a chemical system.*
Scope	
It is the study of energy.	It is the study of transformation of energy.
Related Branch	
Chemical energetics is part of a broader field of chemistry called thermodynamics.	Thermodynamics is a branch of physics and chemistry.

INTERESTING INFORMATION
Thomas Young was the first to use the word energy to the field of physics in 1802.

MULTIPLE CHOICE QUESTIONS

1. The amount of heat in a substance is called enthalpy: ***(K.B)***

(A) Enthalpy (B) Heat content
(C) Heat of reaction (D) Both A & B

2. **In an endothermic reaction heat is:**

(A) Evolved (B) Absorbed
(C) Remains same (D) All of these

3. The word energy was first used by:

(A) Thomas Young (B) Peter
(C) Wohler (D) Funk

5.1 SYSTEM AND SUROUNDING

LONG QUESTION

Q.1 Define system and surrounding. Also define the boundary of the system. ***(K.B)***

Ans: **SYSTEM AND SORROUNDING**

System

Definition

The part of universe which is under study and possesses fixed boundaries is called system.

OR

In chemistry, any physical or chemical change under study may also be called a system.

The chemical reaction includes reactants, products, catalyst, solvent and anything else which is important to study this reaction.

Surrounding

Definition

Everything else which does not fall in this system is called the surrounding.

Example

If you are boiling water in the beaker, the water molecules will be called a system while everything surrounding this like beaker, burner, etc. will be called the surrounding.

Boundary of the System

The boundary is a closed surface that separates a system from its surroundings.

These boundaries can be real or imaginary.

Endothermic Change

When energy is transferred from surrounding to the system, the change is called endothermic.

Sign of energy change

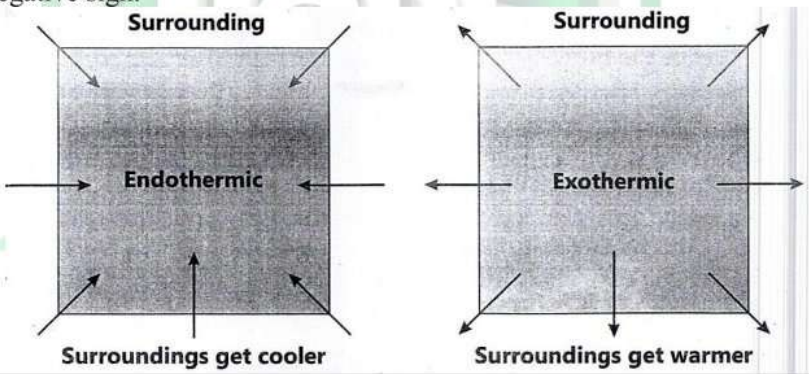
It has a positive sign.

Exothermic Change

When energy is transferred from system to surrounding, the change is called exothermic.

Sign of energy change

It carries negative sign.



INTERESTING INFORMATION

APPLICATIONS OF ENERGY EVOLVED DURING REACTIONS

Energy evolved during a chemical reaction is used in everyday life for following purposes:

- Cooking
- Heating
- Lighting
- Transportation
- Communication
- Entertainment and much more

EXERCISE

Q. Does boiling water in a beaker endothermic or exothermic change? Which form of energy is being transferred in this system?

Ans:
Boiling water in a beaker is an endothermic change. In this system heat energy is being transferred into the kinetic energy.

INTERESTING INFORMATION

IMPORTANCE OF ENTHALPY AND HEAT

Enthalpy is important because it tells us how much heat is present in a system.
Heat is important because we can extract useful work from it.

SHORT QUESTION

Q.1 Define system and surrounding. ***(K.B)***

Ans: **SYSTEM AND SORROUNDING**

System

Definition

The part of universe which is under study and possesses fixed boundaries is called system.

OR

In chemistry, any physical or chemical change under study may also be called a system.

The chemical reaction includes reactants, products, catalyst, solvent and anything else which is important to study this reaction.

Surrounding

Definition

Everything else which does not fall in this system is called the surrounding.

Example

If you are boiling water in the beaker, the water molecules will be called a system while everything surrounding this like beaker, burner, etc. will be called the surrounding.

Q.2 Define the boundary of the system. ***(K.B)***

Ans: **SYSTEM AND SORROUNDING**

Boundary of the System

The boundary is a closed surface that separates a system from its surroundings.

These boundaries can be real or imaginary.

MULTIPLE CHOICE QUESTIONS

1. **The part of universe which is under study and possesses fixed boundaries is called:**
   (A) Surrounding (B) System
   (C) Container (D) None of these
2. **Endothermic heat change is represented by sign:** ***(K.B)***
   (A) +ive (B) -ive
   (C) Zero (D) Both A & B
3. **If an endothermic reaction is allowed to take place in the air, the temperature of the surrounding air:** ***(K.B)***
   (A) Remains same (B) Increase
   (C) Decreases (D) Remains unchanged

5.2 ENTHALPY

LONG QUESTION

Q.1 Define enthalpy or heat content. Also define the boundary of the system. ***(K.B)***

Ans: **ENTHALPY OR HEAT CONTENT**

Definition

The total amount of heat energy present in a molecule under standard conditions (0 ^0C temperature and 760 mmHg pressure) is also called its heat content.

Enthalpy is the measurement of energy in a thermodynamic system.

Quantity of enthalpy

The quantity of enthalpy is equal to the total heat content of a system.

Representation of enthalpy

Enthalpy of a system is represented by (ΔH).

Representation of enthalpy Change

The change in enthalpy which a system undergoes is represented by ΔH.

Measurement of total enthalpy of system

The total enthalpy (H) of a system cannot be measured directly. However, the change in enthalpy (ΔH) brought about in a system can be measured comparatively easily.

Standard enthalpy of reaction

In Chemistry the standard enthalpy of reaction (ΔH^O) is the enthalpy change when reactants in their standard states undergo reaction to produce products in their standard states. This quantity is called the **standard enthalpy change** or **heat of reaction** at constant pressure.

Example

$$2\,CO_{(g)} + O_{2(g)} \longrightarrow 2\,CO_{2\,(g)} \qquad \Delta H^\circ = -566.0\ kJ$$

The reaction in this system is thus exothermic evolving 566 of heat energy which is given to the surrounding.

Q.2 How is enthalpy different from heat?

Ans: **DIFFERENTIATION**

Enthalpy is different from heat in the following ways:

HEAT	ENTHALPY
Definition	
Heat is a form of energy that flows from hot body to a cold body because of a difference in temperature.	*Enthalpy is an essential part of a system since it depends on the number of molecules present in that system, its chemical composition and its structure.*
Unit of Measurement	
We measure heat in joules.	The unit of enthalpy in the International System of Units (S) is the joule (J).
Nature of Heat	
Heat is what we call the transfer of thermal energy.	Heat is not essential part of a system, it just comes and goes. When heat leaves or enters a system, it results in a change of enthalpy. At a constant pressure the enthalpy change is equal to heat evolved or absorbed.

EXERCISE

Q. Can energy be transferred in a form other than heat during a chemical reaction?

Ans: **REASON**

Yes, energy can be transferred in forms other than heat during a chemical reaction, including light, electricity, and sound. It depends upon specific reactions. The most common form of energy exchange in chemical reactions is heat.

EXERCISE

Q. Why it is not possible to calculate the enthalpy of a system?

Ans: **TO CALCULATE ENTHALPY OF SYSTEM**

It's not possible to calculate the enthalpy of a system because enthalpy is a state function, which has initial and final states. We can only measure the change in enthalpy (ΔH) between two states, not the absolute enthalpy of a system at any given point.

SHORT QUESTIONS

Q.1 Define enthalpy or heat content.

Ans: **ENTHALPY OR HEAT CONTENT**

Definition

The total amount of heat energy present in a molecule under standard conditions (0^0 C temperature and 760 mm pressure) is also called its heat content.

Enthalpy is the measurement of energy in a thermodynamic system.

Q.2 Define standard enthalpy of the reaction.

Ans: **STANDARD ENTHALPY OF REACTION**

Definition

*In Chemistry the standard enthalpy of reaction (ΔH^O) is the enthalpy change when reactants in their standard states undergo reaction to produce products in their standard states. This quantity is called the **standard enthalpy change** or **heat of reaction** at constant pressure.*

Example

$$2\,CO_{(g)} + O_{2(g)} \longrightarrow 2\,CO_{2\,(g)} \quad \Delta H^\circ = -566.0\ kJ$$

The reaction in this system is thus exothermic evolving 566 of heat energy which is given to the surrounding.

MULTIPLE CHOICE QUESTIONS

1. The total amount of heat energy present in a molecule under standard conditions (0^0 C temperature and 760 mm pressure) is also called: ***(K.B)***
   (A) Heat content (B) Enthalpy
   (C) Both A & B (D) None of these
2. Boundaries of the system can be: ***(K.B)***
   (A) Real (B) Imaginary
   (C) Both A & B (D) None of these
3. Enthalpy of a system is represented by:
   (A) ΔH (B) H
   (C) E (D) E^o

5.3 EXOTHERMIC AND ENDOTHERMIC REACTIONS

LONG QUESTIONS

Q.1 Write a detailed note on exothermic and endothermic reactions.

Ans: **EXOTHERMIC AND ENDOTHERMIC REACTIONS**

EXOTHERMIC REACTIONS

Definition

Chemical reactions in which heat energy is evolved are called exothermic reactions.

Characteristics of Exothermic Reactions

Heat, which is evolved during an exothermic reaction, goes to the surrounding and the container in which such a reaction is being carried out, gets hot.

Examples

1. **Formation of Liquid water from hydrogen and oxygen**

Hydrogen gas and oxygen gas react to give liquid water in an exothermic reaction,

$$\underset{\text{Hydrogen}}{2H_2(g)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Water}}{2H_2O(l)} + 571.6\ kJ$$

571.6 kJ heat energy is evolved during this reaction.

Sign Convention

If the energy evolved is shown separately it is expressed as $\Delta H = -571.6$ KJ.

Amount of Heat for backward reaction

The same amount of energy will be absorbed when the reaction will move in the backward direction i.e. water will decompose to give hydrogen and oxygen back.

2. **Formation of CO_2 from C and O_2**

Carbon dioxide gas is produced when solid carbon burns in oxygen gas.

$$\underset{\text{Carbon}}{C_{(s)}} + \underset{\text{Oxygen}}{O_{2\,(g)}} \longrightarrow \underset{\text{Carbon dioxide}}{CO_{2\,(g)}} + 393.5\ kJ$$

It is also an exothermic reaction and 393.5 kJ heat energy is evolved during this reaction.

Amount of Heat for backward reaction

When this reaction moves in the backward direction, the same amount of energy i.e. 393.5 KJ, will be absorbed. This reaction has ΔH - 571.6 I $KJmol^{-1}$ of CO_2.

Both the reactions mentioned above are the examples of exothermic changes.

ENDOTHERMIC REACTIONS

Chemical reactions in which heat energy is absorbed are calle endothermic reactions.

Characteristics of Exothermic Reactions

In an endothermic reaction, the absorption of heat from the surrounding will decrease the temperature of the container.

Examples

1. **Formation of HI from hydrogen and Iodine**

The following reactions represent endothermic changes.

$$\underset{\text{Hydrogen}}{H_{2\,(g)}} + \underset{\text{Iodine}}{I_{2\,(s)}} \longrightarrow \underset{\text{Hydrogen Iodide}}{2HI_{(g)}} - 53.08\ kJ$$

The enthalpy change for the reaction is $\Delta H = 53.08$ KJ

Hydrogen gas reacts with solid iodine only at high temperature and 53.08 kJ of heat energy is absorbed.

2. **Formation of NO from nitrogen and oxygen**

Formation of NO in air due to lightening in the clouds.

$$\underset{\text{Nitrogen}}{N_{2\,(g)}} + \underset{\text{oxygen}}{O_{2\,(g)}} \longrightarrow \underset{\text{Nitric Oxide}}{2NO_{(g)}} - 180.6\ kJ$$

The enthalpy change for the reaction is $\Delta H = 180.6$ kJ.

Heat of reaction

Heat, which is evolved or absorbed during a chemical reaction, is called the heat of that reaction.

A physical or a chemical change is almost always accompanied with either absorption or evolution of heat.

INTERESTING INFORMATION

SELF HEATING OR SELF COOLING PACKS

Heat evolved or absorbed during a reaction is used in self-heating or self-cooling packs. These packs contain reactants that undergo an exothermic or an endothermic reaction providing high or low temperature.

Significance of Exothermic Reactions

Our present-day living conditions depend heavily on the availability of energy in its various forms. Exothermic chemical reactions are extensively used to fulfill this requirement. In such reactions, chemical energy is converted into heat energy.

(i) **For Cooking Food**

We burn fuels like gas, oil and coal to cook food.

(ii) **For Heating Purpose**

We burn fuels for other heating purposes in our homes and industry. During this burning process called combustion, compounds present in fuels react with oxygen of the air to produce a large amount of heat.

(iii) **Energy in Biological Systems**

Foods such as fats and carbohydrates are important biological fuels. During metabolism, the chemical energy present in this food is converted to heat to keep us warm.

(iv) **To generate electricity**

A large portion of electricity is produced at power stations by burning fuels such as natural gas and coal. The heat which comes out from their combustion is used to produce steam at high pressure. This high pressure steam is then used to rotate turbines, which in turn generate electricity.

(v) **To derive vehicles**

While driving a vehicle, it is the combustion of petrol or diesel that gives off energy and drives it forward.

(vi) **In fireworks**

The one example of exothermic reactions people seem to enjoy the most is that of fireworks. Fireworks are the result of combustion reactions that yield heat, light and sound. Different metal powders along with oxidizing agents produce a variety of colours when burnt. Fig (5.2)

EXERCISE

1. Why the chemical reaction between sodium metal and water proceeds violently?

Ans: The chemical reaction between sodium metal and water proceeds violently because sodium is unstable and reacts violently with water.

2. Is melting of ice an exothermic or endothermic change?

Ans: It is an endothermic change.

3. Can exothermic reaction be reversed?

Ans: Yes, an exothermic reaction can be reversed. It should be noted that when exothermic reaction is reversed, it becomes an endothermic reaction.

Q.2 Why the chemical reactions are either exothermic or endothermic reactions.

Ans: **WHY CHEMICAL REACTIONS ARE EXOTHERMIC OR ENDOTHERMIC?**

Let us now examine the reason why the chemical reactions are either exothermic or endothermic. A chemical reaction mainly involves the processes which involve bond breaking and bond formation.

Example: (Reaction between H_2 and O_2 to form H_2O)

(i) Breakage of Bond

In the following reaction, the chemical bonds between the atoms present in the molecules of H_2 and O_2 first break to give their atoms.

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

$$\underset{\text{Molecule}}{2H_{2(g)}} \longrightarrow \underset{\text{Atoms}}{4H_{(g)}} \qquad \underset{\text{Molecule}}{O_{2(g)}} \longrightarrow \underset{\text{Atoms}}{2O_{(g)}}$$

(ii) Formation of Bonds

These atoms of hydrogen then form bonds with oxygen atoms to form two molecules of gaseous H_2O.

Energy change during reaction

Breaking of bonds of H_2 and O_2 absorb energy (endothermic process) while making of bonds between H and O evolve energy (exothermic process). In this reaction, weaker bonds are broken i.e. of H_2. Hence less energy is absorbed in the system. While the bonds which are formed in water molecule are stronger and thus greater energy is evolved. Hence, the energy which is evolved is more than the energy which is absorbed. The overall reaction is thus exothermic.

$H_{2(g)} \longrightarrow 2H_{(g)} + 435\ kJ/mol$ (Endothermic)

$O_{2(g)} \longrightarrow 2O_{(g)} + 498\ kJ/mol$ (Endothermic)

$O + H \longrightarrow O-H - 484\ kJ/mol$ (Exothermic)

Total Energy absorbed in the reaction

Since two moles of H_2 take part in the reaction so total energy absorbed in the reaction

$$2H_{2(g)} \longrightarrow 4H_{(g)} + 870\ kJ$$

$$O_{2(g)} \longrightarrow 2O_{(g)} + 498\ kJ/mol$$

$$2H_{2(g)} + O_{2(g)} \longrightarrow 4H_{(g)} + 2O_{(g)} + 1368\ kJ$$

It means 1368 kJ energy is absorbed when 2 moles of H_2 and one mole of O_2 break their bond to convert into atoms

Formation of 4 O-H bonds

Total energy evolved in the formation of 4 O—H bonds.

$$2O_{(g)} + 4H_{(g)} \longrightarrow 2H_2O_{(g)} - 1936\ kJ$$

This is the energy evolved when two moles of water are formed from 4 moles of hydrogen atoms and 2 moles of oxygen atoms.

Energy evolved for formation of one mole of water

Thus for the formation of one mole of water, the energy evolved will be 968 $kJmol^{-1}$.

Energy evolved for formation of two moles of water

(overall energy evolved in this reaction)

Hence the overall energy evolved in this reaction is = -1936 +1368 = -568kJ for two moles of water.

$$2\,H_{2(g)} + O_{2(g)} \longrightarrow 2\,H_2O_{(g)} + 568\ kJ \text{ or } \Delta H = -568\ kJ$$

ENTHALPY CHANGE

(a) Two moles of gaseous water

The enthalpy change for the formation of two moles of gaseous water is thus -568kJ.

(b) One mole of gaseous water

So the enthalpy change for the formation of one mole of gaseous water will be

$$= -\frac{568\ kj}{2\ mól} = -284\ kJ\ mol^{-1}$$

The experimental value of formation of gaseous water = -284.3 kJ
The calculated/theoretical value of formation of gaseous water = -284.3 kJ
Both these values are quite close to each other.

INTERESTING INFORMATION

REACTION OF NITROGEN WITH OXYGEN

Nitrogen of the atmosphere reacts with oxygen to produce not only in the presence of lightning. This is because reaction is highly endothermic, so only lightning can provide enough energy for this reaction to take place.

SAMPLE PROBLEM

Q. Calculate the enthalpy of the following chemical reaction

$$H_{2(g)} + I_{2(g)} \longrightarrow 2\,HI_{(g)}$$

Bond energies of H_2, I_2 and Hl are 436,151 and -299 $kJ\ mol^{-1}$ respectively.

Ans: **NUMERICAL**

Given Data:

Bond dissociation energy of H_2 = 436 kJ/mol^{-1}
Bond dissociation energy of I_2 = 151 kJ/mol^{-1}
Bond formation energy of HI = -299 kJ/mol^{-1}

To Find:

Enthalpy Change of reaction = ?

Calculation:

$$H_2 + I_2 \longrightarrow 2HI$$
$$436 + 151 \longrightarrow 2\,(-299)$$
$$587 \longrightarrow -598$$

Enthalpy Change = - 11

Positive sign indicates that the reaction is endothermic.

Result:

Thus enthalpy change for the reaction is - 11 (heat is evolved)

EXERCISE

Q. Calculate the enthalpy change for the formation of one mole of liquid water.
Ans:
Enthalpy change for the formation of two moles of liquid water = -517.6 KJ
Enthalpy change for the formation of one mole of liquid water = -517.6/2 = -258.8
Result:
Thus enthalpy change for one mole of liquid water is -258.8 KJ/mol

SHORT QUESTIONS

Q.1 Write definition of exothermic reaction.
Ans:

EXOTHERMIC REACTION

Definition
Chemical reactions in which heat energy is evolved are called exothermic reactions.
Examples
Formation of Liquid water from hydrogen and oxygen
Hydrogen gas and oxygen gas react to give liquid water in an exothermic reaction,

$$\underset{\text{Hydrogen}}{2H_2\,(g)} + \underset{\text{Oxygen}}{O_2\,(g)} \longrightarrow \underset{\text{Water}}{2H_2O\,(l)} + 571.6\ kJ$$

571.6 kJ heat energy is evolved during this reaction.

Q.2 Write significance of exothermic reaction.
Ans:

SIGNIFICANCE OF EXOTHERMIC REACTIONS

Our present-day living conditions depend heavily on the availability of energy in its various forms. Exothermic chemical reactions are extensively used to fulfill this requirement. In such reactions, chemical energy is converted into heat energy.

MULTIPLE CHOICE QUESTIONS

1. Formation of water is: ***(K.B)***
(A) Exothermic change (B) Endothermic change
(C) Both A & B (D) None of these

2. Enthalpy of reaction is measured in: ***(K.B)***
(A) Joules (B) Kelvin
(C) Kilograms (D) grams

3. Can an exothermic reaction be reversed? ***(K.B)***
(A) Yes (B) No
(C) Both A & B (D) All of these

5.4 HOW DOES A REACTION TAKE PLACE?

LONG QUESTIONS

Q.1 How does a reaction take place?
Ans:

OCCURRENCE OF CHEMICAL REACTION

Chemical Reaction
Definition
The process in which chemical change occurs in nature and composition of substances is called chemical reaction.
Example

$$2\,H_{2(g)} + O_{2(g)} \longrightarrow 2\,H_2O_{(g)} + 568\ kJ \text{ or } \Delta H = -568\ kJ$$

How does a reaction take place?
A reaction takes place when the reactant molecules collide with each other to give a transition state.
Example
Let us study the following hypothetical reaction.

$$A_2 + B_2 \longrightarrow 2AB$$

(a) State of molecules of Reactants before mixing

Before mixing, the molecules of reactants A and B are in a state of random motion separately colliding with each other and with the walls of container. Kinetic energies possessed by these molecules are not the same, Majority of these molecules possess average kinetic energy but a few possess more than average energy while yet others possess less than average kinetic energy. The molecules which possess more than average kinetic energy may also be called excited molecules.

(b) State of molecules of Reactants after mixing

When the two reactant molecules are mixed together, all these molecules start colliding with each other. The collisions which result by colliding molecules having average or less than average kinetic energies may not be able to produce any result.

Formation of Transition state

But when the two excited molecules from both the reactants collide with each other they may be able to produce the transition state as shown in the following Fig (5.3).

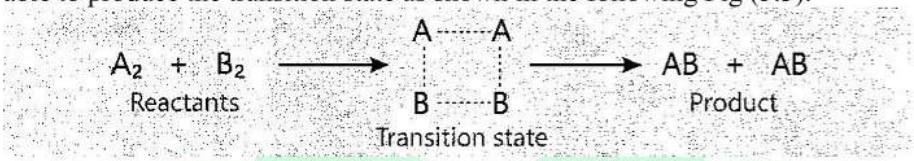


Fig (5.3) Formation of Transition state

Location (representation) of Transition State at the Curve

The transition state is shown at the peak of curve.

Change of Transition State

After a very short period of time the transition state either returns to the reactants or to the products.

Graphical Representation of Progress of Reaction/Energy Profile Diagram

The progress of the reaction can be shown in the form of the following energy profile diagram drawn between path of the reaction and the energy of the reactants and products.

(a) For Exothermic Reaction

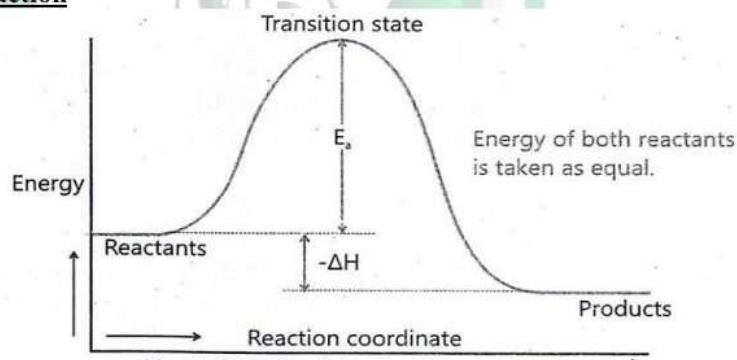


Fig (5.4) Path of Exothermic Reaction

Energy of Transition State

The energy of the transition state is higher than that of reactants or products because the bonds between the reactant or product molecules are being cleaved progressively.

Activation Energy

The minimum amount of energy required to start a chemical reaction is called Activation Energy.

OR

The energy absorbed by the reactant or product molecules in order to be converted into the transition state is called the activation energy (E) of the reaction.

Enthalpy (H) of the reaction

The difference between the energy of reactant and that of the product comes out in the form of heat representing enthalpy (AH) of the reaction. This graph represents the path of an exothermic reaction Fig (5.4).

(b) For Endothermic Reaction

A similar graph can be drawn for an endothermic reaction Fig (5.5).

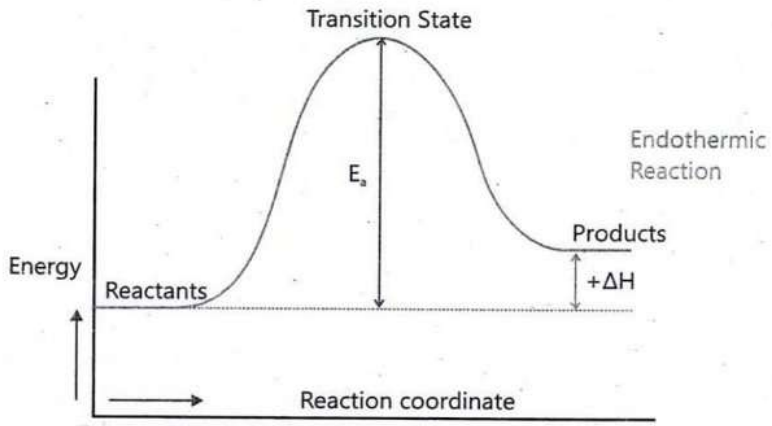


Fig (5.5) Path of Endothermic Reaction

Q.2 What is a catalyst? Describe effect of catalyst on the rate of chemical reaction.

Ans:

CATALYST

Definition

A catalyst is defined as a substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change.

Examples

- Ni acts as a catalyst in the hydrogenation of oil to give banaspati ghee
- Platinum acts as a catalyst in the production of H_2SO_4
- Chlorine acts as a catalyst promoting the breakdown of ozone

Effect of Catalyst on rate of Reaction

An addition of the catalyst in a reaction increases the rate of reaction

Reason

It changes the path adopted by the reactants whereby the activation energy value of the reaction is substantially decreased. As a result, more reactants are now able to be converted into product molecules and hence the rate of reaction will increase Fig (5.6).

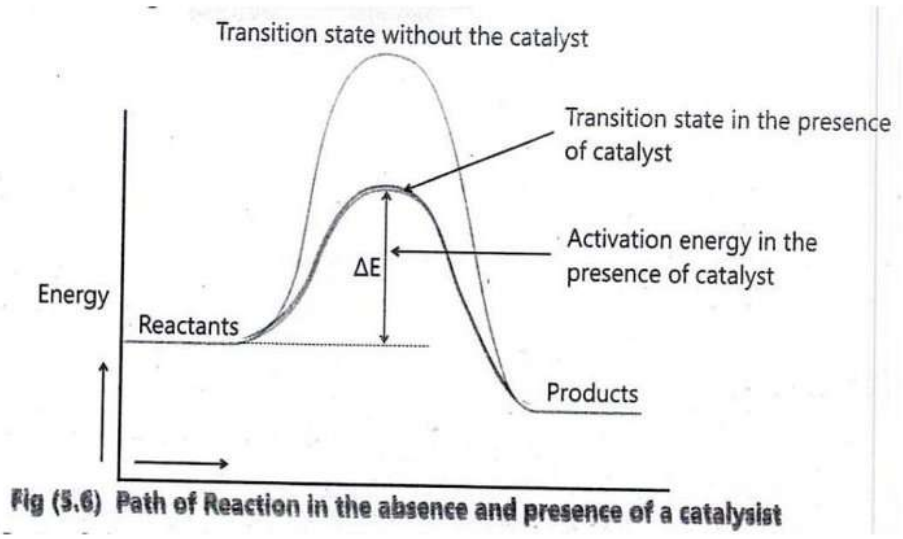


Fig (5.6) Path of Reaction in the absence and presence of a catalysist

INTERESTING INFORMATION

WASTAGE OF ENERGY

Washing clothes at 140^0F uses almost twice the energy as at 140^0F wash. 90% of the energy used by the traditional electric bulb is wasted in producing heat.

EXERCISE

1. Are energy diagrams useful?

Ans:

Yes, energy diagrams are very useful as they provide a graphical representation of energy changes during a chemical reaction. These diagrams help to understand either the reaction is exothermic or endothermic, the activation energy required, and the relative amounts of reactants and products.

EXERCISE

1. Draw an energy profile diagram for a hypothetical reaction which does not evolve or absorb heat.

Ans:

SHORT QUESTIONS

Q.1 What is a catalyst?

Ans:

CATALYST

Definition

A catalyst is defined as a substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change.

Examples

- Ni acts as a catalyst in the hydrogenation of oil to give banaspati ghee.
- Platinum acts as a catalyst in the production of H_2SO_4

Q.2 How does a reaction take place?

Ans:

CHEMICAL REACTION

Definition

The process in which chemical change occurs in nature and composition of substances is called chemical reaction.

Example

$$2\,H_{2(g)} + O_{2(g)} \longrightarrow 2\,H_2O_{(g)} + 568\ kJ \text{ or } \Delta H = -568\ kJ$$

MULTIPLE CHOICE QUESTIONS

1. $2\,H_{2(g)} + O_{2(g)} \longrightarrow 2\,H_2O_{(g)} + 568\ kJ$ or $\Delta H = -568\ kJ$ **. In this reaction which one is/are reactants?**

(A) H_2 and O_2 (B) H_2O
(C) H_2 (D) O_2

2. Burning is: ***(K.B)***

(A) Exothermic (B) Endothermic
(C) Electrolytic reaction (D) Decomposition reaction

3. Energy needed to start a reaction is called: ***(K.B)***

(A) Activation energy (B) Thermal energy
(C) Electrical energy (D) None of these

5.5 AEROBIC AND ANAEROBIC RESPIRATION

LONG QUESTION

Q.1 What is respiration? Describe the types of respiration with the help of examples.

Ans:

RESPIRATION

Definition

Respiration is the process of exchange of oxygen and carbon dioxide between the body and the environment.

OR

A biochemical process in which the cells of an organism obtain energy due to reaction of oxygen and glucose, resulting in the release of carbon dioxide, water, and ATP, is called respiration.

Respiration in Human Beings

The process of respiration in human beings is a continuous process. During this process, we breathe in oxygen and breathe out carbon dioxide. Respiration also carries complex chemical reactions inside the human body.

TYPES OF RESPIRATION

There are two types of respiration.

1. **Aerobic Respiration**

Definition

The type of respiration that occurs in the presence of oxygen is called aerobic respiration.

Nature of Reaction

Aerobic respiration is an exothermic process and involves the following reactions in cytoplasm ($C_3H_4O_3$)

$$\underset{(C_6H_{12}O_6)}{Glucose_{(s)}} \xrightarrow{\text{in cytoplasm}} \underset{+\ Energy}{\overset{(C_3H_4O_3)}{2Pyruvate}} \xrightarrow[\text{in mitochondria}]{O_2} 6CO_{2(g)} + 6H_2O_l + Energy$$

Glycolysis

Breakdown of glucose is called glycolysis.

Reaction of Glycolysis

During glycolysis one molecule of glucose is split into two molecules of pyruvate. This process involves a series of reactions catalyzed by enzymes, with a net production of 2 ATP (Adenosine Triphosphate).

Significance of Glycolysis

When cells of our body require energy for performing the metabolic activities, they use this ATP and break it down to get the required energy. The food we eat undergoes digestion in our body

and the digested food molecules that are absorbed by the cells undergo oxidation to produce energy.

2. **Anaerobic Respiration**

Definition

The type of respiration that occurs in the absence of oxygen is called anaerobic respiration.

Example

In certain organisms like bacteria and algae respiration occurs in the absence of oxygen and it is called anaerobic respiration.

Nature of Reaction

This is also an exothermic process and during this process glucose is converted into carbon dioxide and ethanol with the evolution of energy in cytoplasm in absence of oxygen.

$$Glucose_{(s)} \xrightarrow{\text{in cytoplasm}} Pyruvate + Energy \xrightarrow[\text{Yeast}]{\text{Absence of oxygen}} C_2H_5OH_{(l)} + Co_{2(g)} + Energy$$

Q.2 What is lipids? Describe the significance and formation of lipids.

Ans:

LIPIDS

Definition

Triesters of glycerol with fatty acids are called lipids.

OR

Lipids are a group of organic compounds which include fats, waxes, sterols, etc.

Major Types of Lipids:

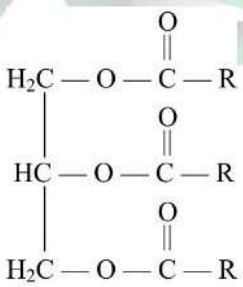
The major types of lipids are as follows:

(i) Oils

(ii) Fats

General formula:

General formula of triglycerides is as under:



Significance of Lipids

Lipids serve as an energy reserve within our body.

About half of the fuel our body needs comes from lipids.

In between meals and during exercise our body relies on this resource to provide energy.

Formation of Glycogen

Glycogen is the primary storage form of glucose. It is stored in the liver and muscles.

Formation of Lipids in adipose cells

If you eat more food than you need in a day, the excess food is stored as lipids in adipose cells.

SHORT QUESTIONS

Q.1 What is difference between ghee and oil? ***(Understanding Base)***
(LHR 2015, GRW 2017, MTN 2017, FSD 2016 G-I, SWL 2016 G-II, DGK 2016 G-II, BWP 2016 G-II)

Ans: **DIFFERENTIATION**

The differences between ghee and oil are as follows:

Ghee	Oil
Physical State	
• It exists in solid form at room temperature.	• It exists in liquid form at room temperature.
Nature	
• These are the triglycerides of **saturated fatty acids.**	• These are the triglycerides of **unsaturated fatty acids.**

Q.2 Give the characteristics of fats. ***(Knowledge Base)***

Ans: **CHARACTERISTICS OF FATS**

The characteristics of fats are as follows:

(i) Fats exist is solid form at room temperature.
(ii) Fats are the triglycerides of saturated fatty acids.
(iii) They are lighter than water.
(iv) They are insoluble in water.
(v) They are poor conductors of heat and electricity and serve excellent insulator for the animal body.

Q.3 What is respiration?

Ans: **RESPIRATION**

Definition

Respiration is the process of exchange of oxygen and carbon dioxide between the body and the environment.

Q.4 What is meant by anaerobic respiration?

Ans: **ANAEROBIC RESPIRATION**

Definition

The type of respiration that occurs in the presence of oxygen is called aerobic respiration.

Nature of Reaction

Aerobic respiration is an exothermic process and involves the following reactions in cytoplasm ($C_3H_4O_3$)

$$\underset{(C_6H_{12}O_6)}{Glucose_{(s)}} \xrightarrow{\text{in cytoplasm}} \underset{+\ Energy}{2Pyruvate\ (C_3H_4O_3)} \xrightarrow[\text{in mitochondria}]{O_2} 6CO_{2(g)} + 6H_2O_l + Energy$$

MULTIPLE CHOICE QUESTIONS

1. Which one does not require oxygen? ***(K.B)***
(A) Aerobic Respiration (B) Anaerobic Respiration
(C) Fermentation (D) None of these

2. Aerobic respiration is an exothermic process and how many molecules of pyruvic acid are produced from one molecule of glucose?
(A) 2 (B) 1
(C) 4 (D) 4

3. Breakdown of glucose is called ***(K.B)***
(A) Glycolysis (B) Glycogenolysis
(C) Gluconeogenesis (D) Glycogenesis

ANSWER KEY

MULTIPLE CHOICE QUESTIONS

INTRODUCTION

1	D	2	B	3	A		

5.1 SYSTEM AND SURROUNDING

1	B	2	A	3	C		

5.2 ENTHALPY

1	C	2	C	3	B

5.3 EXOTHERMIC AND ENDOTHERMIC REACTIONS

1	A	2	A	3	A		

5.4 HOW DOES A REACTION TAKE PLACE?

1	A	2	A	3	A

5.5 AEROBIC AND ANAEROBIC RESPIRATION

1	B	2	A	3	A		

EXERCISE SOLUTION

MULTIPLE CHOICE

1. Tick (V) the correct answer.

1. The following reaction is an exothermic reaction.

$$H_2 + Cl_2 \longrightarrow 2HCl$$

From where does the energy come to break the bond of H_2 and Cl_2

(A) By collisions between the molecules
(B) From sunlight
(C) From the surrounding
(D) collisions of the molecules with the walls of the container

2. Which of the following reactions has the least value of activation energy?

(a) $H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(g)}$

(b) $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

(c) $NaCl_{(aq)} + AgNO_3\,(aq) \longrightarrow AgCl_{(s)} + NaNO_3$

(d) $H_{2(g)} + I_{2(s)} \longrightarrow 2HI_{(g)}$

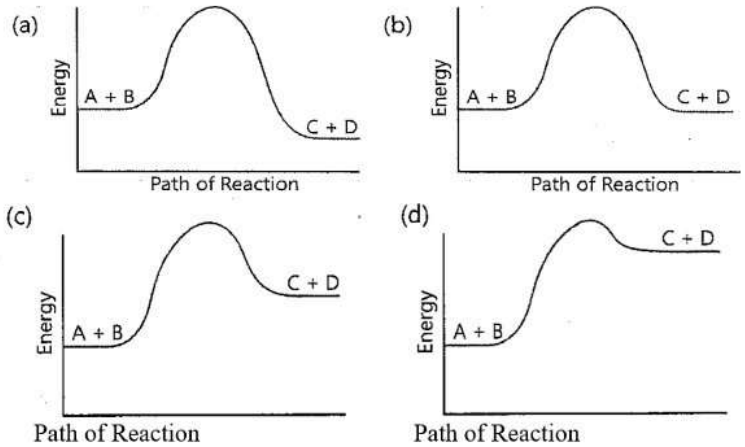
3. Formation of which hydrogen halide from the elements is an endothermic reaction?

(A) HCl (B) HF
(C) HBr (D) HI

4. What are the products of anaerobic respiration?

(A) ATP + CO_2 + H_2O (B) CO_2 + H_2O
(C) ATP + Ethanol + H_2O (D) Ethanol + H_2O

5. Which reaction do you expect to be a reversible reaction?



6. What does it show when a chemical reaction is exothermic?

(A) It shows the bonds which break are weaker than those are formed.
(B) It shows the bond which break are stronger than those are formed.
(C) Exothermic nature of the reaction is not concerned with bond formation or bond breakage.
(D) It shows that the reactants are more stable than the products.

7. When NaOH and HCI are mixed the temperature increases. The reaction is:

(A) endothermic with a positive enthalpy change.
(B) endothermic with a negative enthalpy change.
(C) exothermic with a positive enthalpy change.
(D) exothermic with a negative enthalpy change.

8. The average bond dissociation energy for the C-H bond is 412 KJ mol^{-1}. Which of the following process will have enthalpy change close to 412 KJ mol^{-1}?

(a) $CH_{4(g)} \longrightarrow C_{(g)} + 2H_{2(g)}$
(b) $CH_{4(g)} \longrightarrow C_{(g)} + 2H_{2(g)}$
(c) $CH_{4(g)} \longrightarrow C_{(g)} + 4H_{(g)}$
(d) $CH_{4(g)} \longrightarrow CH_{3(g)} + H_{(g)}$

9. The average bond energies for O-O and O=O are 146 and 496 kJ mol^{-1} respectively. Find the enthalpy in kJ for the following reaction?

$$H-O-O-H_{(g)} \longrightarrow H-O-H_{(g)} + \frac{1}{2} O = O_{(g)}$$

(A) -102kJ
(B) +102kj
(C) +350kJ
(D) +394Kj

10. Why does the following exothermic reaction not occur?

C (diamond) ⟶ C (graphite) $\Delta H = -3kJ\ mol^{-1}$

(A) Structure of diamond is more stable than that of graphite.
(B) Diamond has strong covalent bonds than does the graphite.
(C) The change from diamond to graphite has high activation energy.

(D) Density of graphite is less than that of diamond.

ANSWER KEY

1	B	**2**	C	**3**	D	**4**	C	**5**	A
6	A	**7**	D	**8**	D	**9**	A	**10**	A

QUESTIONS FOR SHORT ANSWERS

2. Questions for Short Answers:

Q.1 What is the difference between enthalpy and enthalpy change?

Ans: **DIFFERENTIATION**

The differences between Enthalpy and enthalpy change are as follows:

Enthalpy	Enthalpy Change
Definition	
• *Enthalpy is an essential part of a system since it depends on the number of molecules present in that system, its chemical composition and its structure.*	• *An* **enthalpy change** *is the heat evolved or absorbed when a reaction takes place at constant pressure.*
Representation	
• It is represented by H.	• It is represented by ΔH.

Q.2 Why is breaking of a bond an endothermic process?

Ans: **BREAKING OF BOND**

The breaking of bond is an endothermic change because it requires heat to overcome the attractive forces between atoms.

Q.3 Depict the transition state for the following reaction.

$$H_2 + C1_2 \longrightarrow 2HCl$$

Ans: **TRANSITION STATE**

In transition state old bonds (in Cl-Cl and H-H) are partially breaking and new bonds (in H-Cl) are partially forming.

Transition State

A transition state in a chemical reaction is a high-energy, unstable molecular configuration that exists momentarily when reactants are in the process of transforming into products.

Q.4 Draw the reaction profiles for two exothermic reactions one of which moves faster than the other.

Ans: **REACTION PROFILES FOR TWO EXOTHERMIC REACTIONS**

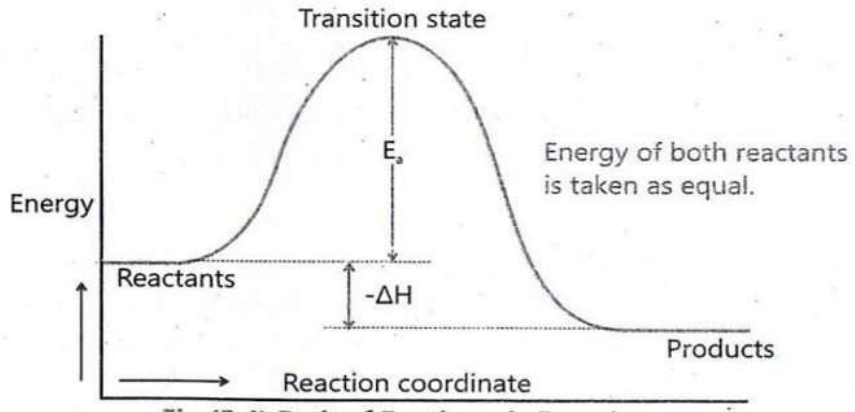
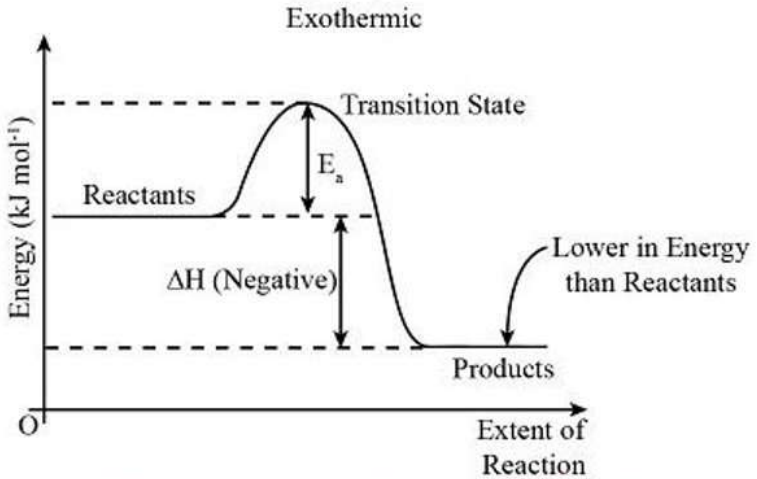


Fig (5.4) Path of Exothermic Reaction



Q.5 What is the role of glycogen in our body?

Ans:

ROLE OF GLYCOGEN

Glycogen is the primary short-term energy reserve of body. Glucose is converted into glucose molecules and stored in the liver and muscles. It can be rapidly broken down into glucose which is released into the bloodstream and maintains blood sugar levels, particularly during exercise or fasting periods.

CONSTRUCTED RESPONSE QUESTIONS

3. Constructed Response Questions

Q.1 Physical changes which usually occur around us are given in the table. Write down whether they are exothermic or endothermic.

Physical change	Exothermic or endothermic	Physical change	Exothermic or endothermic
Conversion of hydrated salt into anhydrous salt		Conduction of electricity by metals	
Burning paper		Dissolving ammonium chloride in water	
Vapourizing liquid nitrogen		Formation of rain from clouds	

Evaporation of dry ice		Dissolving sodium carbonate in water	

Ans: **EXOTHERMIC OR ENDOTHERMIC CHANGE**

Physical change	Exothermic or endothermic	Physical change	Exothermic or endothermic
Conversion of hydrated salt into anhydrous salt	Endothermic	Conduction of electricity by metals	Endothermic
Burning paper	Exothermic	Dissolving ammonium chloride in water	Endothermic
Vapourizing liquid nitrogen	Endothermic	Formation of rain from clouds	Exothermic
Evaporation of dry ice	Endothermic	Dissolving sodium carbonate in water	Exothermic

Q.2 Explain why the reaction between atmospheric gases oxygen and nitrogen does not take place under normal conditions? But in the presence of lightening these gases react to give NO. The reaction stops as soon as the lightening stops.

Ans: **REACTION BETWEEN OXYGEN AND NITROGEN**

The reaction between atmospheric gases oxygen and nitrogen does not take place under normal conditions because these gases do not react with each other to form oxides of nitrogen. The reaction is endothermic and requires very high temperature. Thus in the presence of lightening these gases react to give NO.

$$N_2 + O_2 \longrightarrow 2NO$$

Stopping of Reaction:

The reaction stops as soon as the lightening stops because the temperature drops.

Q.3 A reaction between natural gas (CH_4) and atmospheric oxygen does not take place when you mix them. As soon as you show a burning match stick, the reaction starts immediately and then it continues until one or both of the reactants is/are used up. Explain.

Ans: **START AND SUSTAIN OF CHEMICAL REACTION**

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

When we show a burning match stick, the reaction starts immediately because activation energy for the reaction is provided. Then it continues until one or both of the reactants is/are used up because heat, fuel and oxygen are available to sustain the reaction.

DESCRIPTIVE QUESTIONS

4. Descriptive Questions.

Q.1 Find out the enthalpy change of the following reaction using the given data.

$$N_2 + O_2 \longrightarrow 2NO$$

Bond dissociation energy of N_2 = 958.38 kJ/mol^{-1}

Bond dissociation energy of O_2 = 498 1kJ/mol^{-1}

Bond formation energy of NO = -626 1kJ/mol^{-1}

Ans: **NUMERICAL**

Given Data:

Bond dissociation energy of N_2 = 958.38 kJ/mol^{-1}

Bond dissociation energy of O_2 = 498 $1kJ/mol^{-1}$

Bond formation energy of NO = -626 $1kJ/mol^{-1}$

To Find:

Enthalpy Change of reaction = ?

Calculation:

$$N_2 + O_2 \longrightarrow 2NO$$

$$958.38 + 498 \longrightarrow 2(-626)$$

$$1456.38 \longrightarrow -1252$$

Enthalpy Change = + 204.38

Positive sign indicates that the reaction is endothermic.

Result:

Thus enthalpy change for the reaction is + 204.38 (heat is absorbed)

Q.2 Explain the difference between the terms heat and enthalpy.

Ans: **DIFFERENTIATION**

The differences between heat and enthalpy are as follows:

HEAT	ENTHALPY
Definition	
Heat is a form of energy that flows from hot body to a cold body because of a difference in temperature.	*Enthalpy is an essential part of a system since it depends on the number of molecules present in that system, its chemical composition and its structure.*
Unit of Measurement	
We measure heat in joules.	The unit of enthalpy in the International System of Units (S) is the joule (J).
Nature of Heat	
Heat is what we call the transfer of thermal energy.	Heat is not essential part of a system, it just comes and goes. When heat leaves or enters a system, it results in a change of enthalpy. At a constant pressure the enthalpy change is equal to heat evolved or absorbed.

Q.3 Explain why formation of a bond is always an exothermic process.

Ans: Answer given on page # 137

Q.4 Explain the role of lipids in our body.

Ans: Answer given on page # 146

Q.5 Explain the following terms.

Activation energy, Transition state, Aerobic respiration

Ans: **EXPLANATION OF THE TERMS**

ACTIVATION ENERGY

Answer given on page # 143

TRANSITION STATE

Answer given on page # 150

AEROBIC RESPIRATION

Answer given on page # 145

INVESTIGATIVE QUESTIONS

5. Investigative Questions

Q.1 Why is it essential to cook some of the food items while others we can eat without cooking?

Ans: **EATING OF COOKED AND UNCOOKED FOODS**

It is essential to cook some of the food items because cooking can improve food's taste, texture, and appearance, and make it easier to digest while others we can eat without cooking can alter the nutritional content of food. Thus we can say that Cooked and uncooked food have different nutritional contents and health risks.

Q.2 Why do fireworks look spectacular? What type of chemical compounds undergo chemical reactions during this activity?

Ans: **FIREWORKS LOOK SPECTACULAR**

When the fireworks explode, the heat produced excites the electrons in the metal ions. The electrons quickly release the energy in the form of colored light which was absorbed by them. Thus fireworks look spectacular.

COMPOUNDS IN FIRE WORKS

The chemical compounds undergoing chemical reactions in fireworks are the metal salts. These metal salts produce the colors we see.

TERMS TO KNOW

Terms	Definitions
System and Surrounding	Any physical or chemical change under study is called a system. Everything else which does not fail in this system is called surrounding.
Heat Content	The total amount of heat energy present in a system at standard conditions is called its heat content. The quantity of enthalpy of a system is also called its total heat content.
Standard enthalpy of a reaction	The standard enthalpy of a reaction is the enthalpy change that occurs when reactants in their standard states undergo reaction to produce products in their standard states.
Exothermic reactions	Chemical reactions which take place with the evolution of heat are called exothermic reactions.
Endothermic Reactions	Chemical Reactions which proceed with the absorption of heat are called endothermic reactions.
Formation of Chemical Bond	A chemical reaction always involves breaking and formation of chemical bonds
Exothermic and Endothermic Process	When weaker bonds are broken while stronger bonds are formed, The reaction is overall exothermic and vice versa.
Occuring of Chemical Reaction	A reaction take place when the reactant particles collide to give a transition state which then change into the products.
Activation Energy	The energy needed by the reactant particles to change into transition state is called activation energy.
Enthalpy change of the reaction	The difference between the energy of reactants and that of products is called enthalpy change of the reaction.
Exothermic	The reaction is exothermic if the energy of the products is less than that of

Reaction	reactants and endothermic if the energy of the products is more them that of reactants.
Catalyst	A catalyst increases the rate of-reaction by decreasing its activation energy
Aerobic respiration	The process of respiration in human beings takes place in the presence of oxygen and it is called aerobic respiration.
Anaerobic respiration	In some organisms, the respiration occurs in the absence of oxygen which is called anaerobic respiration.