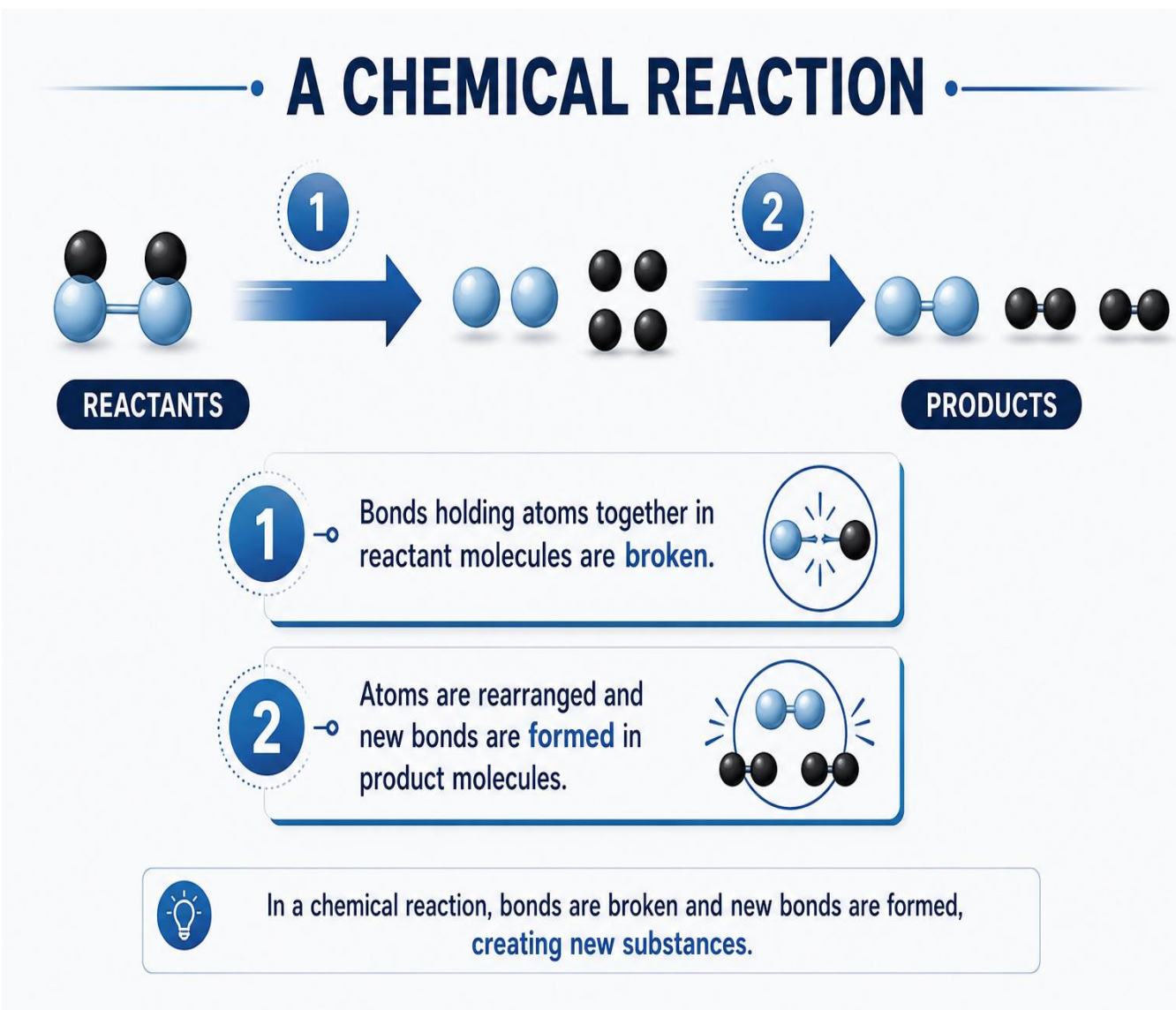


ENERGY AND CHEMICAL CHANGE



- ❑ All chemical reactions involve change in the structure and composition of the reactants to form new products.
- ❑ This is done through the **breaking of “old” bonds in the reactants** and the **formation of “new” bonds in the products**.
- ❑ These changes involve **energy**
- ❑ **Whenever there is bond breaking or bond formation, energy is either released or absorbed.**
- ❑ **Energy is absorbed to break the bonds of the reactant particles.**
- ❑ **Energy is released when new bonds form in the products**

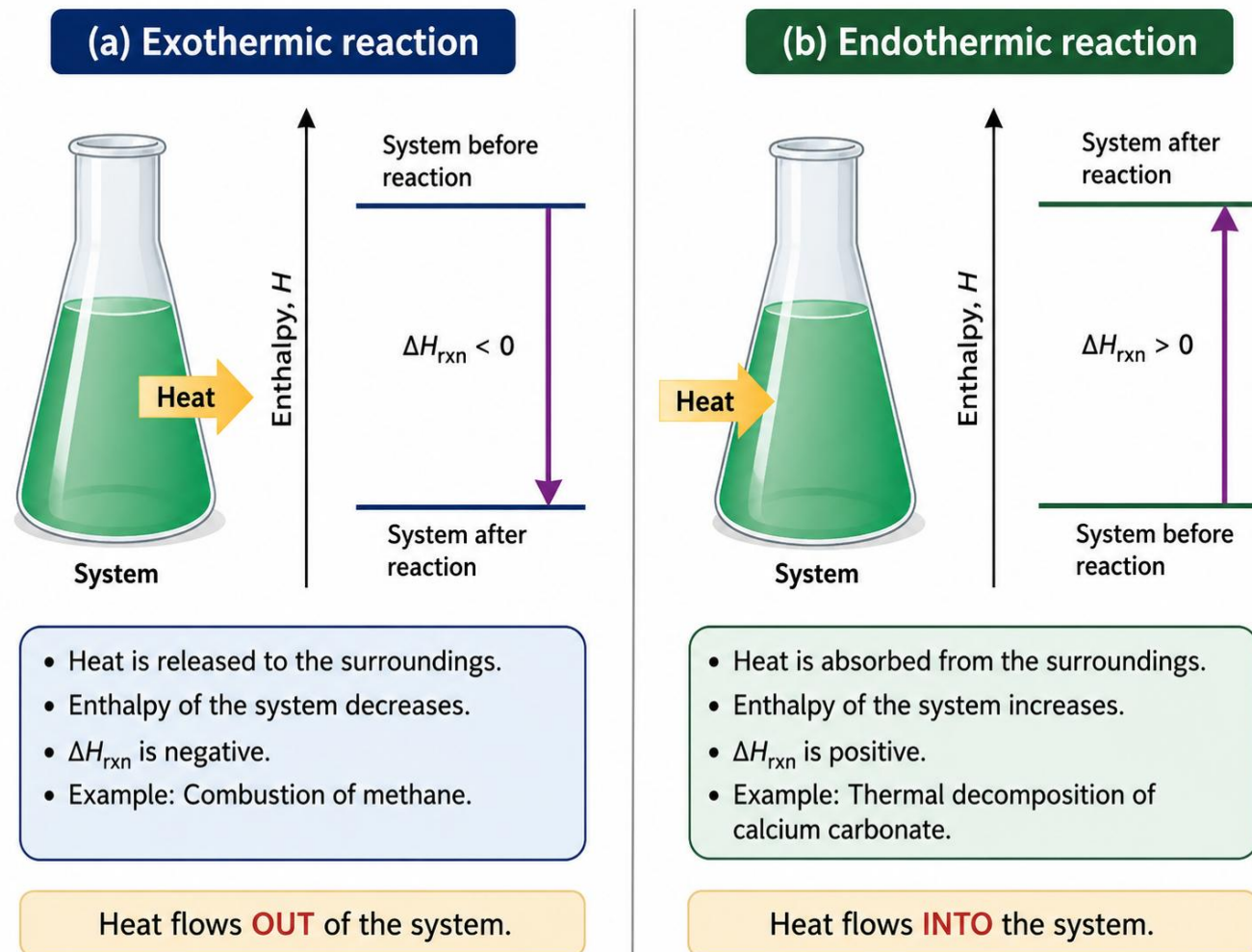


Heat of a reaction

- ❖ In some reactions, we can observe these energy changes as either an **increase or a decrease in the overall energy of the system**.
- ❖ In some reactions we see this as a change in the temperature.
- ❖ In other reactions we can observe this change when a reaction starts to give off light or when a reaction will only work after light is shone on it.
- ❖ The heat of reaction (ΔH), also known as **enthalpy of reaction is defined as the energy absorbed or released per mole in a chemical reaction**.
- ❖ It is the difference between the energy of the products and the reaction.

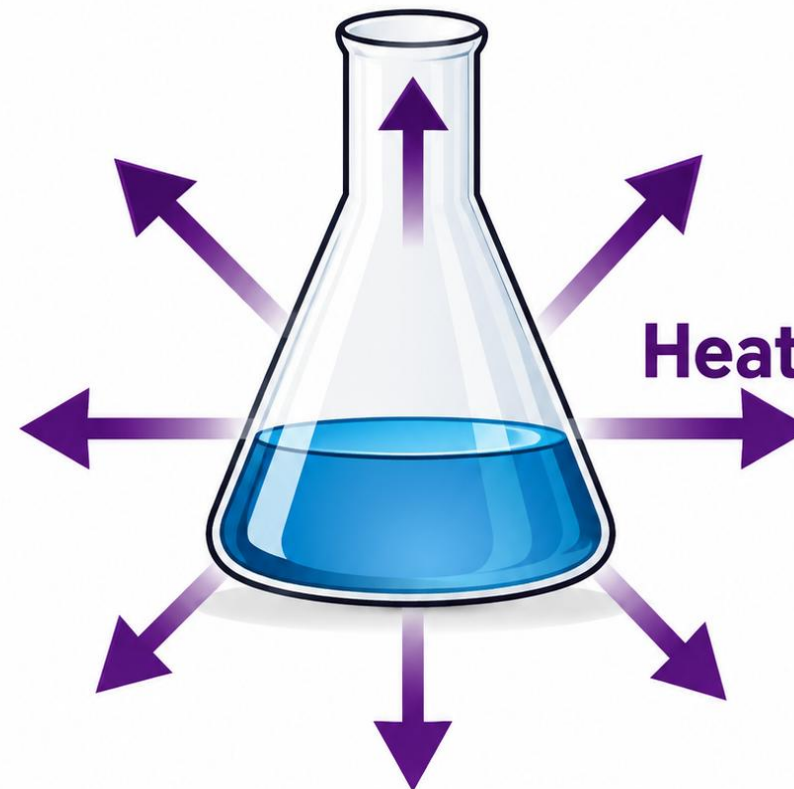
$$\Delta H = E_{\text{products}} - E_{\text{reactants}}$$

- ❖ The **units** for ΔH is **kJmol^{-1}**



Exothermic Reaction

- An exothermic reaction is a reaction that releases energy.
- When a reaction starts, energy is **absorbed** causing the energy of the system to increase, the energy is transferred into the surroundings, and the **temperature of the surroundings increase**
- In an exothermic reaction, **the energy of the reactants is higher than the energy of the products.**
- Reactants $\rightarrow$ Products + Energy released
- The enthalpy change is **negative** ($\Delta H < 0$)



EXOTHERMIC REACTIONS

A reaction that **releases energy** from the system in the form of heat.

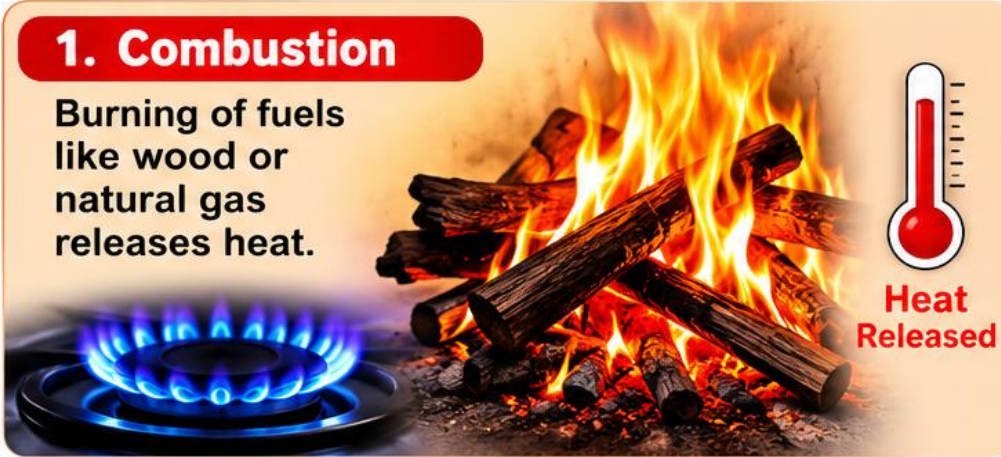


COMMON EXAMPLES OF EXOTHERMIC REACTIONS

Exothermic reactions release heat energy to the surroundings.

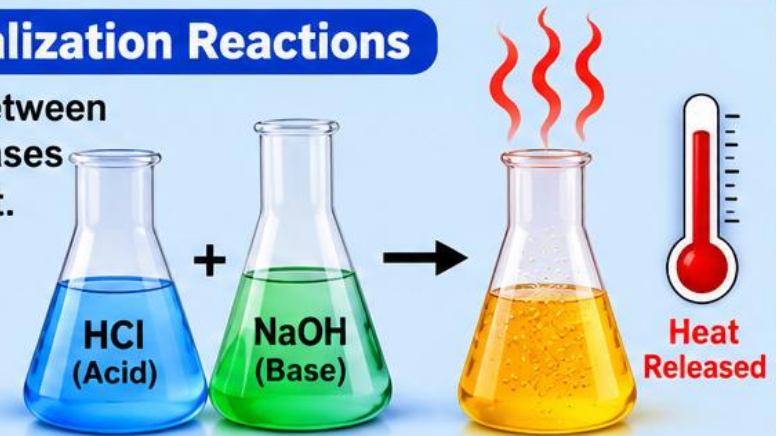
1. Combustion

Burning of fuels like wood or natural gas releases heat.



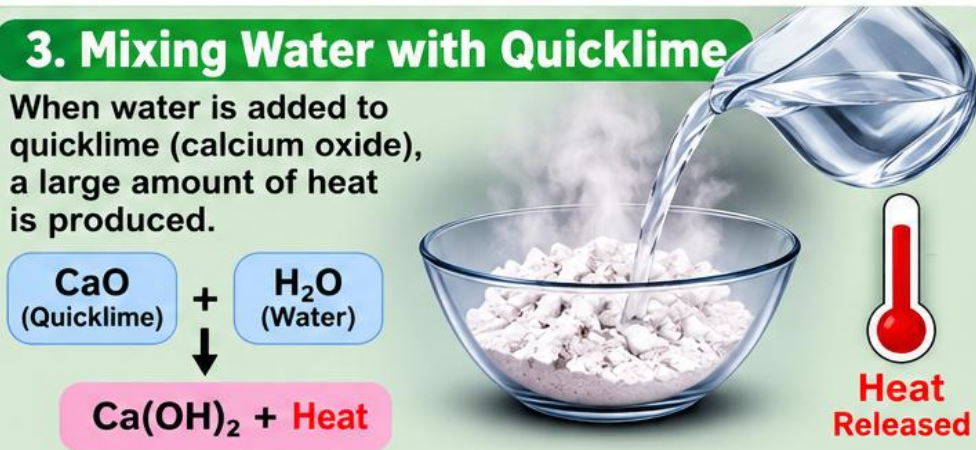
2. Neutralization Reactions

Reactions between acids and bases release heat.



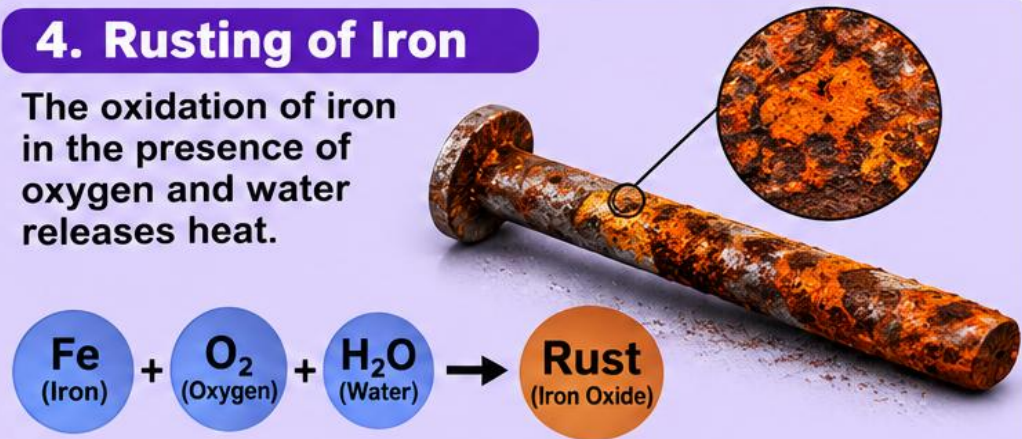
3. Mixing Water with Quicklime

When water is added to quicklime (calcium oxide), a large amount of heat is produced.



4. Rusting of Iron

The oxidation of iron in the presence of oxygen and water releases heat.

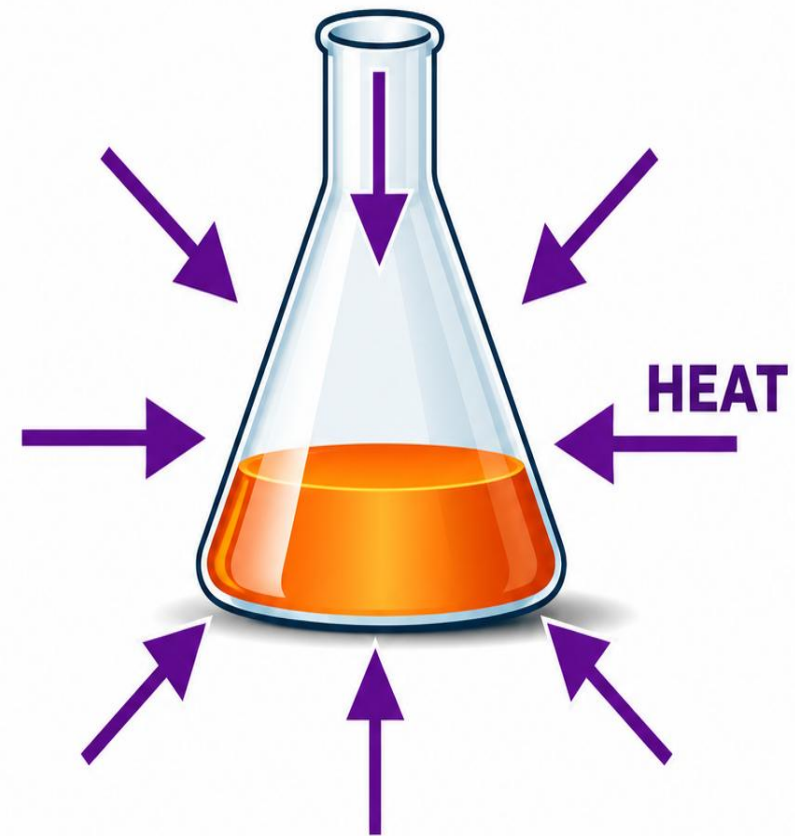


Key Point: In all these reactions, **heat is released** to the surroundings.



Endothermic Reactions

- An endothermic reaction is a chemical reaction that **absorbs energy** from its surroundings, usually in the form of heat, causing a **decrease in the temperature** of the surroundings.
- Essentially, the reaction needs to take in heat to proceed
- In an endothermic reaction, the **energy of the products is higher than the energy of the reactants**
- Reactants + Energy absorbed $\longrightarrow$ Products
- Dissolving ammonium nitrate crystals in water is an endothermic reaction



ENDOTHERMIC REACTION

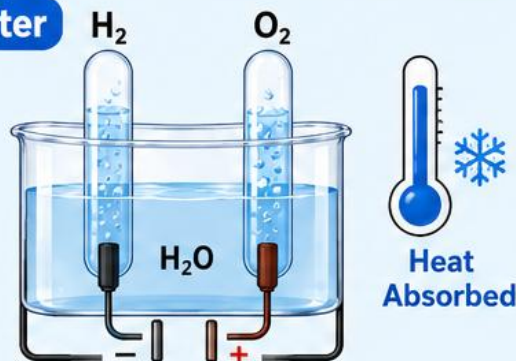
A reaction that the system absorbs energy from its surrounding in the form of heat.

COMMON EXAMPLES OF ENDOTHERMIC REACTIONS

Endothermic reactions absorb heat energy from the surroundings.

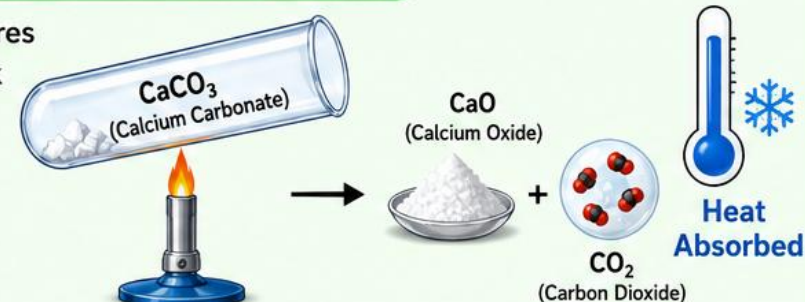
1. Electrolysis of Water

Electrolysis requires energy input (heat or electricity) to split water into hydrogen and oxygen.



2. Decomposition of Calcium Carbonate

This reaction requires heat input to break down calcium carbonate into calcium oxide and carbon dioxide.



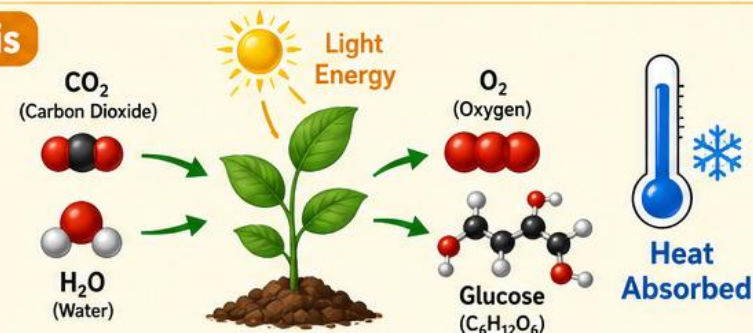
3. Melting of Ice

Ice absorbs heat from the surroundings to transition into liquid water.



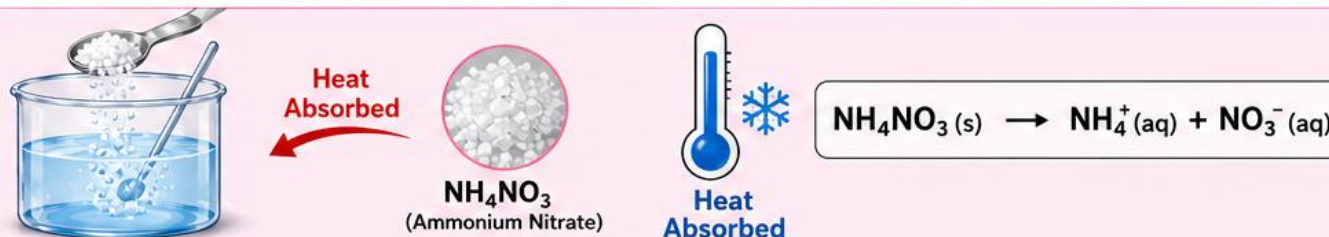
4. Photosynthesis

Plants absorb light energy to convert carbon dioxide and water into glucose and oxygen.



5. Dissolving Ammonium Nitrate

The dissolution of ammonium nitrate in water absorbs heat from the surroundings.

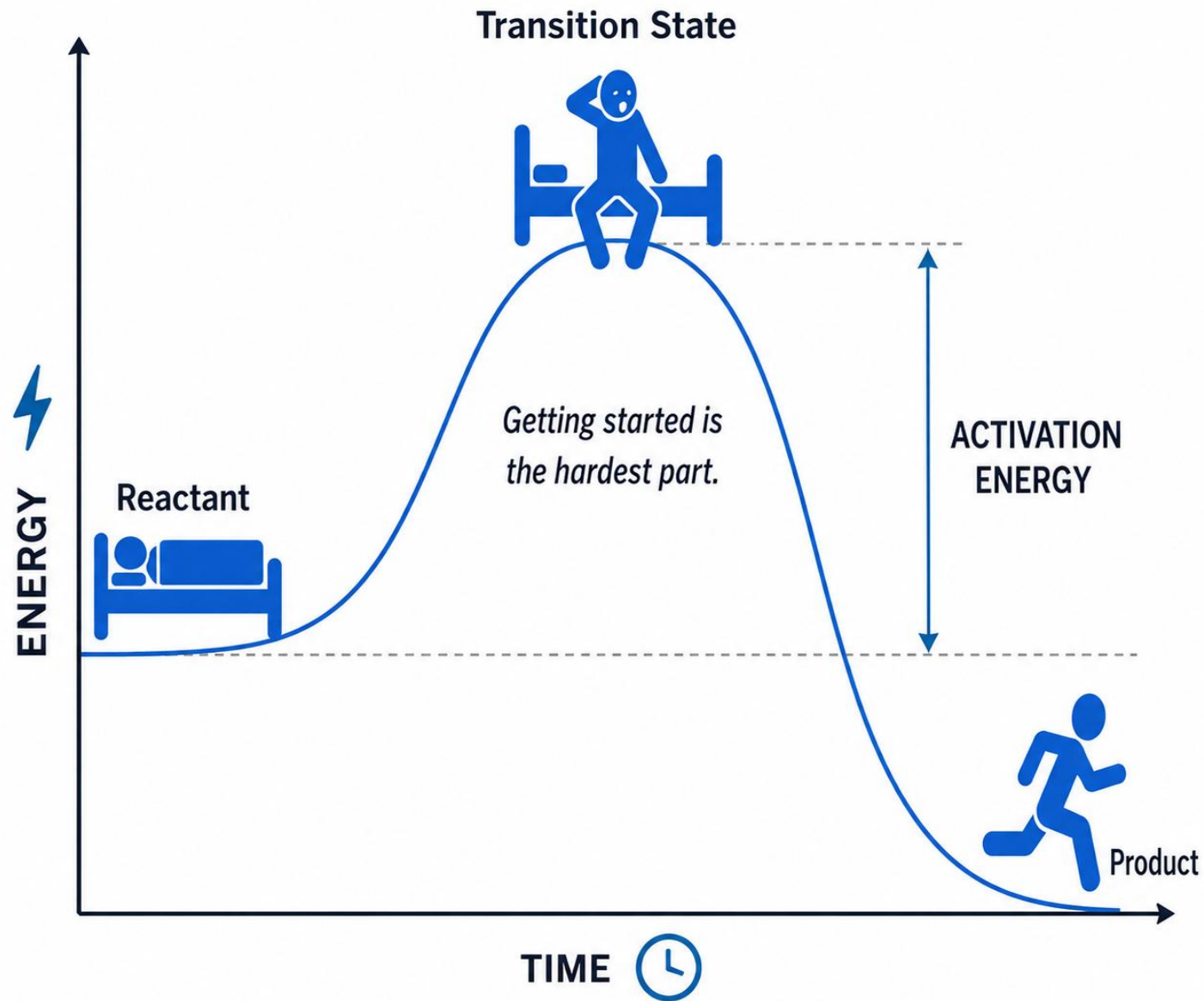


Key Point: In all these reactions, **heat energy is absorbed** from the surroundings, making the surroundings cooler.



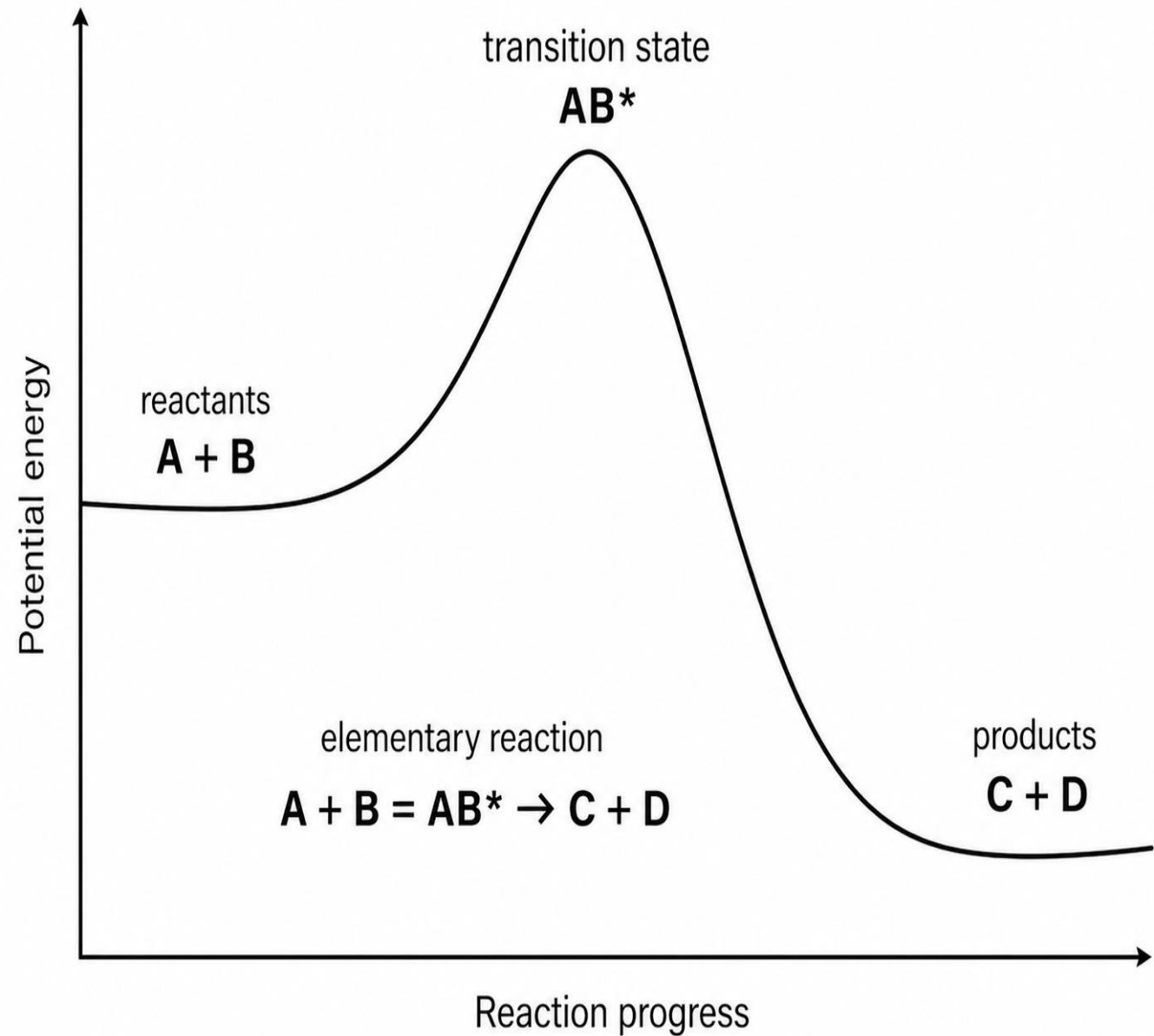
Activation Energy

- For any reaction to begin, molecules must be able to **collide effectively** to start the chemical reaction.
- The particles must **collide with sufficient energy to break the existing bonds and to form new ones**.
- **Activation energy (E_a)** is defined as the **minimum energy needed for a reaction to take place**.
- If reactant particles **do not possess** the required activation energy when **they collide, they bounce off each other without reacting**.
- Only **collisions which have energies equal to or greater than the activation energy** result in a reaction.



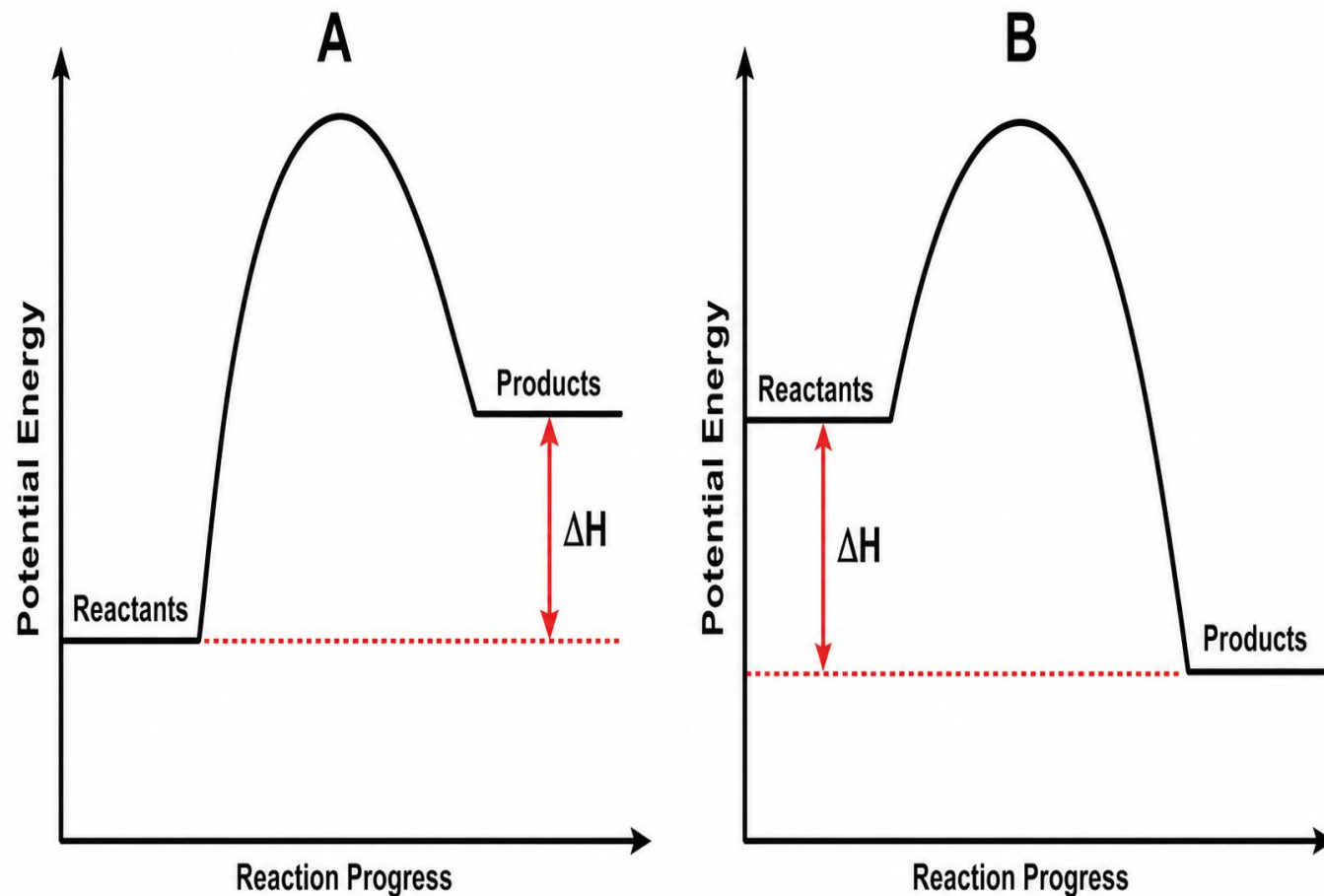
Activated Complex

- ❖ During the course of a reaction, particles form an unstable, intermediate, short-lived group of atoms, before they can form the final product .
- ❖ An activated complex, also known as a transition state, is an unstable, high-energy intermediate state that forms during a chemical reaction when bonds are breaking and forming.
- ❖ **An activated complex is defined as the unstable transition state from reactants to products**
- ❖ **It's a brief point in time where reactants are at their highest potential energy level, and it's the structure that corresponds to the peak of the activation energy barrier**



Potential Energy Profile Diagrams

- Potential energy profile diagrams, also known as reaction coordinate diagrams, are graphical representations of how potential energy changes during a chemical reaction.
- They visually illustrate the energy changes involved in converting reactants to products, including the activation energy and whether the reaction is **endothermic or exothermic**
- The profile shows the potential energy of the reactants at the beginning and the potential energy of the products at the end of the reaction.
- The x-axis represents the reaction coordinate, which is a measure of the reaction's progress.
- It's often depicted as the "distance" between reactants and products or a quasi-chemical index of reaction progress.



Exothermic reactions

- An exothermic reaction is a reaction in which energy is released in the form of light or heat.
- In an exothermic reaction, energy is transferred into the surroundings, and the **temperature of the surroundings increases**
- In an exothermic reaction, the energy of the reactants is greater than the energy of the products as shown in the potential energy vs reaction pathway graph

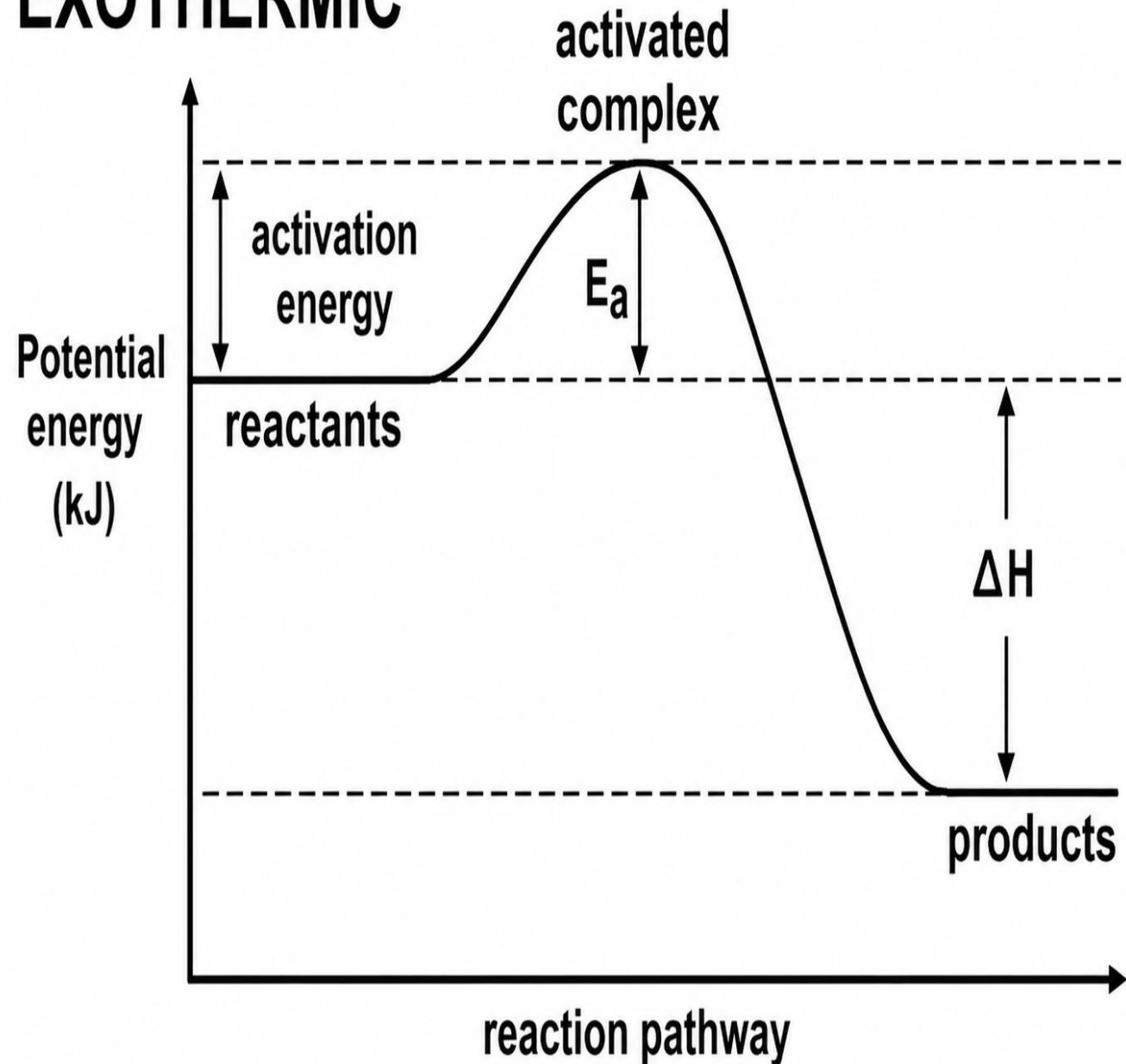
Note:

- ❖ The amount energy absorbed or released in reaction is called the **heat of a reaction or enthalpy of the reaction** (ΔH)
- ❖ It is the difference between the energy of the products and the reaction.

$$\Delta H = E_{\text{products}} - E_{\text{reactants}}$$

- ❖ For an exothermic reaction, $\Delta H < 0$ (negative)

EXOTHERMIC



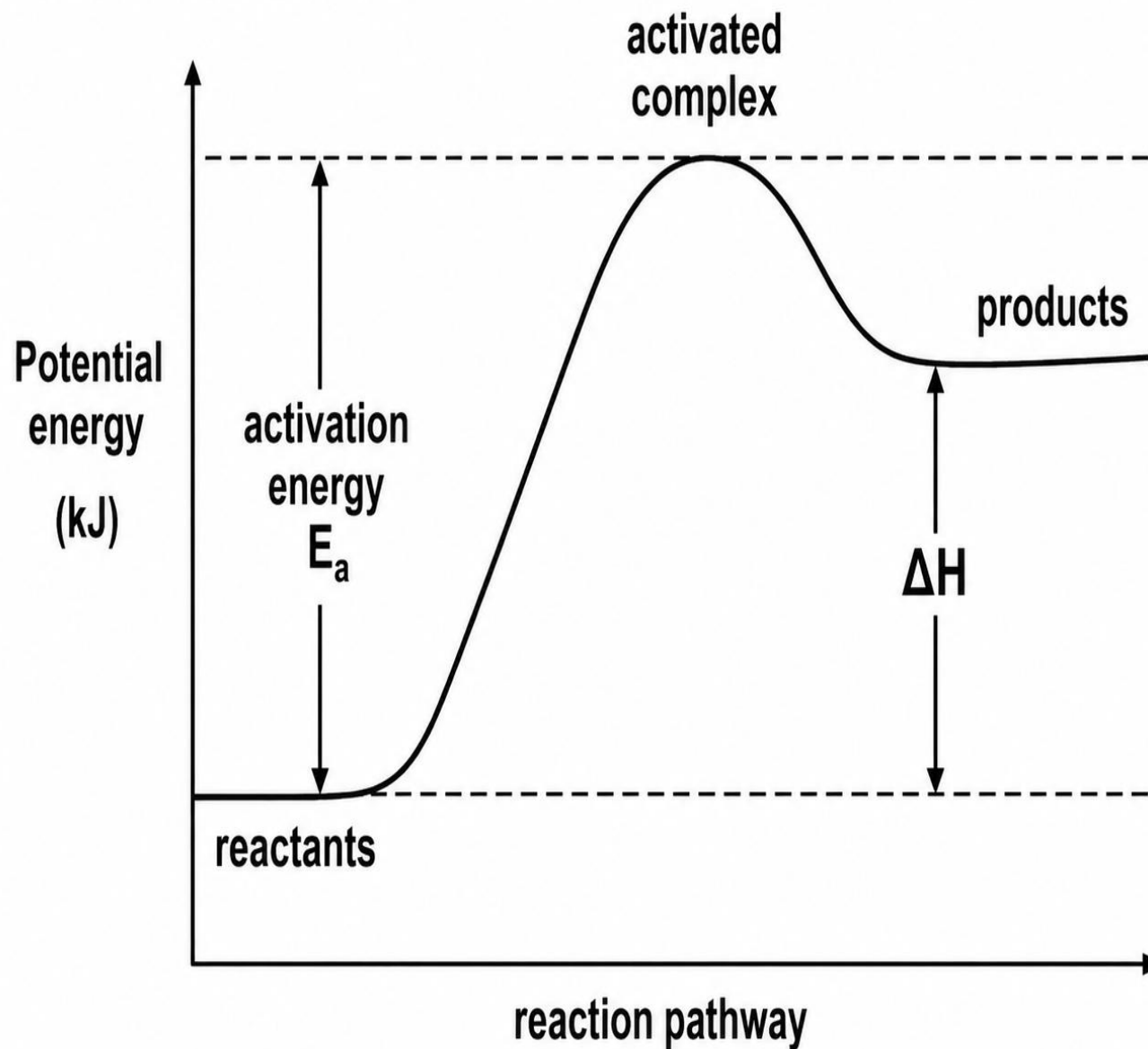
Endothermic reactions

- The endothermic reaction is a reaction where the system absorbs the energy from its surrounding in the form of heat and the temperature of the surroundings decreases
- **In an endothermic reaction, the energy of the reactants is less than the energy of the products** as shown in the potential energy vs reaction pathway graph

- **Note:**

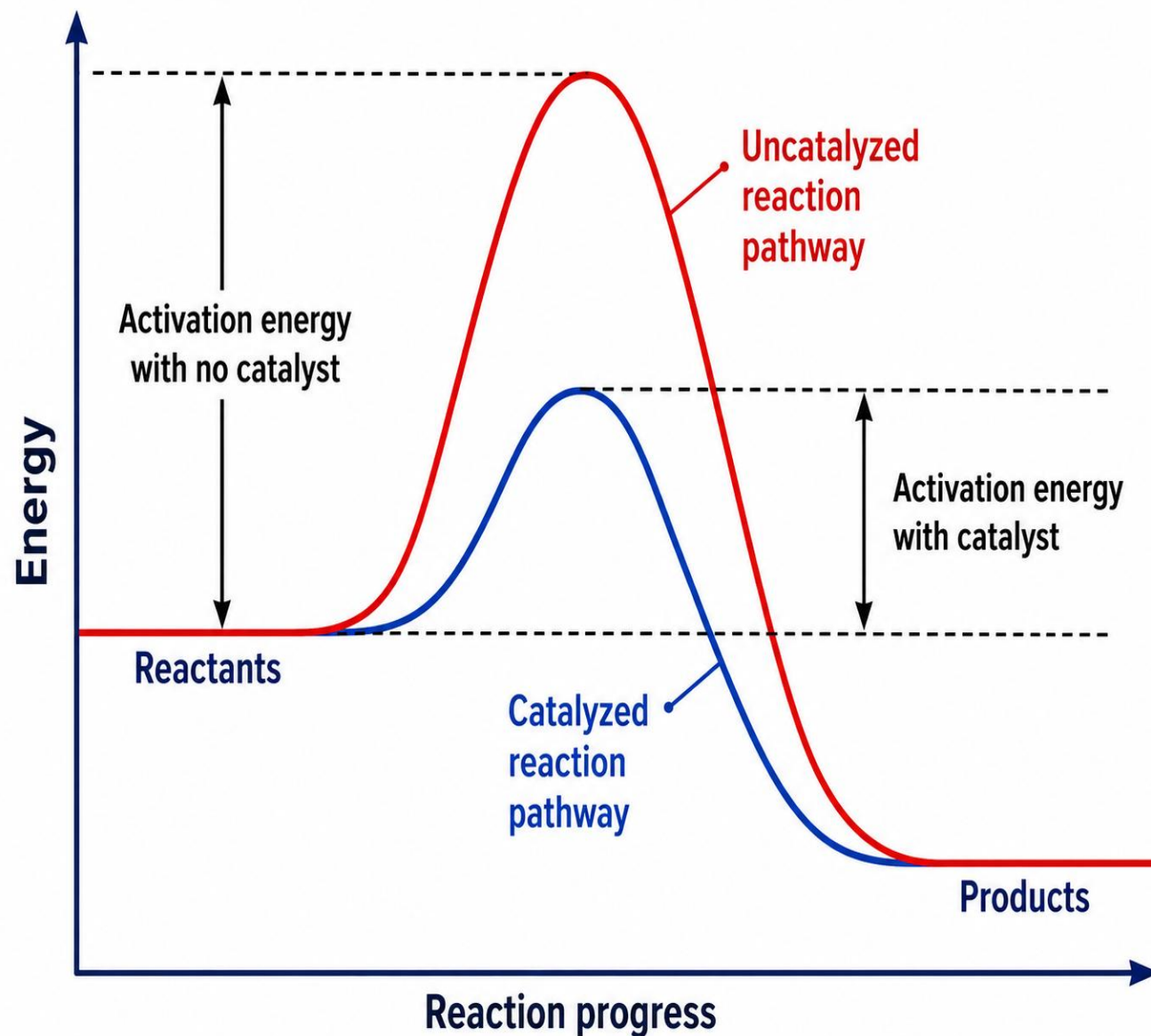
$\Delta H > 0$ (positive) for an endothermic reaction

ENDOTHERMIC



Catalyst

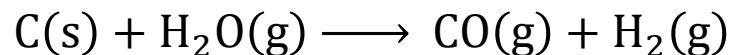
- **A catalyst is a substance that increases the rate of a chemical reaction without itself undergoing a permanent change.**
- **A positive catalyst is a substance that speeds up a chemical reaction without being consumed or permanently altered in the process.**
- It achieves this by lowering the activation energy of the reaction (providing an alternative path of lower activation energy)
- A catalyst works by changing the specific way in which the reaction occurs, called its mechanism.
- The important outcome from the use of a catalyst is that the overall activation energy of the reaction is lowered as shown in the diagram alongside.



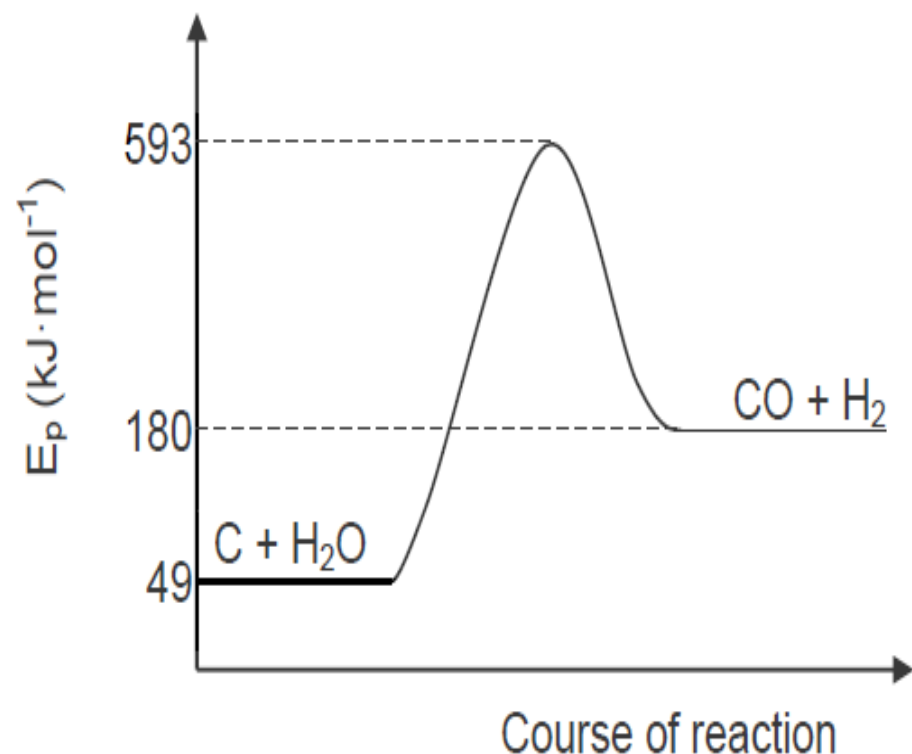
PAST EXAM PAPERS

2019 November Paper 2 Q 7

The balanced equation for the reaction of carbon with steam is as follows:



The graph below, NOT drawn to scale, represents the change in potential energy of the substances during the reaction.



7.1 Define the term *heat of reaction*. (2)

7.2 Is the reaction ENDOTHERMIC or EXOTHERMIC? (2)

Give a reason for the answer. (2)

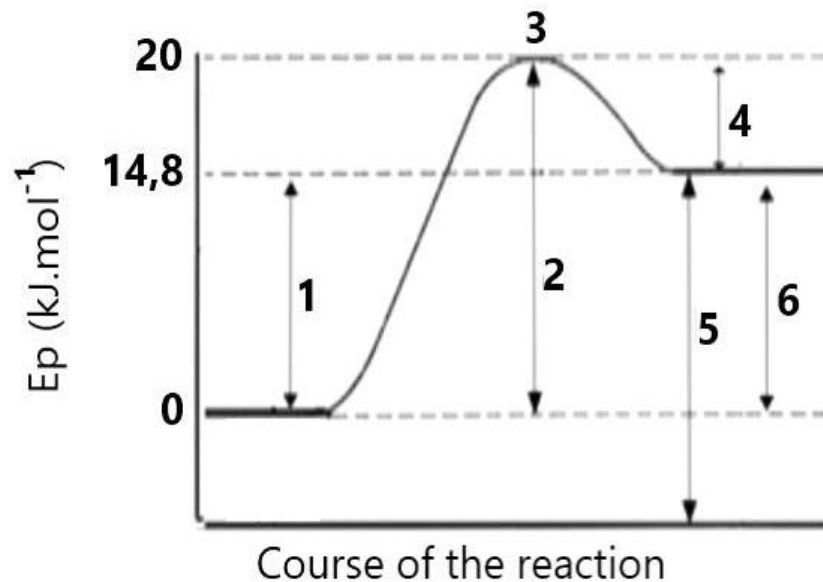
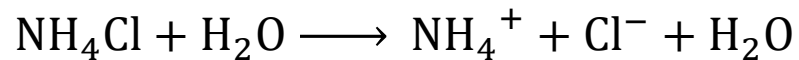
7.3 Use the information on the graph and write down the value of the:

7.3.1 Activation energy (2)

7.3.2 Heat of reaction (2)

2023 Gauteng November Exemplar Paper 2 Q 8

Certain chemical reactions are often used to reduce swelling after an athletic injury. In a lab experiment the following reaction was tested and the sketch graph below was obtained.



8.1 Is this an exothermic or endothermic reaction? (1)

8.2. Explain the answer to QUESTION 8.1. (2)

8.3. State the enthalpy of this reaction. (2)

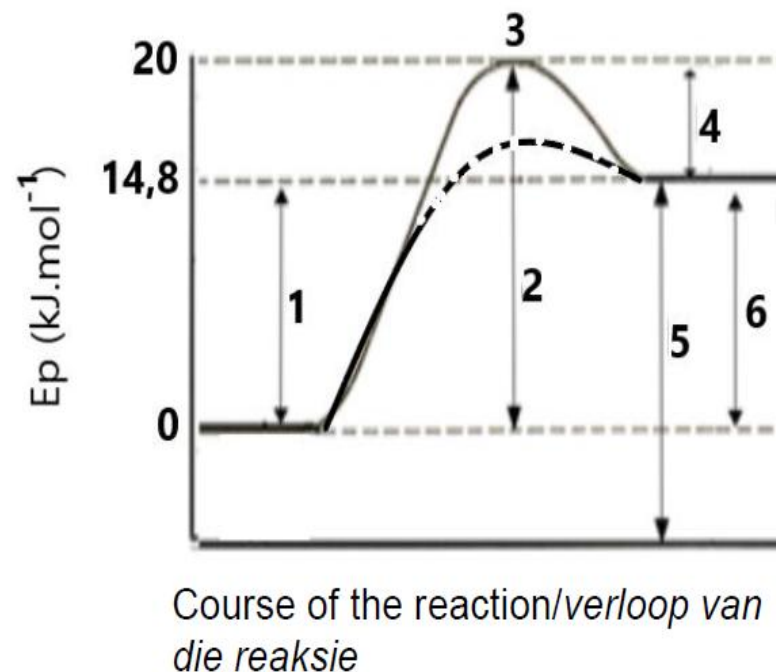
8.4 Which number on the graph represents the enthalpy for the reverse reaction? (1)

8.5 Define *activation energy*. (2)

8.6 Give the number on the graph that represents the activated complex. (1)

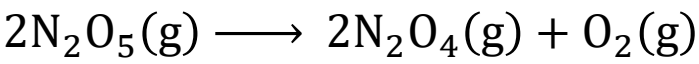
8.7 Explain how a catalyst would affect the activation energy in the reaction. (2)

8.8 Redraw the sketch graph on you answer sheet and use a dotted line to indicate the changes after adding a catalyst. (2)



2024 Eastern Cape November Paper 2 Q 5

Consider the decomposition reaction of dinitrogen pentoxide:



The table below shows the different energies for the above reaction.

Heat the of reactants (H_r)	26,6 $\text{kJ}\cdot\text{mol}^{-1}$
Activation energy (E_a)	6,73 $\text{kJ}\cdot\text{mol}^{-1}$
Heat of the reaction (ΔH)	-7,28 $\text{kJ}\cdot\text{mol}^{-1}$

5.1 Define the term *activation energy*. (2)

5.2 Is the above reaction ENDOTHERMIC or EXOTHERMIC?

Give a reason for the answer. (2)

5.3 Calculate the heat of the products. (2)

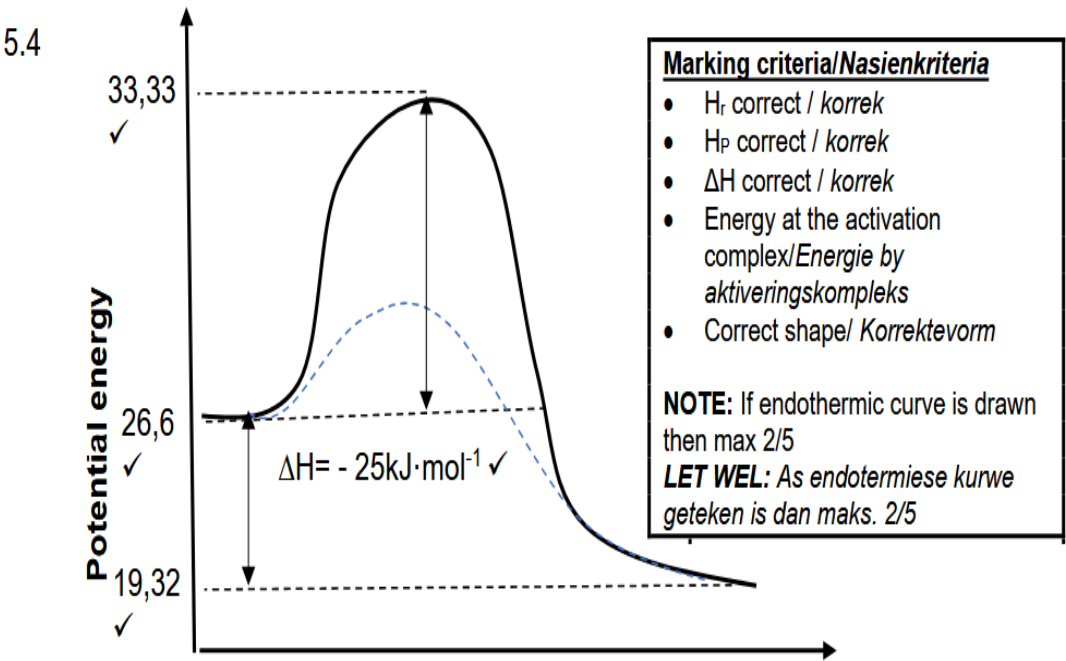
5.4 Draw the potential energy versus course of reaction graph for the above reaction.

On the graph indicate values for:

- Heat of reactants ($H_{\text{reactants}}$)
- Heat of products (H_{products})
- Energy at the activated complex
- Heat of the reaction (ΔH)

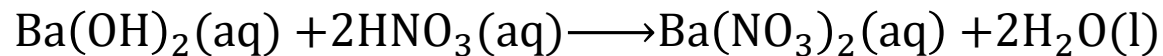
(5)

5.5 On the same graph drawn in QUESTION 5.4, use a dotted line and draw the shape of the graph when a catalyst is added to the original reaction. (2)

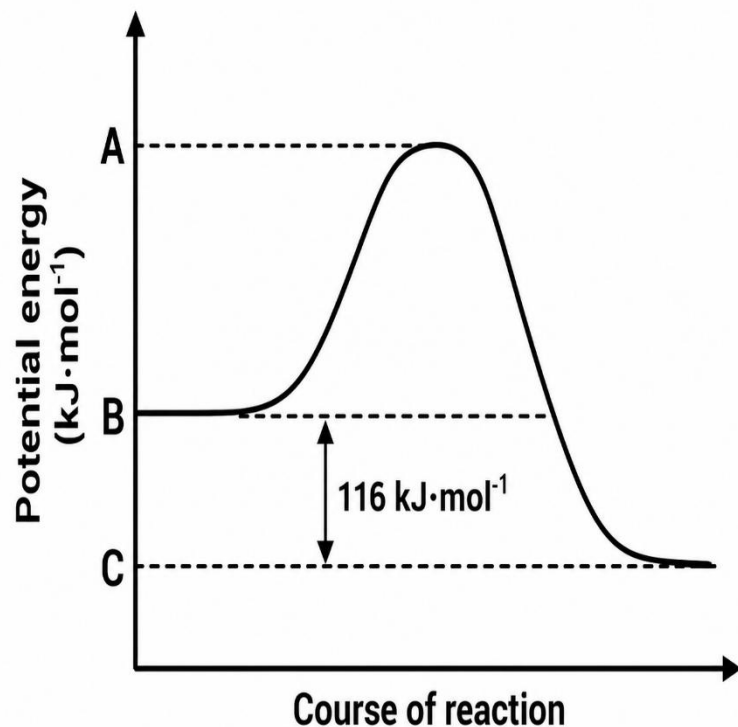


2015 November Paper 2 Q 7

A barium hydroxide solution, $\text{Ba}(\text{OH})_2(\text{aq})$ reacts with a nitric acid solution, $\text{HNO}_3(\text{aq})$, according to the following balanced equation:



The potential energy graph below shows the change in potential energy for this reaction.



7.1 Is this reaction ENDOTHERMIC or EXOTHERMIC? Give a reason for the answer. (2)

7.2 Use energy values **A**, **B** and **C** indicated on the graph and write down an expression for each of the following:

7.2.1 The energy of the activated complex (1)

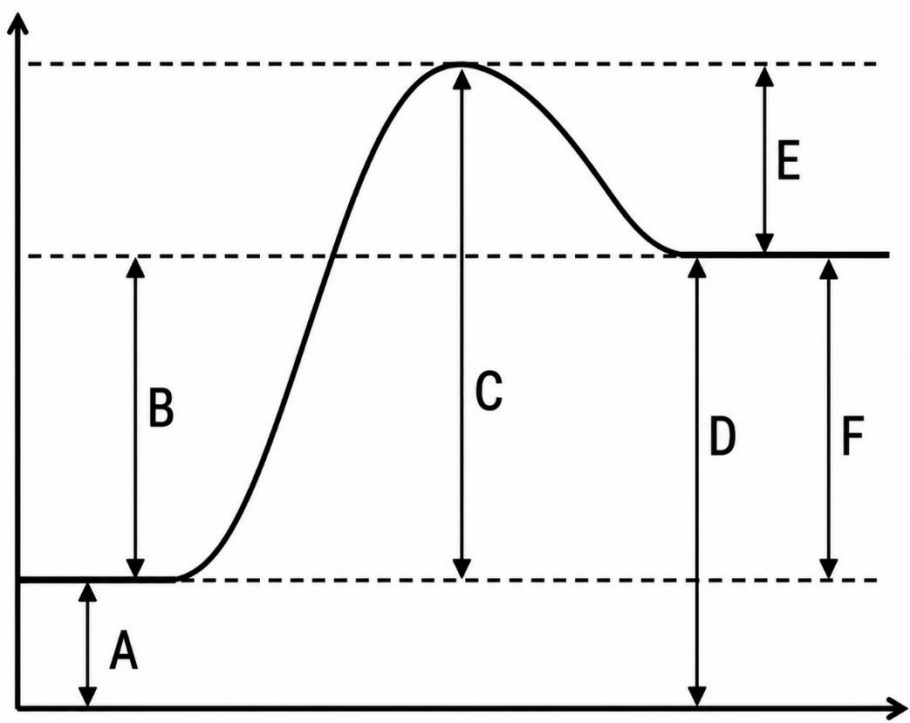
7.2.2 The activation energy for the forward reaction (1)

7.2.3 ΔH for the reverse reaction (1)

7.3 Calculate the amount of energy released during the reaction if 0,18 moles of $\text{Ba}(\text{OH})_2(\text{aq})$ reacts completely with the acid. (3)

2021 Gauteng November Paper 2 Q 6

Chemical cold packs are often used to reduce swelling after an athletic injury. A common example of a chemical ice pack is one that contains water and a packet of ammonium chloride. The cold pack is activated by breaking the barrier separating the water and ammonium chloride, allowing them to mix. The diagram below represents the potential energy changes when a cold pack is activated.



- 6.1 Is this an exothermic or endothermic reaction? (1)
- 6.2 Give ONE reason for the answer to QUESTION 6.1. (1)

- 6.3 Which letter on the diagram represents the activation energy of the forward reaction? (1)
- 6.4 Explain how a catalyst would affect the activation energy in the reaction? (2)
- 6.5 Explain why a “cold pack” would be effective in reducing swelling after an individual had twisted his/her ankle. Refer to the kinetic molecular theory in your answer. (2)

2017 November Paper 2 Q 7

The equation for the combustion of butane gas is given below.



7.1 Define the term *activation energy*. (2)

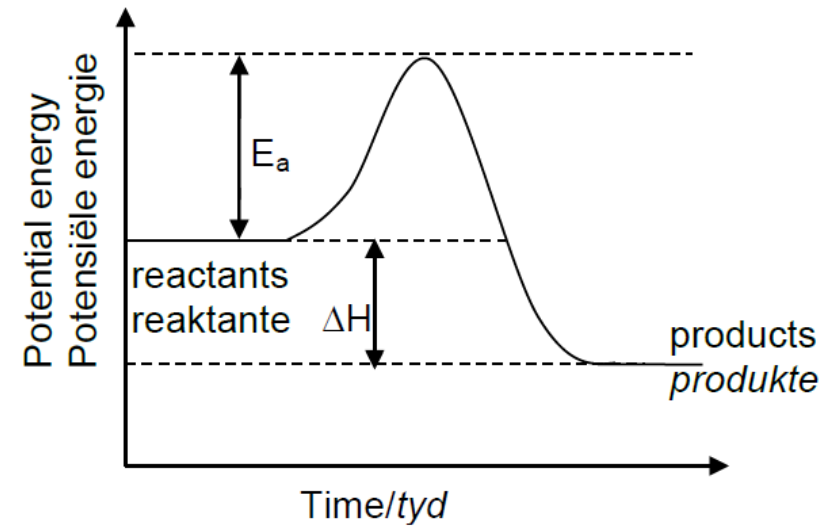
7.2 Is the combustion reaction of butane *exothermic* or *endothermic*? Give a reason for the answer. (2)

7.3 Draw a sketch graph of potential energy versus course of reaction for the reaction above.

Clearly indicate the following on the graph:

- Activation energy
 - Heat of reaction (ΔH)
 - Reactants and products
- (3)

7.4 Determine the empirical formula of butane gas if it consists of 82,76% carbon and 17,24% hydrogen.(4)

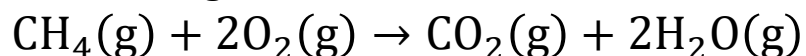


2025 KwaZulu Natal November Paper 2 Q 3

The following table provides the bond energies between atoms.

Bond	Energy (kJ·mol ⁻¹)
C≡C	839
C=O	804
O=O	498
C–C	348
O–O	145
H–O	463
C–O	358
H–C	413

Consider the following reaction:



3.1 Define the term *activation energy*. (2)

3.2 Determine:

3.2.1 The activation energy for the reaction. (3)

3.2.2 The heat of reaction in kJ·mol⁻¹. (4)

3.3 How will the value calculated in QUESTION 3.2.2 be affected if a suitable catalyst is used? Choose from INCREASES, DECREASES or REMAINS THE SAME. Give a reason for your answer. (2)

3.4 24 g of CH₄ reacts completely with excess O₂ at STP.

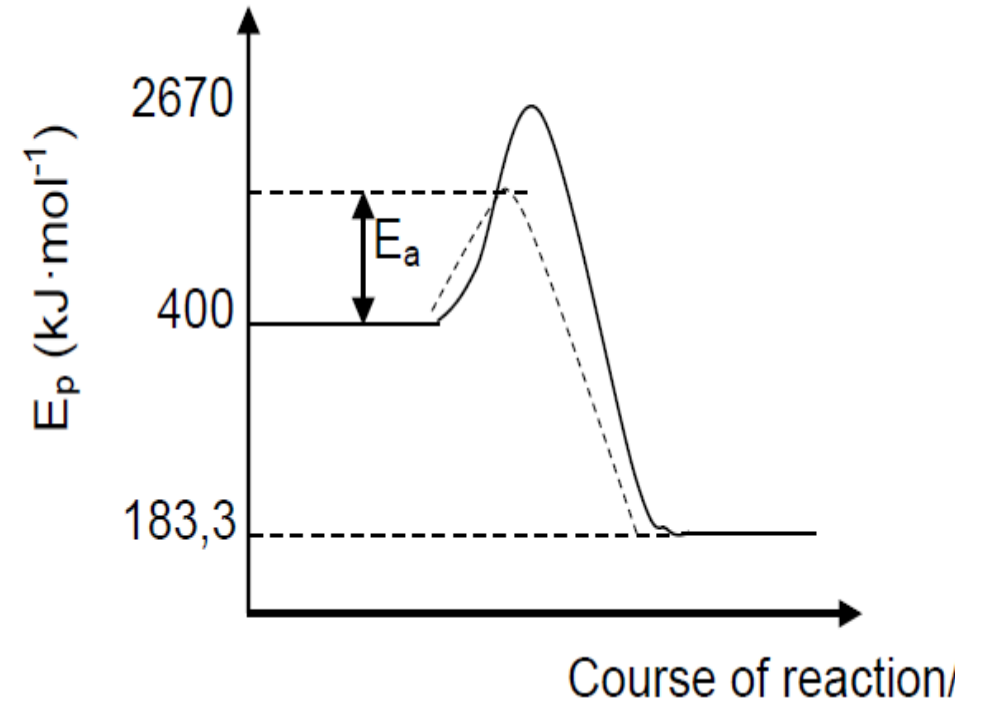
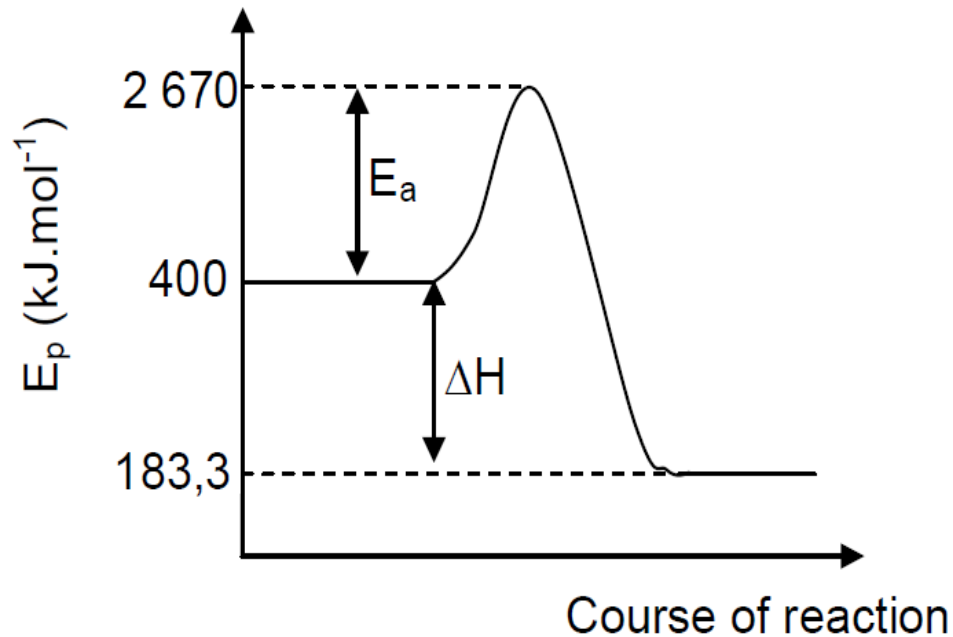
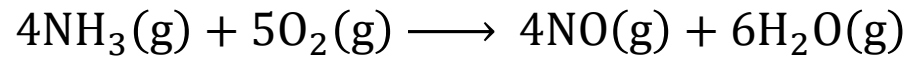
3.4.1 Is there a NET ABSORPTION or a NET RELEASE of energy? (1)

3.4.2 Calculate the energy referred to in QUESTION 3.4.1. (3)

3.4.3 If 5.5 moles of gas are present when the reaction is complete, calculate the initial number of moles of O₂(g) used in the reaction. (5)

2018 November Paper 2 Q 7.1-7.4

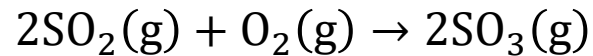
The following reaction between ammonia and oxygen takes place in a closed system at constant pressure and temperature:



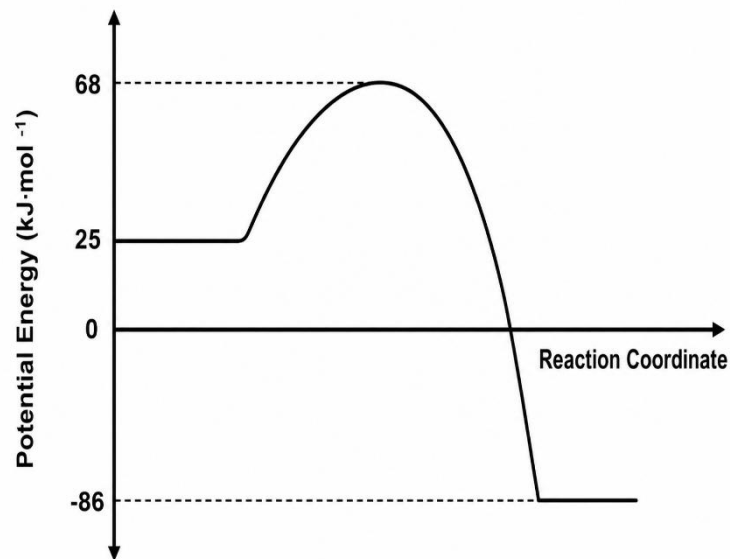
- 7.1 Define the term *activation energy*. (2)
- 7.2 Give a reason why this reaction is exothermic. (1)
- 7.3 Calculate the heat of reaction. (3)
- 7.4 Redraw the graph and indicate with a dotted line the effect of a catalyst on the activation energy. (2)

2024 North West November Paper 2 Q 5

One of the steps in the preparation of sulphuric acid in industry is represented by the following reaction:



The graph below shows the energy change during this reaction.



5.1 Write down the type of reaction represented by the above graph. Choose from EXOTHERMIC or ENDOTHERMIC. Explain your answer. (2)

5.2 Calculate the change in enthalpy for this reaction. (2)

Vanadium pentoxide is added as a catalyst in the above reaction.

5.3 How will the addition of the catalyst affect the following?

Write down only INCREASES, DECREASES or REMAIN THE SAME.

5.3.1 Activation energy. (1)

5.3.2 Heat of reaction. (1)

5.4 At 68 kJ·mol⁻¹ an activated complex is formed.

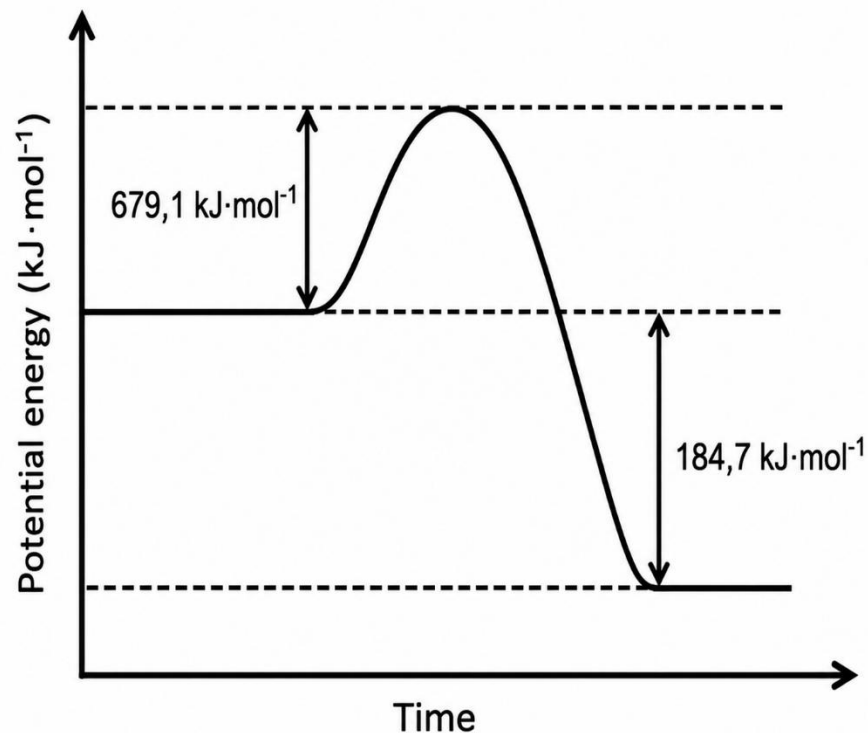
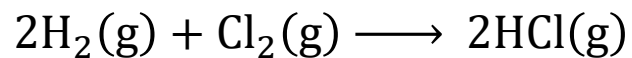
5.4.1 Define the term activated complex. (2)

5.4.2 Write down the activation energy for the reverse reaction. (2)

5.5 Calculate the volume of SO₃ gas formed in the container when 50 cm³ of SO₂ reacts completely with oxygen. (2)

2019 Eastern Cape Exemplar Paper 2 Q 6

The diagram shows the potential energy changes during the following chemical reaction:



6.1 Define *activation energy*. (2)

6.2 Is the reaction EXOTHERMIC or ENDOTHERMIC?

Give a reason for the answer. (2)

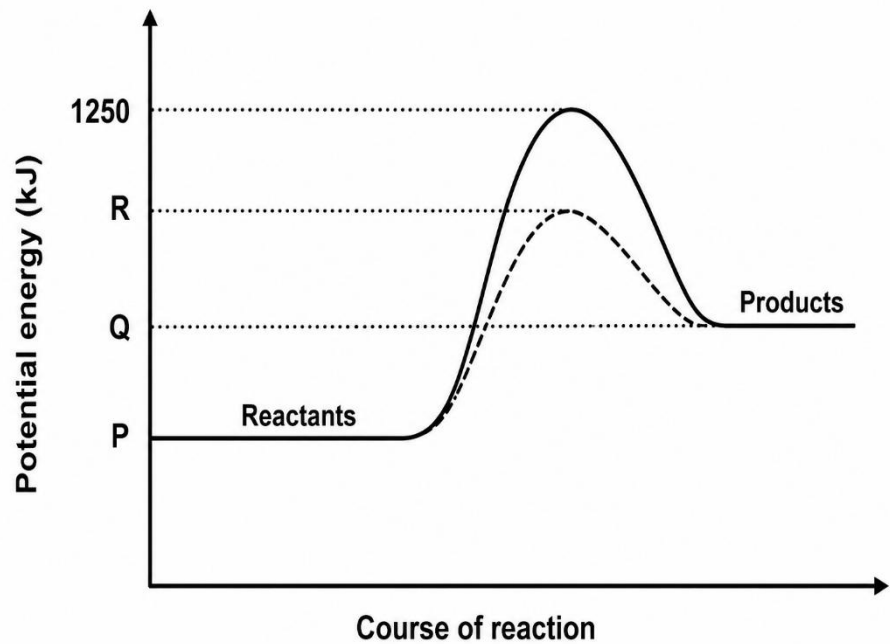
6.3 What is the total bond energy (H₂ and Cl₂) of the reactants? Give a reason for the answer. (3)

6.4 Determine the energy released by the bond formation of the HCl molecule. (3)

6.5 What effect will the addition of a catalyst have on the value 184,7 kJ mol⁻¹? Write down only INCREASE, DECREASE or NO EFFECT. Give a reason for the answer. (2)

2024 Limpopo September Paper 2 Q 2

The sketch graph below shows an energy profile for a chemical reaction.



2.1 Define the term activation energy. (2)

2.2 Is the reaction endothermic or exothermic?

Explain your answer with reference to the energy of the reactants and products. (2)

The following information is given:

- The activation energy without a catalyst is 800 kJ.
- The activation energy with a catalyst is 490 kJ.
- The energy released in the formation of products in the uncatalysed reaction is 520 kJ.

2.3 Calculate the value of each of the following:

2.3.1 P (2)

2.3.2 R (2)

2.3.3 ΔH (2)

2.4 How does a catalyst affect each of the following?

State only INCREASES, DECREASES, or STAYS CONSTANT.

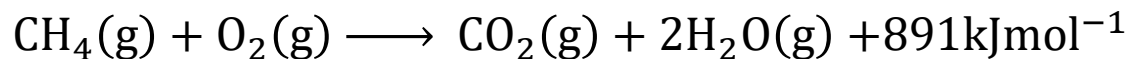
2.4.1 The heat of reaction (1)

2.4.2 Activation energy for the reaction (1)

2.4.3 Energy absorbed during the reaction (1)

2016 November Paper 2 Q 7

Methane is used as an alternative fuel. The combustion of methane releases carbon dioxide and water. The balanced equation for this reaction is:



The activation energy for this reaction is 172 kJmol^{-1}

7.1 Is this reaction ENDOTHERMIC or EXOTHERMIC?

Give a reason for the answer. (2)

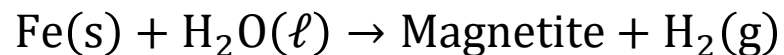
7.2 Explain why all chemical reactions need activation energy. (2)

7.3 Why is this reaction not considered to be environmentally friendly? (2)

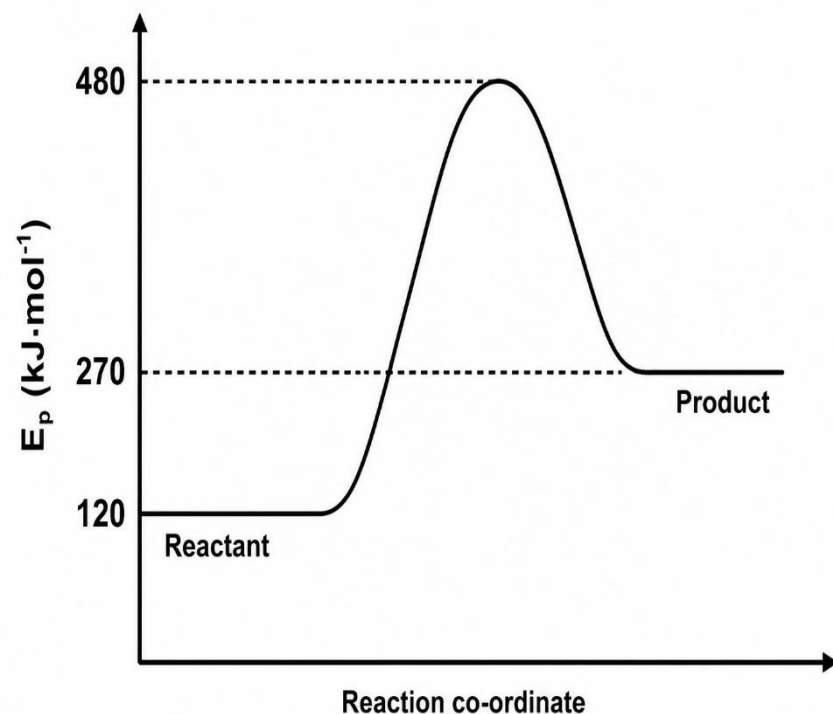
2022 KwaZulu Natal November Paper 2 Q 10

Magnetite is a type of magnetised rock that occurs naturally and is found in the beaks of homing pigeons and some other birds. The magnetite allows these birds to navigate using Earth's magnetic field.

Magnetite can be formed according to the following unbalanced chemical reaction:



10.1 The energy diagram for the above reaction is given below.



10.1.1 What is the activation energy for the forward reaction? (1)

10.1.2 Calculate the heat of reaction (ΔH) for the reverse reaction. (1)

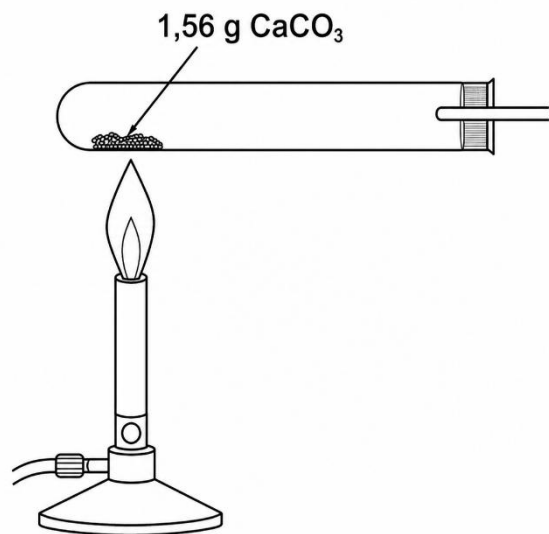
10.1.3 A catalyst is added to the reaction mixture. How does this affect the heat of reaction for the forward reaction? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

10.2

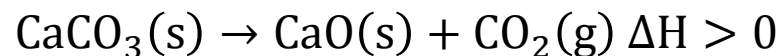
Magnetite consists of 72,41% iron and 27,59% oxygen. Determine the empirical formula of magnetite. (5)

2023 Eastern Cape November Paper 2 Q 5.1

1,56 g of calcium carbonate is heated as shown in diagram below.



The calcium carbonate decomposes according to the balanced equation:



0,163 g of CO₂ is produced during this decomposition.

5.1.1 Is this reaction ENDOTHERMIC or EXOTHERMIC? (1)

5.1.2 Give a reason for your answer in QUESTION 5.1.1. (2)

5.1.3 Describe Avogadro's number. (1)

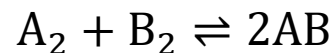
5.1.4 Calculate the following:

(a) Number of CO₂ molecules produced. (4)

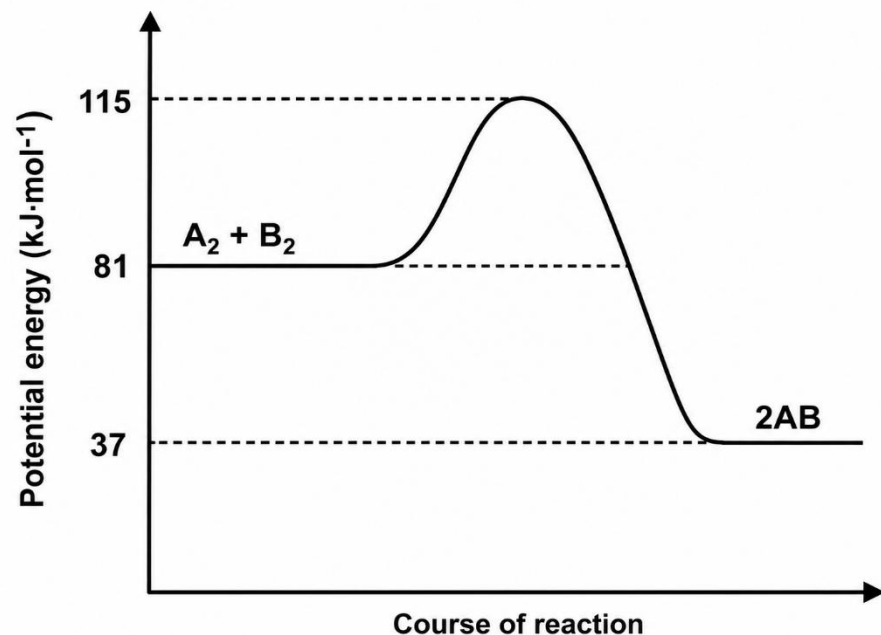
(b) Mass of CaCO₃ that remains unreacted in the flask at the completion of the reaction. (5)

2025 KwaZulu Natal September Paper 2 Q 3

The following reversible reaction takes place in a closed container.



The graph below shows the changes in chemical potential energy during the course of the reaction.



3.1 Is the forward reaction endothermic or exothermic? Give a reason for the answer. (2)

3.2 Calculate ΔH for the forward reaction. (2)

3.3 Define activation energy. (2)

3.4 What is the activation energy for the reverse reaction? (1)

3.5 How does the strength of the bonds within the reactant molecules compare to the strength of the bonds within the product molecules for the forward reaction?

Choose from STRONGER THAN, WEAKER THAN, or OF SIMILAR STRENGTH. Give a reason for the answer. (3)

3.6 Redraw the above graph in your answer book, and label it A. Do not label the axes or show any given values.

On the same set of axes, draw the graph that will be obtained if a catalyst is added. Label this as Graph B. (2)

2020 Eastern Cape November Paper 2 Q 5

Learners study ENDOTHERMIC and EXOTHERMIC reactions by conducting experiments I and II in which the reactions shown in the table below take place.

EXPERIMENT	BALANCED EQUATION
I	$2\text{H}_2\text{O}_2(\ell) \rightarrow 2\text{H}_2\text{O}(\ell) + \text{O}_2(\text{g})$
II	$2\text{H}_2\text{O}(\ell) \rightarrow 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$

The learners measured the initial and final temperatures of the reaction mixtures. They also obtained activation energies for the reactions from a data table. The learners represented their findings in a table as shown below.

EXPERIMENT	Initial (°C)	Final (°C)	Activation energy (kJ/mol)
I	24	36	75
II	24	18	237

- 5.1 Define the term activation energy. (2)
- 5.2 In which experiment (I or II) is the reaction EXOTHERMIC? Explain your answer. (2)
- 5.3 Is the heat of the reaction, ΔH , POSITIVE or NEGATIVE for An EXOTHERMIC reaction? (1)

- 5.4 Write down the general name of a substance that can be added to the reaction mixture in experiment II to reduce the activation energy. (1)
- 5.5 Both reactions produce the same number of moles of oxygen gas. How does the mass of H_2O_2 used in experiment I compare to the mass of H_2O used in experiment II? Write down only SMALLER THAN, LARGER THAN or THE SAME. (2)

CONTINUED.....

5.6 Draw a potential energy versus time graph for the reaction in experiment II.

The following must be shown on the graph.

- Heat of the reaction (ΔH)
 - Activation energy (E_a)
- (3)

EXPERIMENT	BALANCED EQUATION
I	$2\text{H}_2\text{O}_2(\ell) \rightarrow 2\text{H}_2\text{O}(\ell) + \text{O}_2(\text{g})$
II	$2\text{H}_2\text{O}(\ell) \rightarrow 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$

EXPERIMENT	Initial (°C)	Final (°C)	Activation energy (kJ/mol)
I	24	36	75
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