GLEN TUTORIALS

Grade 10 IGCSE Chemistry • Comprehensive Study Notes

Chapter 7: Chemical Energetics | Exam Preparation Material | Syllabus Aligned

REMEMBER — CORE EXAM REVISION POINTS:

- **Exothermic Reactions:** Release heat energy to the surroundings. Temperature of surroundings **increases**. Overall enthalpy change (ΔH) is **negative (–)**.
- **Endothermic Reactions:** Absorb heat energy from the surroundings. Temperature of surroundings **decreases**. Overall enthalpy change (ΔH) is **positive (+)**.
- **Bond Energetics:** Bond breaking requires energy (**Endothermic**, $\Delta H > 0$). Bond making releases energy (**Exothermic**, $\Delta H < 0$).
- **Enthalpy Formula:** ΔH = Energy absorbed to break bonds – Energy released when bonds are formed.
- **Catalysts:** Provide an alternative reaction pathway with a **lower activation energy (E_a)** without changing overall enthalpy change (ΔH).

IMPORTANT KEYWORDS: Exothermic, Endothermic, Enthalpy Change (ΔH), Activation Energy (E_a), Bond Energy, Reactants, Products, Catalyst, Surroundings, Reaction Pathway Diagram.

SECTION 1: IN-CHAPTER CONCEPT QUESTIONS

Question 1: State whether the following changes are physical or chemical:

a. Melting of ice
Answer: Physical change. (It is a state change from solid to liquid water without changing chemical composition).

b. Burning of magnesium
Answer: Chemical change. (Magnesium reacts with oxygen to form a new substance, magnesium oxide).

c. Evaporation of ethanol
Answer: Physical change. (It is a phase change from liquid ethanol to gas; no new bonds or chemical substances are created).

d. Dissolving of sugar in water
Answer: Physical change. (Sugar molecules disperse in water without altering their chemical identity, and sugar can be recovered by evaporating the water).

Question 2: State whether the following changes are exothermic or endothermic:

a. Condensation of steam to water
Answer: Exothermic. Heat energy is **released** to the surroundings as gas molecules lose kinetic energy to transition into a liquid state.

b. Burning of magnesium
Answer: Exothermic. Combustion reactions release large amounts of **heat and light energy** to the surroundings.

c. Addition of concentrated sulfuric acid to water
Answer: Exothermic. Hydration of concentrated acid is a highly heat-releasing process causing a sharp **temperature rise**.

d. Evaporation of a volatile liquid
Answer: Endothermic. The liquid must **absorb energy** from its surroundings to overcome intermolecular forces and change into a gas.

Question 3: What is the most important thing that shows us that a chemical reaction has taken place?

Answer: The most important feature of a chemical reaction is the **formation of one or more new chemical substances** with different properties from the reactants, usually accompanied by an **overall energy change** (heat released or absorbed) that cannot be easily reversed by physical means.

Question 4: Which type of reaction takes in heat from its surroundings?

Answer: An **endothermic reaction** takes in thermal energy from its surroundings, causing the temperature of the surroundings to fall.

Question 5: Draw a reaction pathway diagram for the following reaction, which is exothermic: $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

Answer: In an **exothermic reaction**, reactants have higher energy than products. Heat is released to the surroundings, so energy drops from reactants to products.

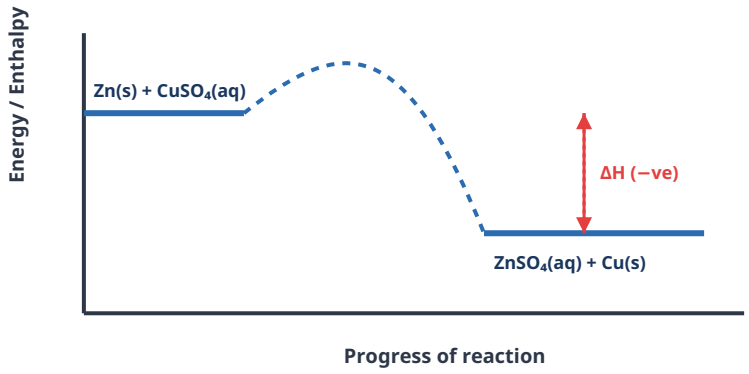


Figure 1: Exothermic Reaction Pathway Diagram for Displacement of Copper by Zinc

- **Reactants:** $Zn(s) + CuSO_4(aq)$ placed at higher energy level.
- **Products:** $ZnSO_4(aq) + Cu(s)$ placed at lower energy level.
- **Enthalpy Change (ΔH):** Indicated with a downward arrow showing heat released.

Question 6: What key features of a reaction pathway diagram would indicate an endothermic reaction?

Answer: An **endothermic reaction pathway diagram** exhibits the following key features:

1. The **energy level of the products is higher** than the energy level of the reactants.
2. The overall enthalpy change arrow (**ΔH**) points **upwards**, indicating that energy is absorbed from the surroundings (ΔH is positive).
3. The peak of the curve representing **activation energy (E_a)** is higher than both reactants and products.

Question 7: Is bond breaking an endothermic or an exothermic process?

Answer: Bond breaking is an **endothermic process**. Energy must be **absorbed/taken in** from the surroundings to overcome and break the chemical bonds holding atoms together.

Question 8: Hydrogen peroxide decomposes to produce water and oxygen. The equation is:
$2H_2O_2(g) \rightarrow 2H_2O(g) + O_2(g)$
Using the following bond energies, calculate the heat change for the reaction and say whether it is exothermic or endothermic.
Bond energies: O–O = 144 kJ/mol, O=O = 498 kJ/mol, O–H = 464 kJ/mol

Detailed Calculation Step-by-Step:

1. Structural Analysis of Reactants and Products:

- **Reactants:** 2 molecules of H_2O_2 (H–O–O–H).
  Each H_2O_2 molecule contains two **O–H bonds** and one **O–O bond**.
  Total in 2 moles of H_2O_2: **4 × O–H bonds** and **2 × O–O bonds**.
- **Products:** 2 molecules of H_2O (H–O–H) + 1 molecule of O_2 (O=O).
  Each H_2O has two O–H bonds (total **4 × O–H bonds**).
  Each O_2 has one double bond (**1 × O=O bond**).

2. Energy absorbed to break bonds (Reactants):

$$\mathbf{4 \times (O{-}H) + 2 \times (O{-}O) = (4 \times 464) + (2 \times 144) = 1856 + 288 = +2144\ kJ}$$

3. Energy released when forming bonds (Products):

$$\mathbf{4 \times (O{-}H) + 1 \times (O{=}O) = (4 \times 464) + (1 \times 498) = 1856 + 498 = -2354\ kJ}$$

4. Enthalpy Change (ΔH):

$$\mathbf{\Delta H = Energy\ In - Energy\ Out = 2144\ kJ - 2354\ kJ = -210\ kJ/mol}$$

Conclusion: Since ΔH is negative (–210 kJ/mol), the reaction is **exothermic**.

Question 9: Explain why every chemical reaction must have an activation energy, even though for some reactions it may have a low value.

Answer: Before new chemical bonds can form to create products, the existing chemical bonds in the reactant molecules must first be **stretched or broken**. Energy is required to overcome the repulsive forces between electron clouds and initiate bond cleavage. The minimum amount of energy colliding particles must possess to react is called the **activation energy (E_a)**.

EXAM TIP FOR BOND ENERGY CALCULATIONS: Always list bonds broken (left side) and bonds formed (right side) in two neat columns. Remember: **ΔH = Total Energy of Bonds Broken – Total Energy of Bonds Formed**. A negative sign indicates an exothermic reaction!

SECTION 2: EXAM-STYLE QUESTIONS

Question 1: Which of the following statements best describes an endothermic reaction? [1 Mark]

A The surroundings of the reaction get warmer.
B The reaction absorbs thermal energy.
C The reaction releases heat energy.
D The temperature of the reaction mixture increases.

Correct Answer: B (The reaction absorbs thermal energy.)

Question 2: Both physical and chemical changes involve changes of energy. Complete the information in the table. [5 Marks]

Process	Temperature change	Chemical or physical
water vapour changing to water	**decrease / release of heat (or increase in surroundings temp)** [a]	**physical**
salt solution to salt and water	increase	**physical** [b]
magnesium plus hydrochloric acid	**increase** [c]	chemical
burning hydrogen to form water	increase	**chemical** [d]
iron rusting	increase	**chemical** [e]

Explanations for markings:
• **[a]** Condensation releases latent heat.
• **[b]** Separation of salt and water by evaporation/distillation is physical.
• **[c]** Acid-metal reactions are exothermic (temperature increases).
• **[d] & [e]** Combustion of hydrogen and rusting are chemical reactions forming new compounds (H_2O and hydrated Fe_2O_3).

Question 3: The equation shows the reaction between sodium hydrogen carbonate and hydrochloric acid:

$NaHCO_3 + HCl \rightarrow NaCl + CO_2 + H_2O$

a. What observation is made as the reaction proceeds? [1 Mark]

Answer: Effervescence / **fizzing** / **bubbling** is observed due to the production of carbon dioxide gas (CO_2).

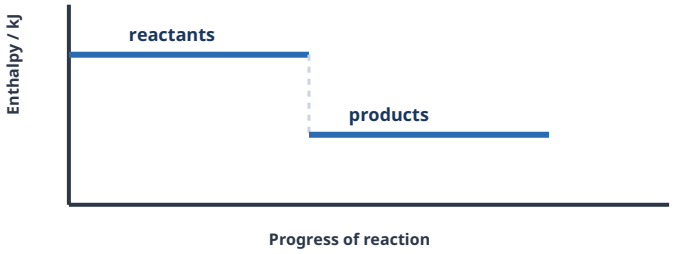
b. At the beginning of the reaction the temperature of the acid is 21 °C, when the reaction is complete the temperature is 16 °C. How do you know when the reaction has finished? [1 Mark]

Answer: The reaction has finished when **fizzing/bubbling stops** (no more gas is evolved) OR when the **temperature stops changing/remains constant**.

c. Is the reaction exothermic or endothermic? Explain your answer. [2 Marks]

Answer: It is **endothermic**. Explanation: The temperature decreased from 21 °C to 16 °C, showing that **thermal energy was absorbed** from the surroundings.

d. A different carbonate is reacted with hydrochloric acid. The reaction pathway diagram for this second reaction is shown below. Is this reaction endothermic or exothermic? Explain your answer using ideas about energy. [2 Marks]



Answer: This reaction is **exothermic**. Explanation: The products have **lower energy/enthalpy than the reactants**, meaning thermal energy is **released** to the surroundings as the reaction proceeds.

Question 4: Nitrogen reacts with hydrogen to form ammonia.

$N_2 + 3H_2 \rightarrow 2NH_3$

The bond energies involved: H–H = 436 kJ/mol, N≡N = 945 kJ/mol, N–H = 391 kJ/mol

a. Calculate the enthalpy change, ΔH, for the reaction. [4 Marks]

- **Bonds Broken (Reactants):**
  1 × N≡N = 1 × 945 = 945 kJ/mol
  3 × H–H = 3 × 436 = 1308 kJ/mol
  Total Energy In = 945 + 1308 = +2253 kJ/mol
- **Bonds Formed (Products):**
  2 × NH_3 molecules (Each NH_3 has 3 N–H bonds, so total 6 × N–H bonds):
  6 × N–H = 6 × 391 = 2346 kJ/mol
  Total Energy Out = –2346 kJ/mol
- **Enthalpy Change (ΔH):**
  ΔH = Energy In – Energy Out = 2253 – 2346 = **–93 kJ/mol**

b. This reaction can be reversed: $2NH_3 \rightarrow N_2 + 3H_2$. What would be the enthalpy change, ΔH, for this reaction? [2 Marks]

Answer: +93 kJ/mol. (The magnitude remains the same, but the sign reverses from exothermic to endothermic).

c. On the energy profile in part a, label 'overall enthalpy change ΔH' and 'activation energy E_a'. [2 Marks]

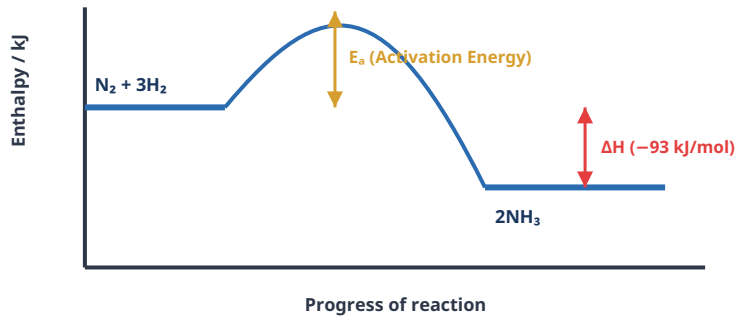


Figure 2: Energy Profile with Activation Energy (E_a) and Enthalpy Change (ΔH)

d. What difference does the catalyst make? [1 Mark]

Answer: A catalyst **lowers the activation energy (E_a)** by providing an alternative reaction pathway, thereby speeding up the reaction rate without affecting the overall enthalpy change (ΔH).