Edexcel GCSE Chemistry

Your notes

Heat Energy Changes in Chemical Reactions

Contents

Heat Energy Changes

Your notes

Heat Energy & Temperature changes

- Chemical reactions occur so that elements can achieve a more **stable energy state** by gaining a full outer shell of electrons
- This is done by chemical bonding (we have already seen ionic and covalent bonding) where **old bonds** are **broken,** and **new bonds** are **formed**
- This process involves the transfer of **energy** into and out of reaction mixtures
- The terms used to describe this are the **system** (what happens in the chemical reaction) and the **surroundings**
- The energy comes from the **chemical bonds** themselves which could be considered as tiny stores of chemical energy
- In the majority of reactions, the energy is in the form of **heat** energy, although sometimes other types of energy are produced such as light or sound
- The changes in heat can be **observed** and **measured** with a thermometer and simple calorimeter

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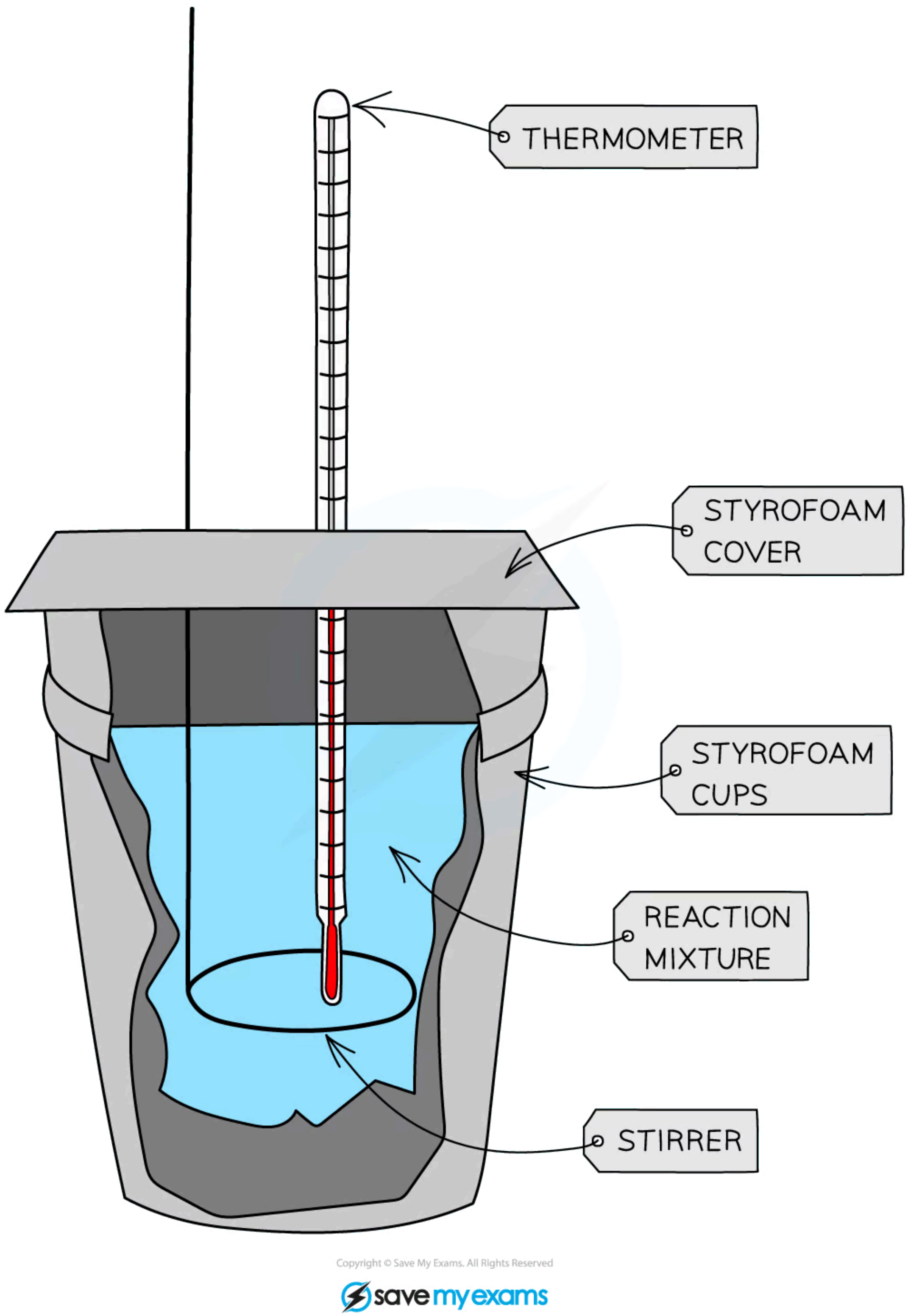
THERMOMETER
STYROFOAM COVER
STYROFOAM CUPS
REACTION MIXTURE
STIRRER
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Diagram showing the apparatus for the calorimetry investigation for displacement, dissolving and neutralisation

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- The following are some examples of heat changes in reactions
  - Salts dissolving in water:
    - These can either take energy **in** or give it **out**
  - Neutralisation reactions:
    - These always give energy **out**
  - Displacement reactions:
    - These can either take energy **in** or give it **out**
  - Precipitation reactions:
    - These always give energy **out**

Exothermic Reactions

- In exothermic reactions energy is given out to the surroundings so the temperature of the surroundings increases
- Combustion, oxidation, and neutralisation reactions are typical exothermic reactions
- Hand warmers used in the wintertime are based on the release of heat from an exothermic reaction
- Self-heating cans of food and drinks such as coffee and hot chocolate also use exothermic reactions in the bases of the containers

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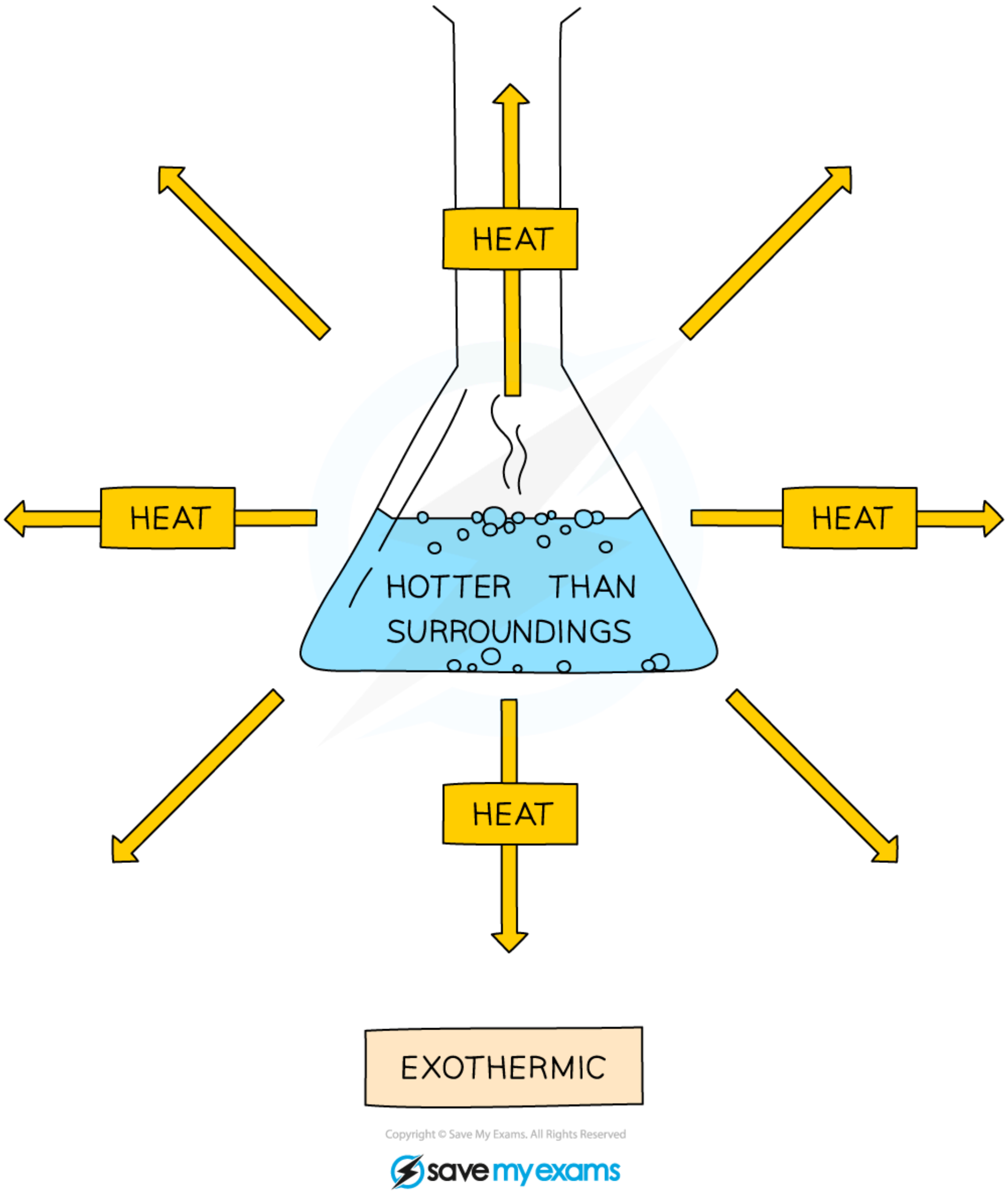

Diagram showing the transfer of heat energy outwards from an exothermic reaction

Endothermic Reactions

- In endothermic reactions energy is taken in from the surroundings so the temperature of the surroundings decreases
- These types of reactions are much less common than the exothermic reactions
- Electrolysis, thermal decomposition reactions and the first stages of photosynthesis are typical endothermic reactions
- Sports injury treatment often use cold packs based on endothermic reactions to take heat away from a recently injured area to prevent swelling

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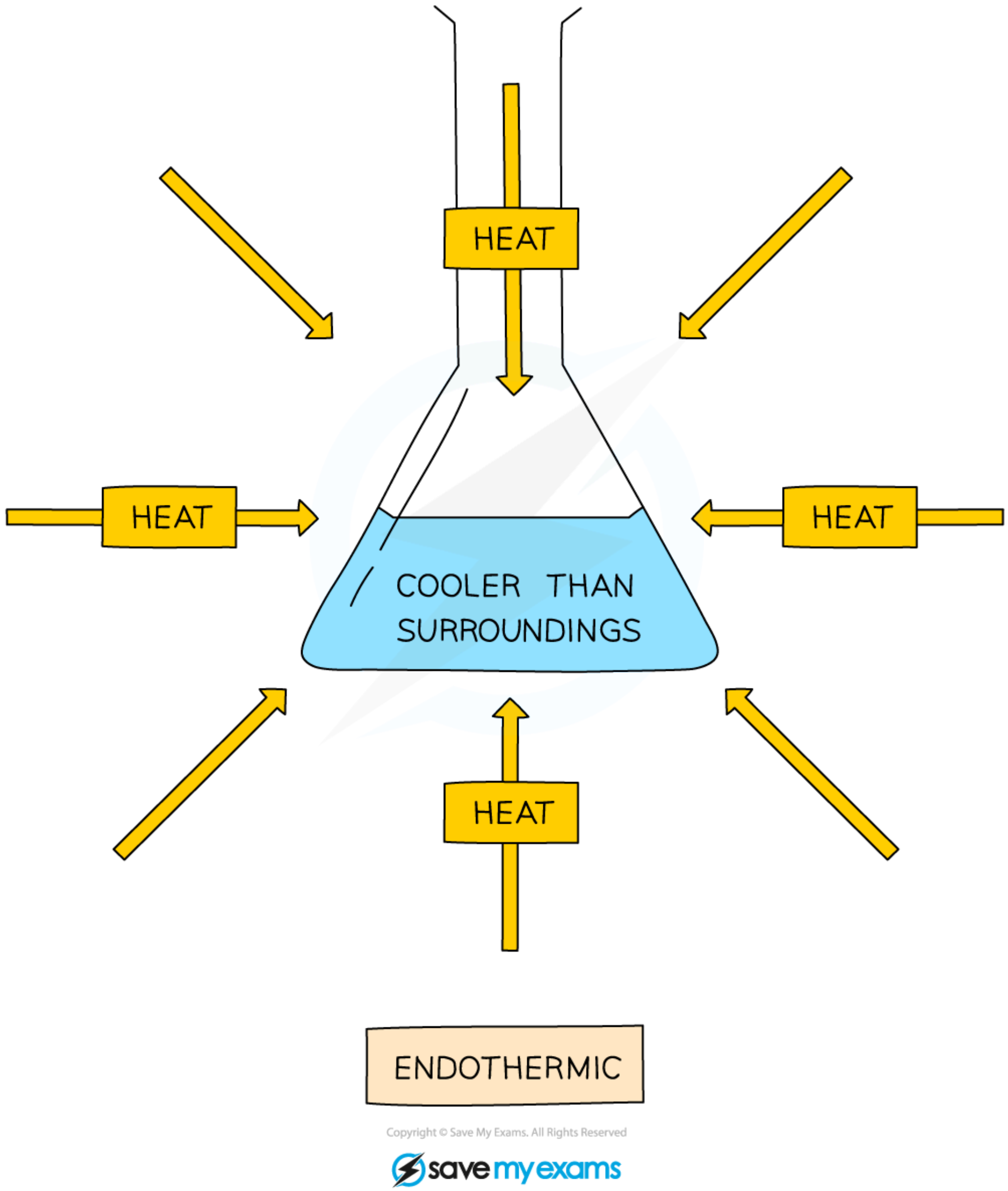

Diagram showing the transfer of heat energy from the surroundings into an endothermic reaction

Examiner Tips and Tricks

To help you remember whether a chemical system is exothermic or endothermic, in **EX**othermic reactions heat **Ex**its the system and in **EN**dothermic reactions heat **ENters** the system.Exothermic reactions always give off heat and they feel hot, whereas endothermic reactions take heat in and they feel cold.

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Bonds & Energy Changes

- Energy is needed to **break bonds** which is absorbed from the reaction surroundings, so bond breaking is an **endothermic** process
- The opposite occurs for **forming bonds** as it releases energy back to the surroundings in an **exothermic** process
- **Both processes** occur in the same chemical reaction, for example, in the production of ammonia:

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

- The bonds in the N-N and H-H molecules must be broken which requires energy while the bonds in the NH_3 molecule are formed which releases energy
- Most reactions occur in a number of steps including **steps** that are exothermic and steps that are endothermic
- Whether a reaction is **overall** endothermic or exothermic depends on the **difference** between the sum of the exothermic steps and the sum of the endothermic steps

Endothermic

- If more energy is absorbed than is released, this reaction is **endothermic**
- More energy is required to break the bonds than that gained from making the new bonds
- The change in energy is positive since the products have more energy than the reactants
- Therefore an endothermic reaction has a **positive** change in energy

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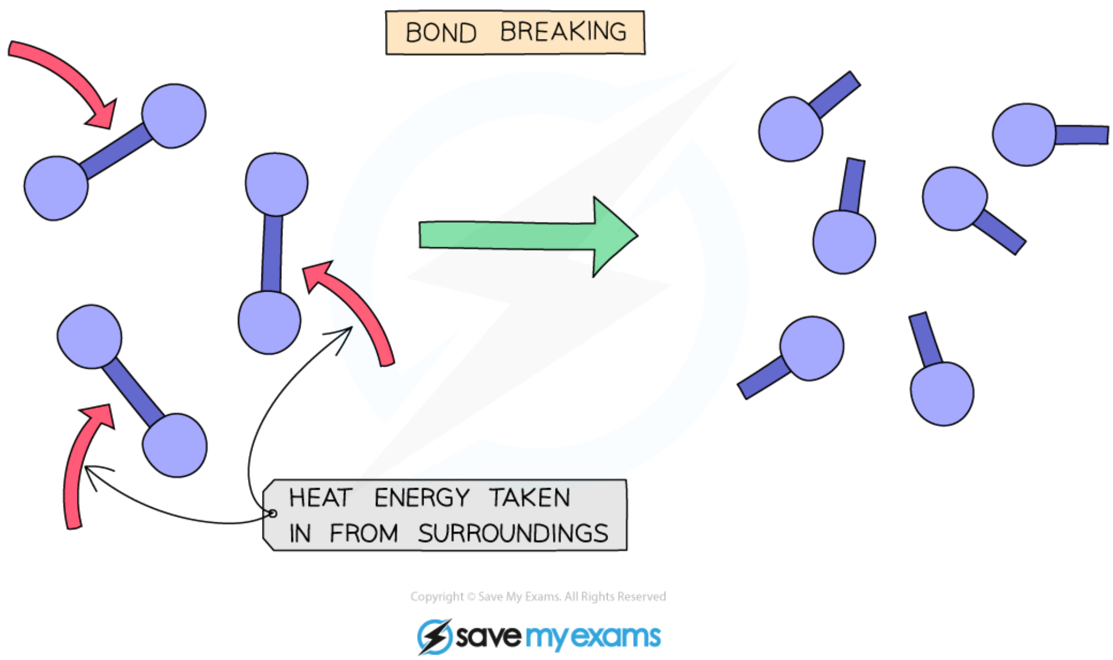
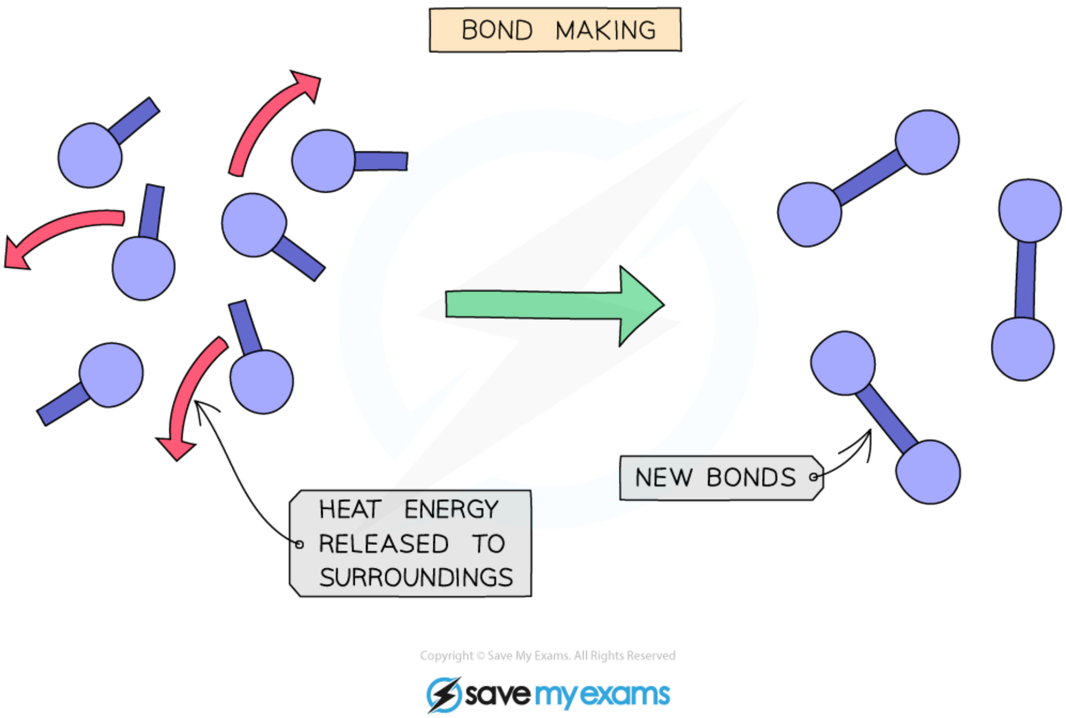


Energy must be absorbed from the surroundings for bonds to be broken

Exothermic

- If more energy is released than is absorbed, then the reaction is **exothermic**
- More energy is released when new bonds are formed than energy required to break the bonds in the reactants
- The change in energy is negative since the reactants have more energy than the products
- Therefore an exothermic reaction has a **negative** change in energy



Making new bonds gives off heat from the reaction to the surroundings

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Examiner Tips and Tricks

Remember bond breaking is ENDothermic and results in the END of the bond.

Bond Energy Calculations

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Bond Energy Calculations

- Each chemical bond has a specific **bond energy** associated with it
- This is the amount of energy required to **break** the bond or the amount of energy given out when the bond is **formed**
- This energy can be used to calculate how much heat would be released or absorbed in a reaction
- To do this it is necessary to know the bonds present in both the reactants and products
- We can calculate the total change in energy for a reaction if we know the bond energies of all the species involved
- Add together all the bond energies for all the bonds in the reactants – this is the 'energy in'
- Add together the bond energies for all the bonds in the products – this is the 'energy out'
- Calculate the energy change using the equation:

Energy change = Energy taken in – Energy given out

Worked Example

Example 1

Hydrogen and chlorine react to form hydrogen chloride gas:

$$H_2 + Cl_2 \longrightarrow 2HCl$$

The table below shows the bond energies. Calculate the energy change for the reaction and deduce whether it is exothermic or endothermic.

Your notes

Bond	Bond energy (kJ/mole)
H–H	436
Cl–Cl	243
H–Cl	432

Answer:

Step	Working out
1. Calculate the energy in	Energy in = 436 + 243 = 679 kJ/Mole
2. Calculate the energy out	Energy out = 2 × 432 = 864 kJ/Mole
3. Calculate the energy change	Energy change = 679 – 864 = –185 kJ/Mole
4. Comment on the result and deduce the nature of the reaction	Energy change is a **negative** number hence energy has been lost to the surroundings and the reaction is **exothermic**

Worked Example

Example 2

Hydrogen bromide decomposes to form hydrogen and bromine:

$$2HBr \longrightarrow H_2 + Br_2$$

The table below shows the bond energies. Calculate the energy change for the reaction and deduce whether it is exothermic or endothermic.

Bond	Bond energy (kJ/mole)
H–Br	366
H–H	436
Br–Br	193

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Answer:

Step	Working out
1. Calculate the energy in	Energy in = 2 × 366 = 732 kJ/Mole
2. Calculate the energy out	Energy out = 436 + 193 = 629 kJ/Mole
3. Calculate the energy change	Energy change = 732 − 629 = +103 kJ/Mole
4. Comment on the result and deduce the nature of the reaction	Energy change is a **positive** number hence energy has been absorbed from the surrounding so the reaction is endothermic

Examiner Tips and Tricks

For bond energy questions, it is helpful to write down a displayed formula equation for the reaction before identifying the type and number of bonds, to avoid making mistakes.

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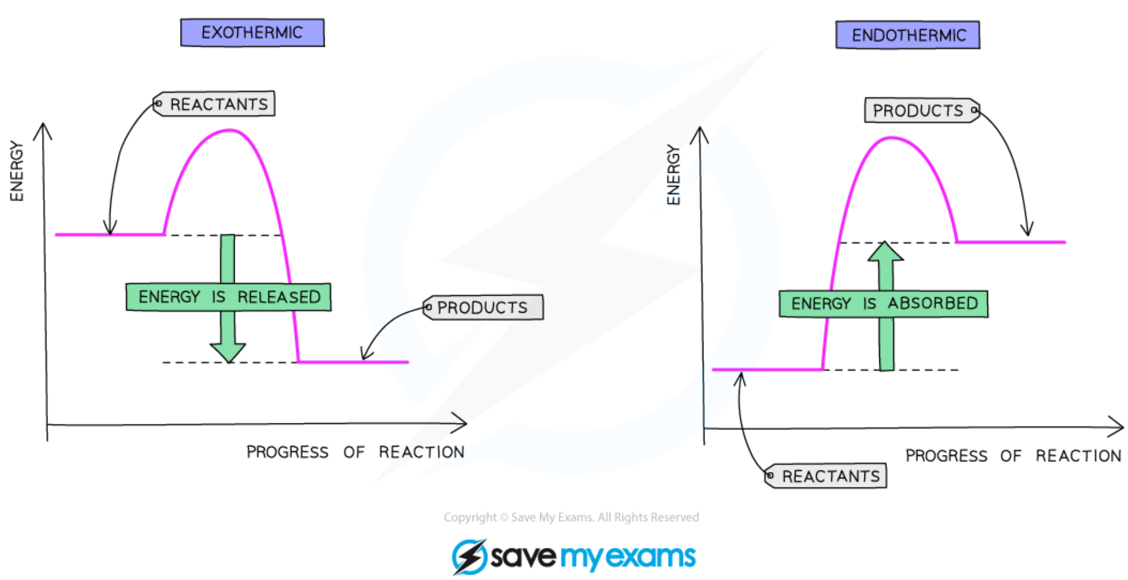
Reaction Profiles

Reaction Profiles

Reaction Profiles

- Reaction profiles (sometimes called energy level diagrams) are graphical representations of the relative energies of the reactants and products in chemical reactions
- The energy of the reactants and products are displayed on the y-axis and the reaction pathway is shown on the x-axis
- Arrows on the diagrams indicate whether the reaction is exothermic (**downwards** pointing) or endothermic (**upwards** pointing)
- The difference in height between the energy of reactants and products represents the **overall energy change** of a reaction
- The initial increase in energy represents the **activation energy** required to start the reaction
- The greater the initial rise then the more energy that is required to get the reaction going e.g., more heat needed



Reaction profile of an exothermic reaction and an endothermic reaction

- Energy is given out in exothermic reactions

- The energy of the products will be **lower** than the energy of the reactants, so the change in energy is **negative**
- This is represented on the reaction profile with a **downwards-arrow** as the energy of the products is lower than the reactants
- Energy is taken in endothermic reactions
- The energy of the products will be **higher** than the energy of the reactants, so the change in energy is **positive**
- This is represented on the reaction profile with an **upwards-arrow** as the energy of the products is higher than the reactants

Examiner Tips and Tricks

You should be able to draw clear and fully labelled reaction profile diagrams for both types of reactions and you should be able to identify a reaction from its reaction profile.

Activation Energy

- The minimum energy the colliding particles need in order to react is known as the **activation energy**
- The **activation energy** can be lowered by the addition of a **catalyst**
- This means that a **higher percentage** of the particles will have the **minimum energy** required to react, hence there are a **higher number** of **successful collision**
- Therefore more product molecules are produced in a shorter time, thus **increasing** the rate of reaction
- **Reaction profile graphs** show the relative energy levels of reactants and products on a graph
- The reaction profile graph below shows the effect of catalysts on reactions

Reaction Profiles Showing ΔH and E_A

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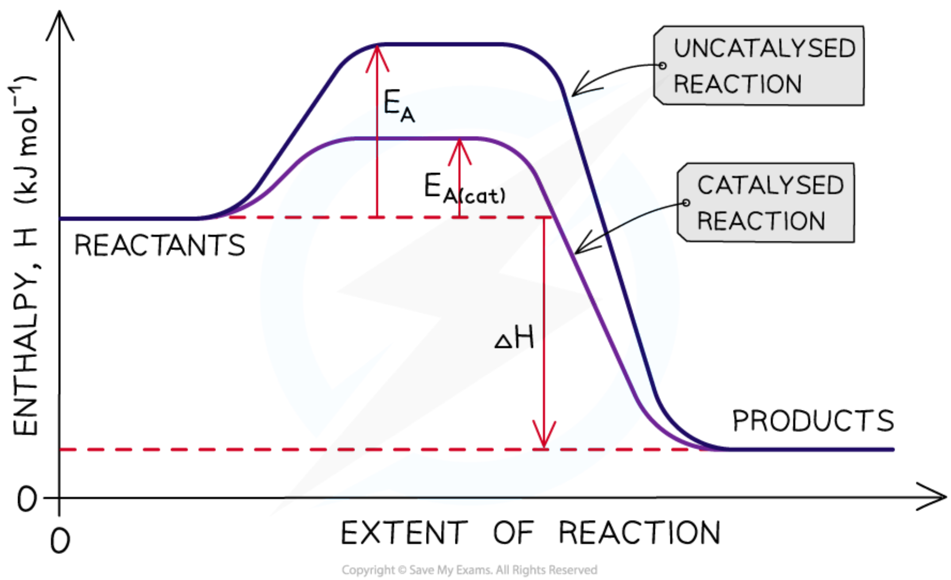

Diagram shows that a catalyst increases the rate of a reaction by providing an alternative pathway which has a lower activation energy

- **Catalysts** provide the reactants another pathway which has a lower activation energy
- By lowering E_a, a **greater proportion** of molecules in the reaction mixture have sufficient energy for an successful collision
- As a result of this, the rate of the catalysed reaction is increased compared to the uncatalyzed reaction

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Molecules with the activation energy lead to successful collisions

Examiner Tips and Tricks

The activation energy is constant for a particular reaction. Reactions with a low activation energy occur readily as little energy is needed to break the bonds and initiate the reaction.