CAIE IGCSE Chemistry

5.1 Exothermic and endothermic reactions

Notes

State that an …

- An exothermic reaction transfers thermal energy (heat) to the surroundings, leading to the temperature of the surroundings increasing
  - Examples of exothermic reactions include; combustion, many oxidisation reactions and neutralisation.
  - Everyday examples of exothermic reactions include; self-heating cans (e.g for coffee) and hand warmers.

- An endothermic reaction takes in thermal energy (heat) from the surroundings, leading to the temperature of the surroundings decreasing
  - Examples of endothermic reactions are thermal decomposition and the reaction of citric acid and sodium hydrogen carbonate.
  - Some sports injury packs are based on endothermic reactions.

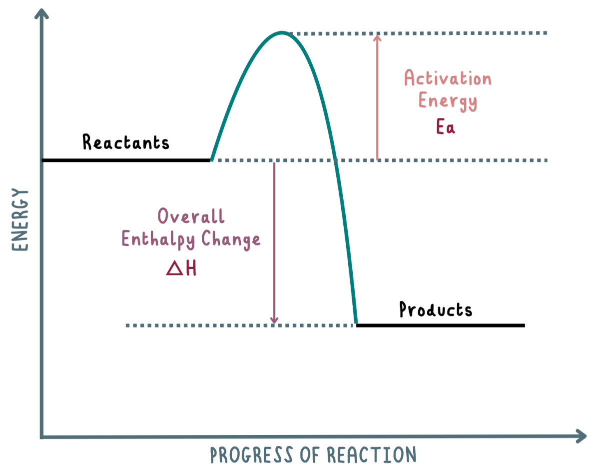
- To distinguish between endothermic and exothermic:
  EXOthermic: Energy EXits into the surroundings
  ENdothermic: Energy ENters from the surroundings

Interpret reaction pathway diagrams showing exothermic and endothermic reactions

- A reaction pathway diagram can be used to show whether a reaction is exothermic or endothermic:
- Reaction pathway diagrams start at the reactants and end at the products, with arrows showing the activation energy, E_a and the overall enthalpy change, ΔH

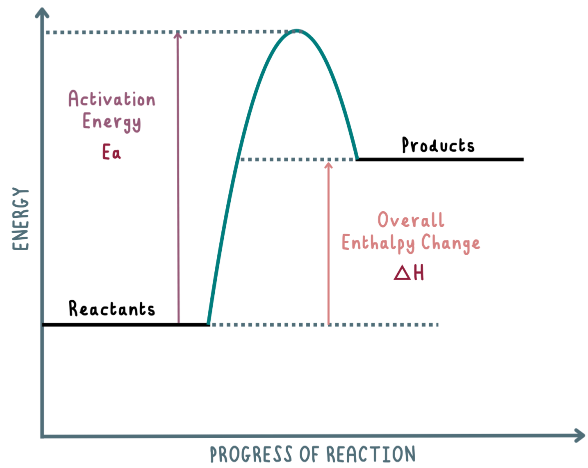
Exothermic reaction pathway diagram

- The reactants are at a higher energy level than the products, showing that energy has been released into the surroundings
- The energy change of the reaction is negative



Endothermic reaction pathway diagram

- The reactants are at a lower energy level than the products, showing that energy has entered into the system from the surroundings
- The energy change of the reaction is positive



(Extended only) State that…

- The enthalpy change, ΔH, of a reaction is the transfer of thermal energy during a reaction.
- The enthalpy change, ΔH, of an exothermic reaction is negative.
- The enthalpy change, ΔH, of an endothermic reaction is positive.

(Extended only) Define activation energy, E_a …

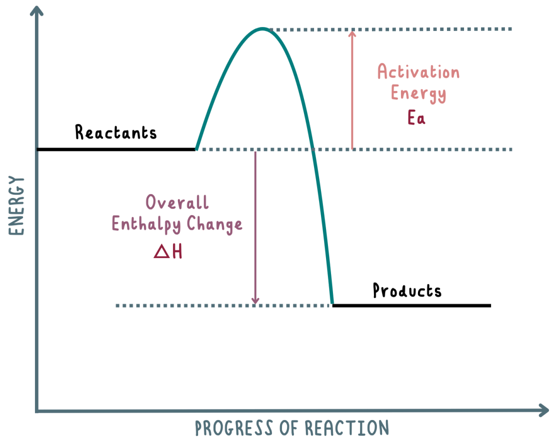
- The activation energy, E_a , is the minimum amount of energy that colliding particles need to have to react
- For chemical reactions to happen, particles must collide 'successfully' but to do so they need enough energy.

(Extended only) Draw and label reaction pathway diagrams for exothermic and endothermic reactions using information provided, to include: (a) reactants (b) products (c) enthalpy change of the reaction, ΔH (d) activation energy, E_a

- The activation energy, E_a , is shown on reaction pathway diagrams with an arrow, beginning at the energy of the reactants up to the maximum energy reached in the reaction (the peak of the pathway).
- The enthalpy change, ΔH, is shown with an arrow from the energy of the reactants to the energy of the products
- 'Energy' is labelled on the y-axis and 'progress of reaction' along the x-axis
- A curved line connects the reactants and products, showing the change of energy over the reaction.

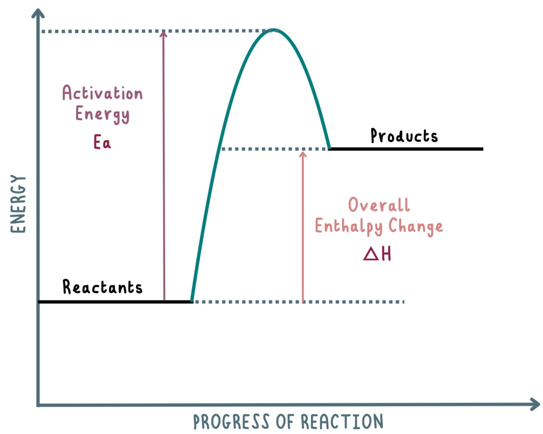
For exothermic reactions:

- Reactants and products are labelled on horizontal lines, with reactants on a higher energy level than the products
- The overall enthalpy change, ΔH, is negative, shown by an arrow pointing downwards from the energy level of the reactants to the products



For endothermic reactions:

- Reactants and products are labelled on horizontal lines, with reactants on a lower energy level than the products
- The overall enthalpy change, ΔH, is positive, shown by an arrow pointing upwards from the energy level of the reactants to the products



(Extended only) State that bond breaking is an endothermic process and bond making is an exothermic process and explain the enthalpy change of a reaction in terms of bond breaking and bond making

- For a chemical reaction to occur:
  - Bonds must be broken in the reactants
  - Bonds are made in the products
- For bonds to break, energy must be taken in from the surroundings: ENDOTHERMIC
- When bonds are made, energy is released into the surroundings: EXOTHERMIC

- The enthalpy change of a reaction is negative (exothermic) when: Energy released making bonds > Energy taken in breaking bonds
- The enthalpy change of a reaction is positive (endothermic) when: Energy taken in breaking bonds > Energy released making bonds

(Extended only) Calculate the enthalpy change of a reaction using bond energies

To calculate the enthalpy change of a reaction using bond energies:

1. Add up the bond energies for every bond in the reactants – totalling the 'energy in'
2. Add up the bond energies for every bonds in the products – totalling 'energy out'
3. Use the following formula to calculate the enthalpy change
   ΔH : energy in – energy out

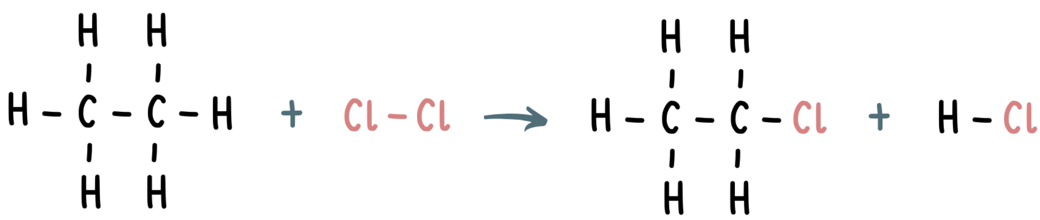
Example 1

Calculate the enthalpy change of the following reaction, using the bond energies given in the table. State whether the reaction is exothermic or endothermic.

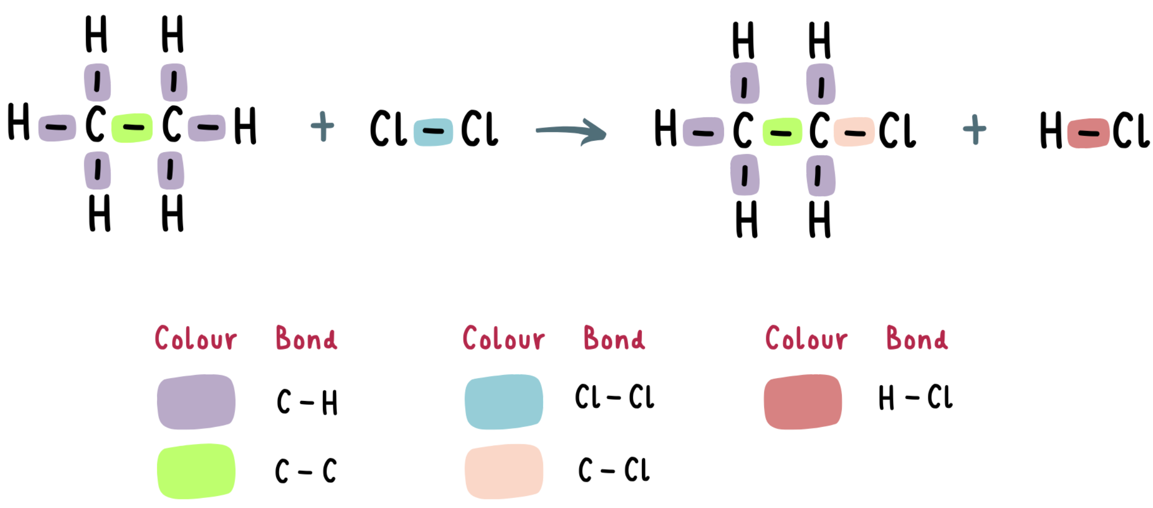
$CH_3CH_3 + Cl_2 \rightarrow CH_3CH_2Cl + HCl$

Bond	Bond energy (kJ/mol)
C-H	413
C-C	346
Cl-Cl	240
C-Cl	327
H-Cl	428

1. Draw out the molecules of every reactant and product to show every bond (if not given in question already)



2. Highlight/label and count every bond in the reactants and products



Reactants (Energy in):

(6 x C-H) + (1 x C-C) + (1 x Cl-Cl) =
(6 x 413) + (1 x 346) + (1 x 240) = 3064 kJ/mol

Products (Energy out):

(5 x C-H) + (1 x C-C) + (1 x C-Cl) + (1 x H-Cl) =
(5 x 413) + (1 x 346) + (1 x 327) + (1 x 428) = 3166 kJ/mol

3. Calculate the enthalpy change of the reaction:
   ΔH : energy in – energy out
   ΔH : 3064 - 3166 = -102 kJ/mol
   The enthalpy change is negative so the reaction is exothermic.

Example 2

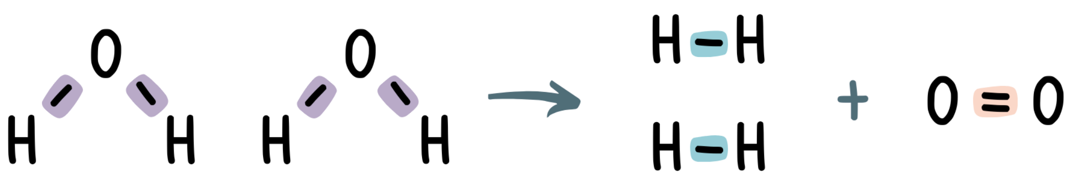
Calculate the enthalpy change of the following reaction, using the bond energies given in the table. State whether the reaction is exothermic or endothermic.

$2\ H_2O \rightarrow 2H_2 + O_2$

Bond	Bond energy (kJ/mol)
O-H	464
H-H	436
O=O	498

1. Draw out the molecules of every reactant and product to show every bond (if not given in question already)

2. Highlight/label and count every bond in the reactants and products



Reactants (Energy in):
(4 x O-H) =
(4 x 464) = 1856 kJ/mol

Products (Energy out):
(2 x H-H) + (1 x O=O) =
(2 x 436) + (1 x 498) = 1370 kJ/mol

3. Calculate the enthalpy change of the reaction:
   ΔH : energy in – energy out
   ΔH : 1856 - 1370 = (+) 486 kJ/mol
   The enthalpy change is positive so the reaction is endothermic.

- Bond energy calculations may require you to rearrange the enthalpy change of a reaction formula to calculate the bond energy of a specific bond.

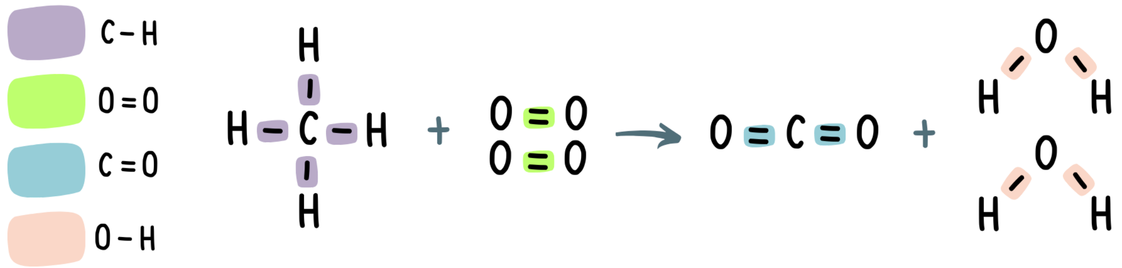
Example 3

The bond energy of the following reaction is -808kJ/mol. Using the given bond energies, calculate the bond energy of the O-H bond.

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

Bond	Bond energy (kJ/mol)
C-H	413
C=O	800
O=O	498
O-H	?

1. Draw out the molecules of all the reactants and products. Highlight each different type of bond.



2. Add up the bond energies that have been given in the reactants and products

Reactants (energy in):
(4 x C-H) + (2 x O=O) =
(4 x 413) + (2 x 498) = 2648 kJ/mol

Products (energy out):
(2 x C=O) + (4 x O-H) =
(2 x 800) + (4 x ?) =

3. Rearrange the enthalpy change of reaction formula to calculate the missing bond energy value

   ΔH : energy in – energy out

   [(4 x C-H) + (2 x O=O)] – [(2 x C=O) + (4 x O-H)] = -808 kJ/mol

   [(4 x 413) + (2 x 498)] – [(2 x 800) + (4 x ?)] = -808 kJ/mol

   1048 – (4 x ?) = -808 kJ/mol

   Rearrange to: 1048 + 808 = (4 x ?)

   So 1856 = (4 x ?)

   ? = O-H bond energy = 1856 ÷ 4 = 464 kJ/mol