Reaction profiles

5.5.1.2 · Chemistry · revision notes

A reaction profile is a simple energy diagram showing how energy changes as reactants turn into products. You need to draw and label profiles for exothermic and endothermic reactions, use them to decide which type a reaction is, and explain what the activation energy is.

Key facts

- Activation energy = minimum energy particles must have to react (when they collide)
- Exothermic profile: products below reactants
- Activation energy = energy at the peak − energy of the reactants
- Both arrows start at the reactants line
- Axes: energy (vertical), progress of reaction (horizontal)
- Endothermic profile: products above reactants
- Overall energy change = energy of products − energy of reactants (negative for exothermic)

Notes

Activation energy

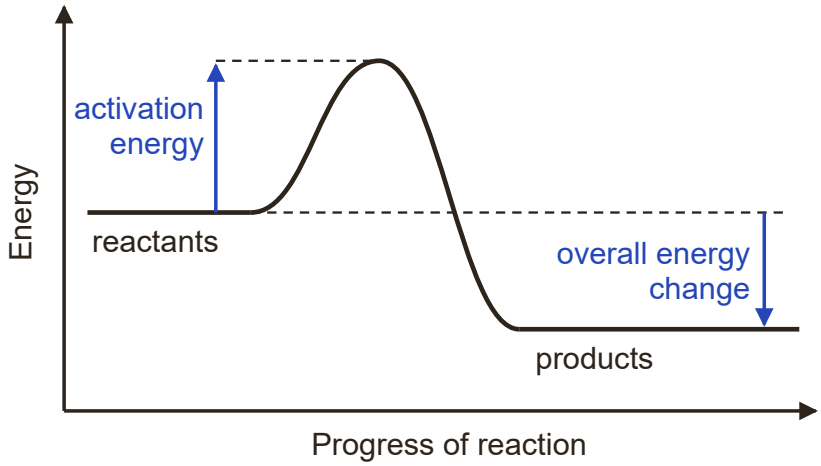
- Chemical reactions can only happen when reacting particles **collide** with enough energy.
- The **activation energy** is the minimum amount of energy that particles must have to react.
- Reactions with a high activation energy need energy to be supplied before they start, e.g. a spark or a flame to light a fuel.
- Once an exothermic reaction starts, the energy it releases gives more particles the activation energy, so the reaction keeps going. This is why a fuel keeps burning after the match is taken away. Grade 8+ only

Drawing a reaction profile

- Label the axes: energy (vertical) and progress of reaction (horizontal).
- Draw a short horizontal line for the reactants on the left and one for the products on the right, at the correct relative heights. Label each line with the names or formulae.
- Join the two lines with a smooth curve that rises to a peak above both, then falls to the products.
- **Activation energy**: an arrow from the reactants line up to the top of the curve.
- **Overall energy change**: an arrow from the reactants line to the products line (down for exothermic, up for endothermic).

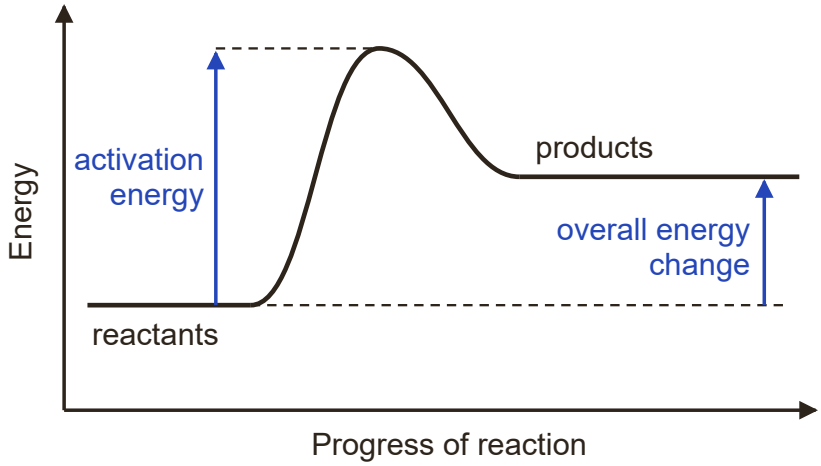
Exothermic or endothermic?

- **Exothermic**: the products are **lower** in energy than the reactants. The difference is the energy released to the surroundings.



Exothermic: products lower than reactants; the overall energy change arrow points down.

- **Endothermic**: the products are **higher** in energy than the reactants. The difference is the energy taken in from the surroundings.



Endothermic: products higher than reactants; the overall energy change arrow points up.

- Both types have a peak: every reaction has an activation energy, even an exothermic one.
- In an endothermic reaction the peak must be above the products, so the activation energy is always bigger than the overall energy change. Grade 7+ only

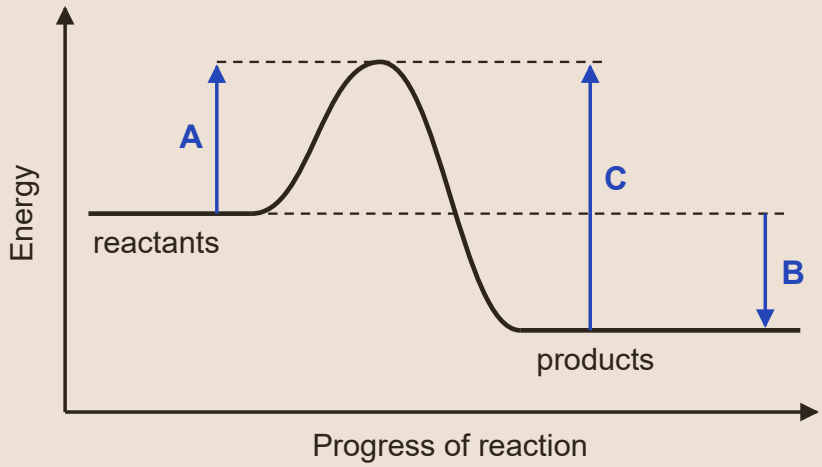
How to answer each type of question

Identify the parts of a given profile

1 to 4 marks | Grade 4

1. Find the reactants (left line) and the products (right line).
2. The arrow from the reactants up to the peak is the activation energy.
3. The arrow between the reactants line and the products line is the overall energy change.
4. Products lower means exothermic; products higher means endothermic.

Example. The diagram shows a reaction profile with three labelled arrows, A, B and C.



(a) Which arrow shows the activation energy? (1)
(b) Which arrow shows the overall energy change? (1)
(c) Is the reaction exothermic or endothermic? Give a reason for your answer. (2)

Model answer.

(a) A (1)

(b) B (1)

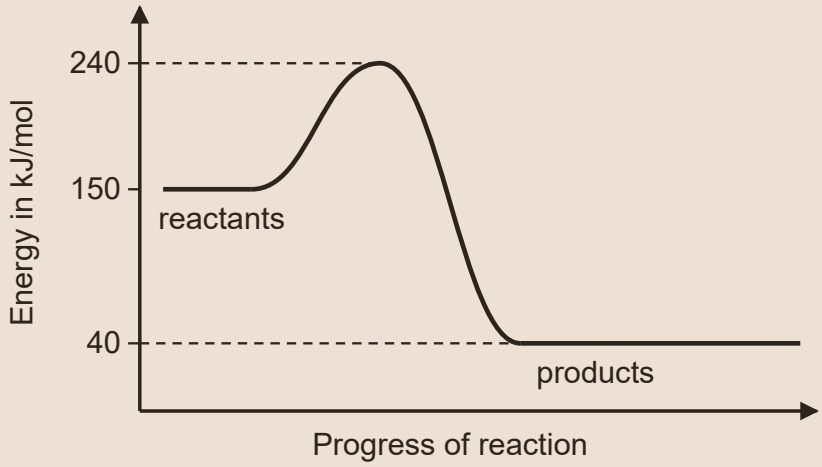
(c) Exothermic (1) because the products have less energy than the reactants / arrow B points down (1)

Calculate values from a reaction profile

2 to 3 marks | **Grade 5**

1. Read the energy of the reactants, the peak and the products from the axis.
2. Activation energy = peak − reactants.
3. Overall energy change = products − reactants. A negative answer means energy is released (exothermic).

Example. On a reaction profile, the reactants are at 150 kJ/mol, the top of the curve is at 240 kJ/mol and the products are at 40 kJ/mol.



(a) Calculate the activation energy. (1)
(b) Calculate the overall energy change and state whether the reaction is exothermic or endothermic. (2)

Model answer.

(a) 240 − 150 = 90 kJ/mol (1)

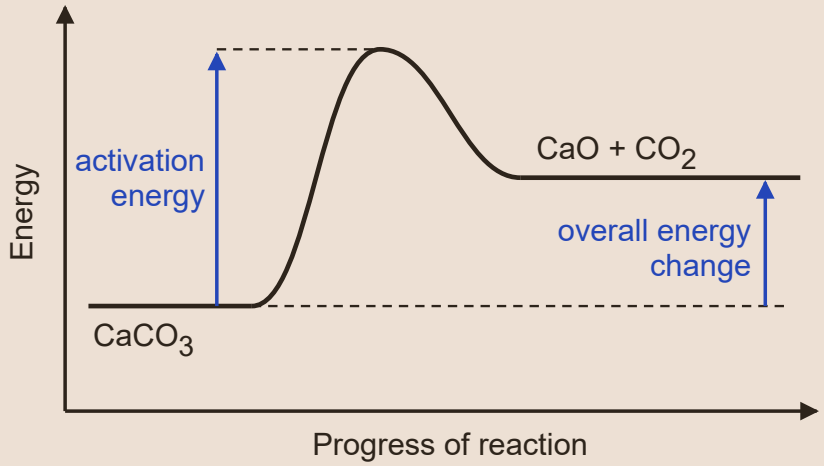
(b) 40 − 150 = −110 kJ/mol (1); exothermic, because the products have less energy than the reactants (1)

Draw a reaction profile 3 to 4 marks **Grade 5**

1. Draw and label the axes: energy (vertical) and progress of reaction (horizontal).
2. Put the reactants and products lines at the correct relative heights and label them.
3. Draw a smooth curve with a peak higher than both lines.
4. Add labelled arrows for the activation energy and the overall energy change, both starting at the reactants line.

Example. The thermal decomposition of calcium carbonate is endothermic.
$CaCO_3 \rightarrow CaO + CO_2$
Draw a reaction profile for this reaction. Label the reactants, the products, the activation energy and the overall energy change. (4)

Model answer.



Products line ($CaO + CO_2$) drawn higher than the reactants line ($CaCO_3$), both labelled (1). A curve rising from the reactants to a peak above the products line, then falling to the products (1). Activation energy: arrow from the reactants line to the peak (1). Overall energy change: arrow from the reactants line up to the products line (1).

Explain the role of activation energy

2 to 3 marks | **Grade 7**

1. Define activation energy: the minimum energy particles need to react.
2. Link it to collisions: particles must collide with at least this much energy.
3. Say what supplying energy (a spark, flame or heating) does at the start.
4. For a reaction that keeps going, say that the energy released provides the activation energy for more particles.

Example. A mixture of methane and air does not react at room temperature, but once it is lit with a spark the methane keeps burning.
Explain why. (3)

Model answer. Particles must collide with at least the activation energy to react; at room temperature the particles do not have enough energy (1). The spark supplies the activation energy, so some particles react (1). Combustion is exothermic, so the energy released gives more particles enough energy to react and the reaction keeps going (1).

Don’t lose marks

- Drawing the activation energy arrow from the products line or from the axis, instead of from the reactants line up to the peak.
- Drawing the overall energy change arrow from the peak down to the products. It goes from the reactants line to the products line.
- Leaving out the hump on an exothermic profile. Every reaction has an activation energy.
- Drawing the peak lower than the products line on an endothermic profile.
- Writing that activation energy is 'the energy given out' or 'the energy of the products'. It is the minimum energy the particles need to react.

More tips

Memory tricks

- Exothermic profiles go downhill overall (energy exits); endothermic profiles go uphill overall.
- Every arrow starts at the reactants line.
- The hump is the activation energy; the step between the two lines is the overall energy change.
- Sense check an endothermic profile: the peak must be higher than the products line, so the activation energy arrow is always longer than the energy change arrow.

Exam technique

- Use a ruler for the arrows and make them start and finish exactly on the levels they measure.
- Label with the exact words the question uses: reactants, products, activation energy and overall energy change.
- If a question adds a catalyst, draw a second, lower peak between the same reactants and products lines: a catalyst lowers the activation energy but does not change the overall energy change (see the rates of reaction notes).
- In 'explain' questions about activation energy, mention both collisions and energy: particles must collide with at least the activation energy to react.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **State what activation energy is**
The minimum amount of energy that particles must have to react when they collide.

Grade 4 — **Label the parts of a reaction profile**
Identify the reactants, products, activation energy and overall energy change on a given profile.

Grade 4 — **Identify exothermic or endothermic from a profile**
Products lower than reactants means exothermic; products higher than reactants means endothermic.

Grade 5 — **Read energy values from a profile**
Activation energy = peak − reactants; overall energy change = products − reactants.

Grade 5 — **Draw a reaction profile**
Show the reactants and products at the correct relative heights, a curve with a peak above both, and labelled arrows.

Grade 7 — **Explain why some reactions need heating to start**
Particles must collide with at least the activation energy, so energy (e.g. a spark or flame) must be supplied at first.

Grade 8 — **Explain why exothermic reactions keep going once started**
The energy released gives more particles at least the activation energy, so the reaction continues without further heating.

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