The effect of temperature changes on equilibrium (HT only)

5.6.2.6 · Chemistry · revision notes

Higher tier only. Changing the temperature of a system at equilibrium changes the relative amount of products, depending on whether the forward reaction is exothermic or endothermic. You need to predict the effect, and use data to decide whether a reaction is exothermic or endothermic.

Key facts

- Heat up → endothermic direction favoured
- Forward reaction exothermic: higher temperature → less product
- Yield falls as temperature rises → forward reaction is exothermic
- Cool down → exothermic direction favoured
- Forward reaction endothermic: higher temperature → more product
- A higher temperature increases the rates of both the forward and reverse reactions

Notes

The rules

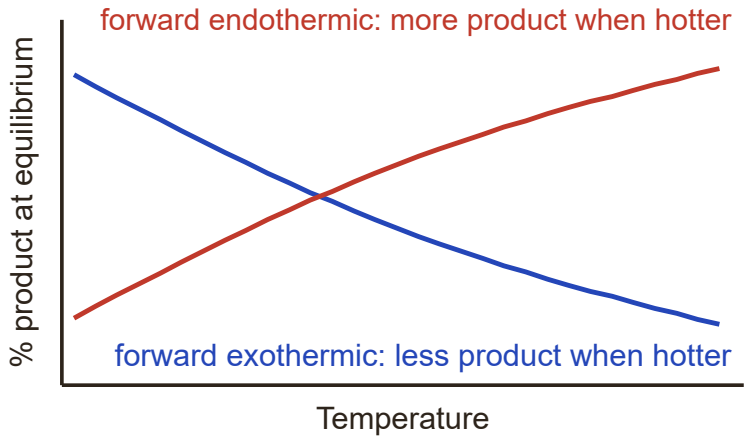
- Increase the temperature: the relative amount of products at equilibrium **increases** for an endothermic reaction and **decreases** for an exothermic reaction.
- Decrease the temperature: the relative amount of products at equilibrium **decreases** for an endothermic reaction and **increases** for an exothermic reaction.
- 'An exothermic reaction' here means the forward reaction is exothermic, so the reverse reaction is endothermic.

Why it happens

- Increasing the temperature: the system counteracts the change by favouring the **endothermic** direction, which takes in energy.
- Decreasing the temperature: the system favours the **exothermic** direction, which releases energy.
- So work out which direction is endothermic: the position shifts that way when the mixture is heated.

Using data and observations

- If the percentage of product at equilibrium goes down as the temperature goes up, the forward reaction is exothermic.
- If the percentage of product goes up as the temperature goes up, the forward reaction is endothermic.



Read the trend to decide whether the forward reaction is exothermic or endothermic.

- Example: $2NO_2$ (brown) $\rightleftharpoons$ N_2O_4 (colourless), where the forward reaction is exothermic. Heating the sealed mixture shifts the position left, so it turns darker brown.
- Temperature also affects rate. For an exothermic reaction, a lower temperature gives a greater amount of product at equilibrium, but the reaction is slower, so equilibrium takes longer to reach. Grade 8+ only

How to answer each type of question

Predict and explain the effect of changing the temperature 2 marks **Grade 6**

1. Find out whether the forward reaction is exothermic or endothermic.
2. Heating: the position shifts in the endothermic direction. Cooling: it shifts in the exothermic direction.
3. State what happens to the amount of product.

Example. Sulfur dioxide reacts with oxygen to form sulfur trioxide.
$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$
The forward reaction is exothermic.
Predict the effect of increasing the temperature on the amount of sulfur trioxide at equilibrium. Explain your answer.

Model answer. The amount of sulfur trioxide decreases (1). Increasing the temperature favours the endothermic direction, which is the reverse reaction, so the position of equilibrium shifts to the left (1).

Use data to decide whether a reaction is exothermic or endothermic

3 marks **Grade 7**

1. Describe the trend: what happens to the amount of product as the temperature rises?
2. Less product at a higher temperature means heating shifts the position left.
3. So the reverse reaction is endothermic and the forward reaction is exothermic (and the opposite for the other trend).

Example. Methanol is made from carbon monoxide and hydrogen.
$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$
The percentage of methanol in the equilibrium mixture at a fixed pressure:

Temperature in °C	200	250	300	350
Percentage of methanol at equilibrium	55	38	21	10

Is the forward reaction exothermic or endothermic? Explain how the data show this.

Model answer. Exothermic (1). As the temperature increases, the percentage of methanol at equilibrium decreases (1). So increasing the temperature shifts the position to the left, which means the reverse reaction is endothermic and the forward reaction is exothermic (1).

Explain a colour change on heating or cooling

3 marks **Grade 8**

1. Use the colour change to say which substance has increased.
2. So say which way the position has shifted.
3. Heating favours the endothermic direction, so name the direction that must be endothermic.

Example. A sealed tube contains colourless gas A in equilibrium with brown gas B.
$A(g) \rightleftharpoons 2B(g)$
When the tube is put into hot water, the mixture turns darker brown.
Is the forward reaction exothermic or endothermic? Explain your answer.

Model answer. Endothermic (1). The mixture turns darker, so more brown gas B has formed and the position of equilibrium has shifted to the right (1). Increasing the temperature favours the endothermic direction, so the forward reaction is endothermic (1).

Explain the choice of temperature (yield and rate) 3 marks **Grade 8**

1. Give the effect on yield: for an exothermic forward reaction, a lower temperature gives more product at equilibrium.
2. Give the effect on rate: a lower temperature makes the reaction slower (less frequent collisions, fewer with the activation energy).
3. Conclude: the temperature chosen gives a reasonable yield in a reasonable time.

Example. The forward reaction in the methanol process is exothermic. A manufacturer uses 250 °C rather than 150 °C, even though the percentage of methanol at equilibrium is higher at 150 °C. Suggest why the manufacturer uses 250 °C.

Model answer. At 150 °C the rate of reaction would be too slow (1), because the particles collide less frequently and fewer collisions have energy equal to or greater than the activation energy (1). At 250 °C a reasonable yield is made in a much shorter time, so more methanol is produced each hour (1).

Don’t lose marks

- Saying that increasing the temperature shifts every equilibrium to the right. It depends on which direction is endothermic.
- Mixing up the forward and reverse directions when the question says 'the reaction is exothermic'.
- Saying a higher temperature slows down the reverse reaction. Heating speeds up both reactions; the position shifts because the endothermic direction is favoured.
- Naming the direction of the shift but forgetting to say what happens to the amount of product.

More tips

Memory tricks

- Heat favours endo: adding heat pushes the reaction in the direction that soaks up heat.
- Treat energy like a substance in the equation: for an exothermic forward reaction, energy is on the product side, so adding heat pushes the position left.
- Data check: product percentage and temperature move in opposite directions → forward reaction exothermic; in the same direction → endothermic.

Exam technique

- Always name the direction that is favoured (endothermic or exothermic, forward or reverse) in your explanation.
- When the question gives a table of yields, quote numbers from it to support your answer.
- In yield-versus-rate questions, give both sides: the effect on the amount of product and the effect on the rate.

What each grade needs

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

Grade 5 **Predict heating an exothermic reaction**
Raising the temperature decreases the relative amount of products at equilibrium.

Grade 6

Predict heating an endothermic reaction

Raising the temperature increases the relative amount of products at equilibrium.

Grade 7

Explain temperature effects using Le Chatelier

Increasing the temperature favours the endothermic direction, which takes in energy.

Grade 7

Deduce the energy change from yield data

If the yield falls as the temperature rises, the forward reaction is exothermic.

Grade 8

Explain colour changes caused by temperature

Link the direction of the shift to the colour of the substance that increases.

Grade 8

Weigh yield against rate when choosing temperature

A lower temperature gives more product for an exothermic reaction, but the rate is slower.

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