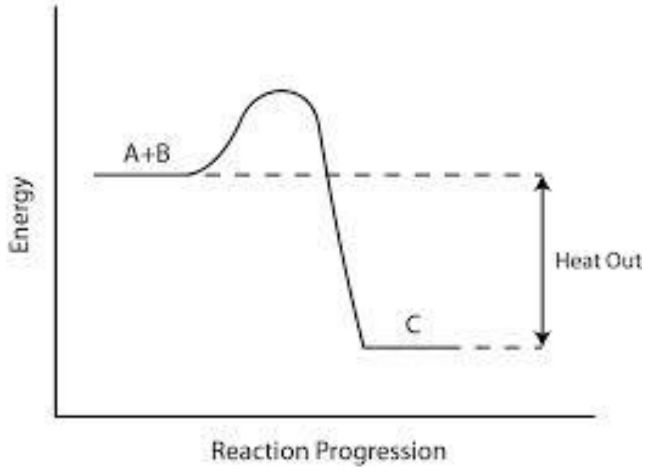
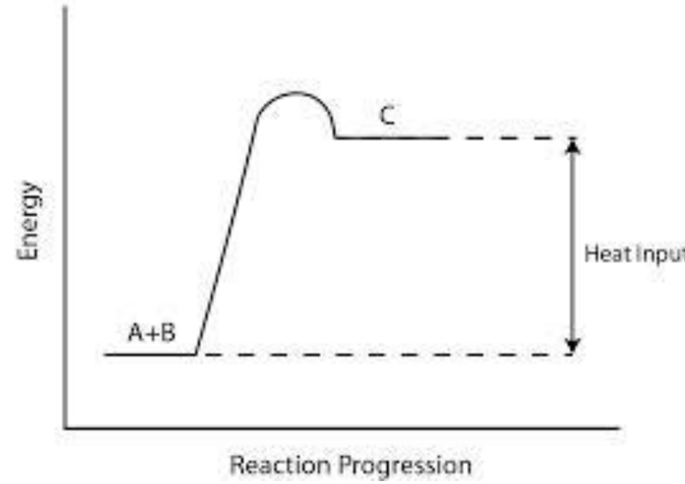
CHEM3.4 Demonstrate understanding of thermochemical principles and the properties of particles and substances

We have covered the underlined part so far. This is:

- Electron configurations with s, p, d orbitals
- Periodic trends (atomic, ionic radii, electronegativity, ionisation energy)
- Lewis diagrams and shapes
- Polarity
- Intermolecular forces and physical properties





Thermochemical principals

Enthalpy

$\Delta H = H_{products} - H_{reactants}$

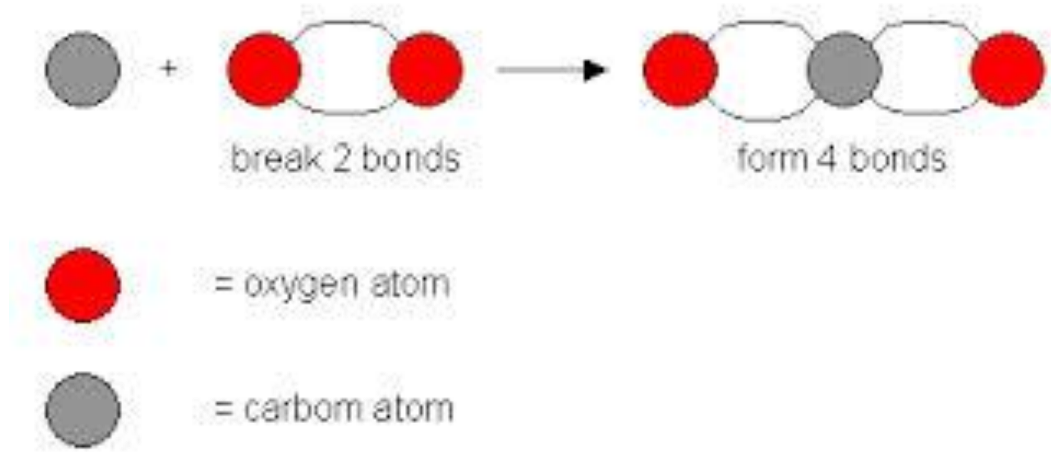
Exothermic

ΔH is –ve

Endothermic

ΔH is +ve

Units: $kJ.mol^{-1}$



Heats of reaction

When chemicals react together there is a transfer of energy.

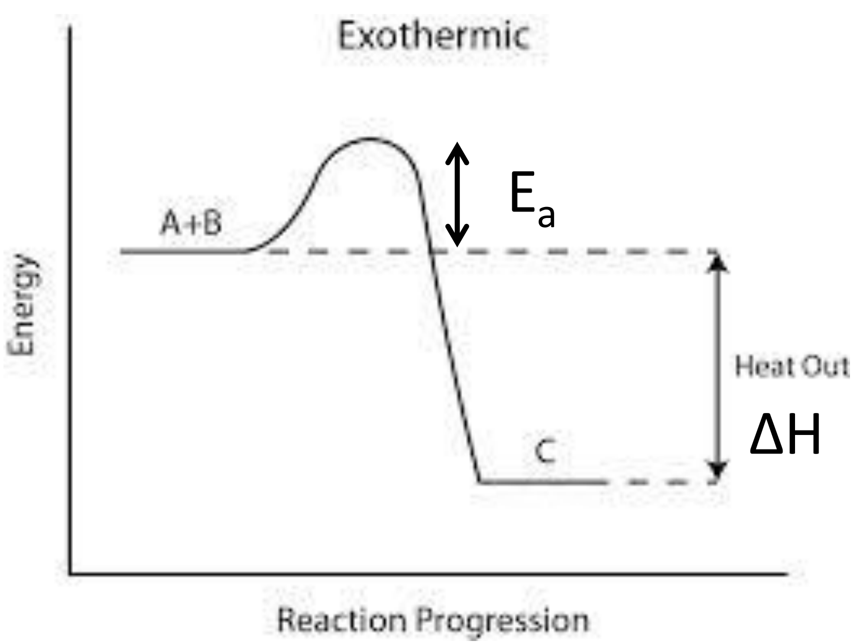
For example: Chemical energy is converted to heat energy when we burn fuels
Chemical energy is converted to heat energy when we digest food

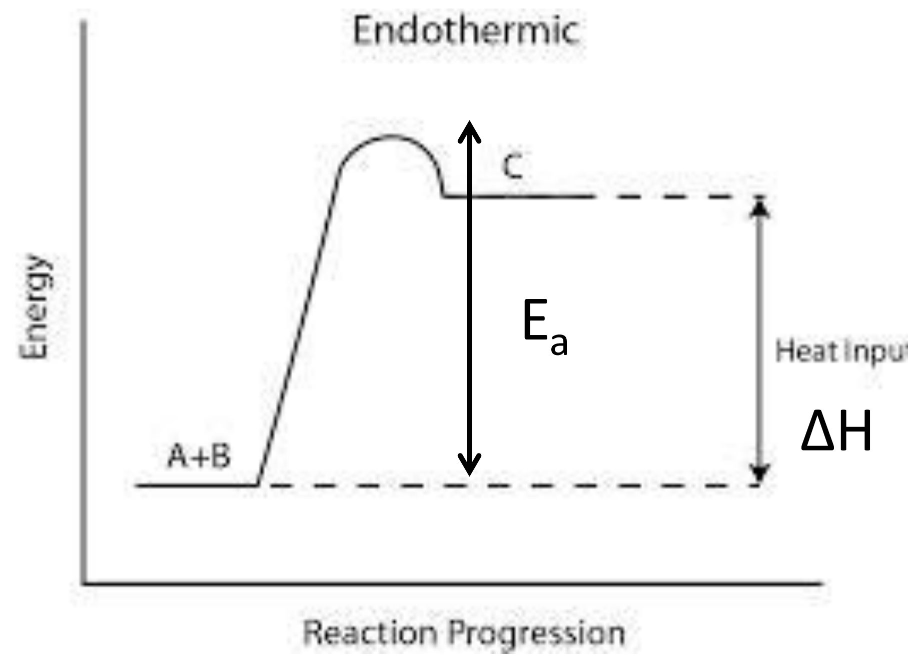
The change in heat content during a reaction is called the change in enthalpy (ΔH) and is measured in $kJ.mol^{-1}$.

$\Delta_r H = H_{products} - H_{reactants}$

Exothermic reactions have a –ve ΔH
Endothermic reactions have a +ve ΔH

Exo and endo thermic reactions





Level 2 2013 Exam Q3 (a)

QUESTION THREE

(a) Dissolving ammonium nitrate in a beaker containing water can be represented by the following equation:

$$NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq) \qquad \Delta_r H^\circ = 25.1 \text{ kJ mol}^{-1}$$

Circle the term below that best describes this process.

exothermic **endothermic**

Circle the description below that best describes what you would observe happening to the beaker during this process.

gets colder **stays the same** **gets warmer**

Explain your choices.

Level 2 2013 Q3 (b)

(b) Glucose is an important source of energy in our diet. The equation below shows the combustion of glucose to form carbon dioxide and water.

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(\ell) \quad \Delta_r H^\circ = -2\,820 \text{ kJ mol}^{-1}$$

(i) Circle the term below that best describes this process.

exothermic **endothermic**

Give a reason for your choice.

Do now:

What are the products from the combustion reactions of the following compounds?

$C + O_2 \rightarrow CO_2$

$CH_3OH + 3/2\ O_2 \rightarrow CO_2 + 2\ H_2O$

$C_5H_{12} + 8\ O_2 \rightarrow 5\ CO_2 + 6\ H_2O$

$S + O_2 \rightarrow SO_2$

Standard heats of reaction

The amount of heat given out is dependent on the amount of reactants involved in the reaction.

$$2\ Ca_{(s)} + O_{2(g)} \rightarrow 2\ CaO_{(s)} \qquad \Delta H = -317.5\ kJ$$

When 2 moles of Ca react with 1 mole of O_2 317.5 kJ of energy is released.
When 1 mole of Ca reacts with ½ a mole of O_2 half as much energy is released (158.75 kJ).

this bit means standard conditions

Standard heat of reaction $\Delta_r H°$

$$2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)} \qquad \Delta_r H°(H_2O_{(l)}) = -570\ kJ.mol^{-1}$$

this bit means per mole of reaction (determined by the chemical equation)

Standard heats of reaction

Standard heat of combustion $\Delta_c H°$

'enthalpy change when 1 mole of a substance is burnt completely with all products and reactants in their standard states'

Always exothermic

$H_{2(g)} + ½ O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta_c H°(H_{2(g)}) = -285\ kJ.mol^{-1}$

only 1 mole of the compound being combusted

Standard heat of formation $\Delta_f H°$

'enthalpy change when 1 mole of a substance is formed from its elements with all products and reactants in their standard states'

For all elements the standard heat of formation is zero

$H_{2(g)} + ½ O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta_f H°(H_2O_{(g)}) = -285\ kJ.mol^{-1}$

elements in their standard states

Standard heats of reaction

Write the equations for:

The enthalpy of formation, $\Delta_f H°$, for zinc oxide

$Zn_{(s)} + ½O_{2(g)} \rightarrow ZnO_{(s)}$

$\Delta_f H°(NH_3)$

$½N_{2(g)} + 1 ½H_{2(g)} \rightarrow NH_{3(g)}$

The enthalpy of combustion, $\Delta_c H°$, for methanol, CH_3OH

$CH_3OH_{(l)} + 1 ½O_{2(g)} \rightarrow CO_{2(g)} + 2 H_2O_{(g)}$

$\Delta_c H°(C_2H_6)$

$C_2H_{6(g)} + 3 ½O_{2(g)} \rightarrow 2 CO_{2(g)} + 3 H_2O_{(g)}$

Workbook pg 51

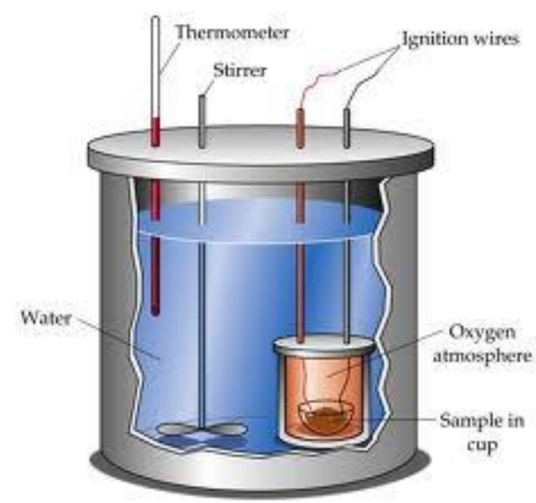
Measuring enthalpy changes

We can't measure the change in enthalpy directly, so we measure the increase or decrease in temperature of another substance, usually water, to work out how much energy has been lost or gained in the reaction.

In the school lab, we measure the temperature change of a reaction with a thermometer and perform calculations.

In industry insulated devices called calorimeters are used to measure the heat transferred to water.

Tomorrow we will be measuring the enthalpy change of a neutralisation reaction.



Calculating standard enthalpy change of a reaction

We need to know the mass, the change in temperature and the specific heat capacity of the solution. ← you will always be given this value

This allows us to work out ΔH.

1^{st} step

$q = m \cdot \Delta t \cdot s$

q: J; m: g; Δt: °C; s: $J.°C^{-1}g^{-1}$

2^{nd} step

Did temp increase or decrease? Increase –ve value, decrease +ve value. This value is ΔH (you may convert to kJ).

3^{rd} step

Work out number of moles in reaction.

Divide ΔH by number of moles to get a value for $\Delta H_r°$ in $kJ.mol^{-1}$

2013 Exam Q2 (b)

(b) (i) When 25.0 mL of a 1.00 mol L^{-1} hydrochloric acid solution, HCl, is added to 25.0 mL of a 1.00 mol L^{-1} ammonia solution, NH_3, a temperature rise of 6.50°C is recorded, as a neutralisation reaction occurs to produce aqueous ammonium chloride and water.

Calculate $\Delta_r H°$ for this neutralisation reaction.

The mass of the mixture is 50.0 g.

Assume specific heat capacity of the aqueous ammonium chloride = 4.18 J g^{-1} $°C^{-1}$

(ii) When the $\Delta_r H°$ for the neutralisation above was found experimentally in a school laboratory, the value obtained was lower than the theoretical value.

Account for the difference in values, and suggest how this difference could be minimised.

2013 Exam Q2 (b)

$HCl + NH_3 \rightarrow NH_4Cl$.

$q = mc\Delta T = 50 \times 4.18 \times 6.5 = 1358.5\ J$

$= 1.3585\ kJ$

exo.

$\Delta_r H^\circ = \frac{-q}{n} = \frac{-1.3585}{0.025 \times 1}$

$n = cV$.

$= -54.3\ kJ\ mol^{-1}$. //

2013 Exam Q2 (b)

(b) It could be due to heat lost to surroundings. So temperature measured is lower. Could carry out experiment in some form of containment to provide insulation.

Or could be experiment not done under standard conditions, i.e 25°C and 1atm pressure. Could adjust the condition to standard conditions for a result closer to the theoretical value. //

Correct answer

Do now:

What is meant by the term $\Delta_c H°(CH_3COOH)$?

The enthalpy change when 1 mole of ethanoic acid is burnt completely with all products and reactants in their standard states

What is meant by the term $\Delta_f H°(CH_3COOH)$?

The enthalpy change when 1 mole of ethanoic acid is formed from its elements with all products and reactants in their standard states

Write equations for each

$\Delta_c H°(CH_3COOH)$ is **$CH_3COOH + 2\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O$**

$\Delta_f H°(CH_3COOH)$ is **$2\ C + O_2 + 2\ H_2 \rightarrow CH_3COOH$**

Today…

Measuring the temperature change in a neutralisation reaction so that we can calculate the enthalpy change of the reaction and then the standard enthalpy change of the reaction ($\Delta H_r°$).

Do now:

Write balanced equations for the following:

$\Delta_f H°(CaO)$ **$Ca + ½\ O_2 \rightarrow CaO$**

$\Delta_c H°(C_4H_{10})$ **$C_4H_{10} + 13/2\ O_2 \rightarrow 4\ CO_2 + 5\ H_2O$**

6 ½

$\Delta_f H°(C_6H_{12}O_6)$ **$6\ C + 3\ O_2 + 6\ H_2 \rightarrow C_6H_{12}O_6$**

Phase changes

What occurs during a phase change?

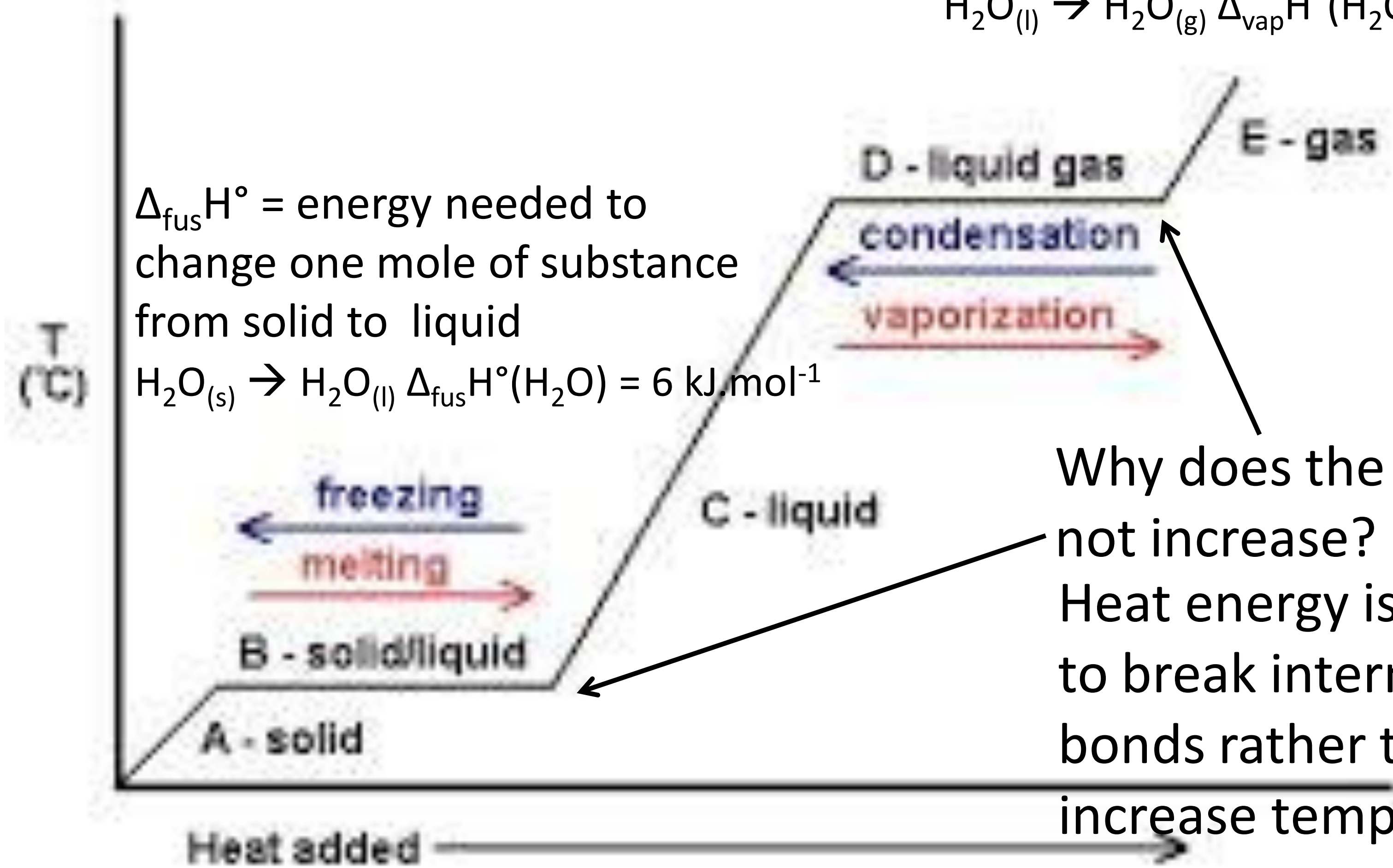
Breaking intermolecular bonds

$\Delta_{vap}H°$ = energy needed to change one mole of substance from liquid to gas

$H_2O_{(l)} \rightarrow H_2O_{(g)}$ $\Delta_{vap}H°(H_2O) = 41.1$ kJ.mol^{-1}

$\Delta_{fus}H°$ = energy needed to change one mole of substance from solid to liquid

$H_2O_{(s)} \rightarrow H_2O_{(l)}$ $\Delta_{fus}H°(H_2O) = 6$ kJ.mol^{-1}



Why does the temperature not increase?

Heat energy is being used to break intermolecular bonds rather than increase temp

Phase changes

Workbook pg 55 and 56

Write equations for:

$\Delta_{fus}H°(NaCl)$ **$NaCl_{(s)} \rightarrow NaCl_{(l)}$**

$\Delta_{vap}H°(C_2H_6)$ **$C_2H_{6(l)} \rightarrow C_2H_{6(g)}$**

$\Delta_{f}H°(CH_3CH_2OH)$ **$2\ C_{(s)} + 3\ H_{2\ (g)} + \frac{1}{2}\ O_{2\ (g)} \rightarrow CH_3CH_2OH_{\ (l)}$**

$\Delta_{fus}H°(NH_3)$ **$NH_{3(s)} \rightarrow NH_{3(l)}$**

What determines the size of $\Delta_{fus}H°$ and $\Delta_{vap}H°$?

The strength of the intermolecular forces. Strong intermolecular forces are harder to break so $\Delta_{fus}H°$ and $\Delta_{vap}H°$ will be higher.

Do now:

Write balanced equations for the following (don't forget your states! $_{(s)}$, $_{(l)}$, $_{(g)}$:

$\Delta_f H°(CH_3Br)$ **$C_{(s)} + 1\ ½\ H_{2(g)} + ½\ Br_{2(l)} \rightarrow CH_3Br_{(g)}$**

$\Delta_{fus} H°(CH_3OH)$ **$CH_3OH_{(s)} \rightarrow CH_3OH_{(l)}$**

$\Delta_{vap} H°(CH_3OH)$ **$CH_3OH_{(l)} \rightarrow CH_3COH_{(g)}$**

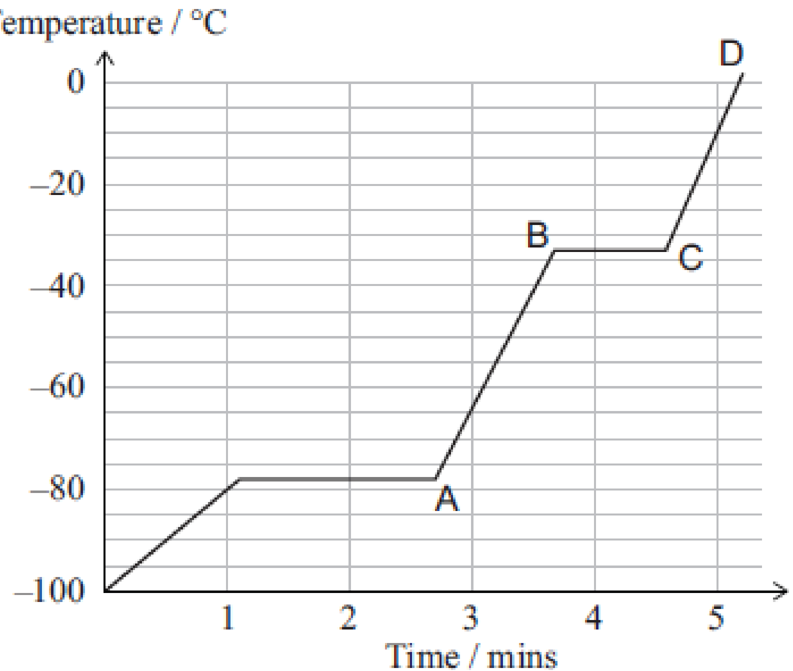
What is the energy being used for in $\Delta_{vap} H°(CH_3OH)$?
To break the intermolecular forces (hydrogen bonding) between the molecules

What will have greatest value $\Delta_{fus} H°(CH_3OH)$ or $\Delta_{vap} H°(CH_3OH)$?
$\Delta_{vap} H°(CH_3OH)$

2014 Exam Q2 d

(d) The following graph shows the change in temperature over a five-minute period for a sample of ammonia, where a constant amount of heat was applied per minute.

Heating curve for ammonia



Key words in the question?

Key words in your answer?

Using the graph above, justify the physical changes occurring to ammonia between points A and D, in terms of the energy of the particles and the intermolecular forces of attraction.

2014 Exam Q2 d

From B to C the energy of heating is going into breaking the intermolecular bonds that are keeping ammonia in the liquid state. The temperature does not increase at this point because at the boiling point the bonds between ammonia molecules need to be broken to allow more movement and see an increase in temperature.

From C to D the temperature increases again as the gas molecules of NH_3 gain increasing thermal energy and move more and more. The energy of heating has no intermolecular bonds to break so can continue to increase the temperature