2 Excess zinc powder is added to 50.00 g of 0.500 mol dm^{-3} copper(II) sulfate solution in a polystyrene cup.
The mixture is stirred and the maximum temperature change determined.

The enthalpy change for the reaction is calculated to be −185 kJ mol^{-1}.

The data book value for this reaction is −217 kJ mol^{-1}.

(a) The percentage error in this experiment is

(1)

- ☒ **A** ±7.37 %
- ☒ **B** ±8.65 %
- ☒ **C** 14.7 %
- ☒ **D** 17.3 %

(b) In the calculation, the specific heat capacity of the liquid is taken to be 4.18 J g^{-1} °C^{-1} rather than the true value of 3.85 J g^{-1} °C^{-1}.

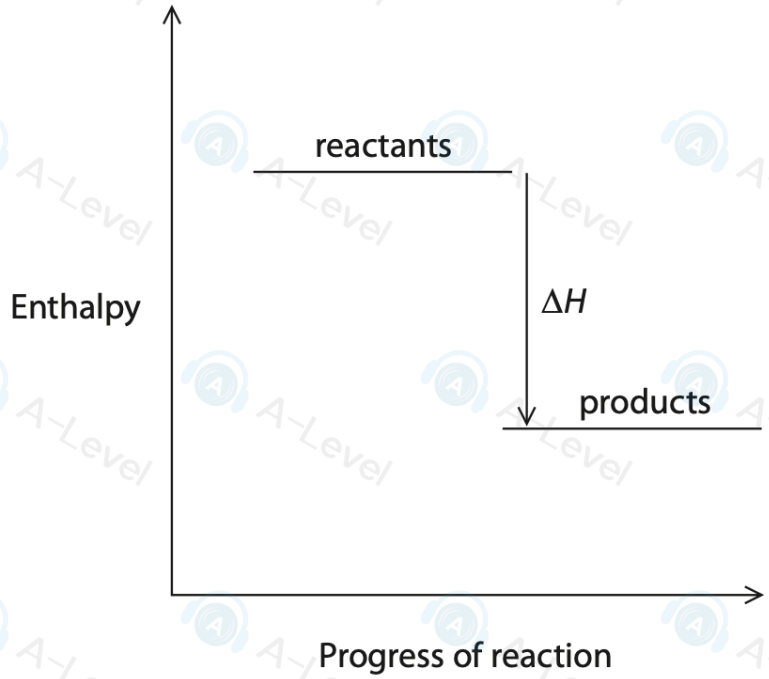
The use of 4.18 J g^{-1} °C^{-1} in the calculation

(1)

- ☒ **A** is partly responsible for the error in the final value obtained
- ☒ **B** lowers the error in the final value obtained
- ☒ **C** has a negligible effect on the final value obtained
- ☒ **D** has a negligible effect compared with the measurement uncertainties

(Total for Question 2 = 2 marks)

1 The enthalpy level diagram for a reaction is shown.



Which is represented by this diagram?

- ☒ **A** $Na(s) \rightarrow Na(g)$
- ☒ **B** $Na(g) \rightarrow Na^+(g) + e^-$
- ☒ **C** $2Cl(g) \rightarrow Cl_2(g)$
- ☒ **D** $NH_4NO_3(s) + aq \rightarrow NH_4^+(aq) + NO_3^-(aq)$

(Total for Question 1 = 1 mark)

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7 Which equation shows the reaction that occurs when the standard enthalpy change of atomisation of iodine is measured?

- ☒ **A** $I_2(s) \rightarrow 2I(g)$
- ☒ **B** $\frac{1}{2}I_2(s) \rightarrow I(g)$
- ☒ **C** $I_2(g) \rightarrow 2I(g)$
- ☒ **D** $\frac{1}{2}I_2(g) \rightarrow I(g)$

3 The standard enthalpy changes of combustion for a series of alkanes are shown.

Alkane formula	$\Delta_c H^{\ominus}$ / kJ mol^{-1}
$C_2H_6(g)$	−1560
$C_3H_8(g)$	−2219
$C_4H_{10}(l)$	−2877
$C_5H_{12}(l)$	−3509

Another alkane has an enthalpy change of combustion of −6125 kJ mol^{-1}.

Which is the most likely formula for this alkane?

☒ **A** C_6H_{14}

☒ **B** C_7H_{16}

☒ **C** C_8H_{18}

☒ **D** C_9H_{20}

(Total for Question 3 = 1 mark)

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3 The enthalpy changes for two reactions are shown.

$$2Fe(s) + 1\tfrac{1}{2}O_2(g) \rightarrow Fe_2O_3(s) \qquad \Delta_r H^{\ominus} = -824\ \text{kJ mol}^{-1}$$

$$C(s) + \tfrac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta_r H^{\ominus} = -111\ \text{kJ mol}^{-1}$$

What is the enthalpy change for the reaction between iron(III) oxide and carbon?

$$Fe_2O_3(s) + 3C(s) \rightarrow 2Fe(s) + 3CO(g)$$

☒ **A** +491 kJ mol^{-1}

☒ **B** +713 kJ mol^{-1}

☒ **C** −491 kJ mol^{-1}

☒ **D** −713 kJ mol^{-1}

(Total for Question 3 = 1 mark)

1 The mean C–F bond enthalpy is +485 kJ mol^{-1}.

Which process has an enthalpy change of +1940 kJ mol^{-1}?

- ☒ **A** $C(g) + 4F(g) \rightarrow CF_4(g)$
- ☒ **B** $C(s) + 2F_2(g) \rightarrow CF_4(g)$
- ☒ **C** $CF_4(g) \rightarrow C(g) + 4F(g)$
- ☒ **D** $CF_4(g) \rightarrow C(s) + 2F_2(g)$

(Total for Question 1 = 1 mark)

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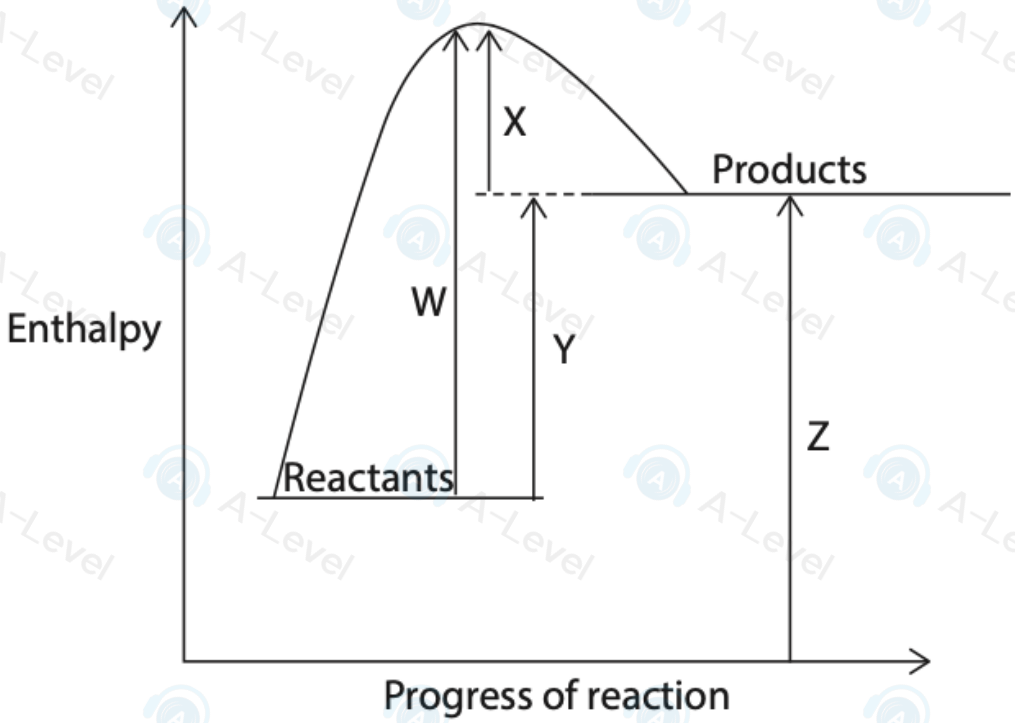
2 The reaction profile for a reaction is shown.



Which arrow represents the activation energy of the forward reaction?

- ☒ **A** letter W
- ☒ **B** letter X
- ☒ **C** letter Y
- ☒ **D** letter Z

2 Which expression gives the standard enthalpy change, in kJ mol^{-1}, for the reaction shown?

$$BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$$

$\Delta_f H^{\ominus}$ values: $BaCO_3(s) = -1216\ kJ\ mol^{-1}$

$BaO(s) = -554\ kJ\ mol^{-1}$

$CO_2(g) = -394\ kJ\ mol^{-1}$

☒ **A** −554 − 394 + 1216

☒ **B** −554 − 394 − 1216

☒ **C** 554 + 394 + 1216

☒ **D** 554 + 394 − 1216

(Total for Question 2 = 1 mark)

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3 Which equation shows the reaction that occurs when the standard enthalpy change of formation of copper(II) carbonate is measured?

☒ **A** $Cu(s) + C(s) + 3O(g) \rightarrow CuCO_3(s)$

☒ **B** $2Cu(s) + 2C(s) + 3O_2(g) \rightarrow 2CuCO_3(s)$

☒ **C** $Cu(g) + C(g) + 1\frac{1}{2}O_2(g) \rightarrow CuCO_3(s)$

☒ **D** $Cu(s) + C(s) + 1\frac{1}{2}O_2(g) \rightarrow CuCO_3(s)$

(Total for Question 3 = 1 mark)

18 This question is about sodium hydroxide.

(a) (i) Write an **ionic** equation for the neutralisation reaction between aqueous sodium hydroxide and hydrochloric acid.
State symbols are not required.

(1)

(ii) State what is meant by standard enthalpy change of neutralisation, $\Delta_{neut}H^{\ominus}$.

(2)

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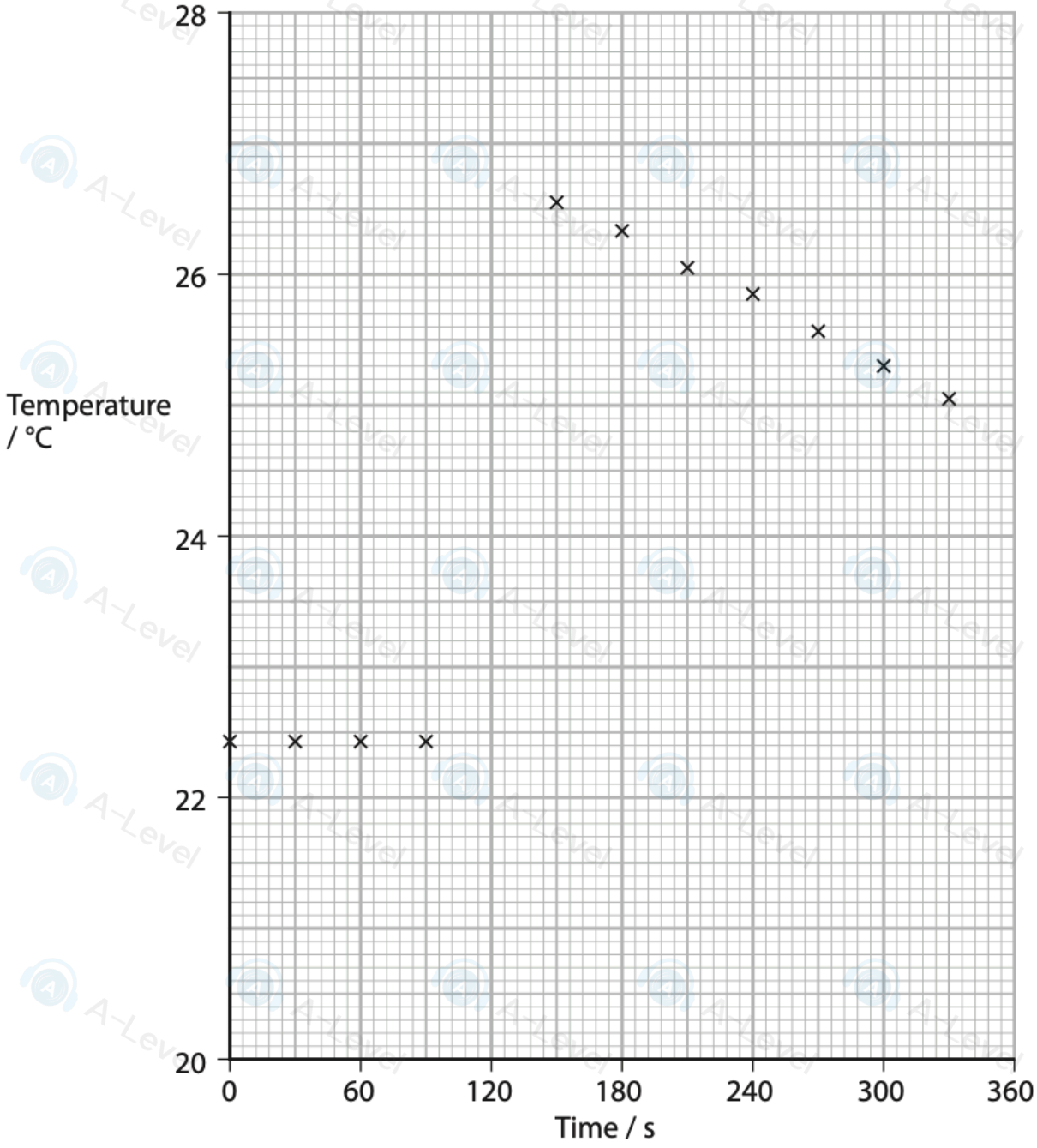
(b) A student carried out an investigation to determine the enthalpy change of neutralisation of aqueous sodium hydroxide by hydrochloric acid.

Method

- separate 25.0 cm^3 samples of 0.80 mol dm^{-3} sodium hydroxide and 0.80 mol dm^{-3} hydrochloric acid were left to reach room temperature
- after two minutes, the solutions were mixed in a copper calorimeter and the temperature was noted at 30 s intervals.

(i) Use the graph shown to determine the maximum temperature change, ΔT, in this experiment. You **must** show your working on the graph.

(2)



(ii) Calculate the enthalpy change of neutralisation using your answers to (a) and (b)(i). Give a sign and units with your answer.
Assume: no energy is used to heat the container.
the specific heat capacity of the solution = 4.2 J °C^{-1} g^{-1}.
the densities of the solutions of NaOH and HCl are 1.0 g cm^{-3}.

(3)

(iii) Explain how, if at all, the enthalpy change of neutralisation obtained in (b)(ii) would differ if the heat capacity of the calorimeter was included in the calculation.

(2)

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(c) Aqueous sodium hydroxide reacts with 1-bromopropane to produce propan-1-ol.

(i) State the type and mechanism of this reaction.

(1)

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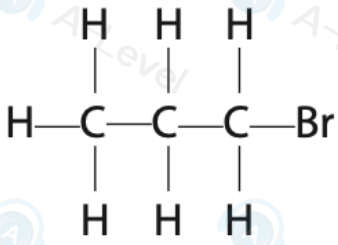
(ii) Complete the mechanism for this reaction.

Include curly arrows, and relevant lone pairs and dipoles.

(3)



(iii) Under different conditions, sodium hydroxide reacts with 1-bromopropane to form propene.
Name the type of reaction and a suitable solvent.

(2)

Type of reaction

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Suitable solvent

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(Total for Question 18 = 16 marks)

16 This question is about magnesium sulfate, a white ionic solid that is very soluble in water.
Hydrated magnesium sulfates have the general formula of $MgSO_4 \cdot xH_2O$, where x is the number of water molecules of crystallisation.

(a) A sample of hydrated magnesium sulfate was heated until all the water had been removed from the crystals.

The mass of the sample decreased from 6.92 g to 6.04 g.

[M_r $MgSO_4$ = 120.4]

(i) State how you could ensure that all the water had been removed from the crystals.

(1)

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(ii) Calculate the number of water molecules of crystallisation, x, in the formula of this sample of hydrated magnesium sulfate.

(3)

(b) The most common form of hydrated magnesium sulfate is $MgSO_4 \cdot 7H_2O$.
A student carried out two experiments to determine the enthalpy change when anhydrous magnesium sulfate forms $MgSO_4 \cdot 7H_2O$.

$$MgSO_4(s) + 7H_2O(l) \rightarrow MgSO_4 \cdot 7H_2O(s)$$

(i) In the first experiment, the student determined the enthalpy change when dissolving anhydrous magnesium sulfate.

$$MgSO_4(s) + (aq) \rightarrow MgSO_4(aq)$$

100.0 g of distilled water was placed in a polystyrene cup and the temperature recorded.

0.0628 mol of anhydrous magnesium sulfate was added to the distilled water, the mixture stirred and the maximum temperature recorded.

Results

Starting temperature of distilled water / °C	16.6
Maximum temperature of solution / °C	29.4

Calculate the enthalpy change for this reaction.
Give your answer to an appropriate number of significant figures and include a sign and units.

[Assume: Specific heat capacity of the solution is $4.18\,J\,g^{-1}\,°C^{-1}$
Density of the solution is $1.00\,g\,cm^{-3}$]

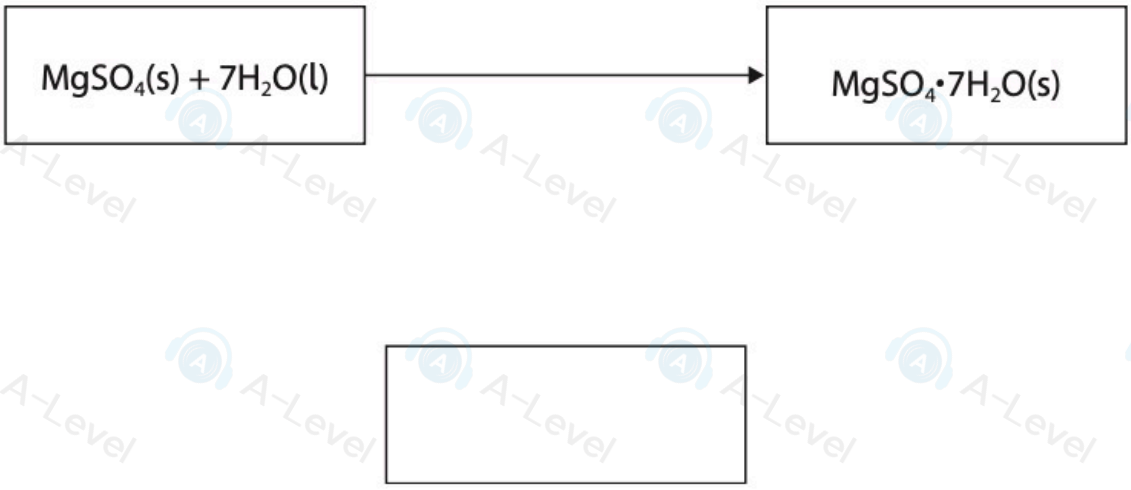
(4)

(ii) In the second experiment, the student determined the enthalpy change when dissolving hydrated magnesium sulfate.

$$MgSO_4 \cdot 7H_2O(s) + (aq) \rightarrow MgSO_4(aq) \qquad \Delta H = +15.8\,kJ\,mol^{-1}$$

Complete the Hess cycle.

(2)



(iii) Calculate the enthalpy change when anhydrous magnesium sulfate forms hydrated magnesium sulfate, using the completed Hess cycle and your answer in (b)(i).

(2)

(c) Magnesium sulfate is very soluble in water.

(i) Draw a labelled diagram showing how both the magnesium ion and the sulfate ion interact with water molecules.

(2)

(ii) Barium ions are toxic in aqueous solution. If a solution containing barium ions enters the body, barium poisoning occurs.

Describe how drinking magnesium sulfate solution can reduce the extent of the poisoning.
Include an ionic equation with state symbols in your answer.

(2)

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(Total for Question 16 = 16 marks)

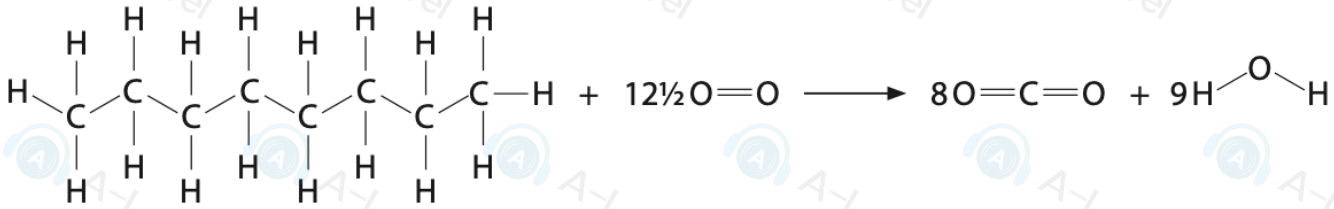
20 This question is about fuels.

The enthalpy change of combustion is the maximum amount of heat energy that can be obtained by the complete combustion of a substance.

Values for the enthalpy change of combustion may be obtained by direct measurement or from mean bond enthalpies. These data may be used to assess the efficiency of fuels.

Petrol is a mixture of a large number of different hydrocarbons containing between four and twelve carbon atoms. Octane, C_8H_{18}, is a typical component of petrol.

(a) The equation for the combustion of octane is shown.



(i) Use mean bond enthalpies to calculate a value for the enthalpy change of combustion of octane.

(4)

Bond	C—C	C—H	O—H	O=O	C=O
Mean bond enthalpy / kJ mol^{-1}	347	413	464	498	805

(ii) The standard enthalpy change of combustion, $\Delta_c H^{\ominus}$, of octane is $-5470\,kJ\,mol^{-1}$.

Give **two** reasons why this value, measured under standard conditions, is different from the value obtained using bond enthalpy data.

(2)

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(iii) When petrol is used to power a car, the energy available is less than the theoretical maximum.
When one kilogram of petrol powers a car, the energy used to move the car is 11 MJ.

Calculate the percentage of the maximum energy that is available to move a car, assuming that this fuel is pure octane.

Use $\Delta_c H^{\ominus} = -5470\,kJ\,mol^{-1}$.

(2)

(iv) Give **two** reasons why the energy used to move the car is less than the theoretical maximum.

(2)

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*(b) Two alternatives to hydrocarbon fuels are hydrogen and ammonia.
Hydrogen burns to form water as the only product but hydrogen is extremely hard to liquefy. Ammonia is easily liquefied but it is toxic.

Compare and contrast the intermolecular forces involved when hydrogen and ammonia liquefy, by describing how these forces are formed.

(6)