1. The table below shows enthalpy changes of formation, $\Delta_f H$.

Compound	$TiCl_4(l)$	$H_2O(l)$	$TiO_2(s)$	$HCl(g)$
$\Delta_f H$ **/ kJ mol^{-1}**	–804	–286	–945	–92

What is the value of the enthalpy change of reaction, $\Delta_r H$, for the reaction in the following equation?

$$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(g)$$

A –63 kJ mol^{-1}

B –53 kJ mol^{-1}

C +53 kJ mol^{-1}

D +63 kJ mol^{-1}

Your answer ☐

[1]

2. Enthalpy values are provided below.

$H_2(g) + I_2(g) \rightarrow 2HI(g)$ $\Delta_r H = -9\,kJ\,mol^{-1}$

Bond	Bond enthalpy / kJ mol^{-1}
H–H	+436
I – I	+151

What is the bond enthalpy, in kJ mol^{-1}, of the H–I bond?

A –596

B –298

C +298

D +596

Your answer ☐ **[1]**

3. A student plans to determine the enthalpy change of **reaction 3.1** shown below.

$$Na_2O(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l)$$ **reaction 3.1**

This enthalpy change can be determined indirectly using Hess' Law from the enthalpy changes of **reaction 3.2** and **reaction 3.3** shown below.

$$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$$ **reaction 3.2**

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) \quad \Delta_r H = -57.6\,kJ\,mol^{-1}$$ **reaction 3.3**

The student will determine the enthalpy change of **reaction 3.2** as outlined below.

- Weigh a bottle containing $Na_2O(s)$ and weigh a polystyrene cup.
- Add about 25 cm^3 of water to the polystyrene cup and measure its temperature.
- Add the $Na_2O(s)$, stir the mixture, and measure the maximum temperature reached.
- Weigh the empty bottle and weigh the polystyrene cup with the final solution.

Mass readings

Mass of bottle + $Na_2O(s)$	= 16.58 g
Mass of empty bottle	= 15.34 g
Mass of empty polystyrene cup	= 21.58 g
Mass of polystyrene cup + final solution	= 47.33 g

Temperature readings

Initial temperature of water	= 20.5 °C
Maximum temperature of final solution	= 55.5 °C

The density and specific heat capacity, *c*, of the solution are the same as for water.

(a)* Calculate the enthalpy change of **reaction 3.2** and the enthalpy change of **reaction 3.1**.

Show all your working.

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..... **[6]**

(b) The uncertainty in each temperature reading is ±0.1 °C.

The uncertainty in each mass reading is ±0.005 g.

Determine whether the mass of Na_2O or the temperature change has the greater percentage uncertainty.

Show all your working.

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..... **[2]**

(c) Suggest a modification to this experiment, using the **same** apparatus, which would reduce the percentage errors in the measurements.

Explain your reasoning.

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..... **[2]**

(d) Sodium oxide, Na_2O, can be prepared by the redox reaction of $NaNO_2$ and sodium metal. Nitrogen gas is also formed.

(i) What is the systematic name for $NaNO_2$?

..... **[1]**

(ii) Using oxidation numbers, with signs, show the element that is oxidised and the element that is reduced in this reaction.

Element oxidised .....

Oxidation number change from ..... to .....

Element reduced .....

Oxidation number change from ..... to .....

[2]

(iii) Construct the equation for this reaction.

Equation ..... **[1]**

4. Which enthalpy change(s) is/are endothermic?

1 The bond enthalpy of the C–H bond

2 The second electron affinity of oxygen

3 The standard enthalpy change of formation of magnesium

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

5. The equation for the combustion of C_7H_8 is shown in the following equation.

$C_7H_8(l) + 9O_2(g) \rightarrow 7CO_2(g) + 4H_2O(l)$

Enthalpy changes of formation are shown in the table.

Substance	$C_7H_8(l)$	$CO_2(g)$	$H_2O(l)$
$\Delta_f H$ / kJ mol^{-1}	+12	−394	−286

Calculate the enthalpy of combustion, in kJ mol^{-1}, for the hydrocarbon C_7H_8.

A −3914

B −692

C +692

D +3914

Your answer ☐ **[1]**

6. This question is about magnesium, bromine and magnesium bromide.

(a) Relative atomic mass is defined as 'the weighted mean mass compared with 1/12th mass of carbon-12'.

Explain what is meant by the term **weighted mean mass**.

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..... **[1]**

(b) **(i)** Draw a 'dot-and-cross' diagram for $MgBr_2$.

Show outer electron shells only.

[2]

(ii) Calculate the total number of **ions** in 1.74 g of magnesium bromide, $MgBr_2$.

Give your answer to **3** significant figures.

number of ions = ... **[3]**

(c)* **Table 16.1** shows some physical properties of magnesium, bromine and magnesium bromide.

Substance	Melting point / °C	Electrical conductivity	
		Solid	Liquid
Magnesium	711	Good	Good
Bromine	−7	Poor	Poor
Magnesium bromide	650	Poor	Good

Table 16.1

Explain the physical properties shown in **Table 16.1** using your knowledge of structure and bonding. **[6]**

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Additional answer space if required

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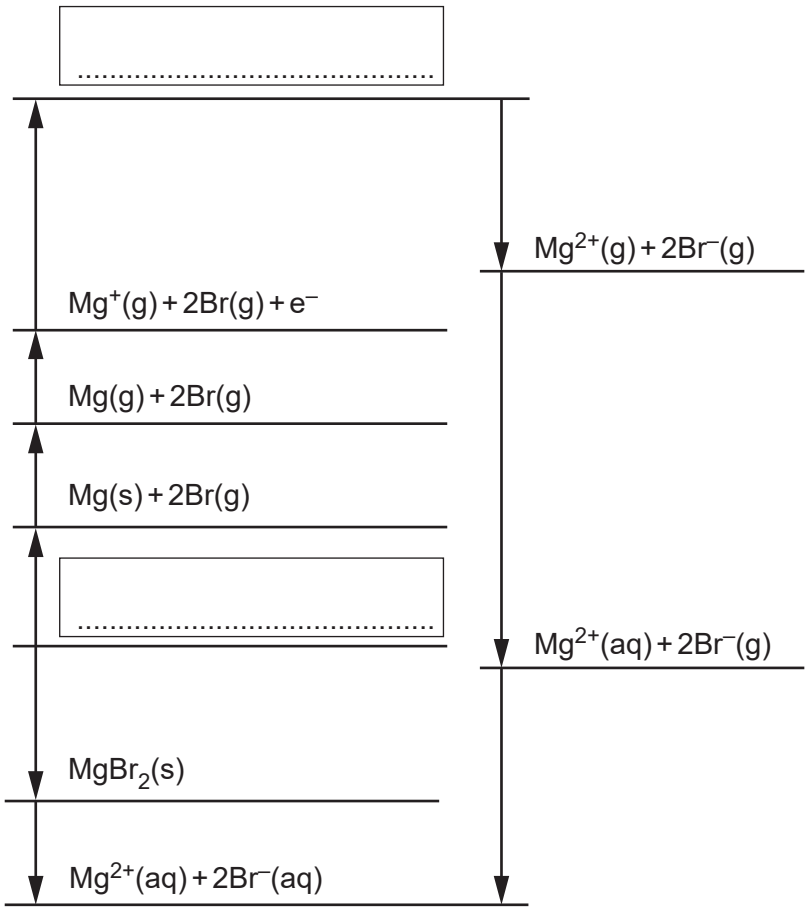
(d) The enthalpy change of hydration of bromide ions can be determined using the enthalpy changes in **Table 16.2**.

Enthalpy change	Energy / kJ mol^{-1}
1st ionisation energy of magnesium	+736
2nd ionisation energy of magnesium	+1450
atomisation of bromine	+112
atomisation of magnesium	+148
electron affinity of bromine	−325
formation of magnesium bromide	−525
hydration of bromide ion	to be calculated
hydration of magnesium ion	−1926
solution of magnesium bromide	−186

Table 16.2

(i) An incomplete energy cycle based on **Table 16.2** is shown below.

On the dotted lines, add the species present, including state symbols.



[2]

(ii) Using your completed energy cycle in **16(d)(i)**, calculate the enthalpy change of hydration of bromide ions.

enthalpy change of hydration = ... kJ mol^{-1} **[2]**

(iii) Write the equation for the lattice enthalpy of magnesium bromide and calculate the lattice enthalpy of magnesium bromide.

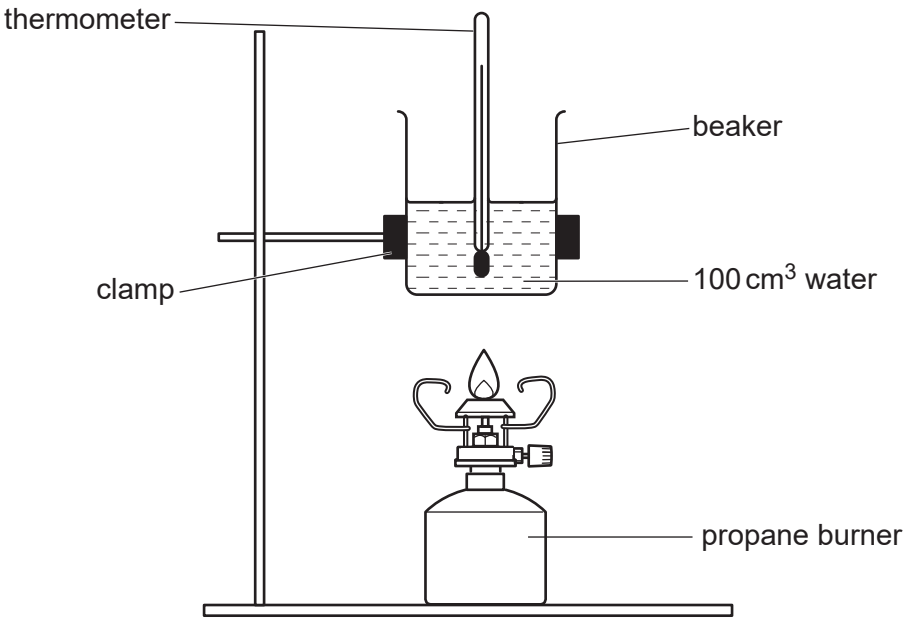
Equation .....

Calculation

lattice enthalpy = ... kJ mol^{-1} **[3]**

7. Propane, C_3H_8, (boiling point −42 °C) is used as 'camping gas'. A student plans to determine the enthalpy change of combustion of propane, $\Delta_c H$ (C_3H_8), by two methods.

(a) The student first carries out an experiment using the apparatus below.



Results

Mass of propane burner before burning / g	99.218
Mass of propane burner after burning / g	98.976
Initial temperature / °C	21.60
Maximum temperature reached / °C	46.10

(i) Determine the enthalpy change of combustion of propane, in kJ mol^{-1}.

Give your answer to **3** significant figures.

$\Delta_c H$ (C_3H_8) = ... kJ mol^{-1} **[3]**

(ii) The student finds that the experimental enthalpy change $\Delta_c H$ (C_3H_8) is much less exothermic than the accurate standard enthalpy change $\Delta_c H$ (C_3H_8) in databases.

One reason could be that the student's experiment had not been carried out under standard conditions.

Suggest **two** other reasons for this difference in enthalpy change.

1 .....

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2 .....

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[1]

(b)* The student determines the standard enthalpy change of combustion of propane using the bond enthalpies in the table. An experiment is not needed.

Bond	Bond enthalpy / kJ mol^{-1}
C−H	+413
C−C	+347
C=O	+805
O=O	+498
O−H	+464

The bond enthalpies can be used to determine the standard enthalpy change of reaction, $\Delta_r H$, for **equation 3.1**:

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$ $\Delta_r H$ **Equation 3.1**

Enthalpy change of vaporisation, $\Delta_{vap}H$

The standard enthalpy change of vaporisation of water, $\Delta_{vap}H$, is the enthalpy change for the conversion of 1 mol of $H_2O(l)$ into 1 mol of $H_2O(g)$ under standard conditions:

$H_2O(l) \rightarrow H_2O(g)$ $\Delta_{vap}H = +40.65\,kJ\,mol^{-1}$

Determine the standard enthalpy change of combustion of propane (boiling point −42 °C) using the $\Delta_r H$ value for **equation 3.1** and $\Delta_{vap} H$ for water. **[6]**

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Additional answer space if required

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