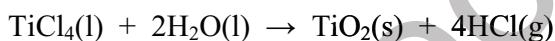


1. The table below shows enthalpy changes of formation, $\Delta_f H$.

Compound	TiCl ₄ (l)	H ₂ O(l)	TiO ₂ (s)	HCl(g)
$\Delta_f H / \text{kJ mol}^{-1}$	-804	-286	-945	-92

Hess cycle

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



A -63 kJ mol^{-1}

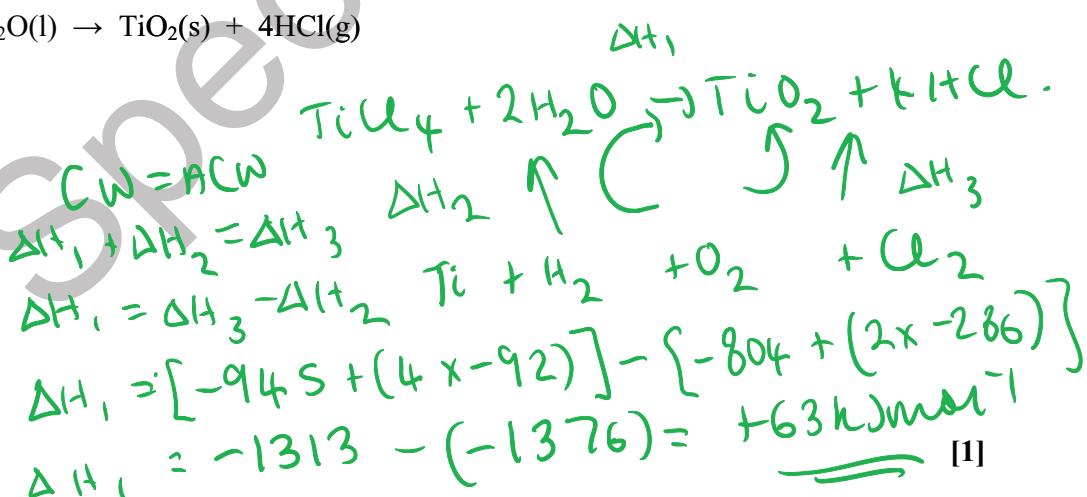
B -53 kJ mol^{-1}

C $+53 \text{ kJ mol}^{-1}$

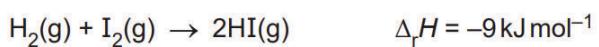
D $+63 \text{ kJ mol}^{-1}$

Your answer

0



2. Enthalpy values are provided below.



Bond	Bond enthalpy /kJ mol ⁻¹
H-H	+436
I-I	+151

$$\begin{aligned} &\text{reactants - products} \\ &= \Delta_r H \end{aligned}$$

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

- A -596
- B -298
- C +298
- D +596

Your answer

$$(436 + 151) = r$$

$$2x = P$$

$$(436 + 151) - 2x = -9$$

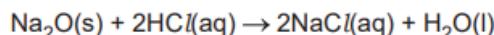
$$587 - 2x = -9$$

$$596 = 2x$$

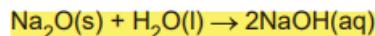
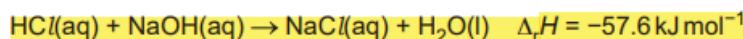
$$298 = x$$

[1]

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

**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.

**reaction 3.2****reaction 3.3**

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

- Weigh a bottle containing $\text{Na}_2\text{O}(s)$ and weigh a polystyrene cup.
- Add about 25 cm^3 of water to the polystyrene cup and measure its temperature.
- Add the $\text{Na}_2\text{O}(s)$, stir the mixture, and measure the maximum temperature reached.
- Weigh the empty bottle and weigh the polystyrene cup with the final solution.

Mass readings

$$\text{Mass of bottle} + \text{Na}_2\text{O}(s) = 16.58 \text{ g}$$

$$\text{Mass of empty bottle} = 15.34 \text{ g}$$

$$\text{Mass of empty polystyrene cup} = 21.58 \text{ g}$$

$$\text{Mass of polystyrene cup} + \text{final solution} = 47.33 \text{ g}$$

Temperature readings

$$\text{Initial temperature of water} = 20.5^\circ\text{C}$$

$$\text{Maximum temperature of final solution} = 55.5^\circ\text{C}$$

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

$$\Delta H_{3.1} = \Delta H_{3.2} + (\Delta H_{3.3}) \times 2$$

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

Show all your working.

$$mc\Delta T = E \text{ (joules)}$$

$$\text{mass of Na}_2\text{O} = 16.58 - 15.34 \\ = 1.24 \text{ g}$$

$$\text{mass of solution} = 47.33 - 21.58 \\ = 25.75 \text{ g}$$

$$\Delta T = 55.5 - 20.5 = 35^\circ\text{C}$$

$$25.75 \times 4.18 \times 35 = 3767.22 \text{ J} \\ = 3.76722 \text{ kJ}$$

$$\text{mol} = \frac{1.24}{(23 \times 2) + 16} = 0.02 \text{ mol}$$

$$3.76722 \text{ kJ} \xrightarrow{\text{AH 3.2}} -188 \text{ kJ mol}^{-1}$$

$$\Delta H 3.1 = -188 + (2 \times -57.6) = -303.2 \text{ kJ mol}^{-1}$$

(b) The uncertainty in each temperature reading is $\pm 0.1^\circ\text{C}$.

The uncertainty in each mass reading is $\pm 0.005\text{g}$.

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

Show all your working.

$$\text{mass: } \frac{0.005 \times 2}{1.24} \times 100 \xrightarrow{\text{mass balance was used twice to find mass of Na}_2\text{O}} = 0.81\%$$

$$\text{temperature: } \frac{0.1 \times 2}{35} \times 100 = 0.57\%$$

So mass of Na_2O has the greater percentage uncertainty [2]

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

*larger denominator
= smaller number*

Explain your reasoning.

*greater mass of Na₂O and a
larger ΔT because both would
reduce % uncertainty*

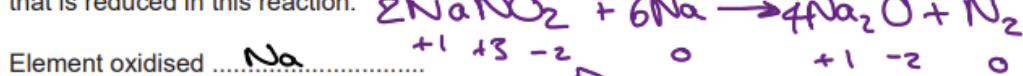
[2]

- (d) Sodium oxide, Na₂O, can be prepared by the redox reaction of NaNO₂ and sodium metal. Nitrogen gas is also formed.

- (i) What is the systematic name for NaNO₂?

Sodium nitrate [1]

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



Element oxidised ... *Na*

Oxidation number change from ... *0* ... to ... *+1* ...

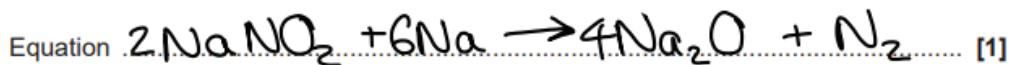
*oxidation
numbers in a
compound must
add up to 0*

Element reduced ... *N*

Oxidation number change from ... *+3* ... to ... *0* ...

[2]

- (iii) Construct the equation for this reaction.



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

- 1 The bond enthalpy of the C-H bond ✓ always + ve
2 The second electron affinity of oxygen ✓ 2nd = + ve
3 The standard enthalpy change of formation of magnesium 1st = - ve
- $O^{-}(g) + e^{-} \rightarrow O^{2-}(g)$

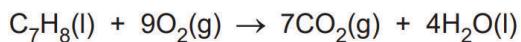
- A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer

B

[1]

5. The equation for the combustion of C₇H₈ is shown in the following equation.



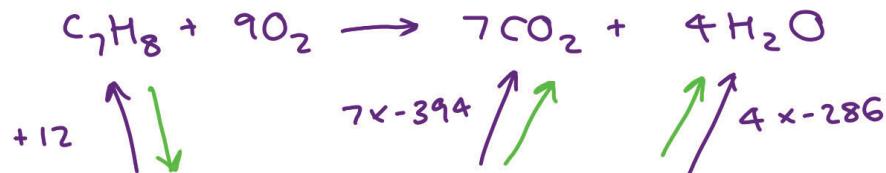
Enthalpy changes of formation are shown in the table.

Substance	C ₇ H ₈ (l)	CO ₂ (g)	H ₂ O(l)
Δ _f H/kJ mol ⁻¹	+12	-394	-286

exothermic = -ve ΔH_r

Calculate the enthalpy of combustion, in kJ mol⁻¹, for the hydrocarbon C₇H₈.

A -3914



B -692

C +692

D +3914

Your answer

$$\begin{aligned}
 & -12 + (7 \times -394) + (4 \times -286) \\
 &= -3914 \text{ kJ mol}^{-1}
 \end{aligned}$$

[1]

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

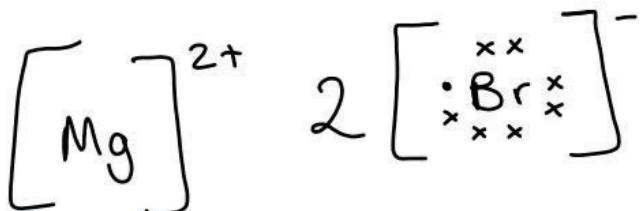
- (a) Relative atomic mass is defined as 'the weighted mean mass compared with 1/12th mass of carbon-12'.

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

The mean taking into account the relative abundancies of the isotopes

[1]

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



$$\frac{1.74}{24.3 + (2 \times 79.9)} = 9.45 \times 10^{-3} \text{ mol}$$

3 ions: Mg^{2+} , Br^- , Br^-

$$9.45 \times 10^{-3} \times 3 = 0.0283 \text{ mol}$$

$$0.0283 \times 6.023 \times 10^{23} = 1.71 \times 10^{22} \text{ ions}$$

Avogadro's constant
number of ions = 1.71×10^{22} [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]

Mg: giant lattice, metallic bonding with delocalised electrons so can conduct

Br: simple molecular, London forces
Induced dipole-dipole interactions between molecules so doesn't conduct

MgBr₂: giant lattice, ionic bonding between oppositely charged ions in solid
ions can't move in solution ions can move and conduct

Metallic and ionic bonds are stronger than London forces so the melting points of Mg and MgBr₂ are greater.

Additional answer space if required

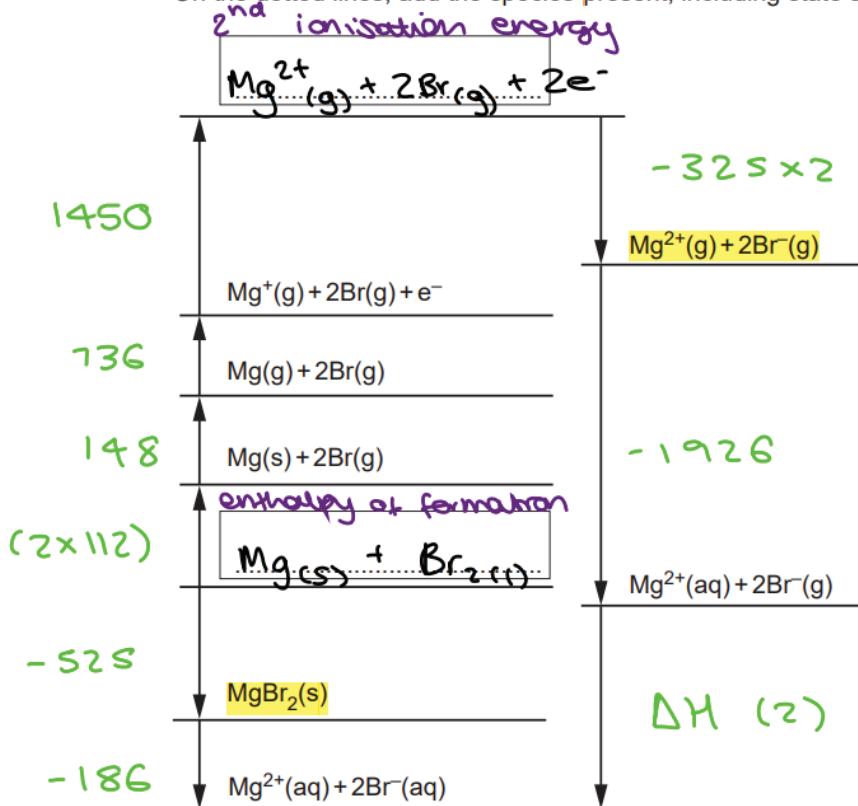
- (d) The enthalpy change of hydration of bromide ions can be determined using the enthalpy changes in **Table 16.2**.

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.



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

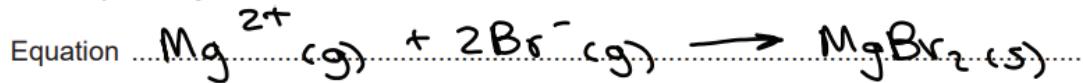
$$1926 + (2 \times 325) - 1450 - 736 - 148$$

$$- (2 \times 112) - 525 - 186 = -693 \text{ kJ mol}^{-1}$$

$$\frac{-693}{2} = -346.5 \text{ kJ mol}^{-1}$$

$$\text{enthalpy change of hydration} = -346.5 \text{ kJ mol}^{-1} [2]$$

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



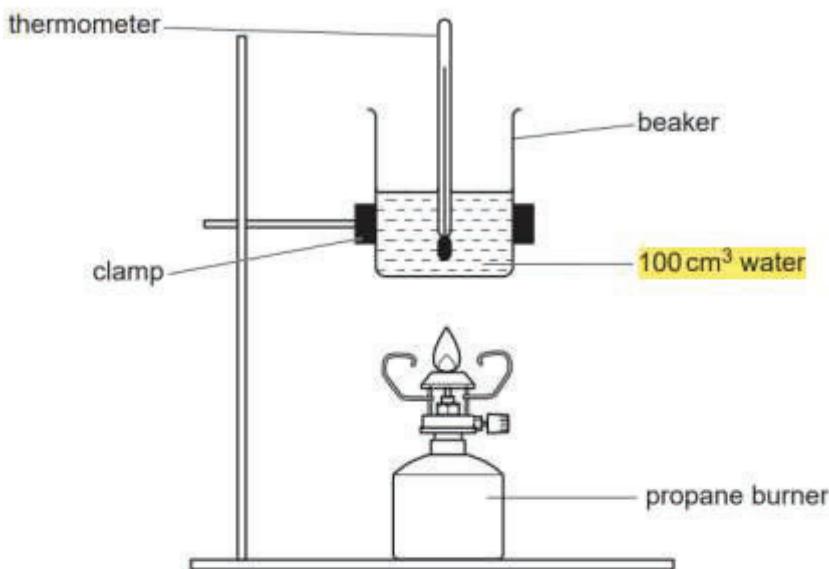
Calculation

$$-1926 + (2 \times -346.5) + 186 = -2433 \text{ kJ mol}^{-1}$$

$$\text{lattice enthalpy} = -2433 \text{ kJ mol}^{-1} [3]$$

7. Propane, C_3H_8 , (boiling point $-42^{\circ}C$) 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/ $^{\circ}C$	21.60
Maximum temperature reached/ $^{\circ}C$	46.10

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

Give your answer to 3 significant figures.

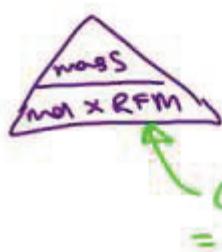
$$q = mc\Delta T$$

$$q = 100 \times 4.18 \times 24.5 = \pm 10241 \text{ J}$$

$$= \pm 10.241 \text{ kJ}$$

$$\begin{aligned} m &= 100 \text{ g} = 100 \text{ cm}^3 \\ c &= 4.18 \text{ J/g } ^{\circ}\text{C} \\ \Delta T &= (46.1 - 21.6) \end{aligned}$$

$$99.218 - 98.976 = 0.242 \text{ g of propane}$$



$$\frac{0.242}{44} = 0.0055 \text{ mol of propane}$$

$$\frac{10.241}{0.0055} = -1862 \text{ kJ mol}^{-1}$$

$\Delta_c H$ is exothermic

$$\Delta_c H (\text{C}_3\text{H}_8) = \frac{-1860}{(3 \text{ SF})} \text{ kJ mol}^{-1} [3]$$

- (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 heat loss/ released to surroundings

2 incomplete combustion/ reaction with Oxygen/air / not everything burns

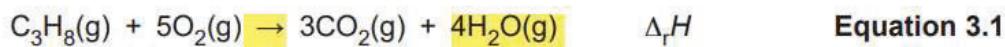
[1]

(3) evaporation of water

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

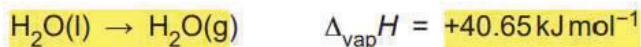
Bond	Bond enthalpy /kJ mol ⁻¹
C-H	+413
C-C	+347
C=O	+805
O=O	+498
O-H	+464

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



treat as minus sign
Enthalpy change of vaporisation, $\Delta_{\text{vap}} H$

The standard enthalpy change of vaporisation of water, $\Delta_{\text{vap}} H$, is the enthalpy change for the conversion of 1 mol of $\text{H}_2\text{O}(\text{l})$ into 1 mol of $\text{H}_2\text{O}(\text{g})$ under standard conditions:

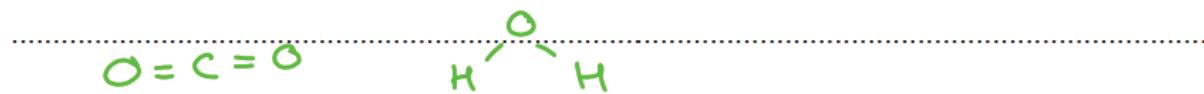


Determine the standard enthalpy change of combustion of propane (boiling point -42°C) using the $\Delta_f H$ value for equation 3.1 and $\Delta_{\text{vap}} H$ for water. [6]

$$(2 \times 347) + (8 \times 413) + (5 \times 498) = \pm 6488 \text{ kJ mol}^{-1}$$



$$(6 \times 805) + (8 \times 464) = \pm 8542 \text{ kJ mol}^{-1}$$



$$6488 - 8542 = -2054 \text{ kJ mol}^{-1} = \Delta_r H$$

$\xrightarrow{4 \text{H}_2\text{O in equation 3.1}}$

$$\Delta_r H - (4 \times \Delta_{\text{vap}} H)$$

$$-2054 - (4 \times 40.65) = -2216.6 \text{ kJ mol}^{-1}$$

Additional answer space if required