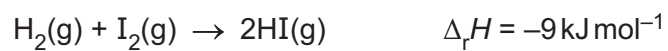


- 1 Enthalpy values are provided below.



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

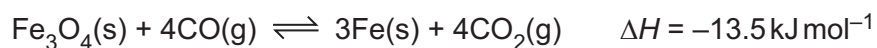
What is the bond enthalpy, in kJ mol^{-1} , of the H–I bond?

- A –596
B –298
C +298
D +596

Your answer

[1]

2(a) Another equilibrium involved in the extraction of iron from Fe_3O_4 is shown below.



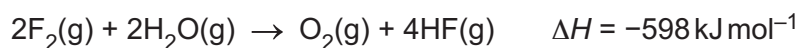
Enthalpy changes of formation, $\Delta_f H$, for $\text{Fe}_3\text{O}_4(\text{s})$ and $\text{CO}_2(\text{g})$ are shown in the table.

Compound	$\Delta_f H / \text{kJ mol}^{-1}$
$\text{Fe}_3\text{O}_4(\text{s})$	-1118.5
$\text{CO}_2(\text{g})$	-393.5

Calculate the enthalpy change of formation, $\Delta_f H$, for $\text{CO}(\text{g})$.

$\Delta_f H$, for $\text{CO}(\text{g})$ = ... kJ mol^{-1} [3]

3(a) Fluorine reacts with steam as shown in the equation below.



Average bond enthalpies are shown in the table.

Bond	Average bond enthalpy / kJ mol^{-1}
O–H	+464
O=O	+498
H–F	+568

(i) Explain what is meant by the term *average bond enthalpy*.

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

(ii) Calculate the bond enthalpy of the F–F bond.

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

- 4 Sulfuric acid is an important chemical used to make detergents, fertilisers and dyes. It is manufactured in a multi-step process.
- (a) In the first step of the manufacture of sulfuric acid, sulfur dioxide, SO_2 , can be made from the combustion of hydrogen sulfide, H_2S , shown in **Reaction 1**.



- (i) Explain why the enthalpy change for **Reaction 1** has a negative value.

Use ideas about enthalpy changes associated with bond breaking and bond making.

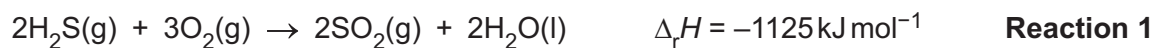
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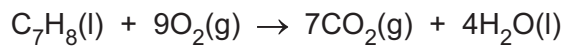
- (ii) Calculate the standard enthalpy change of formation, $\Delta_f H^\ominus$, of hydrogen sulfide using the enthalpy change for **Reaction 1**, and the standard enthalpy changes of combustion below.

Substance	$\Delta_c H^\ominus / \text{kJ mol}^{-1}$
S(s)	-296.8
H ₂ (g)	-285.8



$\Delta_f H^\ominus$ of hydrogen sulfide = ... kJ mol^{-1} [3]

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



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

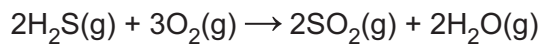
Your answer

[1]

- 6 Bond enthalpies are given in the table.

Bond	H-S	O=O	S=O	O-H
Bond enthalpy /kJ mol ⁻¹	+346	+498	+531	+464

What is the enthalpy change, in kJ mol⁻¹, for the reaction below?

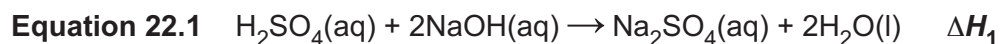


- A -174
B -1102
C -1794
D -2098

Your answer

[1]

7(a) Sulfuric acid reacts with sodium hydroxide as shown in **Equation 22.1**.



This is a neutralisation reaction.

A student carries out an experiment to determine the enthalpy change ΔH_1 and uses this value to deduce the enthalpy change of neutralisation, $\Delta_{\text{neut}}H$.

The student measures out two solutions:

- 25.0 cm³ of 1.60 mol dm⁻³ H₂SO₄(aq)
- 55.0 cm³ of 1.50 mol dm⁻³ NaOH(aq) (an excess).

The temperature of each solution is the same.

The student mixes the two solutions. The temperature increases by 13.0 °C.

(i) Show that NaOH is in excess.

[2]

- (ii) Calculate the enthalpy change, ΔH_1 , for **Equation 22.1**, and deduce the value for the enthalpy change of neutralisation, $\Delta_{\text{neut}}H$, in kJ mol^{-1} .

Assume that the densities of all solutions and the specific heat capacity, c , of the reaction mixture are the same as for water.

enthalpy change, $\Delta H_1 = \dots\dots\dots \text{kJ mol}^{-1}$

enthalpy change of neutralisation, $\Delta_{\text{neut}}H = \dots\dots\dots \text{kJ mol}^{-1}$ **[4]**

- (iii) The student repeats the experiment using 50.0 cm^3 of $1.60 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4$ and 110.0 cm^3 of $1.50 \text{ mol dm}^{-3} \text{ NaOH}$.

Predict the increase in temperature.

Explain your reasoning.

.....

.....

.....

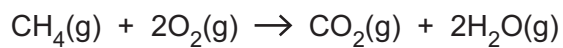
.....

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

- 8 Bond enthalpies are shown in the table.

Bond	C–C	C–H	O–H	C–O	C=O	O–O	O=O
Bond enthalpy / kJ mol ⁻¹	347	435	464	358	805	144	498

What is the enthalpy change, in kJ mol⁻¹, for the reaction below?



- A -730
B -544
C +544
D +730

Your answer

[1]

9 This question is about energy changes.

(a) Magnesium reacts with aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$ as shown below.



A student adds an excess of magnesium to 100.0 cm^3 of $0.400 \text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$.
The initial temperature is 20.0°C .

(i) Determine the maximum temperature reached in this reaction.
Give your answer to **3** significant figures.

Assume that the specific heat capacity and density of the solution are the same as for water, and that there are no heat losses.

maximum temperature reached = ... $^\circ\text{C}$ [4]

- (ii) The student wants to repeat the experiment, but there is not enough $\text{AgNO}_3(\text{aq})$ left to use another 100.0 cm^3 portion.

The student decides to modify the method by adding an excess of magnesium to 50.0 cm^3 of $0.400\text{ mol dm}^{-3}\text{AgNO}_3(\text{aq})$.

Predict, with reasons, how this modification would affect the maximum temperature reached. Assume that there are no heat losses.

.....

.....

.....

..... [1]

- (b) Nitric acid is manufactured from ammonia in a multi-stage process.
The equation for the first stage in this process is shown in **Reaction 17.1**.



Some standard enthalpy changes of formation are shown in the table.

Compound	$\Delta_f H^\ominus / \text{kJ mol}^{-1}$
$\text{NH}_3(\text{g})$	-46
$\text{H}_2\text{O}(\text{l})$	-286

- (i) Explain the term **enthalpy change of formation**.

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

- (ii) Calculate the standard enthalpy change of formation, $\Delta_f H^\ominus$, of $\text{NO}(\text{g})$.

$\Delta_f H^\ominus$ of $\text{NO}(\text{g}) = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

10 This question is about enthalpy changes of reactions involving hydrocarbons.

(a) A student determines the enthalpy change of combustion, $\Delta_c H$, of heptane, C_7H_{16} , using the method outlined below.

- Add 150 g of water to a beaker and measure its temperature.
- Weigh a spirit burner containing heptane and use it to heat the water.
- Extinguish the flame and record the maximum temperature reached by the water.
- Reweigh the spirit burner.

The temperature of the water increased by 10.5°C .

The spirit burner decreased in mass by 0.133 g.

Use the student's results to determine the enthalpy change of combustion of heptane, $\Delta_c H (C_7H_{16})$, in kJ mol^{-1} .

$\Delta_c H (C_7H_{16}) = \dots\dots\dots \text{kJ mol}^{-1}$ **[3]**

- (b) Nonane, C_9H_{20} , can be broken down by heat to form pentane, C_5H_{12} , and ethene, C_2H_4 .



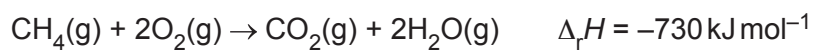
The enthalpy changes of combustion of $\text{C}_9\text{H}_{20}(\text{g})$ and $\text{C}_2\text{H}_4(\text{g})$ are shown in the table below.

Hydrocarbon	$\Delta_c H / \text{kJ mol}^{-1}$
$\text{C}_9\text{H}_{20}(\text{g})$	-6171
$\text{C}_2\text{H}_4(\text{g})$	-1411

Use ΔH in **Reaction 1** and the enthalpy changes of combustion in the table to determine the enthalpy change of combustion of $\text{C}_5\text{H}_{12}(\text{g})$.

$$\Delta_c H (\text{C}_5\text{H}_{12}(\text{g})) = \dots\dots\dots \text{kJ mol}^{-1} \quad [2]$$

- 11 Methane reacts with oxygen as shown in the equation:



The table shows some bond enthalpies.

Bond	O–H	O=O	C=O
Bond enthalpy / kJ mol ⁻¹	+464	+498	+805

What is the bond enthalpy, in kJ mol⁻¹, of the C–H bond in methane?

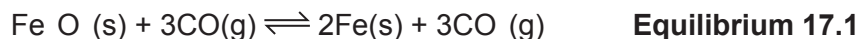
- A +109
B +367
C +435
D +568

Your answer

[1]

12 This question is about carbon monoxide and carbon as reducing agents in industry.

(a) Iron(III) oxide, Fe_2O_3 , can be reduced by carbon monoxide to form iron.



Some standard enthalpy change of formation values are shown in the table.

Substance	$\text{Fe}_2\text{O}_3(\text{s})$	$\text{CO}(\text{g})$	$\text{Fe}(\text{s})$	$\text{CO}_2(\text{g})$
$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	−824	−111	0	−394

(i) Explain why the standard enthalpy change of formation of Fe has a value of 0 kJ mol^{-1} .

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

(ii) Calculate the enthalpy change, $\Delta_r H$, for the forward reaction in **Equilibrium 17.1**.

$\Delta H = \dots\dots\dots \text{ kJ mol}^{-1}$ [2]