Past-paper walk-through

Hess's law ▪ 5.2

eXercise

Questions in this set

- 9701/14 N25 Q9 ▪ 1 mark
- 9701/22 N25 Q3 ▪ 14 marks
- 9701/34 N25 Q1 ▪ 11 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 9

9701/14 N25 ▪ Q9 ▪ 1 mark

9 The data shown are needed for this question.

$\Delta H_f^{\ominus}(P_4O_{10}(s)) = -3012\,kJ\,mol^{-1}$

$\Delta H_f^{\ominus}(H_2O(l)) = -286\,kJ\,mol^{-1}$

$\Delta H_f^{\ominus}(H_3PO_4(s)) = -1279\,kJ\,mol^{-1}$

What is $\Delta H^{\ominus}$ for the reaction shown?

$$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(s)$$

Question 9

A $-9844\ \text{kJ mol}^{-1}$

B $-388\ \text{kJ mol}^{-1}$

C $-97\ \text{kJ mol}^{-1}$

D $+2019\ \text{kJ mol}^{-1}$

Solution 9

Answer: **B**

Why

- $\Delta H = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$.
- Products: $4(-1279) = -5116$. Reactants: $-3012 + 6(-286) = -4728$.
- $\Delta H = -5116 + 4728 = -388$ kJ mol^{-1}.

Question 3

9701/22 N25 ▪ Q3 ▪ 14 marks

3 The alkanes are a homologous series of organic molecules. Alkanes are generally unreactive and are commonly used as fuels.

(a) Define homologous series.

Question 3

(b) Give two reasons to explain the general unreactivity of alkanes.

Question 3

Question 3

[2]

(c) Alkanes with low relative molecular mass, M_r, are more useful than those found in heavier crude oil fractions.

Name the process that is used to obtain alkanes with low M_r from heavier crude oil fractions.

Question 3

(d) Hexane, C_6H_{14}, has four structural isomers.

Fig. 3.1 shows hexane and two of its structural isomers.

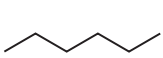
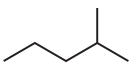
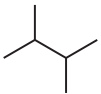
hexane	A	B	C	D
				

Fig. 3.1

(i) Complete Fig. 3.1 by drawing structures for **C** and **D**, the other two structural isomers of hexane. [2]

(ii) **A**, **B** and hexane have different boiling points.

Question 3

Question 3

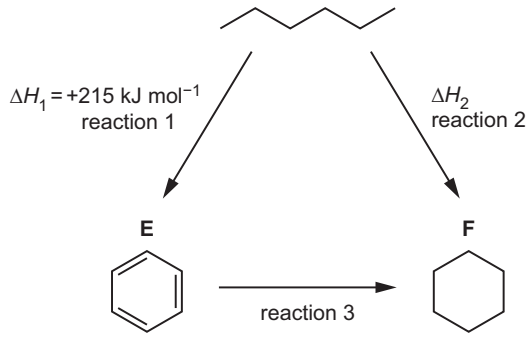
Arrange **A**, **B** and hexane in order of increasing boiling point.

Explain your answer.

Question 3

[3]

(e) Hexane can be converted into compounds **E** and **F** at high temperature and pressure. Fig. 3.2 shows the reaction scheme involving hexane, **E** and **F**.



Question 3

Fig. 3.2

Question 3

(i) Identify a suitable reagent for reaction 3.

Question 3

(ii) Use the data in Fig. 3.2 and in Table 3.1 to calculate the enthalpy change of reaction 2, ΔH_2.

Table 3.1

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
	−156
	+48

Question 3

Question 3

Question 3

(iii) Write an equation for the complete combustion of hexane.

Question 3

[Total: 14]

Solution 3

(a)

Mark scheme

- M1 (family of molecules / compounds / series with) same general formula
- OR (family of molecules where) molecular formula differs (only) by (units of) CH2(n). **M2**
- similar chemical properties / reactions
- 2

Solution 3

(b)

Mark scheme

- M1 strong C—H (bonds) M2
- non-polar (C—H / molecule / bonds)
- 2

Solution 3

(c)

Mark scheme

- cracking
- 1

Solution 3

(d)(i)

Mark scheme

- 2

(d)(ii)

Mark scheme

- M1 B $<$ A $<$ hexane. **M2**
- hexane / unbranched has stronger / more IMFs **M3**
- hexane / unbranched requires most / more energy
- 3

Solution 3

(e)(i)

Mark scheme

- H2 ((g)) OR hydrogen (gas)
- 1

Solution 3

(e)(ii)

Mark scheme

- M1 $+215 + (-156) - (+48) =$ M2
- $+11$ kJ mol–1
- 2

Solution 3

(e)(iii)

Mark scheme

- C6H14 + 9½O2 → 6CO2 + 7H2O
- 1

Question 1

9701/34 N25 ▪ Q1 ▪ 11 marks

1 Sodium carbonate can be manufactured using a two-step process. The first step involves making sodium hydrogencarbonate, $NaHCO_3$, which is then converted into sodium carbonate, Na_2CO_3, in the second step of the process by the following reaction.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

In this experiment you will determine the enthalpy change, ΔH_r, for this reaction. You will do this by calculating the enthalpy changes when separate samples of sodium hydrogencarbonate and sodium carbonate are added to excess hydrochloric acid, $HCl(aq)$. You will then combine these values using Hess's law.

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g) \qquad \Delta H_1$$

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g) \qquad \Delta H_2$$

FB 1 is 2.0 mol dm^{-3} hydrochloric acid, HCl.
FB 2 is sodium hydrogencarbonate, $NaHCO_3$.
FB 3 is sodium carbonate, Na_2CO_3.

Question 1

(a) Method

Experiment 1

- Support a cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 20.0 cm^3 of **FB 1** into the cup.
- Weigh the container with **FB 2**. Record the mass.
- Measure the temperature of the acid in the cup. Record this temperature.
- Carefully add all of the **FB 2**, in small portions to avoid acid spray. Stir to dissolve. Record the lowest temperature.
- Reweigh the container with any residual **FB 2**. Record the mass.
- Calculate and record the mass of **FB 2** used.
- Calculate and record the decrease in temperature.

Experiment 2

- Support the second cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 20.0 cm^3 of **FB 1** into the second cup.
- Weigh the container with **FB 3**. Record the mass.
- Measure the temperature of the acid in the cup. Record this temperature.
- Carefully add all of the **FB 3**, in small portions to avoid acid spray. Stir to dissolve. Record

Question 1

Carefully add all of the **FB 2**, in small portions to avoid acid spray. Stir to dissolve. Record the highest temperature.

- Reweigh the container with any residual **FB 3**. Record the mass.
- Calculate and record the mass of **FB 3** used.
- Calculate and record the increase in temperature.

Keep FB 1 for use in Question 3.

Results

Question 1

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the amount, in mol, of **FB 2** that reacts with **FB 1** and the amount, in mol, of **FB 3** that reacts with **FB 1**.

Experiment 1	Experiment 2

Question 1

amount of **FB 2** = ... mol	amount of **FB 3** = ... mol

[2]

(ii) Calculate the energy changes, in J, for each reaction.

Experiment 1	**Experiment 2**

Question 1

energy change = ... J	energy change = ... J

[1]

(iii) Calculate the enthalpy change, ΔH, in $kJ\,mol^{-1}$ for each reaction.

Experiment 1	**Experiment 2**

Question 1

ΔH_1 = ... kJ mol^{-1} *sign* *value*	ΔH_2 = ... kJ mol^{-1} *sign* *value*

[2]

(iv) Construct an enthalpy cycle and use Hess's law to determine the enthalpy change, ΔH_r, for the reaction shown.
Show your working.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

(If you were unable to calculate values in **(b)(iii)** then assume that ΔH_1 is +27.3 kJ mol^{-1} and that ΔH_2 is –24.9 kJ mol^{-1}. These may **not** be the correct values.)

Question 1

Question 1

Question 1

sign *value*

[2]

[Total: 11]

Solution 1

(a) Mark scheme

- I
- Unambiguous headings AND units for all six recorded readings and calculated values in experiment 1:
- ▪
- (mass of) container + FB 2 / solid / g
- ▪
- (mass of) container (+ residue) / g
- ▪

Solution 1

- (mass of) FB 2 / solid (used / added) / g
- ▪
- initial temperature OR temperature of FB 1 / oC
- ▪
- final temperature / oC
- ▪
- temperature change / oC
- 1
- II
- ▪

Solution 1

- All four weighings recorded to same decimal places (either 2 or 3).
- ▪
- All four temperatures recorded to .0 or .5°C
- 1
- III Correct subtractions to give all four calculated values:
- ▪
- mass of FB 2 used and mass of FB 3 used
- ▪
- changes in temperature for experiments 1 and 2.
- 1

Solution 1

- Accuracy (Q) marks
- Calculate the candidate's temperature to mass ratio for experiment 1 to 2 d.p.: Ratio = T (experiment 1) / mass of FB2.
- Calculate the supervisor's ratio for experiment 1 to 2 d.p.
- Calculate the difference, , between the candidate's value (rounded to 2 d.p.) and the supervisor's value (rounded to 2 d.p.).
- IV award if 0.50
- 1

Solution 1

(b)(i) Mark scheme

- M1: Correctly calculates both Mr values:
- Mr of $NaHCO_3$ = 84 AND Mr of Na_2CO_3 = 106
- 1
- M2: Correctly calculates both amounts using subtractions from (a)
- n = mass in (a) / Mr (mol)
- AND both answers given to 2–4 sf
- 1

Solution 1

(b)(ii)

Mark scheme

- Correctly calculates both values of energy change
- energy change $= 20 \times 4.18 \times \Delta T$ (J)
- AND both answers given to 2–4 sf
- 1

Solution 1

(b)(iii) Mark scheme

- M1: Correct display of ΔH = (b)(ii) / (b)(i) for experiment 1 or experiment 2.
- 1
- 9701/34
- October/November 2025
- Question Answer
- M2: Correctly uses ΔH = (b)(ii) / ((b)(i) $\times$ 1000)
- AND + sign for $\Delta H1$ AND – sign for $\Delta H2$
- AND both answers given to 2–4 sf

Solution 1

- 1

Solution 1

(b)(iv) Mark scheme

- M1: Drawing of enthalpy cycle
- 1
- M2: Correctly calculates $\Delta Hr = 2\Delta H1 - \Delta H2$
- 1
- 9701/34
- October/November 2025
- Question Answer