

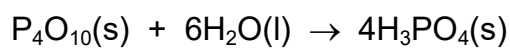
9 The data shown are needed for this question.

$$\Delta H_f^\ominus(\text{P}_4\text{O}_{10}(\text{s})) = -3012 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\ominus(\text{H}_2\text{O}(\text{l})) = -286 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\ominus(\text{H}_3\text{PO}_4(\text{s})) = -1279 \text{ kJ mol}^{-1}$$

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



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

B -388 kJ mol^{-1}

C -97 kJ mol^{-1}

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

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

(a) Define homologous series.

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

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

1
2 [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.

..... [1]

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

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

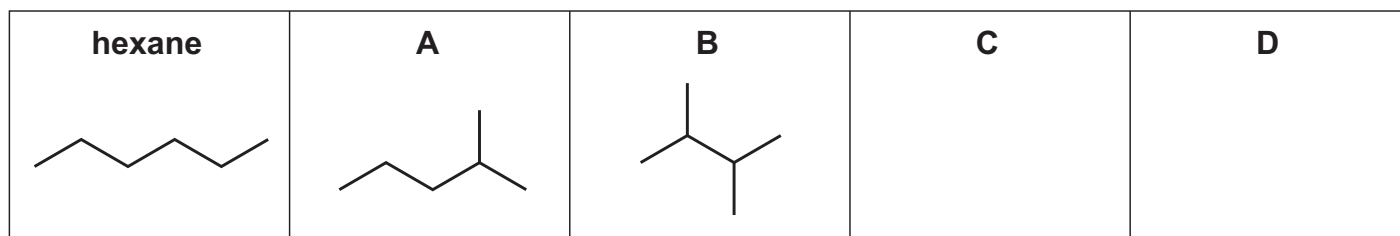


Fig. 3.1

(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.

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

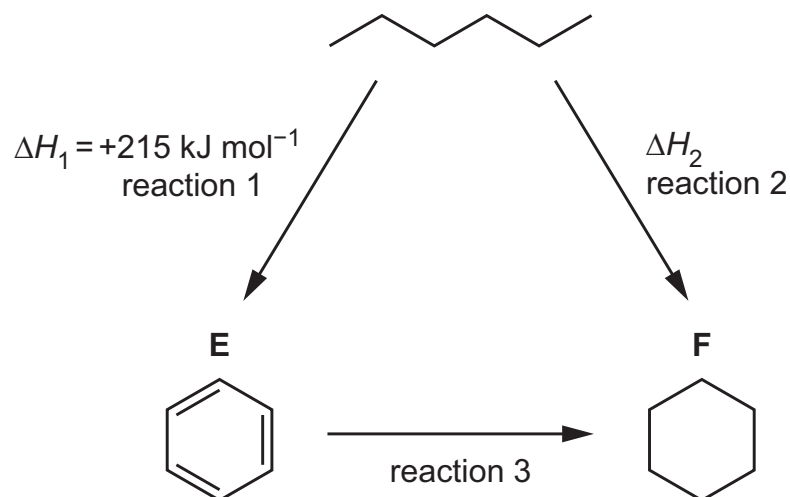
Explain your answer.

lowest < < highest

.....
.....
.....

[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**.

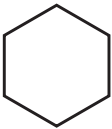
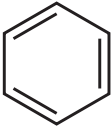


- (i) Identify a suitable reagent for reaction 3.

..... [1]

- (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

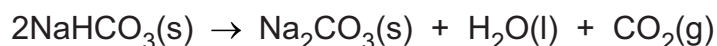
compound	enthalpy change of formation, $\Delta H_f^\circ / \text{kJ mol}^{-1}$
	-156
	+48

$\Delta H_2 = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

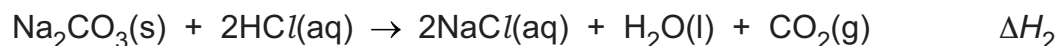
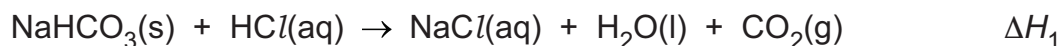
- (iii) Write an equation for the complete combustion of hexane.

..... [1]

- 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.



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, $\text{HCl}(\text{aq})$. You will then combine these values using Hess's law.



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 .

(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 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

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
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
energy change = J	energy change = J

[1]

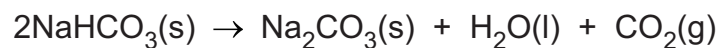
- (iii) Calculate the enthalpy change, ΔH , in kJ mol^{-1} for each reaction.

Experiment 1	Experiment 2
$\Delta H_1 = \dots\dots\dots \text{kJ mol}^{-1}$ <i>sign</i> <i>value</i>	$\Delta H_2 = \dots\dots\dots \text{kJ mol}^{-1}$ <i>sign</i> <i>value</i>

⑤

[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.



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

$$\Delta H_r = \begin{array}{cc} \text{.....} & \text{.....} \\ \text{sign} & \text{value} \end{array} \text{ kJ mol}^{-1}$$

[2]

[Total: 11]