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, HC*l*(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, HC*l*.
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**
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.)

ΔH_r = ... kJ mol^{-1}
sign *value*

[2]

[Total: 11]