7 When 1.0 mol of ethanoic acid, CH_3COOH, in aqueous solution is neutralised by an excess of aqueous sodium hydroxide, 55 kJ mol^{-1} of energy is released.

Which statement about this reaction is correct?

A The reaction is exothermic because only bond breaking takes place.

B The reaction is exothermic because only bond forming takes place.

C The reaction is exothermic because more energy is given out in breaking bonds than is taken in to form bonds.

D The reaction is exothermic because more energy is given out in forming bonds than is taken in to break bonds.

8 In an experiment, 1.60 g of a fuel is burnt. 45.0% of the energy released is absorbed by 200 g of water. The temperature of the water rises from 18.0 °C to 66.0 °C.

What is the total energy released per gram of fuel burnt?

A 25 100 J **B** 55 700 J **C** 89 200 J **D** 143 000 J

9 When 0.47 g of a hydrocarbon is completely burnt in air, the energy released heats 200 g of water from 23.7 °C to 41.0 °C.

What is the amount of energy absorbed, in Joules, by the water?

A $0.47 \times 4.18 \times 17.3$

B $0.47 \times 4.18 \times (273 + 17.3)$

C $200 \times 4.18 \times 17.3$

D $200 \times 4.18 \times (273 + 17.3)$

10 One commercially available ‘heat pad’ contains iron, activated carbon and water. The ‘heat pad’ is activated by air. This causes the pad to get hotter.

Which statement describes the chemical reaction occurring in the ‘heat pad’ when it is exposed to air?

A The reaction is endothermic and iron gains electrons.

B The reaction is endothermic and iron loses electrons.

C The reaction is exothermic and iron gains electrons.

D The reaction is exothermic and iron loses electrons.

10 In an experiment to measure the enthalpy change of neutralisation of hydrochloric acid, $20\,cm^3$ of solution containing 0.04 mol of HCl is placed in a plastic cup of negligible heat capacity.

A $20\,cm^3$ sample of aqueous sodium hydroxide containing 0.04 mol of NaOH, at the same initial temperature, is added and the temperature rises by 15 K.

If the heat capacity per unit volume of the final solution is $4.2\,J\,K^{-1}\,cm^{-3}$, what is the enthalpy change of neutralisation of hydrochloric acid?

A $\dfrac{20 \times 4.2 \times 15}{0.04}\,J\,mol^{-1}$

B $40 \times 4.2 \times 15 \times 0.08\,J\,mol^{-1}$

C $\dfrac{40 \times 4.2 \times 15}{0.04}\,J\,mol^{-1}$

D $\dfrac{20 \times 4.2 \times 15}{0.08}\,J\,mol^{-1}$

2 When hydrated sodium thiosulfate is dissolved in water the temperature of the liquid changes. You will carry out an experiment to determine the enthalpy change, ΔH, when one mole of hydrated sodium thiosulfate dissolves in water.

FA 3 is hydrated sodium thiosulfate, $Na_2S_2O_3•5H_2O$.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 30.0 cm^3 of distilled water into the cup.
- Measure the temperature of the water in the cup. Record this in the space for results.
- Weigh the container with **FA 3**. Record the mass.
- Tip all the **FA 3** into the cup.
- Stir the mixture until the minimum temperature is obtained. Record this temperature.
- Weigh the container with any residual **FA 3**. Record the mass.
- Calculate and record the mass of **FA 3** added.
- Calculate and record the temperature change.

Results

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the amount, in mol, of hydrated sodium thiosulfate added.

amount of $Na_2S_2O_3•5H_2O$ = ... mol [1]

(ii) Calculate the energy change, in J, in your experiment.

energy change = ... J [1]

(iii) Calculate the enthalpy change, ΔH, in $kJ\,mol^{-1}$, when 1.00 mol of hydrated sodium thiosulfate dissolves in water. Show your working.

ΔH = ... $kJ\,mol^{-1}$
sign *value* [1]

(c) The value calculated in **(b)(iii)** can be used to determine the enthalpy change, ΔH_r, for the following reaction.

$$Na_2S_2O_3(s) + 5H_2O(l) \rightarrow Na_2S_2O_3{\bullet}5H_2O(s)$$

Outline the method of one further experiment you would need to carry out to obtain the data necessary to calculate the value of ΔH_r.
Show how you would use your results from this experiment and **(b)(iii)** to calculate ΔH_r.

Do **not** carry out your experiment.

method ....

....

....

calculation ....

....
[4]

[Total: 11]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:
- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write ‘no change’.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used. If a solid is heated, a hard-glass test-tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

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.

(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]