Core practical 8: Calculate the enthalpy change for the thermal decomposition of potassium hydrogencarbonate

Objective

- To calculate the molar enthalpy change for two reactions and use Hess's law to determine the enthalpy change for the reactions

Safety

- Wear goggles.
- 2 mol dm^{-3} hydrochloric acid is an irritant.
- Potassium carbonate is an irritant.

Specification links

- Practical techniques 1, 4, 11
- CPAC 1a, 2a, 2b, 2c, 2d, 3a, 3b, 4a, 4b

Procedure

1. Place approximately 3 g of solid potassium carbonate into a test tube. Accurately weigh the test tube and its contents.
2. Use a burette to dispense 30 cm^3 of 2 mol dm^{-3} hydrochloric acid into a polystyrene cup, which is supported in a beaker.
3. Measure the temperature of the acid.
4. Continue measuring the temperature whilst adding potassium carbonate to the acid and stirring. Record the highest temperature reached.
5. Reweigh the empty test tube.
6. Repeat steps 1 to 5 using approximately 3.5 g of potassium hydrogencarbonate instead of potassium carbonate. This time record the lowest temperature reached.

Notes on procedure

- Students may puncture the polystyrene cup with the thermometers.
- If the potassium carbonate is hydrated, the temperature increase will be smaller than expected.

Answers to questions

1. Heat energy must be supplied; hence, the temperature change measured is not solely due to the decomposition.
2. moles hydrochloric acid = $2 \times \frac{30}{1000} = 0.06$ mol

   mol K_2CO_3 = $\frac{3}{138.2} = 0.022$ mol

   this reacts with 0.0434 moles of hydrochloric acid

   mol $KHCO_3$ = $\frac{3.5}{100.1} = 0.035$ mol

   this reacts with 0.035 moles of hydrochloric acid
3. Reaction 1 – diagram shows exothermic reaction

   Reaction 2 – diagram shows endothermic reaction

   Reaction 3 – diagram shows endothermic reaction
4. Polystyrene is a better insulator than glass. Therefore, less heat energy is lost to/gained from the surroundings, so temperature changes are more accurate.

Sample data

Mass of test tube with potassium carbonate/g	25.12
Mass of test tube after emptying out potassium carbonate/g	23.04
Mass of potassium carbonate used/g	2.08
Start temperature/°C	23.2
Highest temperature/°C	28.4
Temperature change/°C	5.2

Mass of test tube with potassium hydrogencarbonate/g	25.67
Mass of test tube after emptying out potassium hydrogencarbonate/g	22.34
Mass of potassium hydrogencarbonate used/g	3.33
Start temperature/°C	23.1
Lowest temperature/°C	19.2
Temperature change/°C	–3.9

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All the maths you need

- Understand and use the symbols: =, <, <<, >>, >, ∝, ~ and
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.
- Solve algebraic equations.

Equipment

- 2 test tubes
- 2 mol dm^{-3} dilute hydrochloric acid
- solid potassium carbonate
- solid potassium hydrogencarbonate
- thermometer able to read up to 50 °C or more
- polystyrene cup
- 250 cm^3 or 400 cm^3 beaker
- burette, clamp and stand
- stirring rod
- mass balance (2 d.p.)
- spatula

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Analysis of results

1. Tabulate your results:

Mass of test tube with potassium carbonate/g	
Mass of test tube after emptying out potassium carbonate/g	
Mass of potassium carbonate used/g	
Start temperature/°C	
Highest temperature/°C	
Temperature change/°C	

Mass of test tube with potassium hydrogencarbonate/g	
Mass of test tube after emptying out potassium hydrogencarbonate/g	
Mass of potassium hydrogencarbonate used/g	
Start temperature/°C	
Lowest temperature/°C	
Temperature change/°C	

The equations for the reactions occurring are:

reaction 1: $K_2CO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + CO_2(g) + H_2O(l)$

reaction 2: $KHCO_3(s) + HCl(aq) \rightarrow KCl(aq) + CO_2(g) + H_2O(l)$

2. Calculate the energy change for each reaction in J.
   The specific heat capacity of water is 4.2 J g^{-1} $°C^{-1}$.
3. Calculate the enthalpy change, ΔH, for each reaction in kJ mol^{-1}.
   Assume that the hydrochloric acid is in excess.
4. Use your results to calculate the enthalpy change for the thermal decomposition of potassium hydrogen carbonate:
   reaction 3: $2KHCO_3(s) \rightarrow K_2CO_3(s) + CO_2(g) + H_2O(l)$

Learning tips

- The heat capacity of the final solution can be assumed to be the same as the heat capacity of water. The volume of water made in the reaction is so small it can be ignored.
- For exothermic reactions the enthalpy change, ΔH, is negative.
- Beware of the incorrect use of the equals sign. It is very easy to end up stating that a negative number equals a positive number.

Questions

1. Why is it not possible to measure the enthalpy change for the decomposition of potassium hydrogencarbonate directly?
2. Show that the hydrochloric acid is in excess in both reactions.
3. Draw energy level diagrams for reactions 1, 2 and 3.
4. Explain why the reactions are conducted in a polystyrene cup rather than a glass beaker.

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Equipment per student/group	Notes on equipment
2 test tubes	
2 mol dm^{-3} dilute hydrochloric acid	At least 60 cm^3 per student
solid potassium carbonate	3 g per student. This should be anhydrous and dried before use.
solid potassium hydrogencarbonate	3.5 g per student
thermometer that reads up to 50 °C or more	
polystyrene cup	With lids if possible
250 cm^3 or 400 cm^3 beaker	
burette, clamp and stand	
stirring rod	
mass balance (2 d.p.)	
spatula	

Notes