Calibration of a calorimeter using a neutralisation reaction

Objective:
To calibrate a solution calorimeter by determining its heat capacity using the neutralisation reaction between hydrochloric acid (HCl) and sodium hydroxide (NaOH).

Prior knowledge: $H^+ (aq) + OH^- (aq) \rightarrow H_2O(l)$ $\Delta H = -57.1$ kJ/mol

Materials:

- 1 M HCl solution (50 mL)
- 1 M NaOH solution (50 mL)
- A 100 mL solution calorimeter
- 2 X Thermometers 0 – 100°C
- Measuring cylinder (50 mL)
- Stirring rod
- Stopwatch or timer

Procedure:

Step 1 - Measure 50 mL of 1 M HCl using a measuring cylinder and pour it into the dry calorimeter. Make sure the thermometer is already placed on the lead of the calorimeter.

- Measure 50 mL of 1 M NaOH using a separate measuring cylinder.

Step 2 - Allow both solutions to reach the same temperature. Record the initial temperature of both the HCl solution in the calorimeter and the NaOH in the measuring cylinder.

Step 3 - Quickly add the 50 mL of NaOH solution to the HCl in the calorimeter and immediately seal the calorimeter with the lid and thermometer inserted and stir gently for 20 seconds.

Step 4 - Record the temperature of the water every 30 seconds for 5 minutes. Make sure the solution is well stirred and record your results in an appropriate table.

Step 5 - Accurately plot the temperature vs time graph for the set of results.

Data Collection:

Trial/time(sec)	0	30	60	90	120	150	180	210	240	270	300
(°C)											

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Calculations:

1. Using the graph drawn, determine the ΔT for each trial.

2. **Determine the heat energy, in kJ, released by the reaction**

3. **Calculate the calibration factor C_f of the Calorimeter**

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Questions:

1. **Why is it important to ensure that both solutions are at the same initial temperature before mixing?**

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2. **What assumptions are made when calculating the C_f?**

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3. **Consider the theoretical reaction A + B → C. If the temperature change is 6.5°C when 0.10 mol of A completely reacts with excess B, calculate the ΔH of the reaction given that the same solution calorimeter is used.**

4. **What is the purpose of calibrating the calorimeter before measuring the ΔH of a reaction?**

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5. **An unrelated solution calorimeter with 100g of water was calibrated and its C_f was found to be 0.55 kJ/°C. A temperature rise of 6.3 degrees was observed when 0.10 mol of compound B reacted fully with excess reactant G according to the equation below.**

   A(aq) + G(aq) → 2R(aq)

   Two calculations were performed to obtain the ΔH of the reaction above. These calculations are shown below.

   Calculation 1

   Energy released = 0.55kJ/°C X 6.3 °C = 3.5 kJ

   Energy per mol of A = 3.5 kJ/0.1 =35 kJ/mol

   A(aq) + G(aq) → 2R(aq) **ΔH = - 35kJ**

   The second calculation was performed using Q = 4.18 X mass X ΔT

   a. Complete the working out for calculation 2.

   Calculation 2

   Energy released = ____

   Energy per mol of A = ____

   ΔH = ____

   b. Explain the difference between the two calculation and suggest, with a reason which calculation has greater validity.

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6. **Explain how important is it that the total volume of water or solution in the solution calorimeter remains constant after it has being calibrated.**

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Determination of the ΔH of an exothermic reaction.

Background
A reaction commonly used to heat cans of soup or self-heating meals is the exothermic reaction between calcium oxide (quicklime) and water. This reaction produces calcium hydroxide according the equation given below.

$$CaO\ (s) + H_2O\ (l) \rightarrow Ca(OH)_2\ (aq) \quad \Delta = ?$$

This reaction is highly exothermic and can raise the temperature of the surrounding liquid or food contents, making it ideal for self-heating food packaging.

Aim: **To Measure ΔH of the Reaction between calcium oxide and water using a calibrated solution calorimeter.**

Materials:

- Approximately 2 grams of calcium oxide (quicklime)
- 50 mL of distilled water
- 100 mL solution calorimeter (which was previously calibrated)
- 1 X Thermometer (0-100 ^{o}C)
- Stirring rod
- Balance (± 0.01 g)
- Graduated cylinder (50 mL)

Procedure:

Step 1 - Weigh approximately 2.00 g of calcium oxide and record its mass.

Step 2 - Measure 50.0 g of distilled water at room temperature, using the electronic balance and pour it into the calorimeter.

Step 3 - Record the initial temperature of the water.

Step 4 - Add the calcium oxide to the water in the calorimeter, quickly seal the lid, and stir the mixture gently.

Step 5 – Stir the solution well and record the temperature every 30 seconds for five minutes.

Step 6 – Graph the results and use the graph to obtain the ΔT of the water.

Data Collection:

Trial/time(sec)	0	30	60	90	120	150	180	210	240	270	300
(°C)											

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1. **Determine the ΔT using the graph of temperature vs time.**

2. **Calculate the mol of calcium oxide reacted .** Molar mass of CaO (56.08 g/mol)

3. Calculate the amount of energy released by the mol of CaO calculated in question 2 above.

4. Calculate the ΔH of the reaction $CaO (s) + H_2O (l) \rightarrow Ca(OH)_2 (aq)$ Δ = ?

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Questions

1. What is the resolution of the data?

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2. What assumptions are made in this calorimetry experiment?

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3. Given the exothermic reaction below suggest a reason why calcium oxide is used in self-heating cans and not anhydrous copper sulfate, which also reacts exothermically with water?

$$CuSO_4\,(s) + 5H_2O\,(l) \rightarrow CuSO_4{\cdot}5H_2O\,(s) \quad \Delta H = -11.7 kJ/mol$$

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4. If 1.80 g of calcium oxide is mixed with 50 mL of distilled water in a new calorimeter whose C_f has been calculated at 0.500 kJ/°C, calculate the enthalpy change (ΔH) in kJ/mol if the temperature of the water increased by 4.6 °C.

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5. Provide one plausible suggestion, other than conducting multiple trials, that can be implemented in the school laboratory, as to how the validity of the results could be improved?

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