

IB Chemistry IA – Hess's Law

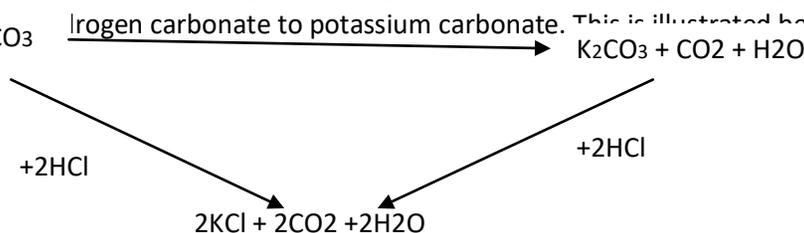
Aim:

It is difficult to determine the enthalpy change of this reaction directly. To determine the enthalpy change indirectly the reaction of potassium hydrogen carbonate with hydrochloric acid can be compared with the reaction of potassium carbonate with hydrochloric acid.

Raw Data:

Substance	Trial 1		Trial 2		Average	
	Mass/g ± 0.05	Temperature rise/ °C ± 0.5	Mass/g ± 0.05	Temperature rise/ °C ± 0.5	Mass/g ± 0.05	Temperature rise/ °C ± 0.05
Potassium carbonate	2.70	+6.5	2.87	+6.1	2.79	+6.3
Potassium hydrogen carbonate	3.60	- 8.2	3.40	- 7.7	3.50	-8.0

According to Hess's law, the total enthalpy is the same doesn't matter the pathway a reaction takes. Therefore, by arranging the two reactions (Potassium carbonate + HCl & Potassium hydrogen carbonate + HCl) in triangle, we can get a sort of vector diagram that gives a pathway from potassium hydrogen carbonate to potassium carbonate. This is illustrated below:



To calculate the overall enthalpy evolved, we calculate the enthalpy of the two separate reactions first, and we do this by using the formula $(Q = mc\Delta T)/\text{number of moles}$, where m is the mass of the solution, in this case the solution used is hydrochloric acid and it is assumed to have the same density as water hence 30ml of it weighs 30g; c is the specific heat capacity of the solution and is assumed at the same value for water as well, at $4.18 \text{ J g}^{-1} \text{ } ^\circ\text{C}^{-1}$; T is the temperature change after the reaction, I will take the average.

Calculations:

Q of Potassium carbonate + hydrochloric acid: $30 \times 4.18 \times 6.3 = 790.02\text{J}$

Number of moles of K_2CO_3 : $2.79 / (39.098 \times 2 + 12.011 + 16 \times 3) = 0.0202\text{M}$

Enthalpy change of reaction per mole: $\Delta H_1 = 790.02 / 0.0202 \approx 39110\text{J} \approx 39\text{kJ mol}^{-1}$

Uncertainty: $(0.05/30) + (0.05/2.79) + (0.5/6.3) = 0.1\% + 1.8\% + 8.0\% = 9.9\%$

$9.9\% \times 39 = 3.9 \approx \pm 4$

Q of Potassium hydrogen carbonate + HCl: $30 \times 4.18 \times 8 = -1003.2\text{J}$

Number of moles of KHCO_3 : $3.50 / (39.098 + 1.0079 + 12.011 + 16 \times 3) = 0.035\text{M}$

Enthalpy change of reaction per mole: $\Delta H_2 = -1003.2 / 0.035 \approx -28663\text{J} \approx -29\text{kJ mol}^{-1}$

Uncertainty: $(0.05/30) + (0.05/3.50) + (0.5/8) = 0.1\% + 1.4\% + 6.3\% = 7.8\%$

$7.8\% \times 29 = 2.262 \approx \pm 2$

Total uncertainty: $2 \times 2 + 4 = \pm 8$

Total Enthalpy evolved = $\Delta H = 2 \times \Delta H_2 + \Delta H_1 = 29 \times 2 + 39 = 97 \pm 8\text{kJ mol}^{-1}$

Literature value: $\Delta H = 92\text{kJ mol}^{-1}$

Conclusion:

By comparing the calculated enthalpy per mole to the literature value for the thermal decomposition of potassium hydrogen carbonate, we see the difference is in fact very small, only +5, showing my experiment to be rather successful and the results to be accurate. The discrepancies of my calculated enthalpy to the literature value could be resulted from the fact that I assumed many properties of the solution to be the same as water, as well as the loss of heat to surroundings.

The decomposition of potassium carbonate is endothermic: the more limiting agent I have (potassium carbonate), the most temperature decrease is obtained, this is also shown its the positive ΔH value. It is the opposite for the decomposition of potassium hydrogen carbonate, and the relationship between the IV and DV is the fact that the more mass of potassium hydrogen carbonate is added to the acid, the higher temperature increase. Overall the enthalpy

evolved for the decomposition of potassium hydrogen carbonate into potassium carbonate indirectly is exothermic, hence we are told in the research question “thermal decomposition of potassium hydrogen carbonate”.

Evaluation:

The percentage error of the actual value to the literature value is $(97-92)/92 \approx 0.05 = 5\%$ I wouldn't be using error bars however, as a graph is not drawn. However we can see the results are very reliable and accurate because the total uncertainty propagated is $\pm 8\text{kJ mol}^{-1}$ and the value 92 is in the range of $97 \pm 8\text{kJ mol}^{-1}$. Or it can be expressed in percentage, **97kJ mol⁻¹ ± 8%**

The followings are reasons that contribute to the uncertainty:

Weakness	Significance	Improvement
Assumption of the properties of HCl same as water (systematic)	Quite and most significant amongst the rest, because this directly effects the value of enthalpy.	Find out the specific heat capacity and density of 2mol dm ⁻³ hydrochloric acid.
Assumption of only the solution to be the mass (systematic)	Slightly because the mass of the limiting reagent added is very small relative to the acid.	Include the mass of all reactants when performing calculations.
Errors from equipment - fluctuation of digital balance (systematic) & human error of reading off thermometer and measuring devices (random)	slightly because again its amount is relatively small.	Use measuring cylinders and balance with even smaller scales and if possible try to use digital measuring devices that don't fluctuate.
Heat loss to the environment (random)	Quite, heat dissipation is easily done and constantly spreading without our knowledge.	Use a bomb calorimeter which is a close system where heat cannot escape.
Not all heat produced by the reaction is instantly read off by thermometer. (random)	slightly, this lowers the maximum temperature recorded.	Plot a graph of the reaction and extrapolate from the constant rate of decrease of temperature later to find out what the initial increased temperature should be.
Only performing the experiment twice (random)	generates random human errors- hence imprecise	repeat the experiment 5 times or more

Weakness	Significance	Improvement
range of data (random)	this effects the precision of the results, as only 2 IVs were done.	Best to test with 10 different value of mass (IV) and average the results.