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Course: FVS Chemistry AB 19.3

Teacher: Kerr

Question: How can you use Hess's Law to determine a reaction's enthalpy when you can't do so using a calorimeter?

Claim: Hess's Law accurately describes the enthalpy of an unknown reaction where other reactions' enthalpies (such that those reactions can be summed to the unknown reaction) are known.

Data:

Measurement	Reaction 1 ($Mg + HCl$)	Reaction 2 ($MgO + HCl$)
Mass of HCl (g)	100.50	100.57
Mass of solid (g)	0.20	1.57
Total mass of reactants, m (g)	100.70	102.14
Initial temperature ($^{\circ}C$)	22.5	22.7
Temperature furthest from initial temperature ($^{\circ}C$)	31.3	30.2
ΔT ($^{\circ}C$)	8.8	7.5
Heat released, $q = cm\Delta T$ (J)	3700	3200
Moles of solid reactant (mol)	0.00823	0.0397
Enthalpy of reaction, $\Delta H = \frac{-q}{mol} * \frac{kJ}{1000J}$ (kJ/mol)	-450	-81

Combination of ΔH_1 , ΔH_2 , and ΔH_3 needed (using Hess's Law): $\Delta H_{rxn} = -655 \frac{kJ}{mol}$

Reaction Equation	ΔH (kJ/mol)
Reaction 1: $Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$	-450
Reaction 2: $MgO(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$	-81
Reaction 3: $H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l)$	-286 (published value)
Magnesium Combustion: $Mg(s) + \frac{1}{2}O_2(g) \longrightarrow MgO(s)$	-655

The published value for this reaction is -603 kJ/mol. Percent error of experimental value: 8.62%

Evidence:

This experiment measured two chemical reactions, but three were used based off of commonly known values. The first of these is $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$. The enthalpy of this reaction was measured and recorded accurately because HCl was in excess, so the only limiting factor was the metal (Mg), of which the weight and molar mass was known. ΔT was also determined, and because a coffee cup calorimeter was used, that was able to be converted into released energy (q). The same process was completed for the dissolution of MgO in HCl by the reaction $MgO + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$. Their respective enthalpies of reaction were $-450 \frac{kJ}{mol}$ and $-81 \frac{kJ}{mol}$. The third previously known reaction was the combination of gaseous diatomic hydrogen and oxygen into water. This reaction is impossible to conduct with our tools because it requires a bomb calorimeter to contain the gaseous components. Its enthalpy of reaction was $-286 \frac{kJ}{mol}$.

From these, the reversal of the second reaction provided $H_2O(l) + MgCl_2(aq) \rightarrow MgO(s) + 2HCl(aq)$ at an enthalpy of $81 \frac{kJ}{mol}$. This allowed the “cancelling” of hydrochloric acid, magnesium chloride, hydrogen, and water when summing the chemical equations. After summation, we are left with $Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$ at a total enthalpy of $-450 - (-81) - 286 = -450 + 81 - 286 = -655 \frac{kJ}{mol}$ by Hess’s Law. Because this is so similar to the previously published value of $-603 \frac{kJ}{mol}$ (an experimental error of 8.62%, well within bounds of statistical significance), it can be considered to be an accurate measure of the enthalpy of the reaction (specifically magnesium combustion; however, this generalises).

Justification (Reasoning) of the Evidence:

Hess’s Law’s accuracy makes sense because it’s logically consistent with enthalpy’s property of being a state function. Starting with the assumed 0 enthalpy of elements in their standard form, most bonds release energy, and by conservation of energy, they must have proportionately lower potential energy. This is the energy of formation and is constant between all samples of a substance. In order for energy to be conserved during non-formation or -decomposition chemical reactions, the potential energy difference between products and reactants (enthalpy) must be equal to energy released. This is the foundation of Hess’s Law: the known enthalpy amounts allow given compounds’ enthalpies of formation to be treated like variables (because enthalpy of formation is an intrinsic property determined only by the identity of the substance and is identical between all samples of the substance) and thus the chemical equations summed like linear equations. This demonstrates the generality of the specific magnesium combustion example shown here.