EXPERIMENT 7

CALORIMETRY (PART II)

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Part A

Intermolecular Forces

Speed of evaporation is a measure of the strengths of intermolecular forces.

For instance:
Acetone evaporates readily off your skin.
Water evaporates more slowly off your skin.

Today we will test:

Methanol	CH_3OH
Acetone	CH_3COCH_3
Isopropanol	$(CH_3)_2CHOH$
Pentane	$CH_3(CH_2)_3CH_3$
Hexane	$CH_3(CH_2)_4CH_3$

Part B

Calorimetry II

HESS'S LAW: If two (or more) chemical equations are combined by addition/subtraction to give an overall chemical equation, the corresponding enthalpy changes (ΔH_n) can also combined by addition/subtraction, in parallel, to give the enthalpy change for the overall reaction (ΔH_{rxn}).

-or-

The overall reaction's enthalpy change (ΔH_{rxn}) is the sum of the reaction enthalpies of the steps (n) into which the overall reaction be divided (ΔH_n).

-or-

The overall reaction's enthalpy change (ΔH_{rxn}) is always the same, regardless if the overall process occurs in one step or through a series of steps (n).

An Example

$$2 \times [\ Ag^+ (aq) + Cl^- (aq) \rightarrow AgCl (s)\ ] \qquad 2\times\Delta H_{rxn\ 1}$$

$$2\ AgCl (s) + 2\ OH^- (aq) \rightarrow Ag_2O (s) + 2\ Cl^- (aq) + H_2O (l) \qquad \Delta H_{rxn\ 2}$$

$$2\ AgCl (s) + 2\ OH^- (aq) \rightarrow Ag_2O (s) + H_2O (l) \qquad \Delta H_{rxn\ 3}$$

↓

We can write the (overall) reaction 3 as:

$$\text{rxn } 3 = 2 \times (\text{rxn } 2) + \text{rxn } 1$$

↓

We can write the overall enthalpy change for reaction 3 as:

$$\Delta H_{rxn\ 3} = 2 \times (\Delta H_{rxn\ 1}) + \Delta H_{rxn\ 2}$$

This isn't the only way we can calculate the overall enthalpy change though.

Part B

Enthalpies of Formation

The standard enthalpy of formation (or formation enthalpy) of a substance (ΔH_f^o) is the standard enthalpy change of the reaction (ΔH_{rxn}^o) in which one mole of the substance is formed from its elements in their standard states.

The standard enthalpy of formation for an element in its standard state is zero.

Some Examples

These represent formation enthalpies.

$C\ (s,\ graphite) + O_2\ (g) \rightarrow CO_2\ (g)$ $\qquad \Delta H_f^o = -393.5\,\frac{kJ}{mol}$

$C\ (s,\ graphite) + \frac{1}{2}\ O_2\ (g) \rightarrow CO\ (g)$ $\qquad \Delta H_f^o = -110.5\,\frac{kJ}{mol}$

These represent reaction enthalpies.

$CO\ (g) + \frac{1}{2}\ O_2\ (g) \rightarrow CO_2\ (g)$ $\qquad \Delta H_{rxn}^o = -283.0\,\frac{kJ}{mol}$

$2C\ (s) + O_2\ (g) \rightarrow 2\ CO\ (g)$ $\qquad \Delta H_{rxn}^o = -221.0\,\frac{kJ}{mol}$

$$\Delta H_{rxn}^o = \sum n_p \Delta H_f^o(\text{products}) - \sum n_R \Delta H_f^o(\text{reactants})$$

Today

Reactions of Interest

$Mg\ (s) + 2\ H^+\ (aq) \rightarrow Mg^{2+}\ (aq) + H_2\ (g)$ $\Delta H^o_{B1} = ?$

$MgO\ (s) + 2\ H^+\ (aq) \rightarrow Mg^{2+}\ (aq) + H_2O\ (l)$ $\Delta H^o_{B2} = ?$

Purpose

$Mg\ (s) + \frac{1}{2}\ O_2\ (g) \rightarrow MgO\ (s)$ $\Delta H_f(MgO) = ?$

Let's apply Hess's Law to our reactions

Mg (s)	+	2 H^+ (aq)	→	Mg^{2+} (aq)	+	H_2 (g)	ΔH_{B1}
Mg^{2+} (aq)	+	H_2O (l)	→	MgO (s)	+	2 H^+ (aq)	$-\Delta H_{B2}$
H_2 (g)	+	½ O_2 (g)	→	H_2O (l)			$-\Delta H_f^o\ (H_2O)$
Mg (s)	+	½ O_2 (g)	→	MgO (s)			$\Delta H_f(MgO)$

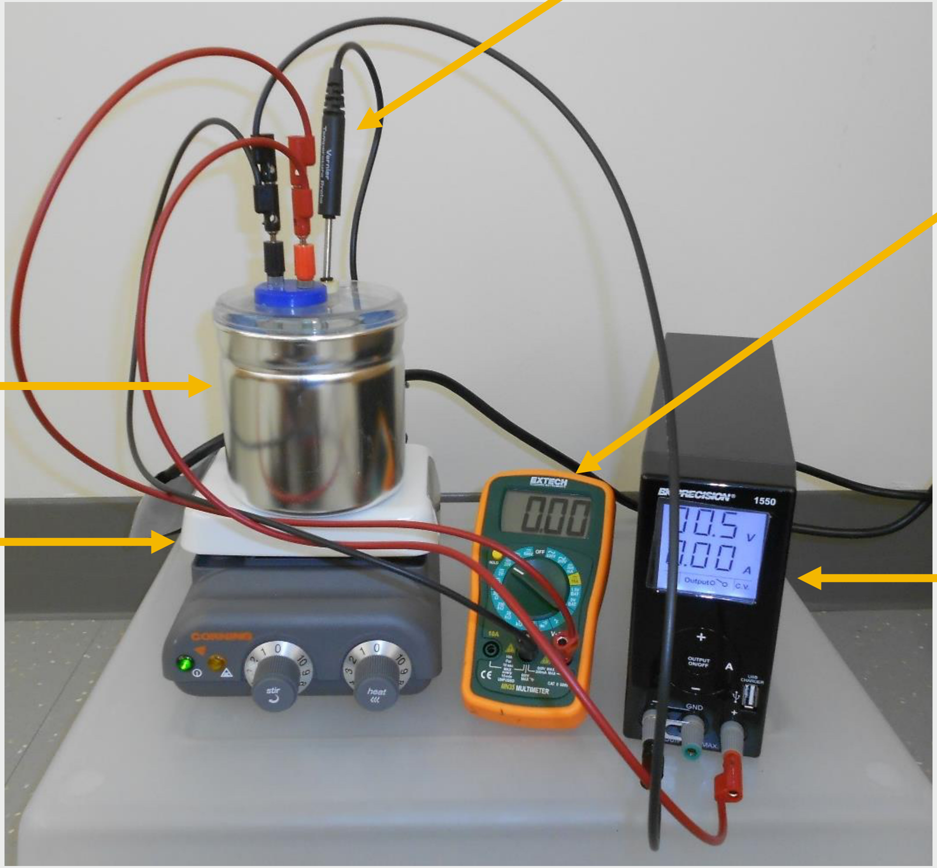
↓

We can write the overall enthalpy change, which is a formation enthalpy, as:

$$\Delta H_f(MgO) = \Delta H_{B1} - \Delta H_{B2} + \Delta H_f^o(H_2O)$$

Calorimeter

Thermocouple temperature sensor (TTS)
→ *read to 0.01 °C*



Voltmeter
(measures voltage, V)
→ *start at 0 V*

Calorimeter
(resistor inside)

Stir plate
(stir bar inside)

Power supply &
Ammeter
(measures current, A)
→ *start at 0 A*
→ *bring to ~0.5 V*

Overview

Part A: Intermolecular Forces

5 samples total

get 1 liquid sample from hood
clamp TP to stand and slant down
collect data for ~10 s
add one drop of solution onto TP
collect data until temperature rises
do a duplicate run on same liquid

↓

Part B0: Set Up the Calorimeter

~60 mL water in beaker
increase current from 0 → ~1.50 A

↓

Part B1/B2: Reactions of Interest

~60 mL HCl in beaker
mini-balance: ~mass of Mg/MgO → analytical balance: exact mass
after 2 mins: add Mg
when temperature is stable: turn on output
after ~150 sec: turn off output
collect data for another 2 mins

Notes

1. Change temperature precision to 0.01 °C
2. Change time precision to 0.1 s.
3. Change data collection duration to 1000 s.
4. Take 25 mL 1 M HCl in your 100 mL graduated cylinder.

   Add water to the 60 mL mark.

   Transfer this to your 100 mL beaker.