INVESTIGATION 5.2.1 MOLAR ENTHALPY OF A CHEMICAL CHANGE

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Experimental Design

(a) $n_{NaOH} = C_{NaOH}V_{NaOH}$

$= 1.0 \text{ mol/L} \times 50 \text{ mL}$

$n_{NaOH} =$ 50 mmol, which would require 25 mmol of acid to be completely consumed

$n_{H_2SO_4} = C_{H_2SO_4}V_{H_2SO_4}$

$= 1.0 \text{ mol/L} \times 30 \text{ mL}$

$n_{H_2SO_4} = 30 \text{ mmol}$

Analysis

(b) (i) $m_{total} = m_{NaOH_{(aq)}} + m_{H_2SO_{4(aq)}}$

$= 30 \text{ g} + 50 \text{ g}$

$m_{total} = 80 \text{ g}$

(ii) temperature change, ΔT

(Sample answer)

$\Delta T = 8.0°\text{C}$

(iii) $q = 80\ (4.18)\ \Delta T$ J

$= 2675$ kJ

$q = 2.7$ kJ

(iv) $n_{NaOH} =$ 50 mmol or 0.050 mol

(v) $\Delta H_{neut} =$ (2.7 kJ)/0.050 J/mol = –54 kJ/mol

Evaluation

(c) $\% \text{ difference} = \dfrac{|\text{accepted value} - \text{experimental value}|}{\text{accepted value}} \times 100\%$

The accepted value is –57 kJ/mol, which would imply an experimental error of about 5%.

(d) Errors could occur in measurements of mass or temperatures, or as a consequence of heat loss to the air.

Synthesis

(e) (i) The acid would still be in excess, so that the ΔH would be unchanged.
(ii) The base solution would be less than fully reacted, so that the ΔT and ΔH values would be low.

INVESTIGATION 5.3.1 COMBUSTION OF ALCOHOLS

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Prediction

(a) (Sample answer) The ΔH_{comb} values would become greater because the reactant molecules are larger.
(The trend is correctly guessed but the rationale is not. In fact, bond breakage in larger molecules requires more energy input but this is more than compensated for by the larger number of bonds formed exothermically in water and carbon dioxide products.)

Analysis

(b) **Ethanol**:

(i) $q = (m_{water})\ (4.18 \text{ J/g•°C})\ (\text{T})$

$= 100 \text{ g} \times 4.18 \text{ J/g•°C} \times 20.0°\text{C}$

$q = 8200 \text{ J, or } 8.2 \text{ kJ}$

(ii) heat produced per gram of ethanol $= \dfrac{q}{m_{\text{ethanol}}}$

$= \dfrac{8.2\ \text{kJ}}{0.94\ \text{g}}$

$= 8.7$ kJ/g mol

(iii) $n_{\text{ethanol}} = \dfrac{m_{\text{ethanol}}}{M_{\text{ethanol}}}$

$= \dfrac{0.94\ \text{g}}{46.0\ \text{g/mol}}$

$n_{\text{ethanol}} = 0.0204$ mol

(iv) heat produced per mole of ethanol $= \Delta H_{\text{comb}}$

$\Delta H_{\text{comb}} = \dfrac{q}{n_{\text{ethanol}}}$

$= \dfrac{8.2\ \text{kJ}}{0.0204\ \text{mol}}$

$\Delta H_{\text{comb}} = -402$ kJ/mol

Similarly, in order to produce a temperature change of 20.0°C, typically 0.83 g of propanol and 0.70 g of butanol need to be burned. All of these values are a fraction of the expected values but the trends in values calculated for these alcohols follow that predicted trend: the larger the alcohol, the larger the heat of combustion (ethanol 402 kJ/mol; propanol 605 kJ/mol; butanol 880 kJ/mol).

(c) $CH_3CH_2OH_{(l)} + 3\ O_{2(g)} \rightarrow 2\ CO_{2(g)} + 3\ H_2O_{(g)} + 402\ \text{kJ}$

$CH_3CH_2CH_2OH_{(l)} + \frac{9}{2} O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)} + 605\ \text{kJ}$

$CH_3CH_2CH_2CH_2OH_{(l)} + 6\ O_{2(g)} \rightarrow 4\ CO_{2(g)} + 5\ H_2O_{(g)} + 880\ \text{kJ}$

(d) $CH_3CH_2OH_{(l)} + 3\ O_{2(g)} \rightarrow 2\ CO_{2(g)} + 3\ H_2O_{(g)} + 402\ \text{kJ}$

$CH_3CH_2OH_{(l)} + 3\ O_{2(g)} \rightarrow 2\ CO_{2(g)} + 3\ H_2O_{(g)} \quad \Delta H = -\ 402\ \text{kJ}$

$\Delta H = 2\ (-402\ \text{kJ})$
$\Delta H = -804\ \text{kJ}$
Since the reaction is exothermic, the PE diagram will resemble Figure 6(a) on p. 318.

(e) (Answers will vary.) The experimental heats of combustion follow the observed trend but are typically about one-third of the accepted values because of the considerable loss of heat to the surroundings.

Evaluation

(f) There is considerable loss of heat to the surroundings.

(g) (Answers will vary.) All of these values are a fraction of the expected values, but the trends in values calculated for these alcohols follow the predicted trend: the larger the alcohol, the larger the heat of combustion (ethanol 402 kJ/mol; propanol 605 kJ/mol; butanol 880 kJ/mol). The Experimental Design was not ideal because of the amount of heat lost to the surroundings. Minimizing heat loss would be an improvement.

Synthesis

(h) (Answers will vary.) Factors could include heat produced per gram, availability of the fuel, transportation cost and safety, and the extent to which the fuel combusts cleanly.