Multi-Step Energy Calculations

Step 1: *Find H^o general*
-use Hess's law
-from equation
-use calorimetry

Step 2: *Find n (specific)*
-use mass (molar mass)
-use concentration
-use $n = \Delta H / H^o$

Step 3: *Find ΔH (specific)*
-use $\Delta H = nH^o$

Sample Problem

Ex. $2NaHCO_{3(s)}$ + 129.2kJ ⟶ $Na_2CO_{3(s)}$ + $CO_{2(g)}$ + $H_2O_{(g)}$

What quantity of energy, ΔH_r, is required to decompose 100. kg of $NaHCO_{3(s)}$?

Step 1: Hr (general)

$\Delta H_r = nH_r$

$H_r = \frac{\Delta H_r}{n} = \frac{129.2\text{ kJ}}{2\text{ mol}} = 64.6\text{ kJ/mol}$

Step 2: n (specific)

$100\,000\text{ g } NaHCO_3 \times \frac{1\text{ mol } NaHCO_3}{84.01\text{ g } NaHCO_3} = 1190.334\text{ mol}$

Step 3: ΔHr (specific)

$\Delta H_r = nH_r$

$\Delta H_r = (1190.334\text{ mol})(64.6\,\frac{\text{kJ}}{\text{mol}})$

$\Delta H_r = 76\,900\text{ kJ}$

Sample Problem

Ex. $ZnS_{(s)} + 3/2O_{2(g)} \longrightarrow ZnO_{(s)} + SO_{2(g)}$

What quantity of energy, ΔH_r, can be obtained from roasting of 50.0kg of zinc sulfide ore?

Step 1: Hr (general)

$\Delta H_r = \Sigma nH_{fp} - \Sigma nH_{fr}$

$\Delta H_r = -853.3\ kJ$

$\Delta H_r = nH_r$

$(-853.3\ kJ) = (1\ mol)H_r$

$H_r = -853.3\ kJ/mol$

Step 2: n (specific)

$50\,000g\ ZnS \times \frac{1\ mol\ ZnS}{97.44g\ ZnS} = 513.136\ mol\ ZnS$

Step 3: ΔH_r

$\Delta H_r = nH_r$

$\Delta H_r = (513.136\ mol)(-853.3\ \frac{kJ}{mol})$

$\Delta H_r = -438\,000\ kJ$

Multi-Step Energy Calculations can be used when energy produced in one chemical reaction is used to heat another substance. These calculations are very similar to calorimetry calculations.

total enthalpy change = quantity of heat

$$\Delta H_r = -q$$

Sample Problem

What mass of octane is completely burned during the heating of 20.L of aqueous ethylene glycol automobile coolant from -10°C to 70°C? The volumetric heat capacity of aqueous ethylene glycol is 3.7 kJ/L°C.

Ex. $2C_8H_{18(l)} + 25O_{2(g)} \longrightarrow 18H_2O_{(g)} + 16CO_{2(g)}$

Step 1: Hr (general)

$$\Delta H_r = \Sigma nH_{fP} - \Sigma nH_{fR}$$

$$\Delta H_r = \left[(18\ mol)\left(-241.8\ \frac{kJ}{mol}\right) + (16\ mol)\left(-393.5\ \frac{kJ}{mol}\right)\right] - \left[(2\ mol)\left(-250.1\ \frac{kJ}{mol}\right) + (25\ mol)\left(0\ \frac{kJ}{mol}\right)\right]$$

$$\Delta H_r = -10148.2\ kJ$$

$$\Delta H_r = nH_r$$

$$(-10148.2\ kJ) = (2\ mol)H_r$$

$$H_r = -5074.1\ kJ/mol$$

Step 2: n (specific)

$$\Delta H_r = -q$$

$$nH_r = -vC\Delta T$$

$$n = \frac{-(20.L)\left(3.7\ \frac{kJ}{L\cdot °C}\right)(80.°C)}{-5074.1\ \frac{kJ}{mol}}$$

$$n = 1.1667\ mol$$

Step 3: m (specific)

$$1.1667\ mol\ C_8H_{18} \times \frac{114.26g\ C_8H_{18}}{1\ mol\ C_8H_{18}} = \boxed{130\ g\ C_8H_{18}}$$

Worksheet #1-5