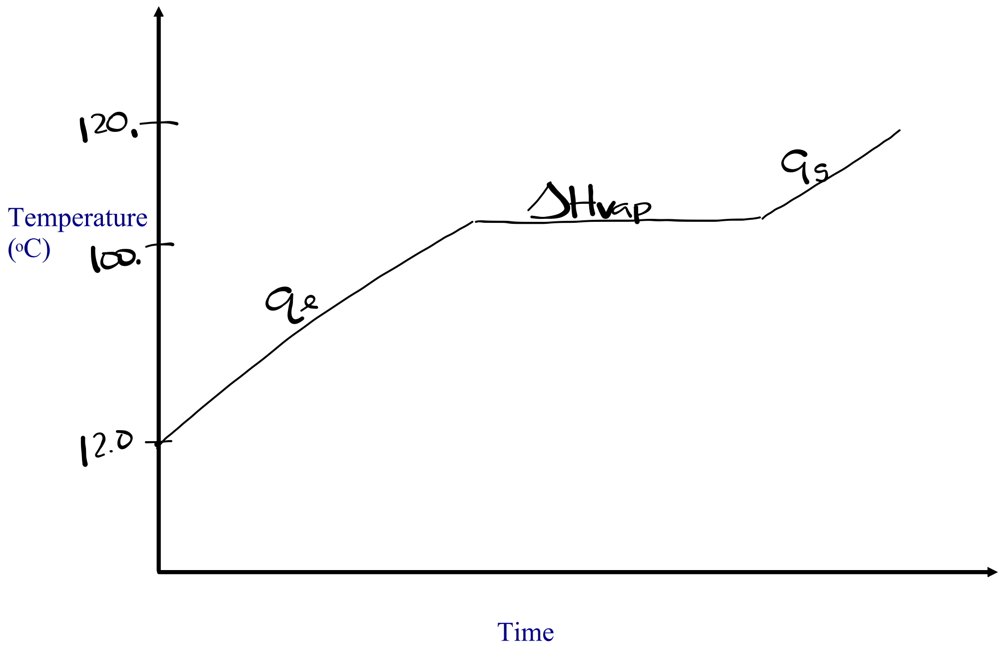
Energy Changes / Reaction Enthalpies

Major Topics

- Total Energy
- Calorimetry
- Hess' Law
- Heats of Formation
- Multi-Step Problems

Total Energy

Calculate the total energy change if 25.0g of water at 12.0°C is completely converted to steam at 120°C.



$q_l = mC\Delta T$

$q_l = (25.0g)(4.19 \frac{J}{g \cdot °C})(88.0°C)$

$q_l = 9218\ J$

$\Delta H_{vap} = nH_{vap}$

$\Delta H_{vap} = \left(\frac{25.0g}{18.02g/mol}\right)\left(\frac{40.8kJ}{mol}\right)$

$\Delta H_{vap} = 56.6\ kJ$

$q_g = mC\Delta T$

$q_g = (25.0g)(2.01 \frac{J}{g \cdot °C})(20.0°C)$

$q_g = 1005\ J$

$\Delta E_T = q_l + \Delta H_{vap} + q_g$

$\Delta E_T = (9.218kJ) + (1.005kJ) + (56.603kJ)$

$\Delta E_T = 66.8\ kJ$

$$q = mC\Delta T$$
$$= vC\Delta T$$

$$\Delta H = nH$$

Calorimetry

7.37 g of sodium nitrate is dissolved in 100. mL of water at an initial temperature of 16.3°C. The final temperature of the solution is 25.1°C. Calculate the molar enthalpy of solution, H_s, for sodium nitrate.

$NaNO_3$

m = 7.37g

H_s = ?

H_2O

V = 100.mL

T_i = 16.3°C

T_f = 25.1°C

E gain/lost $NaNO_3$ = E gain/lost H_2O

$$\Delta H_s = -q$$

$$nH_s = -vC\Delta T$$

$$\left(\frac{7.37g}{85.00g/mol}\right)H_s = -(0.100L)\left(4.19\frac{kJ}{L\cdot{}^\circ C}\right)(8.8^\circ C)$$

$$H_s = -42.5\ \frac{kJ}{mol}$$

Hess' Law

$$2NO_{2(g)} \longrightarrow N_{2(g)} + 2O_{2(g)} \qquad H_r = ?$$

Calculate the standard enthalpy change for this reaction using the following information:

① $N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$ $\Delta H_r = -91.8$ kJ

② $NO_{2(g)} + \frac{7}{2}H_{2(g)} \longrightarrow NH_{3(g)} + 2H_2O_{(l)}$ $\Delta H_r = 85.5$ kJ

③ $H_2O_{(l)} \longrightarrow H_{2(g)} + \frac{1}{2}O_{2(g)}$ $\Delta H_r = 285.8$ kJ

Rev ①

④ $2NH_{3(g)} \rightarrow N_{2(g)} + 3H_{2(g)}$ $\Delta H_r = 91.8$ kJ

② × 2

⑤ $2NO_{2(g)} + 7H_{2(g)} \rightarrow 2NH_{3(g)} + 4H_2O_{(l)}$ $\Delta H_r = 171$ kJ

③ × 4

⑥ $4H_2O_{(l)} \rightarrow 4H_{2(g)} + 2O_{2(g)}$ $\Delta H_r = 1143.2$ kJ

Heats of Formation

Ex. What is the standard molar enthalpy of combustion of methane fuel?

$\Delta H_r = ?$

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

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

$$\Delta H_r = \left[(1\,mol)(-393.5\,\tfrac{kJ}{mol}) + (2\,mol)(-241.8\,\tfrac{kJ}{mol})\right] - \left[(1\,mol)(-74.1\,\tfrac{kJ}{mol}) + (2\,mol)(0\,\tfrac{kJ}{mol})\right]$$

$$\Delta H_r = -802.7\,kJ$$

$$\Delta H_r = nH_r$$

$$H_r = \frac{\Delta H_r}{n} = \frac{-802.7\,kJ}{1\,mol} = -802.7\,\frac{kJ}{mol}$$

Multi-Step Problems

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)

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

Step 2: n (specific)

$$100\,000\ g\ NaHCO_3 \times \frac{1\ mol\ NaHCO_3}{84.01\ g\ NaHCO_3} = 1190.33\ mol$$

Step 3: ΔHr (specific)

$$\Delta H_r = nH_r$$

$$\Delta H_r = (1190.33\ mol)(64.6\ \frac{kJ}{mol})$$

$$\Delta H_r = 76900\ kJ$$

Chemical Equilibrium

Major Topics

- **Equilibrium Law**
- **Le Chatelier's Principle**
- **Water Equilibrium**

You Should Know...

- General formulas of alkanes, alkenes, alkynes, and cyclic compounds
- Aromatic compounds
- Pi bonds
- Characteristics of organic compounds

Equilibrium Law

A mixture of H_2 and I_2 is allowed to react at 448°C. When the equilibrium is established the concentrations of the participates are found to be $[H_2]$ = 0.46 mol/L, $[I_2]$=0.39 mol/L, and [HI] = 3.0 mol/L. Calculate the value of K at 448°C from these data.

Le Chatelier's Principle

$2SO_{2(g)} + O_{2(g)} \longleftrightarrow 2SO_{3(g)} + \text{energy}$

⇒remove $SO_{3(g)}$

⇒cool system (low T)

⇒decrease volume (increase pressure)

Water Equilibrium

A solution of calcium hydroxide, $Ba(OH)_2$, has a pH of 4.25. Calculate the pOH, concentration of hydrogen ions, concentration of hydroxide ions, and the concentration of the $Ba(OH)_2$ solution.