Representing Enthalpy Changes

Thermochemical Equations

* A balanced chemical equation that includes the heat transfer

$$2\,H_{2\,(g)} + O_{2\,(g)} \rightarrow 2\,H_2O_{(l)} + 571.6\ kJ$$

$$MgCO_{3\,(s)} + 117.3\ kJ \rightarrow MgO_{(s)} + CO_{2(g)}$$

* To write a thermochemical equation, you must know:
  * the balanced chemical equation
  * heat of reaction for the substance

Thermochemical Equations

* You can also △ H values in thermochemical equations

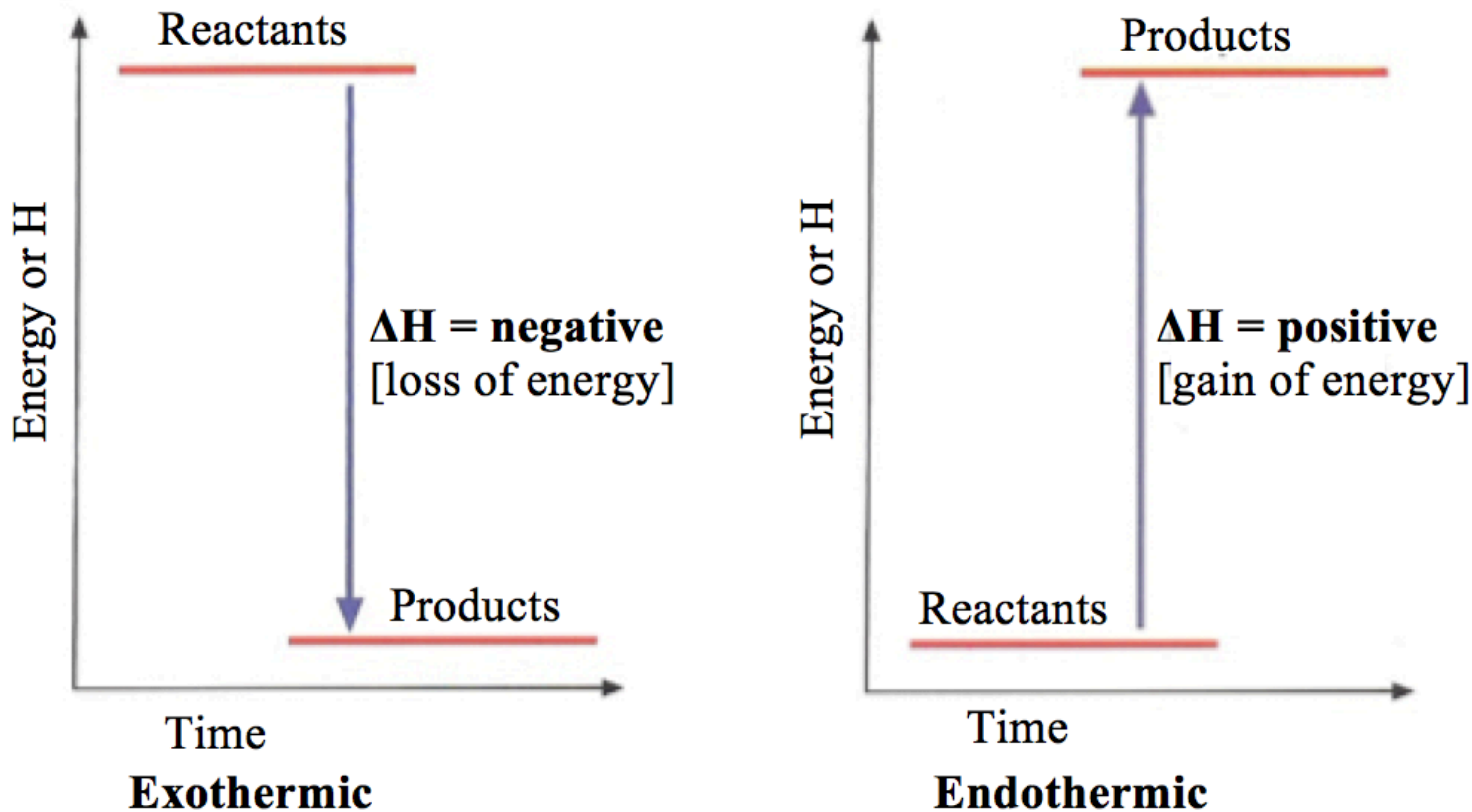
$$2\ H_{2\,(g)} + O_{2\,(g)} \rightarrow 2\ H_2O_{(l)} \qquad \Delta H_{rxn} = -571.6\ kJ$$

$$MgCO_{3\,(s)} \rightarrow MgO_{(s)} + CO_{2(g)} \qquad \Delta H_{rxn} = 117.3\ kJ$$

* Remember:
    * exothermic reactions have -ΔH
    * endothermic reactions have +ΔH

Potential Energy Diagrams

* **exothermic reactions:** products are lower in energy than reactants (energy lost to surroundings)
* **endothermic reactions:** products are higher in energy than reactants (energy absorbed from surroundings)


Reactants
Energy or H
ΔH = negative
[loss of energy]
Products
Time
Exothermic
Products
Energy or H
ΔH = positive
[gain of energy]
Reactants
Time
Endothermic

Homework

* Pg 295 # 7-10

Molar Enthalpy

First Law of Thermodynamics

* The first law of thermodynamics states that energy can be converted from one form to another but cannot be created or destroyed

$$E_{system} = -E_{surroundings}$$

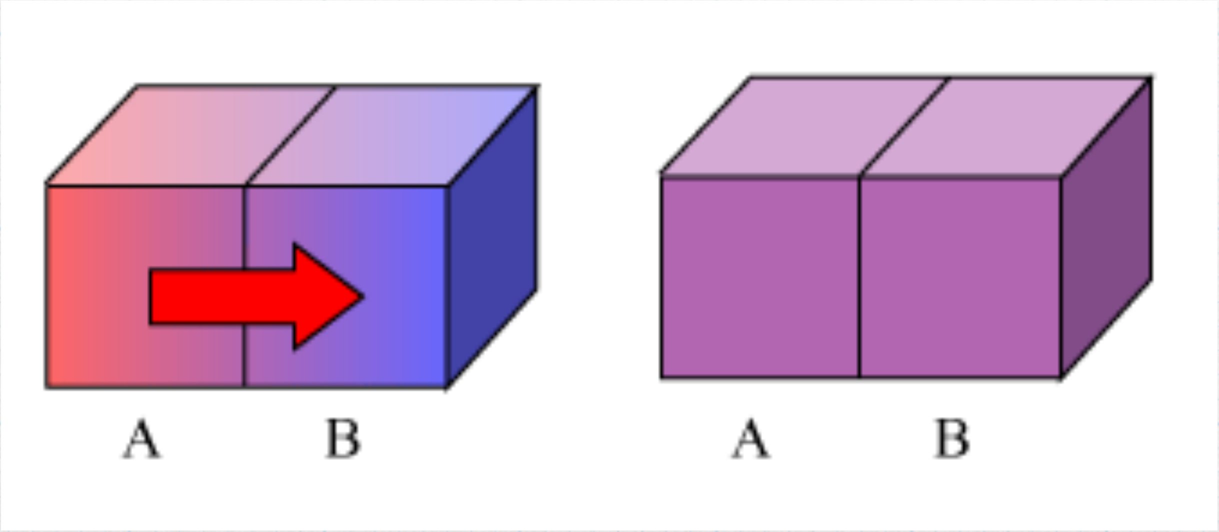
Enthalpy

- Enthalpy ($\triangle H$): is the measure of the total energy of a thermodynamic system plus pressure times volume
  - $\triangle H = \triangle E + \triangle (PV)$

Most reactions we study we assume $\triangle PV$ is zero, so for our purposes $\triangle H = \triangle E = Q$

Second Law of Thermodynamics

* The second law of thermodynamics states that when two objects are in close contact, heat is always transferred from the object of a higher temperature to an object of lower temperature until the two objects are the same temperature (thermal equilibrium)



Molar Enthalpy (ΔH_x)

* **Molar Enthalpy:** is the enthalpy change associated with a physical, chemical, or nuclear change involving one mole of a substance.

Molar Enthalpy (ΔH_x)

* A thermochemical equation represents the energy change that accompanies a chemical reaction.

$$2\ H_{2\,(g)} + O_{2\,(g)} \rightarrow 2\ H_2O_{(g)} + 483.6\ kJ$$

Molar Enthalpy (ΔH_x)

* The equation representing the energy released when ONE mole of H_2 combusts would be

$$H_{2\,(g)} + \frac{1}{2}\,O_{2\,(g)} \rightarrow H_2O_{(g)} + 241.8\ \text{kJ}$$

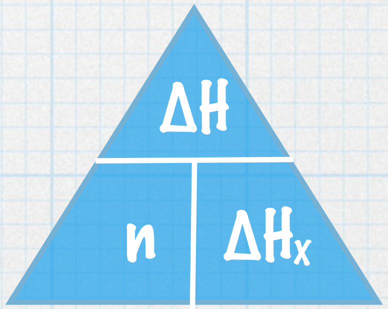
Examples of Molar Enthalpies of Reactions

Solution ($\triangle H_{sol}$)	$NaBr_{(s)} \rightarrow Na^{+}_{(aq)} + Br^{-}_{(aq)}$
Combustion ($\triangle H_{comb}$)	$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$
Vaporization ($\triangle H_{vap}$)	$CH_3OH_{(l)} \rightarrow CH_3OH_{(g)}$
Freezing ($\triangle H_{fr}$)	$H_2O_{(l)} \rightarrow H_2O_{(s)}$
Neutralization ($\triangle H_{neut}$)	$NaOH_{(aq)} + 1/2H_2SO_{4(aq)} \rightarrow 1/2Na_2SO_{4(aq)} + H_2O_{(l)}$
Formation ($\triangle H_f$)	$C_{(s)} + H_{2(g)} + 1/2O_{2(g)} \rightarrow CH_3OH_{(l)}$

* The amount of energy involved in a change depends on the quantity of matter undergoing that change.

* To calculate an enthalpy change, ΔH (kJ), for some amount other than a mole, use the formula

$$\Delta H = n\,\Delta H_x$$



n = # of moles

ΔH_x = molar enthalpy (kJ/mol)

Example

* $H_2O_{(l)}$ + 40.8 kJ → $H_2O_{(g)}$
* Thus the molar enthalpy of vaporization for water is ΔH_{vap} = 40.8 kJ/mol
    * How much energy is needed to boil 90.10 g of water?

* Given:
  * ΔH_{vap} = 40.8 kJ/mol
  * m = 90.10 g
  * M_{H_2O} = 18.02 g/mol

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- Required:
  - ΔH (and therefor n)

- **Given:**
  - ΔH_{vap} = 40.8 kJ/mol
  - m = 90.10 g
  - M_{H_2O} = 18.02 g/mol
- **Required:**
  - ΔH (and therefor n)
- **Equation:**
  - n=m/M and ΔH = (n) (ΔHx)

* $n = m/M$
* $n = (90.10 g) / (18.02 g/mol)$
* $n = 5.00 mol$

* $\Delta H = (n)(\Delta H_x)$
  * $(5.00 \text{ mol})(40.8 \text{ kJ/mol})$
  * $= 204 \text{ kJ}$

Therefore 204 kJ of energy is required to boil 90.10 g of water.

Example

* A common refrigerant (Freon-12, molar mass 120.91 g/mol) is alternately vaporized in tubes inside a refrigerator, absorbing heat, and condensed in tubes outside the refrigerator, releasing heat. This results in energy being transferred from the inside to the outside of the refrigerator. The molar enthalpy of vaporization for the refrigerant is 34.99 kJ/mol. If 500.0 g of the refrigerant is vaporized, what is the expected enthalpy change ΔH?

* **Given:**
  * ΔH_{vap} = 34.99 kJ/mol
  * m = 500.0 g
  * M = 120.91 g/mol

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* **Given:**
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  * M = 120.91 g/mol
* **Required:**
  * ΔH (and therefor n)
* **Equation:**
  * n=m/M and ΔH = n ΔHx

* $n = m/M$
* $$n = \frac{(500.0\ g)}{120.91\ g/mol}$$
* $n = 4.135\ mol$

* $n = m/M$
* $n = \frac{(500.0\ g)}{120.91\ g/mol}$
* $n = 4.135\ mol$
* $\Delta H = n\,\Delta H_x$
* $\Delta H = (4.135\ mol)(34.99\ kJ/mol)$
* $\Delta H = 144.7\ kJ$

Therefore 144.7 kJ of energy is transferred.

Homework

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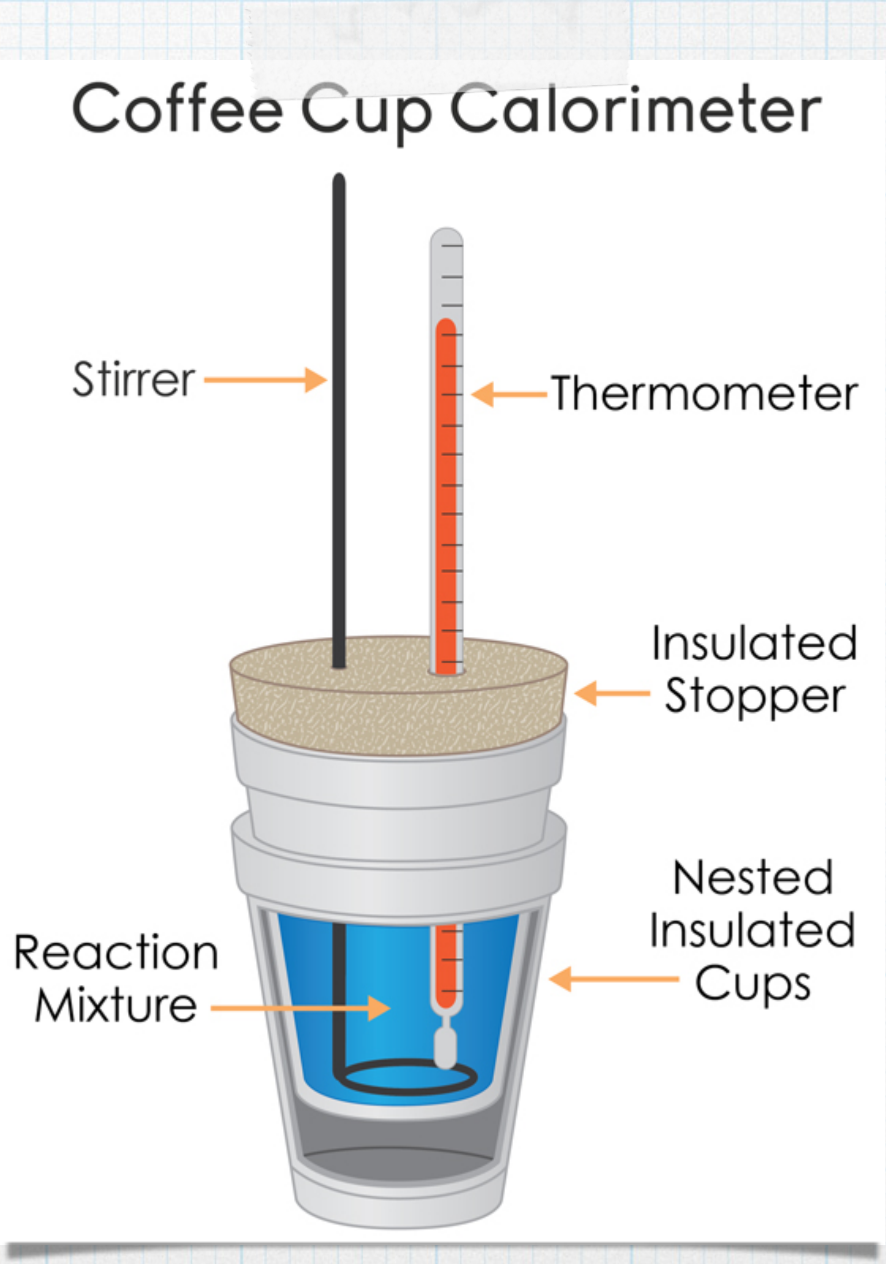
Calculations Using a Calorimeter

Calorimeter

* **Calorimeter:** device used to measure the heat released or absorbed during a chemical or physical process.



Calorimetry

* The analysis is based on the law of conservation of energy: the total energy change of the chemical system is equal to the total energy change of the surroundings

$$\Delta H_{system} = -\, q_{surroundings}$$

Example

* In a calorimetry experiment, 5.56 g of sodium chloride is dissolved in 75.0 mL of water at an initial temperature of 24.9°C. The final temperature of the solution is 23.7°C. What is the molar enthalpy of solution of sodium chloride?

- **Given:**
  - $m = 75.0\ mL \times 1\ g/mL = 75.0\ g$
  - $c = 4.18$ $m = 5.56g$
  - $\Delta T = 23.7 - 24.9 = -1.2$ $M_{NaCl} = 58.44\ g/mol$
- **Required:**
  - ΔH_{sol}
- **Equation:**
  - $n=m/M$, $Q= mc\Delta T$, $\Delta H = n\ \Delta Hx$,

First Find Q

$Q = mc\Delta T$
$Q = (75.0)(4.18)(-1.2)$
$Q = -376.2\ J$

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$Q = mc\Delta T$

$Q = (75.0)(4.18)(-1.2)$

$Q = -376.2$ J

Then Find n

$n = m / M$

$n = (5.56 \text{ g}) / (58.44 \text{ g/mol})$

$n = 0.0951$ mol

First Find Q

$Q = mc\Delta T$

$Q = (75.0)(4.18)(-1.2)$

$Q = -376.2$ J

Then Find n

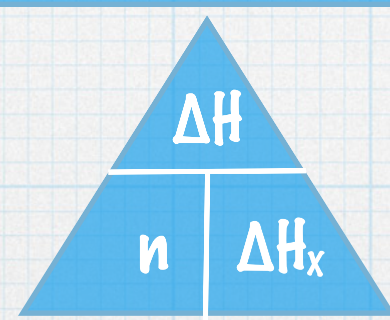
$n = m / M$

$n = (5.56\text{ g}) / (58.44\text{ g/mol})$

$n = 0.0951$ mol

*heat lost by water = heat absorbed by chemical system therefore $\Delta H = -q$

Now Find ΔH_{sol}



$\Delta Hsol = -q/n$

$\Delta Hsol = -(-376.2) / (0.0951)$

$\Delta Hsol = 3.96 \times 103$ J/mol

or 3.96 kJ/mol

Therefore the molar enthalpy of solution is 3.96 kJ/mol

Example

* A 50.00 mL volume of 0.300 mol/L $CuSO_{4(aq)}$ is mixed with 50.00 mL of $NaOH_{(aq)}$. The initial temperature of both solutions is 21.40°C. After mixing the two solutions in a calorimeter the peak temperature is 24.60°C. Determine the enthalpy of change for the reaction.

First Find Q

We know c and △ T, we need m

$$V_{Total} = V_{CuSO_4} + V_{NaOH}$$

$$V_{Total} = 50mL + 50mL$$

$$m = Vd$$

$$m = (100\ mL)(1.00\ g/mL)$$

$$m = 100\ g$$

$Q = mc\Delta T$

$Q = (100)\ (4.19)\ (24.60 - 21.40)$

$Q = 1.341 \times 10^3$ J OR 1.34 kJ

First Find Q

We know c and $\triangle T$, we need m

$$V_{Total} = V_{CuSO_4} + V_{NaOH}$$

$$V_{Total} = 50mL + 50mL$$

$$m=Vd$$

$$m= (100\ mL)(1.00\ g/mL)$$

$$m= 100\ g$$

$Q = mc\Delta T$

$Q = (100)\ (4.19)\ (24.60 - 21.40)$

$Q = 1.341 \times 10^3$ J OR 1.34 kJ

Then Find n

$n = cV$

$n = (0.3\ mol/L)\ (0.05\ L)$

$n= 0.0150$ mol

First Find Q

We know c and $\triangle T$, we need m

$$V_{Total} = V_{CuSO_4} + V_{NaOH}$$

$$V_{Total} = 50mL + 50mL$$

$$m = Vd$$

$$m = (100\ mL)(1.00\ g/mL)$$

$$m = 100\ g$$

$Q = mc\Delta T$

$Q = (100)(4.19)(24.60 - 21.40)$

$Q = 1.341 \times 10^3$ J OR 1.341 kJ

Then Find n

$n = cV$

$n = (0.3\ mol/L)(0.05\ L)$

$n = 0.0150$ mol

$\Delta H_{system} = -q$

$\Delta H_{system} = -1.341$ kJ

Now Find $\Delta H_{reaction}$

$\Delta H_{reaction} = (-1.341\ kJ)/(0.0150\ mol)$

$= -89.4$ kJ/mol

Homework

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