

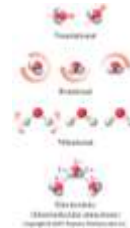
Molar Enthalpy (5.2)

Energy Changes in Physical and Chemical Reactions

The First Law of Thermodynamics

Internal Energy, U.

- Total energy (potential and kinetic) in a system.



- Translational kinetic energy.
- Molecular rotation.
- Bond vibration.
- Intermolecular attractions.
- Chemical bonds.
- Electrons.

Molar Enthalpy

- Energy changes involved for 1 mole of a substances... (ΔH)

- Solution (ΔH_{sol})
- Combustion (ΔH_{comb})
- Vapourization (ΔH_{vap})
- Freezing (ΔH_{fr})
- Neutralization (ΔH_{neut})
- Formation (ΔH_{f})

• Example: see page 306-307

- Each change has a specific energy requirement

- Exothermic:
 - energy is written as a product
 - ΔH is negative!(energy is released)
- Endothermic:
 - Energy is written as a reactant
 - ΔH is positive! (energy is absorbed)

Ways to Show Enthalpy

- Adding energy to the reaction
- ΔH values for a reaction (+/-)
- Molar Enthalpies for substances (+/-)
- Graphical Representation

Molar Enthalpies

- We can use these values to calculate total energy required for a specific process if we know:

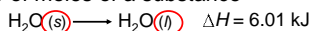
- The amount of substance changing
- The molar enthalpy for that process

Example:

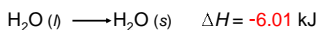
- Vapourization enthalpy (ΔH_{vap}) for Freon is 35kJ/mol
- A refrigerator contains 500g of Freon (121 g/mol)
- Calculate the total energy required

Thermochemical Equations

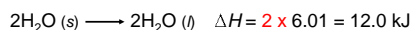
- The stoichiometric coefficients always refer to the number of moles of a substance



- If you reverse a reaction, the sign of ΔH changes

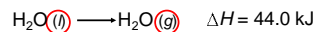
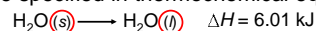


- If you multiply both sides of the equation by a factor n , then ΔH must change by the same factor



Thermochemical Equations

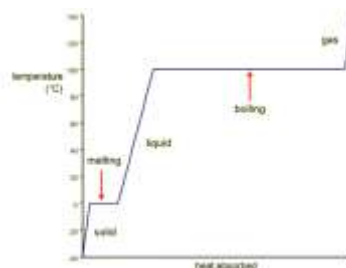
- The physical states of all reactants and products must be specified in thermochemical equations.



Combined Calculations

- We can combine our equations for q and ΔH !
- Recall $q = m c \Delta T$
- $\Delta H_{\text{total}} = n \Delta H_{\text{(for the process)}}$
- Therefore:
- $n \Delta H_{\text{(for the process)}} = m c \Delta T$

Heating Curve for Water



Phase Change Calculation

- Eg. What quantity of energy is liberated as 14.3g of water condenses at its boiling point?

$$\Delta H = nH = 14.3 \text{ g} \times \frac{1 \text{ mol}}{18.02 \text{ g}} \times \frac{-40.65 \text{ kJ}}{1 \text{ mol}}$$

$$= -32.3 \text{ kJ}$$

So, 32.3 kJ of energy are released as 14.3g condenses

Energy Calculations

- solid: $q = mc\Delta T$, $c = 2.00 \text{ J/g}\cdot^\circ\text{C}$
- s to l: $\Delta H = nH$, $H = 6.01 \text{ kJ/mol}$
- liquid: $q = mc\Delta T$, $c = 4.19 \text{ J/g}\cdot^\circ\text{C}$
- l to g: $\Delta H = nH$, $H = 40.65 \text{ kJ/mol}$
- gas: $q = mc\Delta T$, $c = 2.02 \text{ J/g}\cdot^\circ\text{C}$

Combined Problems

- If a sample undergoes phase changes as well as temperature changes, the energy involved in each step must be calculated separately and then added together, taking care that common units are used. (Generally, molar enthalpies are expressed in units of **kJ/mol**, whereas specific heat capacities are expressed as **J/g•°C**)
- The most complicated question of this type would involve two phase change calculations and three changes in heat.

What is the energy change for a 22.4g sample of water that is cooled from 35°C to -12°C under standard conditions?

At 35°C, water is a liquid. As energy is removed, it cools to 0°C. At 0°C, it freezes. As more energy is removed, the solid water cools further.

We must calculate the energy change for two different phases as well as one phase change.

Cooling liquid:

$$q = mc\Delta T = (22.4\text{g})(4.19\text{J/g}\cdot^\circ\text{C})(-35^\circ\text{C}) \\ = -3285 \text{ J} = -3.285 \text{ kJ}$$

Freezing:

$$\Delta H = nH = (22.4\text{g} / 18.02\text{g/mol})(-6.01\text{kJ/mol}) \\ = -7.47 \text{ kJ}$$

Cooling Ice:

$$q = mc\Delta T = (22.4\text{g})(2.00\text{J/g}\cdot^\circ\text{C})(-12^\circ\text{C}) \\ = -538 \text{ J} = -0.538 \text{ kJ}$$

$$\Delta E_{\text{total}} = 11.3 \text{ kJ}$$