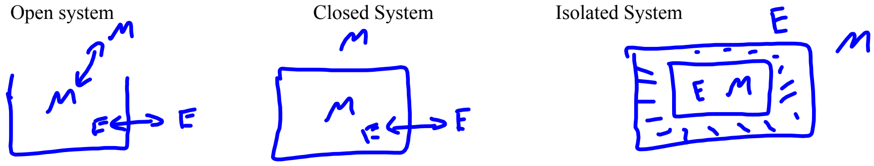
What is Thermochemistry?

Thermochemistry is the study of chemical reactions involving a change in energy

To study energy changes in chemical reactions, chemists need to use and ***isolated*** system

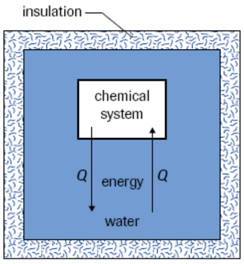
Open system Closed System Isolated System

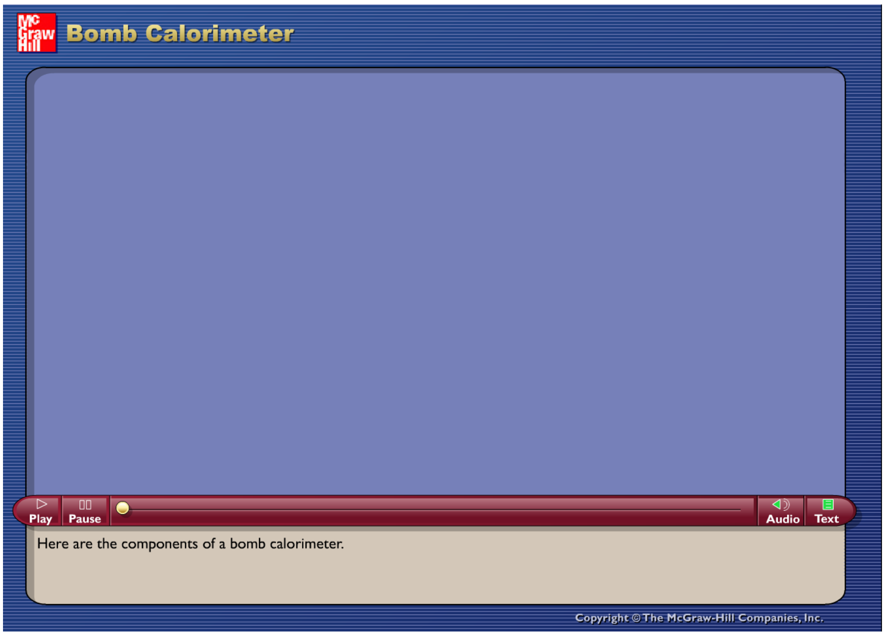


Calorimetry is the technological process of using an isolated system to measure energy changes of a chemical system

A ***calorimeter*** is an isolated system that contains the chemical system (reactants and products) surrounded by water

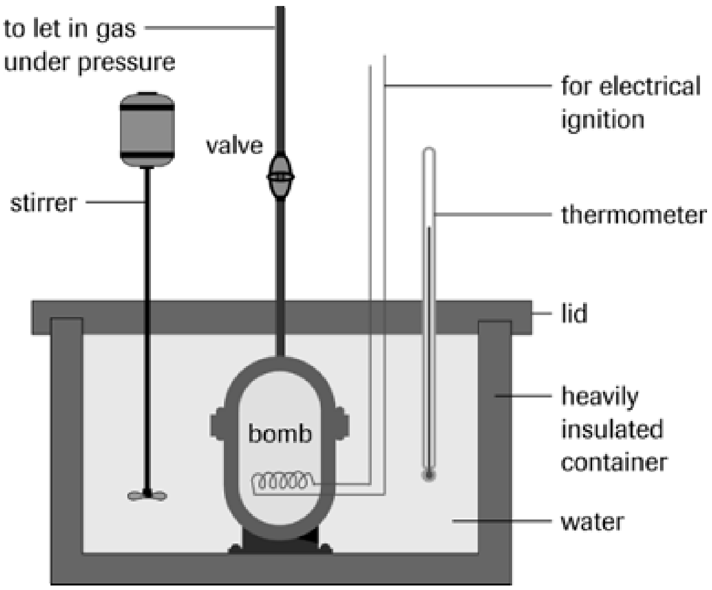
Energy is transferred between the chemical system and the water





By measuring the amount of energy gained/lost by water, chemists can determine the amount of energy gained/lost by the chemical reaction http://www.youtube.com/watch?v=ohyA9amFfsc

Bomb Calorimeter



The reactants are placed inside the calorimeter's bomb, which is surrounded by the calorimeter water. Once the calorimeter is sealed and the initial temperature measured, the combustion reaction is initiated by an electric heater or spark. Stirring is essential in order to obtain a uniform final temperature for the water.

Enthalpy and Enthalpy Change (pg 487-489)

Enthalpy (symbol is **H**) is the total **kinetic** and **chemical** **potential** energy that a chemical system has

In simple terms, enthalpy is the total amount of energy that a chemical system possesses.

Kinetic energy can be in the form of:

- moving electrons within an atom
- vibration of atoms connected by chemical bonds
- rotation and translation of molecules made up of these atoms

Chemical Potential energy can be in the form of:

- covalent and/or ionic bonds between atoms/ions
- intermolecular forces between entities

Enthalpy change is the difference in enthalpy between the reactants and products for a chemical system

Enthalpy change has the symbol **ΔH**

In simple terms, enthalpy change is how much energy a chemical reaction absorbs or releases as it occurs

Enthalpy change can be found two ways

- Empirically, using calorimetry
- Theoretically, using Hess's Law

Enthalpy change has the symbol **ΔH**

Using Caloimetry to find Enthalpy Change

reactants and products

When investigating a chemical system in a calorimeter, the enthalpy change of the chemical system is indirectly measured by the water in the calorimeter.

$$\Delta H_{(system)} = Q_{(calorimeter)}$$

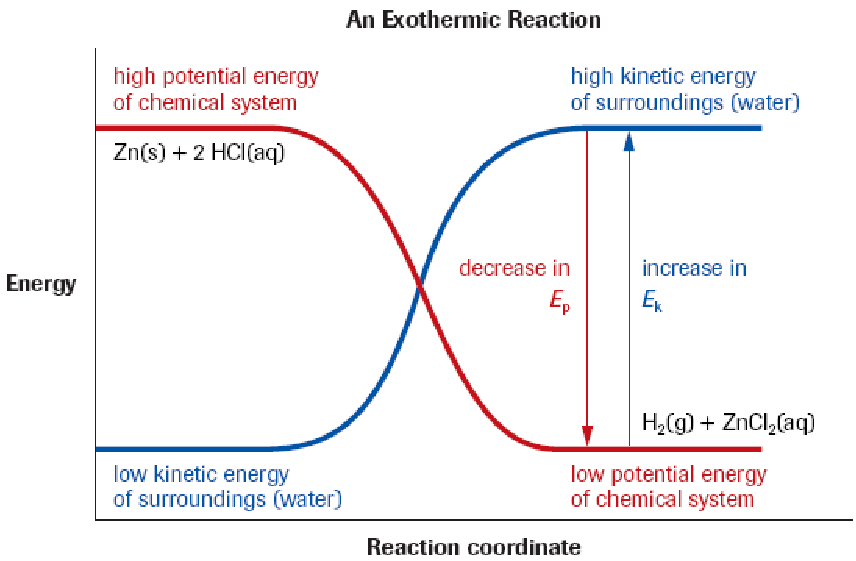
change in E_p of the chemical system ← ΔH (system) = Q (calorimeter) → change in E_k of water in the calorimeter

Exothermic chemical reactions will see a **decrease** in enthalpy. As a result, the energy o the surroundings (calorimeter water) will see an increase in temperature (energy)

- We use a **negative (-) sign** to communicate this loss of enthalpy

Endothermic chemical reactions will see a **increase** in enthalpy. As a result, the energy of the surroundings (calorimeter water) will see an decrease in temperature (energy)

- We use a **positive (+) sign** to communicate this gain of enthalpy



Solving Calorimetry Questions

There are 6 assumptions made so that calorimetry works: (bottom of pg 486)

1. all the energy lost/gained by the chemical system is gained/lost by the calorimeter (the system is isolated)

2. all the material of the system is conserved (the system is isolated)

3. the specific heat capacity of water over the temperature range is 4.19 J/g°C

4. the specific heat capacity of dilute aqueous solutions is 4.19 J/g°C

5. the density of dilute aqueous solutions is the same as that of water (1.0 g/mL)

6. the thermal energy gained or lost by the rest of the calorimeter is negligible

Symbols and subscripts

This means the enthalpy change of reaction

$\Delta_r H$

$\Delta_c H$: ← What does this symbol mean?

The following symbols are used by IUPAC to denote a chemical process or reaction.

Table 2 Symbols for a Reaction

Subscript	Meaning
r	any reaction specified
c	complete combustion
f	formation
d	decomposition
sol	solution
dil	dilution

For example, $\Delta_c H$ denotes the change in enthalpy (ΔH) of combustion (c) for a specified combustion reaction.

Calorimetry Problems

When solving calorimetry problems remember that the enthalpy change of the chemical system equals the energy gained/lost by the calorimeter.

$$\underset{\text{(system)}}{\Delta H} = \underset{\text{(calorimeter)}}{Q}$$

Example 1:

In a simple calorimetry experiment involving a burning candle and a can of water, the temperature of 100 mL of water increases from 16.4 °C to 25.2 °C when the candle is burned for several minutes. What is the enthalpy change?

$\Delta_c H = Q$

$\Delta_c H = mc\Delta t$

$= (100\ g)(4.19\ J/g\cdot°C)(8.8\ °C)$

$= 3687.2\ J$

$= -3.69\ kJ$ $\quad -3.69 \times 10^3\ J$

More Examples

When 50 mL of 1.0 mol/L hydrochloric acid is neutralized completely by 75 mL of 1.0 mol/L sodium hydroxide in a polystyrene cup calorimeter, the temperature of the total solution changes from 20.2 °C to 25.6 °C. Determine the enthalpy change that occurs in the chemical system.

$m = 125\,g$

$c = 4.19\,J/g\cdot°C$

$\Delta t = 5.4\,°C$

$\Delta_n H = Q$

$= mc\Delta t$

$= (125\,g)(4.19\,J/g\cdot°C)(5.4\,°C)$

$= 2828.25\,J$

$\Delta_n H = -2.8\,kJ$ or $-2.8 \times 10^3\,J$

Ethanol is often added to gasoline as a renewable component that reduces harmful emissions. The mixture is known as gasohol. In a research laboratory, the combustion of 3.50 g of ethanol in a sophisticated calorimeter causes the temperature of 3.63 L of water to increase from 19.88 °C to 26.18 °C. Use this evidence to determine the [redacted] enthalpy of combustion of ethanol.

H_2O

$\Delta_c H = Q$

$= mc\Delta t$

$= (3630\,g)(4.19\,J/g\cdot°C)(6.3\,°C)$

$= 95821.11\,J$

$\Delta_c H = -95.8\,kJ$

Molar Enthlapies

Molar enthalpy change of reaction is the enthalpy change in a chemical system per mole of a chemical undergoing change in the system

The IUPAC symbol for molar enthalpy for a specified reaction is $\Delta_r H_m$.

$\Delta_r H$ = J or kJ $\Delta_r H_m$ = J/mol or kJ/mol

In order to calculate enthalpy change from their respective molar quantities we have the following equation:

enthalpy change of reaction   chemical amount   molar enthalpy of reaction

$$\Delta_r H = n\,\Delta_r H_m$$

kJ = mol × kJ/mol

for example, $\Delta_c H = n\,\Delta_c H_m$ (c for combustion)

$\Delta_r H$

Predict the change in enthalpy due to the combustion of 10.0 g of propane used in a camp stove (**Figure 6**).

First, you have to determine the change in enthalpy for the combustion, $\Delta_c H$, using the equation

$$\Delta_c H = n\,\Delta_c H_m$$

To calculate $\Delta_c H$ you need to know the chemical amount (n) and the molar enthalpy of combustion ($\Delta_c H_m$). You can calculate the chemical amount from the mass and molar mass. The molar enthalpy of combustion of propane (producing water vapour) is −2 043.9 kJ/mol.

$$\Delta_c H = n\,\Delta_c H_m$$

$$= \left(\frac{10\text{ g}}{44.11\text{ g/mol}}\right)(-2043.9\text{ kJ/mol})$$

$$= -463.36\ldots\text{ kJ} = \boxed{-463\text{ kJ}}$$