Energy

The capacity to do work
or to produce heat.

Law of Conservation of Energy

Energy can be converted from one form to another but can neither be created nor destroyed.

(E_{universe} is constant)

The Two Types of Energy

Potential: due to position or composition - can be converted to work

Kinetic: due to motion of the object

$$KE = {}^{1}/_{2}\, mv^2$$

(m = mass, v = velocity)

Temperature v. Heat

Temperature reflects random motions of particles, therefore related to kinetic energy of the system.

Heat involves a transfer of energy between 2 objects due to a temperature difference

State Function

Depends only on the present state of the system - not how it arrived there.

It is independent of pathway.

System and Surroundings

System: That on which we focus attention

Surroundings: Everything else in the universe

Universe = System + Surroundings

Exo and Endothermic

Heat exchange accompanies chemical reactions.

Exothermic: Heat flows **out** of the system (to the surroundings).

Endothermic: Heat flows **into** the system (from the surroundings).

First Law

First Law of Thermodynamics: The energy of the universe is constant.

First Law

$$\Delta E = q + w$$

ΔE = change in system's internal energy

q = heat

w = work

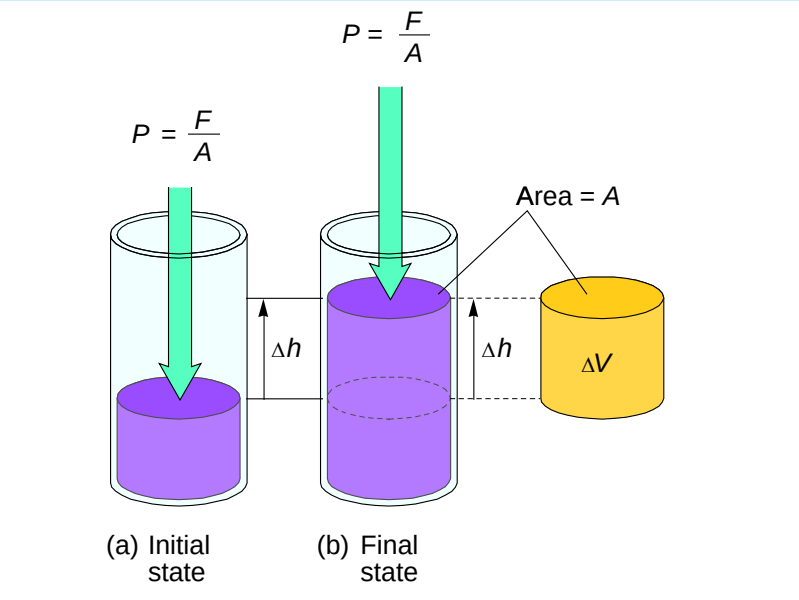
Work

work = force × distance

since pressure = force / area,

work = pressure × volume

$$w_{system} = -P\Delta V$$



a) The piston is moving a distance Δh against a pressure P, does the work on the surroundings

b) Since the volume of a cylinder is the area times its height, the change of volume of the gas is given by Δh x A = ΔV

Enthalpy

$$\text{Enthalpy} = H = E + PV$$

$$\Delta E = \Delta H - P\Delta V$$

$$\boldsymbol{\Delta H = \Delta E + P\Delta V}$$

At constant pressure,

$$\boldsymbol{q_P = \Delta E + P\Delta V},$$

where $q_P = \Delta H$ at constant pressure

ΔH = energy flow as heat (at constant pressure)

Heat Capacity

$$C = \frac{\text{heat absorbed}}{\text{increase in temperature}} = \frac{\text{J}}{^\circ\text{C}} \text{ or } \frac{\text{J}}{\text{K}}$$

Some Heat Exchange Terms

specific heat capacity

heat capacity per gram = J/°C g or J/K g

molar heat capacity

heat capacity per mole = J/°C mol or J/K mol

Hess's Law

Reactants $\rightarrow$ Products

The change in enthalpy is the same whether the reaction takes place in one step or a series of steps.

Calculations via Hess's Law

1. If a reaction is reversed, ΔH is also reversed.

$$N_2(g) + O_2(g) \rightarrow 2NO(g) \quad \Delta H = 180 \text{ kJ}$$

$$2NO(g) \rightarrow N_2(g) + O_2(g) \quad \Delta H = -180 \text{ kJ}$$

2. If the coefficients of a reaction are multiplied by an integer, ΔH is multiplied by that same integer.

$$6NO(g) \rightarrow 3N_2(g) + 3O_2(g) \quad \Delta H = -540 \text{ kJ}$$

Standard States

Compound

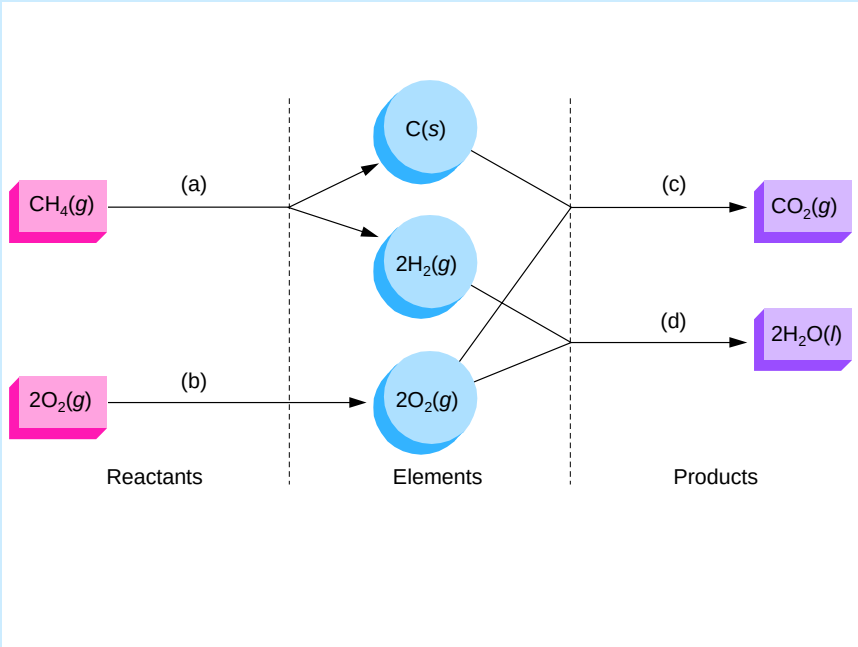
- For a gas, pressure is exactly 1 atmosphere.
- For a solution, concentration is exactly 1 molar.
- Pure substance (liquid or solid), it is the pure liquid or solid.

Element

- The form [$N_2(g)$, $K(s)$] in which it exists at 1 atm and 25°C.

Change in Enthalpy

Can be calculated from enthalpies of formation of reactants and products.



$$\Delta H_{rxn}^\circ = \Sigma n_p \Delta H_f^\circ(\text{products}) - \Sigma n_r \Delta H_f^\circ(\text{reactants})$$