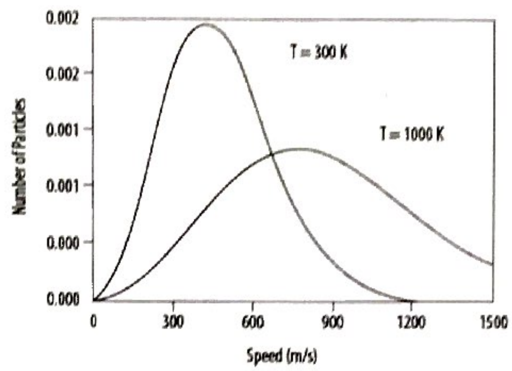
Totally Epic AP Chem Review: Thermochem Basics!

Thermochemistry: deals with the energy changes that occur during chemical reactions.

Temperature: measure of the average Kinetic energy of the particles of a substance

- → Temperature is an intensive property: amount of matter doesn't affect it!
- → The Kelvin temperature is directly proportional to the average kinetic energy. For example, doubling the Kelvin temperature doubles the average kinetic energy.
- → As absolute zero is approached (0 K), the particles approach zero kinetic energy.

A Maxwell-Boltzmann distribution shows how the particles at a high temperature have greater kinetic energies than those at a low temperature.



Capable of being

Thermal energy: internal energy of an object due to the Kinetic energy of its particles

Heat (q): amount of thermal energy transferred from one object to another

- → heat is an extensive property (depends on how much of a substance you have), unlike temperature.
- → Heat always flows from a warmer object to a cooler object.

In thermochemistry, the universe is divided into two ~~halves~~ parts:

a. the System: the substance of interest

b. the Surroundings: whatever is outside the system

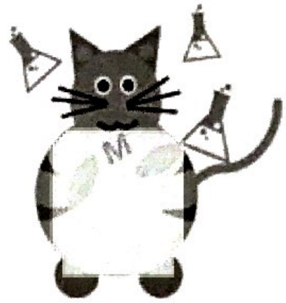
Specific Heat Capacity (C): amount of heat (energy) required to raise temperature of 1 g of a substance by 1 K (1°C)

- → Units are $\frac{J}{g\,°C}$ or $\frac{J}{g\,K}$
- → Metals have relatively low specific heats - relatively less energy is required to raise their temperatures.
- → Water has a relatively high specific heat - requires much more energy to achieve a similar temp change.

$$\text{Specific Heat Capacity } (C_p) = \frac{\text{quantity of heat supplied}}{\text{(mass of object)(temperature change)}}$$

Substance	Specific Heat (J/g · K)
Al	0.902
H_2O (l)	4.184
Glass	0.84

How to calculate heat transferred: **mCAT!**



$$q = mC\Delta T$$

q = heat transferred
m = mass of substance
c = specific heat capacity
$\Delta T = T_{final} - T_{initial}$ = change in temperature

ΔT Object	Sign of ΔT	Sign of *q*	Direction of Heat Transfer
Increase	+	+	Heat transferred into object
Decrease	–	–	Heat transferred out of object

Enthalpy Change (ΔH): amount of energy absorbed or released as heat by a system when the pressure is constant; measured in units of J/mol rxn = $\frac{J}{mol_{rxn}}$

per mol rxn

$$\Delta H_{rxn} = \frac{q}{mol_{rxn}}$$

- ➔ Enthalpy change can be applied to physical or chemical changes
- ➔ The magnitude of ~~enthalpy~~ heat change is directly proportional to the moles of reactants and products involved in the change, but NOT enthalpy!
- ➔ the sign of enthalpy change (+ or –) indicates direction of energy flow

Standard Enthalpy Change: (ΔH°): enthalpy changed measured at Standard conditions

- Thermochemistry standard conditions are NOT the same as gas laws STP
- Thermochemistry standard conditions are: 25°C and 1 atm

Enthalpy Changes of Different Types of Reactions

You will encounter a variety of Subscripts following the ΔH, however, they are simply indicating a Specific type of reaction or change of state.

Examples

ΔH°_{comb} = Enthalpy of Combustion (Heat Energy Released during Combustion Reactions)

ΔH°_{neut} = Enthalpy of Neutralization (Heat Energy Released during Acid-Base Neutralization Reactions)

ΔH°_{soln} = Enthalpy of Solution (Heat Energy Released/Absorbed Dissolving a Solute in Water)

ΔH°_{vap} = Enthalpy of Vaporization (Heat Energy Absorbed to Convert from Liquid to Gas Phase)

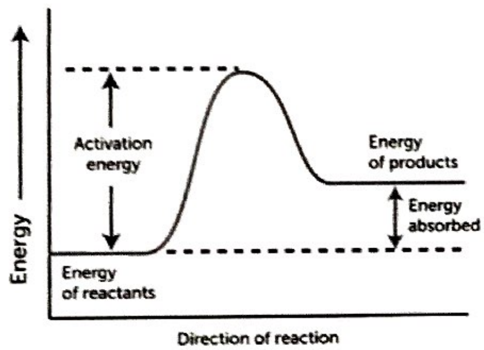
ΔH°_{fus} = Enthalpy of Fusion (Heat Energy Absorbed to Convert from Solid to Liquid Phase)

ΔH°_{f} = Enthalpy of Formation (Heat Energy Released during Formation of 1 Mole of a Substance)

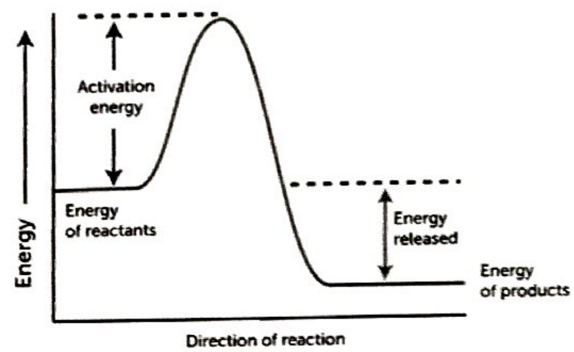
Two Thermochemical Reaction Types

Endothermic $+\Delta H$	Exothermic $-\Delta H$
Energy is absorbed (by system)	Energy is released (by system)
$+q/mol_{rxn} = +\Delta H_{rxn}$	$-q/mol_{rxn} = -\Delta H_{rxn}$
Break "end" bonds/IMFs	Form new bonds/attractions
Energy appears in reactants	Energy appears in products
The energy added (to a rxn) (for endo AND exo) will always be positive value!	

Endothermic Reaction



Exothermic Reaction



Thermochemical equation: chemical equation that includes the enthalpy change

Let's Try! Complete the chart below.

Equation with Separate ΔH°_{rxn}	Thermochemical Equation	Endo- or exothermic?
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ $\Delta H_{comb} = -890 \frac{kJ}{mol_{rxn}}$	$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O + 890\text{ kJ}$	exo
$H_2O(l) \rightarrow H_2O(g)$ $\Delta H_{vap} = 44\text{ kJ/mol}_{rxn}$	$44\text{ kJ} + H_2O_{(l)} \rightarrow H_2O_{(g)}$	endo
$2\,C_2H_6 + 7\,O_2 \rightarrow 4\,CO_2 + 6\,H_2O$ $\Delta H^\circ_{rxn} = -3120\text{ kJ/mol}_{rxn}$	↑	exo

$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O + 3120\text{ kJ}$

Energy Stoichiometry! 😊

Enthalpy is commonly measured in kJ/mol$_{rxn}$, but what is a mole of reaction?

$$1 \text{ mol}_{rxn} = 1 \text{ mole of reaction} = \text{stoichiometric \# of reactants/ products}$$

For the combustion of ethane: $2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$ + 3120 kJ

When 1 mole of reaction has occurred,

- 2 mol of C_2H_6 reacted
- 7 mol of O_2 reacted
- 4 mol of CO_2 were produced
- 6 mol of H_2O were produced
- 3120 kJ heat released!

Luckily for us, the enthalpy of a reaction, when measured in kJ/mol$_{rxn}$, can act as a conversion factor between the amount of chemicals which react and the energy that is absorbed or released by the reaction!

Example 1: Give the following reaction, $2\ Fe + 3\ CO_2 \rightarrow 3\ CO + Fe_2O_3$ ($\Delta H = +25$ kJ/mol$_{rxn}$) what energy change occurs when 6.00 moles of carbon dioxide react?

$$6.00 \text{ mol } CO_2 \times \frac{1 \text{ mol}_{rxn}}{3 \text{ mol } CO_2} \times \frac{25 \text{ kJ}}{1 \text{ mol}_{rxn}} = \boxed{50.0 \text{ kJ absorbed}}$$

Example 2: Give the following reaction, $N_2 + 3\ H_2 \rightarrow 2\ NH_3$ ($\Delta H = -324$ kJ/mol$_{rxn}$) what mass of hydrogen must have reacted if 525 kJ of heat energy were released?

$$-525 \text{ kJ} \times \frac{1 \text{ mol}_{rxn}}{-324 \text{ kJ}} \times \frac{3 \text{ mol } H_2}{1 \text{ mol}_{rxn}} \times \frac{2.016 \text{ g } H_2}{1 \text{ mol } H_2} = \boxed{9.80 \text{ g } H_2}$$

(↑ released)