Energy and Rates [Thermochemistry]

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SCH 4U1

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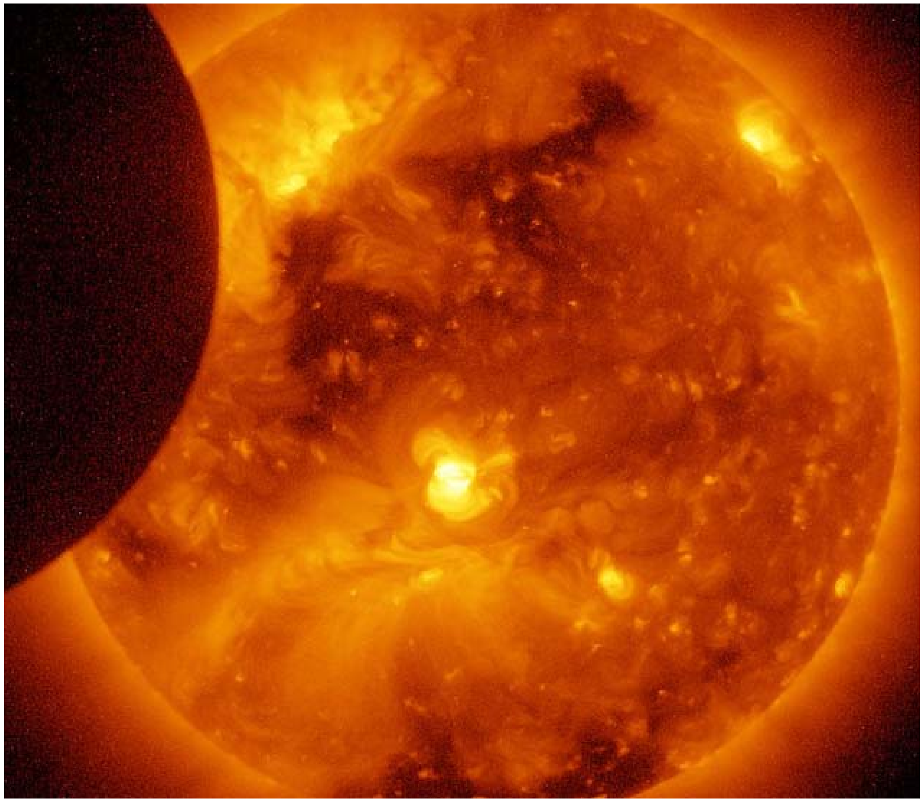
Chemistry = the study of matter and its transformations

Thermochemistry = the study of energy changes that accompany these transformations



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Let us take the example of a welding torch. Welding things together involves ethyne and oxygen as reactants.

-the products produced are carbon dioxide gas, water vapour, and energy.

kinetic energy resulting from motion of the molecules
-the end result is a physical change, the melting of metal

The chemical system – the substances undergoing change. –a set of reactants and products under study. –usually represented by a chemical equation.

The surroundings = the system's environment – capable of absorbing or releasing thermal energy.

- In our example, the system can be represented by the following chemical equation:

$C_2H_2(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g) + \text{energy}$

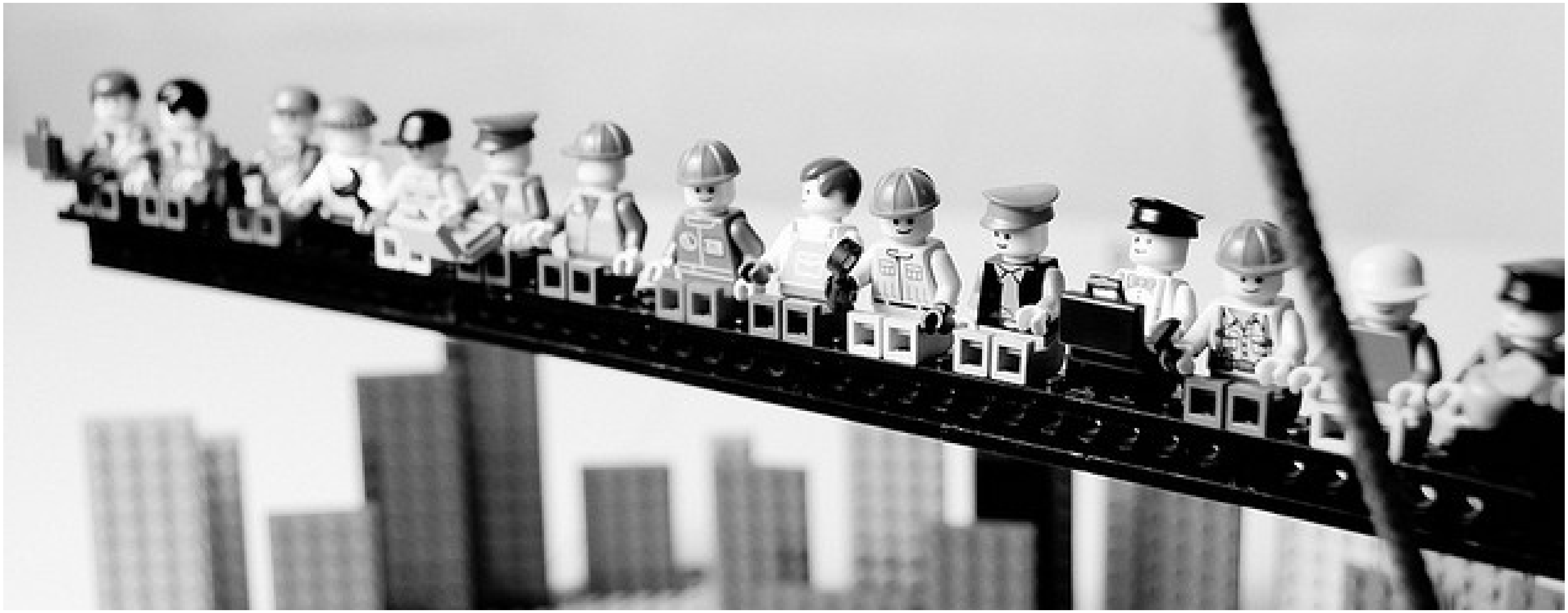
The surroundings = anything that could absorb the thermal energy that has been released, like metal parts, air, the welder’s clothing.

- When this reaction occurs, heat (q) is transferred between substances.

-an object can possess thermal energy but not heat. –it is the transfer

When heat transfers between a system and its surroundings, measurements of the temperature of the surroundings are used to classify the change as being **exothermic** or **endothermic**

- Temperature (T) is the average kinetic energy of particles in a sample of matter.



- In our example: the welding torch reaction is exothermic because heat flows to the surroundings.

Chemical Energy in system ⟶ heat energy ⟶ Surroundings

Metal and Air

Chemical systems may be open or closed.

Open – matter and energy can flow into or out of the system

Closed – an ideal system in which neither matter nor energy can move in or out.

Heat Content (H) = the heat content of a substance, it refers to how much energy is stored in the substance.

Also known as **enthalpy**.

Chemical systems have different forms of energy, both kinetic and potential.

i.e. Moving electrons within atoms, vibrations of molecules, potential energy of molecules connected by bonds.

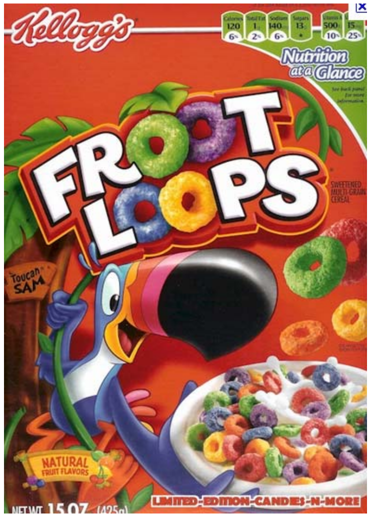
Units

We will be using two different types of units for heat content.

1. calorie (cal), kilocalorie (kcal)

One calorie is the quantity of heat required to raise the temperature of 1 gram of liquid water 1°C. –that is a a small quantity of heat so we often use kcal = 1000 calories.

The more widely known Calorie is with a big C, and it actually equals 1000 calories. So 500 Calories is 500 kcal or 500×10^3 calories



2. joule (J), kilojoule (kJ)

- The joule is the energy required to exert a force of 1 Newton for 1 metre.
- Therefore 1 Joule = 1 N•m = 1 kg•m^2/s^2

…if a 2 kg object is moving at a velocity of 1.0 m/s the kinetic energy is

Kinetic energy **= 1/2 mv2 = 1/2 (2.0 kg) (1.0 m/s)2**
=1.0 kg x m2 / s2 = 1.0 joule

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Converting

- When converting from one type of unit to the other, use the following relationships:
- 1 cal = 4.18 J   or   1 kcal = 4.18 kJ

If you drop a six-pack of soft drinks on your foot, the kinetic energy of impact is about 1-2 calories, = 4-10 joules.

Heat of Reaction (ΔH): The heat of reaction refers to how much energy is released or absorbed when a reaction occurs. Heat of reaction is also referred to as change in heat content or enthalpy change

$$\Delta H = H(\text{products}) - H(\text{reactants})$$

Types of Enthalpy Change

Physical Change

-energy used to overcome intermolecular forces

-highest

Chemical Change

-Energy changes overcome electronic structure and chemical bonds within the particles

-medium

Nuclear Change

-Energy changes overcome the forces between protons and neutrons in nuclei

-lowest

When methane reacts with oxygen in a bunsen burner, enough heat is transferred to the surroundings to increase the temperature and even cause a change of state.

We use calorimetry to measure energy changes in a system.

-it depends on careful measurements of mass changes and temperature changes.

- Mass, temperature change, and type of substance are combined to represent the quantity of heat (q) transferred:

$$q = mc\,\Delta T$$

c = specific heat capacity = the quantity of heat required to raise the temperature of a unit mass of a substance 1 C or 1 K

See Table 1 of textbook pg 301

When 600 ml of water in an electric kettle is heated from 20 C to 85 C to make a cup of tea, how much heat flows into the water?

First we need to find the mass of the water.

m = dV = 1.00 g/ml x 600 ml

= 600 g

Now use our formula:

q = ? **m** = 600 g **c** = 4.18 J(gxC) **ΔT** = 85C-20C=65C

What would be the final temperature if 250.0 J of heat were transferred into 10.0 g of methanol initially at 20 C?

Given:

Molar Enthalpies

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

-above is a thermochemical equation

-combustion of 1 mol of hydrogen with 0.5 mol of oxygen to form 1 mol of water vapour.

The enthalpy change per mole of a substance is called the molar enthalpy

Molar Enthalpy

Molar enthalpy is represented by the symbol ΔHx where x is the letter or combination of letters to indicate the type of change happening.

$$\Delta H_{comb} = -241.8 \text{ kJ/mol}$$

This represents the molar enthalpy of combustion of hydrogen.

<u>Types of Reactions</u>: Reactions may be classified as <u>endothermic</u> or <u>exothermic</u>.

a) An **endothermic reaction** is one in which energy is absorbed.

eg. $C (s) + H_2O(g) + 131 kJ \longrightarrow CO(g) + H_2(g)$

With this type of reaction, H (products) > H(reactants). Thus, ΔH is always positive for an endothermic reaction. The above reaction may also be written in ΔH notation as:

eg. $C (s) + H_2O(g) \longrightarrow CO(g) + H_2(g) \qquad \Delta H = +131 kJ/mol$

b) An **exothermic reaction** is one in which energy is released.

eg. $CO(g) + \frac{1}{2} O_2(g) \longrightarrow CO_2(g) + 393 kJ$

With this type of reaction, H(products) < H(reactants). Thus, ΔH is always negative for an exothermic reaction. The above reaction may also be written in ΔH notation, as :

eg. $CO(g) + \frac{1}{2} O_2(g) \longrightarrow CO_2(g) \qquad \Delta H = - 393 kJ/mol$

Notice that the ΔH term is negative since this is an exothermic reaction.

Table 1 Some Molar Enthalpies of Reaction (ΔH_x)

Type of molar enthalpy	Example of change
solution (ΔH_{sol})	$NaBr_{(s)} \rightarrow Na^+_{(aq)} + Br^-_{(aq)}$
combustion (ΔH_{comb})	$CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$
vaporization (ΔH_{vap})	$CH_3OH_{(l)} \rightarrow CH_3OH_{(g)}$
freezing (ΔH_{fr})	$H_2O_{(l)} \rightarrow H_2O_{(s)}$
neutralization (ΔH_{neut})*	$2\ NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow 2\ Na_2SO_{4(aq)} + 2\ H_2O_{(l)}$
neutralization (ΔH_{neut})*	$NaOH_{(aq)} + 1/2\ H_2SO_{4(aq)} \rightarrow 1/2\ Na_2SO_{4(aq)} + H_2O_{(l)}$
formation (ΔH_f)**	$C_{(s)} + 2\ H_{2(g)} + 1/2\ O_{2(g)} \rightarrow CH_3OH_{(l)}$

* Enthalpy of neutralization can be expressed per mole of either base or acid consumed.

** Molar enthalpy of formation will be discussed in more detail in Section 5.5.

Molar Enthalpy

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We can express the molar enthalpy of a physical change like this:

$$H_2O_{(l)} + 40.8\ kJ \rightarrow H_2O_{(g)}$$

The ΔH_{vap} = *40.8 kJ/mol*

Molar enthalpies for changes in state of selected substances

Chemical Name	Formula	Molar enthalpy of fusion (kJ/mol)	Molar enthalpy of vaporization (kJ/mol)
sodium	Na	2.6	101
chlorine	Cl_2	6.40	20.4
sodium chloride	NaCl	28	171
water	H_2O	6.03	40.8
ammonia	NH_3	–	1.37
freon-12	CCl_2F_2	–	34.99
methanol	CH_3OH	–	39.23
ethylene glycol	$C_2H_4(OH)_2$	–	58.8

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

Duh.

Twice the mass of ice will require twice the amount of energy to melt.

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

What amount of ethylene glycol would vaporize while absorbing 200.0 kJ of heat?