

Unit 11 Thermochemistry

Energy - measure of the ability to cause change to occur, i.e. work.

Units of energy:

Joule (J) = newton x meter or $J = N \times m$

Types of Energy - five main forms of energy:

Mechanical (Kinetic and Potential)

Chemical

Electromagnetic

Heat (Thermal)

Nuclear

Kinetic energy - energy of motion; depends on both mass and velocity; the faster an object moves, the greater the kinetic energy

Potential Energy- amount of energy that is stored.

3 types **Elastic** e.g. pulling a rubber band back and holding

Chemical e.g. burning a match

Gravitational e.g. boulder resting on top of a hill

Chemical energy - energy stored in the bonds of atoms and molecules

Electromagnetic Energy- a form of energy that is reflected or emitted from objects in the form of electrical and magnetic waves that can travel through space; moving electric charges.

Thermal Energy- internal energy or thermal energy of a substance is determined by the movement of the molecules and the potential energy of the arrangement of molecules.

Temperature - measure of the average kinetic energy of the molecules.

Heat (q) - energy transferred from a warmer substance to a colder one by the collisions of molecules.

Units of Thermal Energy: joule (J) or calorie (c).

calorie - amount of heat needed to raise 1 g of a substance 1 degree Celsius.

Calorie (food calorie, with a capital C) is 1000 cal (1 kcal)

1 cal = 4.18 joules or 1 kcal = 4180 J

$$\text{specific heat capacity} = \frac{q}{m \times \Delta T} = \frac{\text{heat (joules or calories)}}{\text{mass (g) x change in } T^{\circ}\text{C}}$$

(c_p)

Nuclear Energy -when the nucleus of an atom splits, nuclear energy is released. Nuclear energy is the most concentrated form of energy.

Law of Conservation of Energy- energy can be converted from one form to another, but it can neither be created nor destroyed.

Heat Energy - if a substance gets hotter, then something else must get colder.

$$\text{heat}_{\text{lost}} = \text{heat}_{\text{gained}}$$

Temperature measures the average kinetic energy of the particles in a sample of matter:

$$\text{Kinetic Energy} = \frac{1}{2} mv^2$$

Methods of Energy Transfer

Energy transfer as heat can occur in 3 ways:

Conduction- transfer of energy as heat between particles as they collide with a substance or between 2 objects in contact.

Convection- transfer of energy by the movement of fluid with different temperature. **Convection current** - cycle of a heated fluid that rises and then cools and falls.

Radiation- transfer of energy by electromagnetic waves. This energy transfer does not need any matter since it travels in waves.

Thermochemical Equation - balanced, stoichiometric chemical equation that includes the enthalpy change, ΔH

Enthalpy (ΔH) - transfer of energy in a reaction; change in heat.

$$\Delta H = H_{\text{products}} - H_{\text{reactants}}$$

$$H_{\text{products}} < H_{\text{reactants}}, \Delta H \text{ is negative}$$

$$H_{\text{products}} > H_{\text{reactants}}, \Delta H \text{ is positive}$$

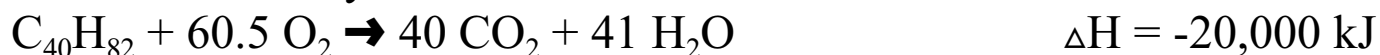
Writing Thermochemical Equations

For example, Burning one mole of wax releases 20,000 kJ of heat energy.

This could be written as:



Instead we usually write:

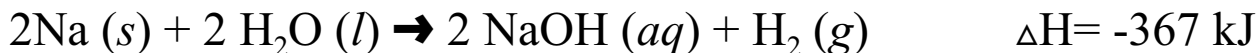


Example 1

Reacting 2 moles of solid sodium with 2 moles of water to produce 2 mole of aqueous sodium hydroxide and 1 mole of hydrogen gas will release 367 kJ of energy.



or



Example 2

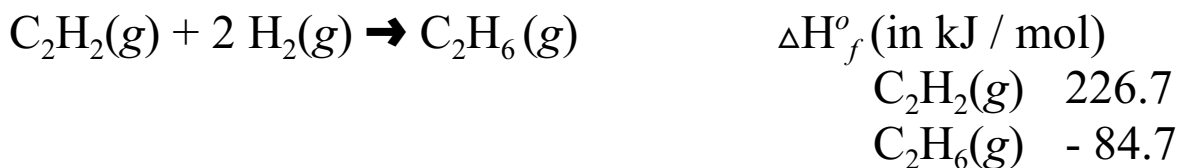
184.6 kJ of energy is needed to produce 1 mole of hydrogen gas and 1 mole of chlorine gas from 2 moles of hydrogen chloride gas.



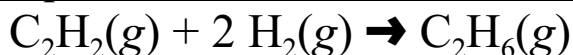
or



How to write Thermochemical equations using Standard Heat of Formations



Write the equation for the heat of formation of $\text{C}_2\text{H}_6(g)$



1 mol of $\text{C}_2\text{H}_2(g)$ and 1 mol $\text{C}_2\text{H}_6(g)$

And

$$\Delta\text{H}_{\text{rxn}}^\circ = [\Delta\text{H}_f^\circ \text{ products}] - [\Delta\text{H}_f^\circ \text{ reactants}]$$

$$\Delta\text{H}_{\text{rxn}}^\circ = [\text{C}_2\text{H}_6(g)] - [\text{C}_2\text{H}_2(g)]$$

Therefore

$$\Delta H_{\text{rxn}}^{\circ} = [-84.7 \text{ kJ/mol}] - [226.7 \text{ kJ/mol}] = -331.4 \text{ kJ/mol}$$

Endothermic/ Exothermic equations

Exothermic reactions release heat from the system to the surroundings so the temperature will rise.

ΔH° will be **negative** because the reaction loses heat.

ΔH° can be written into the chemical equation as a **product**.

Endothermic reactions absorb heat from the surroundings into the system so the temperature will decrease.

ΔH° will be **positive** because the reaction absorbs heat.

ΔH° can be written into the chemical equation as a **reactant**.

Example 3

How much energy does it take to raise the temperature of 50 g of aluminum ($c_p = 0.9025 \text{ J/g}^{\circ}\text{C}$) by 10°C ?

Using $Q = m \times c_p \times (T_f - T_i)$

$$Q = (50\text{g}) (0.9025 \text{ J/g}^{\circ}\text{C}) (10^{\circ}\text{C})$$

$$Q = 451.3 \text{ J}$$

Example 4

If we add 30 J of heat to lead ($c_p = 0.1276 \text{ J/g}^{\circ}\text{C}$) with a mass of 10 g, how much will its temperature increase?

Using $Q = m \times c_p \times \Delta T$

$$30\text{J} = (10\text{g}) (0.1276 \text{ J/g}^{\circ}\text{C}) (\Delta T)$$

$$23.5^{\circ}\text{C} = \Delta T$$

Calorimetry - science of measuring the heat of chemical reactions or physical changes. To do calorimetry, heat of combustion and mass must be given OR during a calorimetry procedure, the heat released during a chemical or physical change is transferred to another substance, such as water, which undergoes a temperature change.

Example 5

Propane is a commonly used fuel. 1 mol of C_3H_8 releases 2,220 kJ of heat during combustion. The molar mass of C_3H_8 is 44.1 g/mol. How much heat is released if a firework contains 67.8 g of C_3H_8 ?

1st step: convert grams C_3H_8 to moles C_3H_8

$$67.8 \text{ g C}_3\text{H}_8 \quad 1 \text{ mol C}_3\text{H}_8 \\ \times \frac{\text{-----}}{44.1 \text{ g C}_3\text{H}_8} = 1.54 \text{ mol C}_3\text{H}_8$$

2nd step: use the heat of combustion of propane to calculate energy (heat) released

$$1.53 \text{ mol C}_3\text{H}_8 \quad 2,220 \text{ kJ} \\ \times \frac{\text{-----}}{1 \text{ mol}} = 3413.06 \text{ kJ} \quad \therefore >3410 \text{ kJ released}$$

For heat transferred to another object, the equation is: $-Q_1 = Q_2$
One will be losing energy ($-Q_1$), the other will be gaining energy (Q_2).

Example 6

175 grams of hot aluminum (100°C) is dropped into an insulated cup that contains 40.0 mL of ice cold water (0°C). Determine the final temperature, T_f .

1st set up expressions for energy released and energy absorbed.

$$\begin{array}{ll} -Q_1 = - (175 \text{ g}) (0.900 \text{ J/g}^\circ\text{C}) (T_f - 100^\circ\text{C}) & \text{for aluminum} \\ Q_2 = (40.0 \text{ g}) (4.184 \text{ J/g}^\circ\text{C}) (T_f - 0.0^\circ\text{C}) & \text{for cold water} \end{array}$$

2nd put the expressions together, i.e. $-Q_1 = Q_2$

$$- (175 \text{ g}) (0.900 \text{ J/g}^\circ\text{C}) (T_f - 100^\circ\text{C}) = (40.0 \text{ g}) (4.184 \text{ J/g}^\circ\text{C}) (T_f - 0^\circ\text{C})$$

3rd solve for T_f

$$- 157.5 (T_f - 100^\circ\text{C}) = 167.4 (T_f - 0.0^\circ\text{C})$$

$$- 157.5 T_f + 15750^\circ\text{C} = 167.4 T_f$$

$$15750^\circ\text{C} = 324.9 T_f \quad \therefore T_f = 48.5^\circ\text{C}$$