Chapter 7: Electronic Structure of the Atom

October 13, 2022

Chemistry Department, Cypress College

Class Annoucements

Lab

- Experiment 12 - Single Displacement Reactions
- Recall indications for chemical reaction (color, solids, temp, etc.)
- Reminder - Need 70% of laborator points to pass the course

Lecture

- Finally graded homework 3 and go over homework 5 (EC for students who present)
- Finish up Ch 6 and worksheet 7; begin discussion on Ch 7 - Electronic Structure of the Atom
- Quiz and Homework assignment released Fri, Oct 14th at 3pm

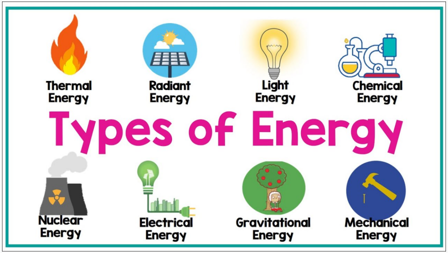
Outline

Review: Energy Changes

Electromagnetic Radiation and Energy

Bohr Model of the H Atom

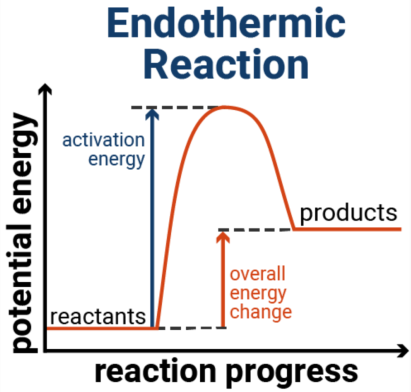
Law of Conservation of Energy



Energy is neither created nor destroyed

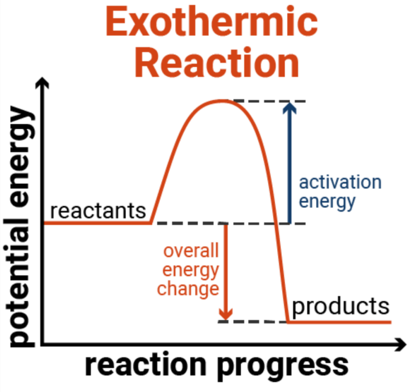
- Energy can be converted from form to another e.g. mechanical, chemical, thermal, nuclear, electrical and vibrational energy
- Converting from one energy form to another is never 100% efficient; there is always a loss of energy measured in Joules (J)

Endothermic Reaction Diagram



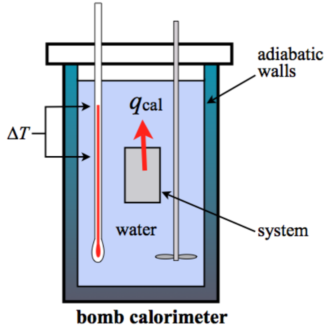
- **Recall Potential energy** - ability to do work; $\Delta E_{\text{products}} > \Delta E_{\text{reactants}}$
- **Activation energy** - minimum energy to start the reaction; determines the rate at which the reaction undergoes

Exothermic Reaction Diagram



- **Potential energy** - $\Delta E_{\text{products}} < \Delta E_{\text{reactants}}$
- Products are more stable than reactants since preference for lower energy state

Calorimetry

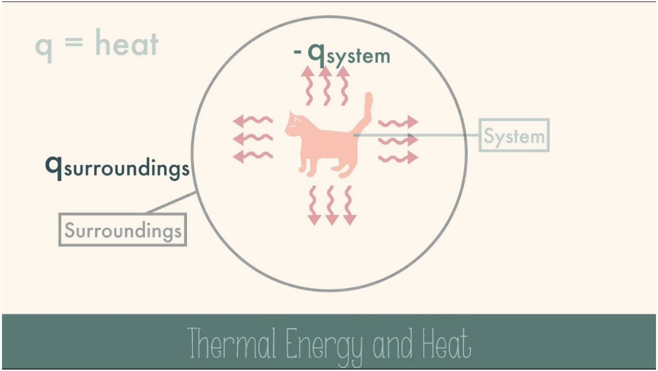


$$q = mC\Delta T \tag{1}$$

where q is heat, m is the mass (g), C is specific heat capacity (J/(°C g)) and T is temperature (°C)

- Performed at constant-pressure (atomospheric pressure)
- Bomb Calorimeter is Insulated where the heat evolved by the reaction is absorbed by the water
- **Specific Heat Capacity** - the amount of heat (q) required to heat an object 1°C/g

Relating Conservation of Energy

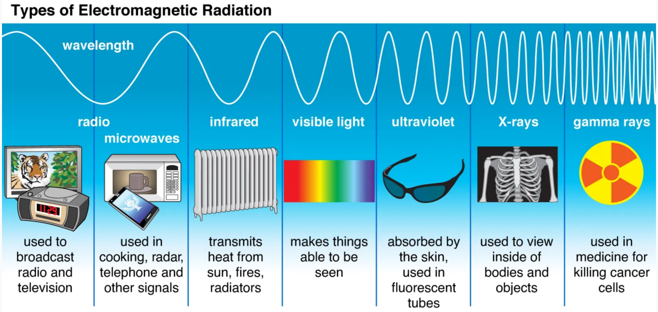


$q_{\text{system}} + q_{\text{surrounding}} = 0$ where q is the heat

Negative sign indicate released heat and positive sign indicates absorbed heat

Outline

Electromagnetic Radiation

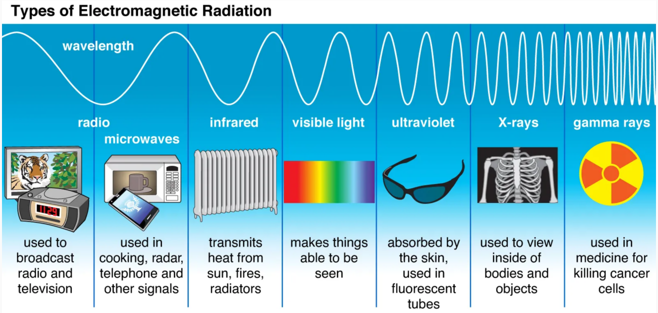


- Different types of radiation that are a form of energy

$$E = \frac{hc}{\lambda} = h\nu \tag{2}$$

where λ is the wavelength (m), c is the speed of light (3.00×10^{8} m/s), h is the Planck constant (6.626×10^{-34} J s) and E is energy (J)

Electromagnetic Radiation

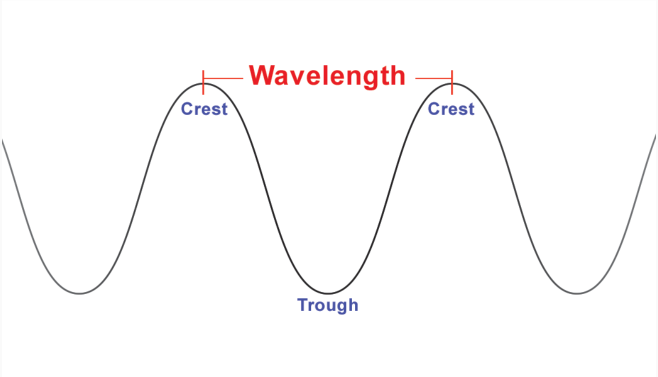


Relationship of speed of light (c) to frequency in $1/s$ or Hz (ν) and wavelength in m (λ)

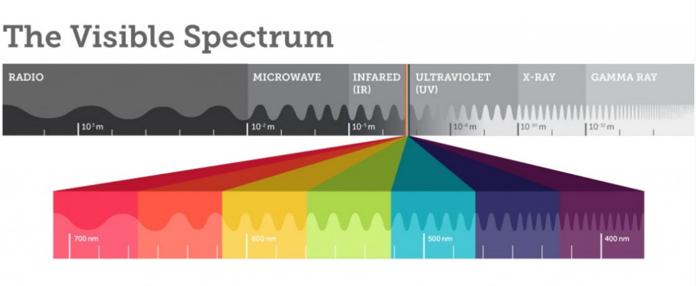
$$c = \nu\lambda \tag{3}$$

Speed of light is 3.00×10^8 m/s

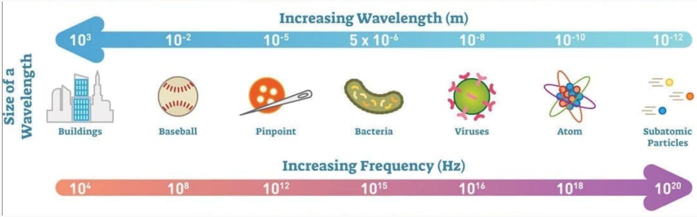
What is a wavelength and frequency?



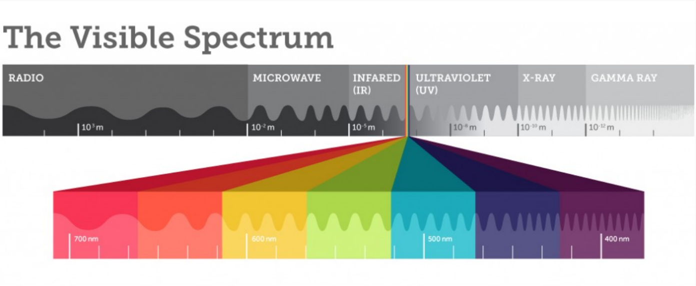
Relating to Visible Light



Visible light range from 700nm to 400nm; ROYGBV



Revisit: Radiation Energy



$$E = \frac{hc}{\lambda} = h\nu \quad (4)$$

- High frequency and larger wavelengths lead to higher radiation energy
- Energy are contained in packages known as photons; Eqn 4 computes the energy for 1 photon

Practice: Sunlight Energy

The sun emits a wide range of electromagnetic radiation including visible, infrared, and ultraviolet light.

a) Which type of light has the longest wavelength: visible, infrared, or ultraviolet?

b) Which has the highest frequency?

c) Which is composed of the highest-energy photons

Example: Calculating λ, ν, and E

Infrared light emitted from a TV remote control or from a wireless computer mouse has a wavelength of 805nm.

a) What is the frequency of the light?

b) What is the energy of its photons?

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a)

$$\nu\lambda = c$$

$$\nu = \frac{c}{\lambda} = \frac{3.00 \times 10^{8}\text{m/s}}{8.05 \times 10^{-7}\text{m}} = 3.73 \times 10^{14}\text{Hz}$$

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$$\begin{aligned} \nu\lambda =& c \\ \nu =& \frac{c}{\lambda} = \frac{3.00 \times 10^{8}\mathrm{m/s}}{8.05 \times 10^{-7}\mathrm{m}} = 3.73 \times 10^{14}\mathrm{Hz} \end{aligned}$$

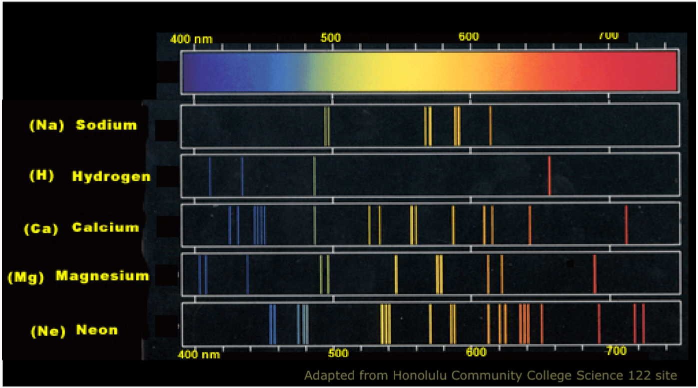
b)

$$\begin{aligned} E =& h\nu = 6.626 \times 10^{-34}\mathrm{J\ s} \times 3.73 \times 10^{14}\mathrm{Hz} \\ =& 2.47 \times 10^{-19}\mathrm{J} \end{aligned}$$

Practice: TV Remote

If a 60-mW TV remote emits a total energy of light of 6.0×10^4 J/s with photon energy of 2.47×10^{-19} J/photon, what is the best estimate of the number of photons emitted from the TV remote in 1 second: 100 photons and 10^{23} photons.

Atomic Spectra



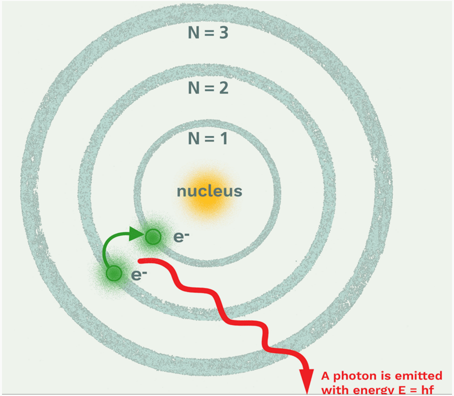
- Continuous spectra is given at the top and discrete lines are emitted by atoms
- **Q:** Why are there discrete lines for the atomic spectra?

Outline

Bohr Model

- Energy is quantized
- Electrons orbit the nucleus in orbits that have a set size and energy
- The energy of the orbit is related to its size; the lowest energy is found in the smallest orbit
- Radiation is absorbed or emitted when an electron moves from one orbit to another

Bohr Model of the H Atom



$$\Delta E = E_{\text{final}} - E_{\text{initial}} \tag{5}$$

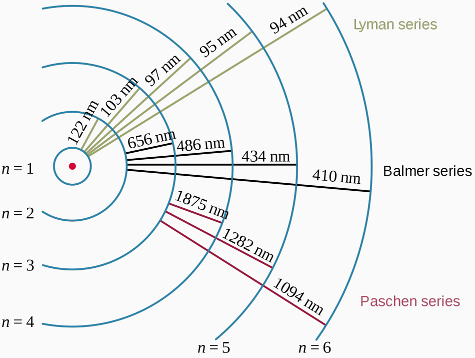
Note: Keep in mind of sign conventions ($\Delta E > 0$ and $\Delta E < 0$)

Limitation of the Bohr Model

- Violates the Heisenberg Uncertainty Principle
- Poor predictions regarding the spectra of larger atoms
- Does not predict the relative intensities of spectral lines

Example: H atom spectra

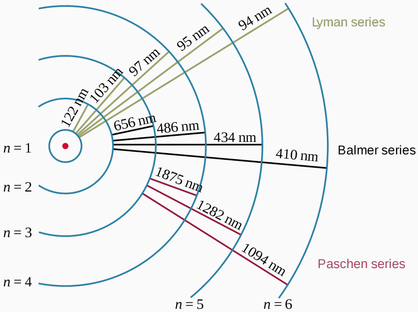
Use the Bohr model of the hydrogen atom and the hydrogen line spectrum to answer the following. What is the photon energy that produces the transition between $n = 2$ and $n = 4$? Which transition from the figure has the highest transition energy?



$$\frac{1}{\lambda} = -R_H\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) \tag{6}$$

where λ is the wavelength, R_H is Rydberg constant (1.09×10^7 m^{-1}) and n is the orbit state

Note: Only applicable to hydrogen-like atoms



Practice: Using the Rydberg Equation

Use the Rydberg formula to predict which electronic transition in a hydrogen atom has the longest wave length: from $n = 2$ to $n = 1$, from $n = 3$ to $n = 2$, or form $n = 4$ to $n = 3$.