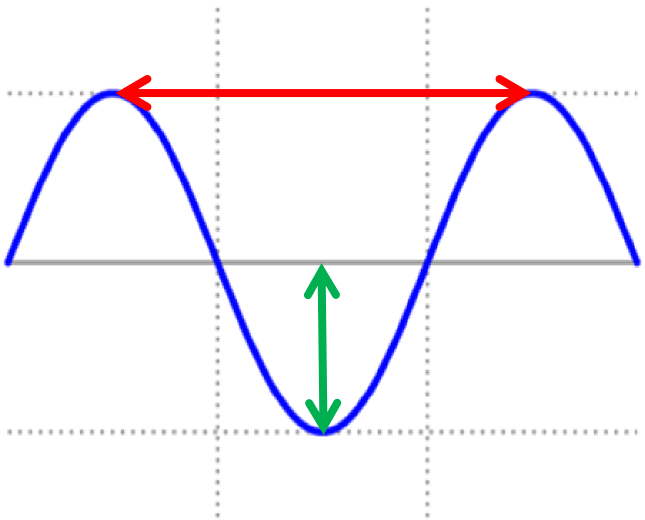
Chapter 6 Part 1

Dr. Turner

Electromagnetic waves

- The green line indicates the amplitude
- The distance between two adjacent crests or troughs is a wavelength and is indicated by the red line
- A period is the amount of time that it takes for the wave to travel one wavelength
- The number of periods that occurs per second is the frequency



Electromagnetic waves and light

- Electromagnetic radiation is light
- The wavelength and frequency of waves are related by the speed of light

$$c = \lambda\nu$$

- c is the speed of light in a vacuum and is equal to $2.998 \times 10^{8} \frac{\mathrm{m}}{\mathrm{s}}$
- λ is the wavelength (in m)
- ν is the frequency (in s^{-1})

Electromagnetic waves

What wavelength of electromagnetic radiation corresponds to a frequency of $3.45 \times 10^{13}\ s^{-1}$?

A. 8.69×10^{-6} m
B. 1.15×10^{5} m
C. 7.65×10^{-29} m
D. 9.10×10^{-6} m
E. 8.99×10^{-6} m

Photons

- Due to the wave-particle duality, light waves may also be expressed as photons.
- The energy of a photon may be expressed as

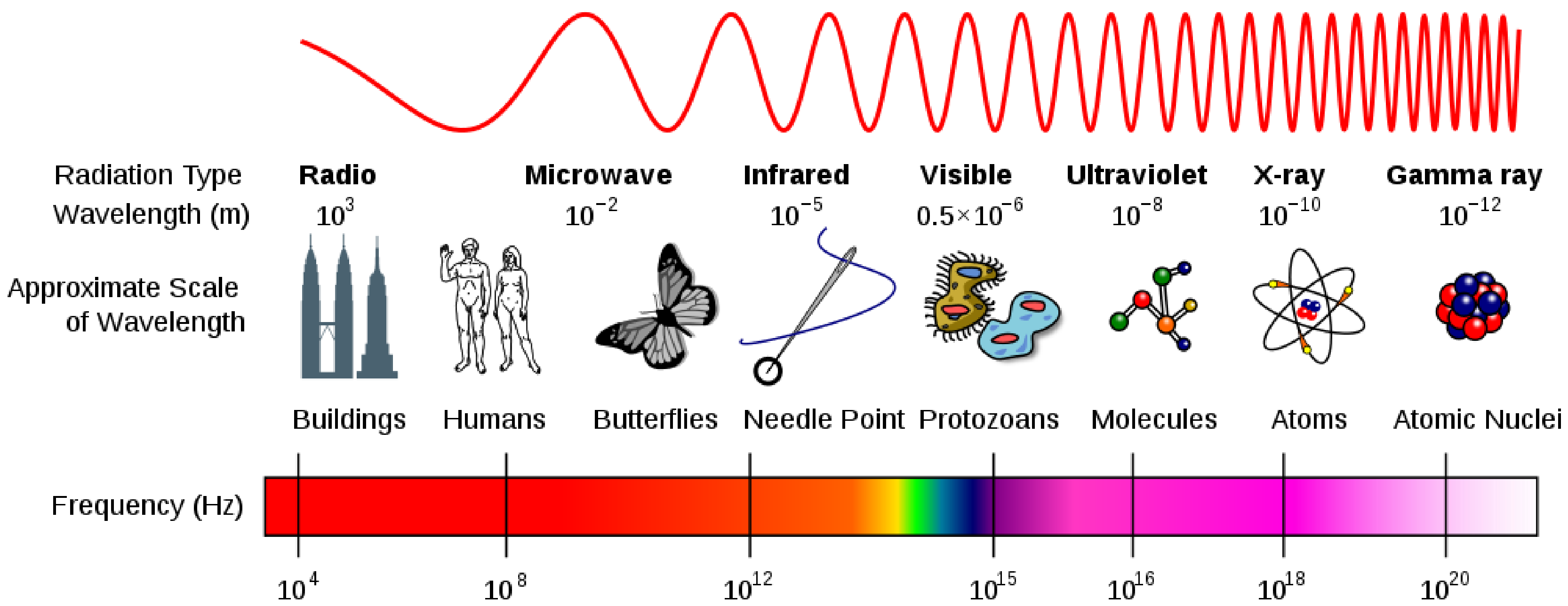
$$E = h\nu = \frac{hc}{\lambda}$$

- E is the energy of the photon in joules
- h is Planck's constant, 6.626×10^{-34} Js
- The energy of a photon is related to its frequency

Photons

A lamp releases a photon with a wavelength of 535 nm. Calculate the energy of this photon.

Electromagnetic spectrum



Electromagnetic waves

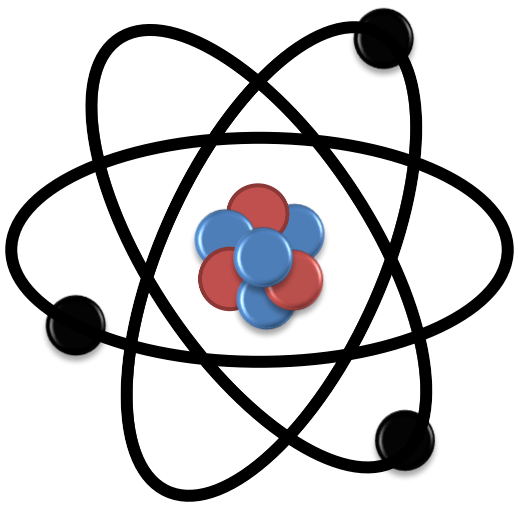
Which of the following statements is (are) true?

I. The product of wavelength and frequency of light is a constant
II. As the energy of electromagnetic radiation increases, its frequency decreases
III. As the wavelength of light increases, its frequency increases

A. I only
B. II only
C. III only
D. I and III only
E. II and III only

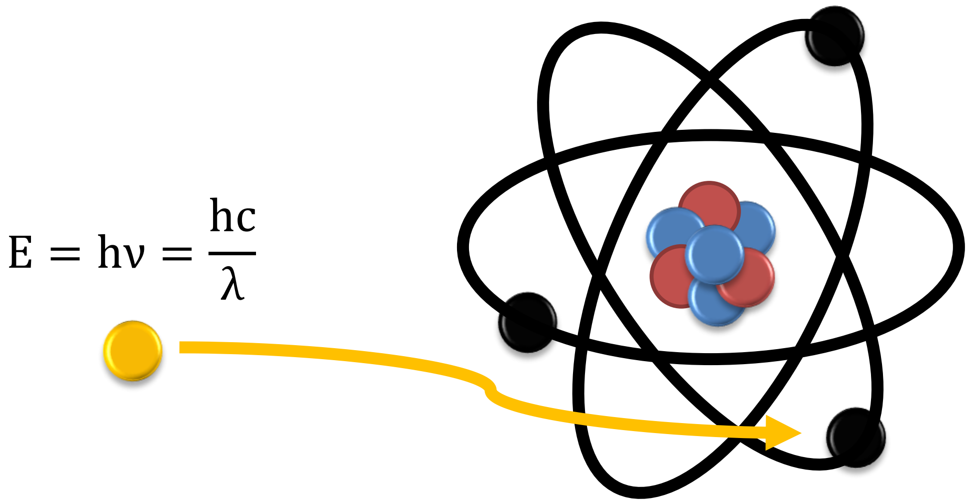
The photoelectric effect

- The photoelectric effect is exhibited when light is shone on a substance, and electrons are ejected from the surface of the substance. This occurs if the photon has enough energy to knock the electron out of orbit.
- This discovery is what won Albert Einstein a Nobel Prize



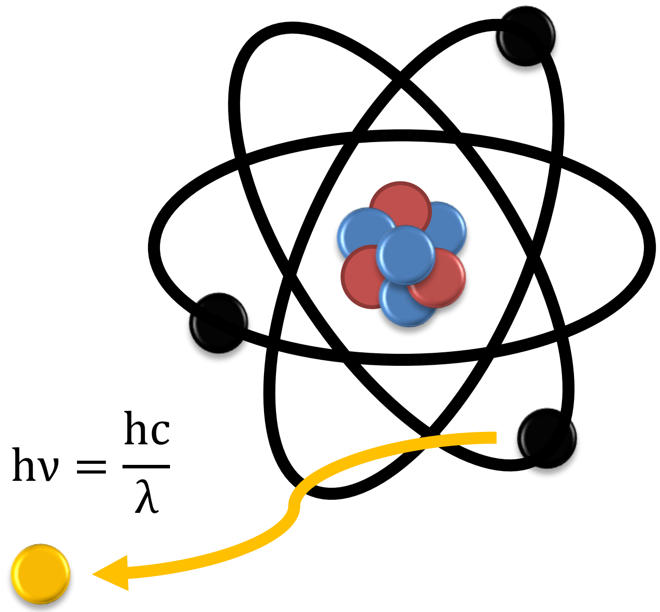
The photoelectric effect

- The incoming photon has an energy of $E = h\nu = \frac{hc}{\lambda}$



The photoelectric effect

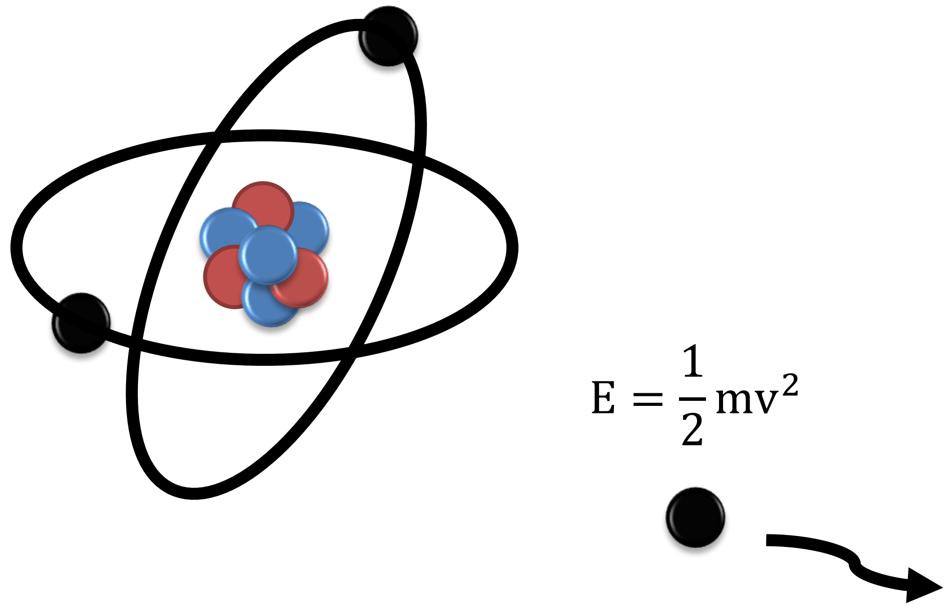
- If the photon doesn't have enough energy to knock the electron out of orbit, the photon is reflected with the same energy that it had before



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

The photoelectric effect

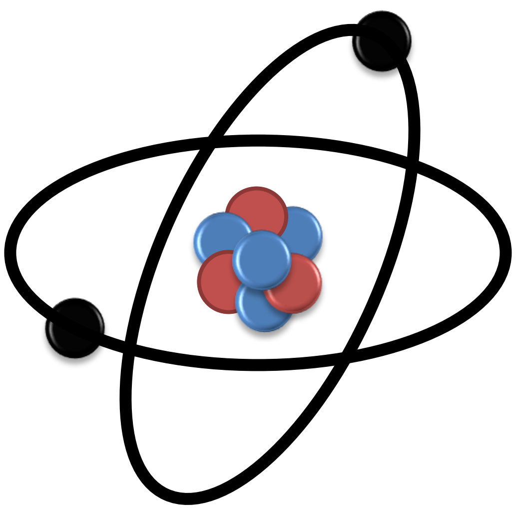
- If the photon ($E_{photon} = h\nu = \frac{hc}{\lambda}$) has more than enough energy to knock the electron out of orbit, the energy required to knock the electron out of the orbit is lost, and all of the remaining energy from the photon is transferred to the electron as kinetic energy ($KE_{electron} = \frac{1}{2}mv^2$).



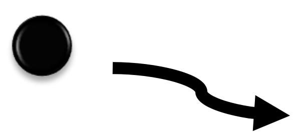
The photoelectric effect

Thus,

$$E_{photon} = \Phi + KE_{electron}$$



$$KE = \frac{1}{2}mv^2$$



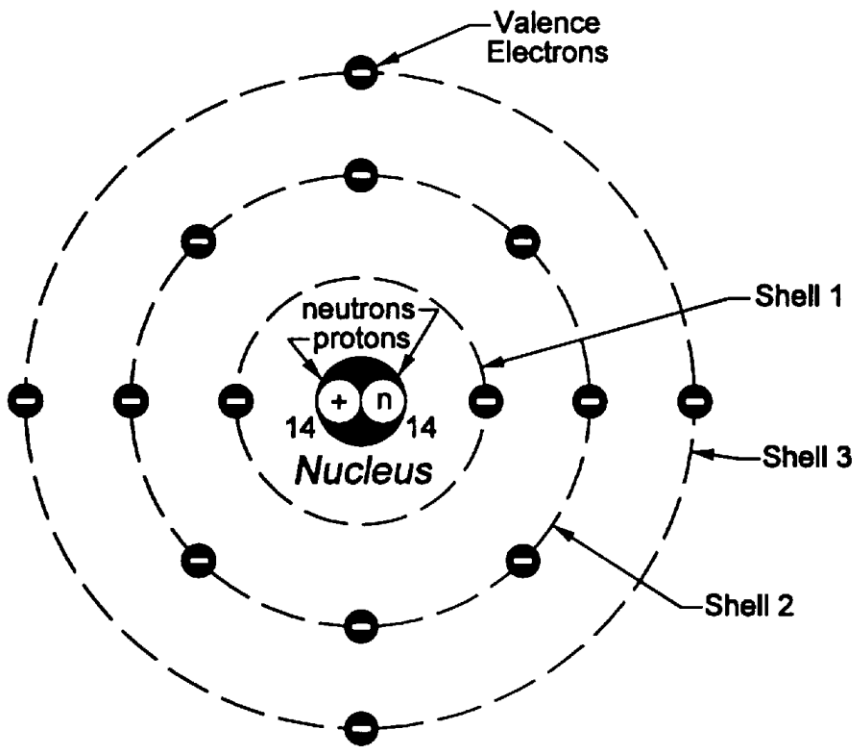
The minimum energy necessary to remove an electron from the atom is called the work function, Φ

The photoelectric effect

Light with a wavelength of 425 nm fell on a potassium surface, and electrons were ejected at a speed of $4.88 \times 10^5 \, \frac{\text{m}}{\text{s}}$. If the formula for kinetic energy is $\text{KE} = \frac{1}{2}\text{mv}^2$ and the mass of an electron is 9.109×10^{-31} kg, what energy was expended in removing an electron from the metal?

The Bohr model

- The principle quantum number (n) denotes energy level in the Bohr model
- The lowest energy configuration of an atom or molecule is called its ground state
- When an electron is excited to a higher energy level (n quantum number), this is called an excited state



The Bohr model

- Energy in the Bohr model is expressed as

$$E_{e^-} = -2.179 \times 10^{-18} \mathrm{J} \left(\frac{1}{n^2} \right)$$

- Accordingly, the energy change of an atom resulting from the transition between two different energy levels is expressed as

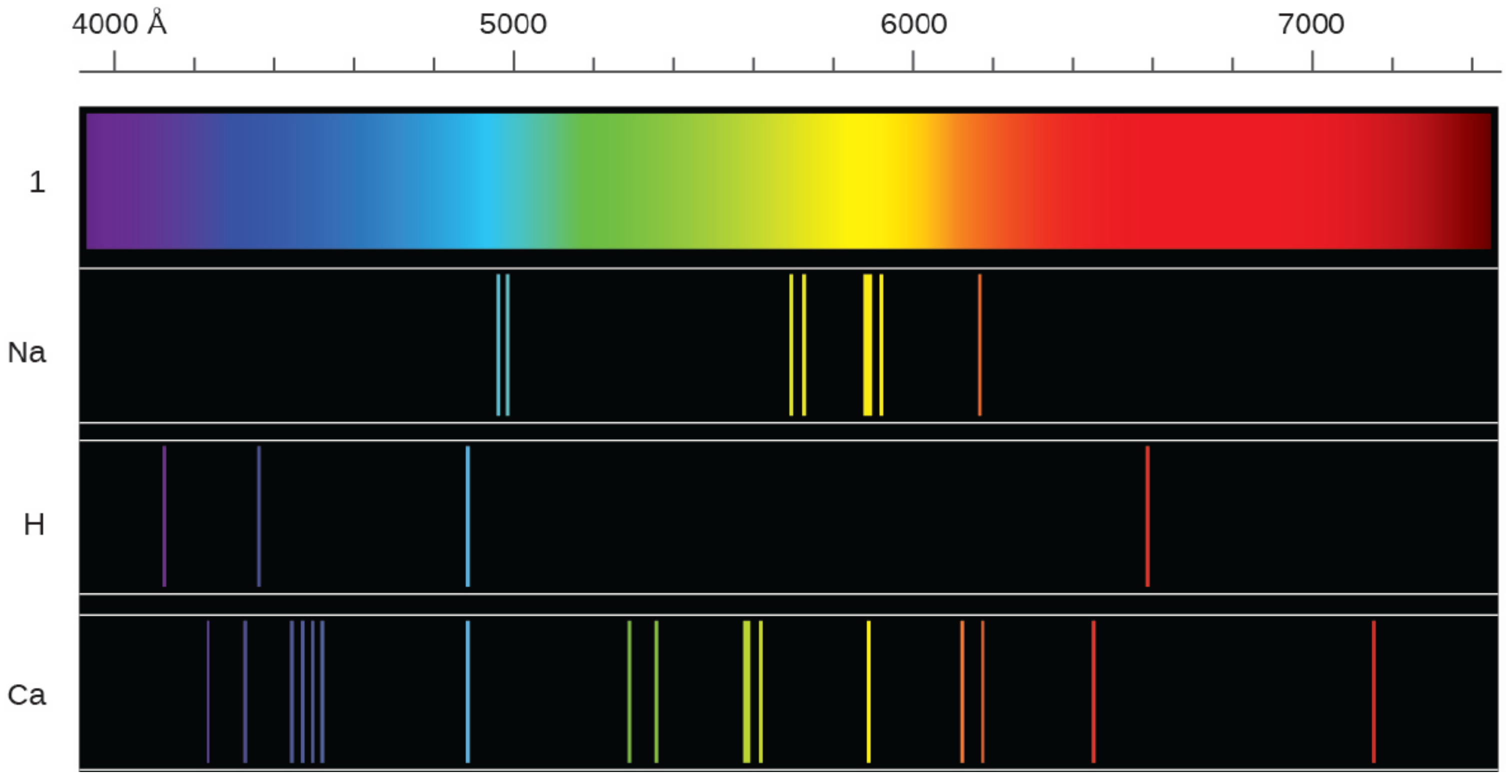
$$\Delta E_{atom} = -2.179 \times 10^{-18} \mathrm{J} \left(\frac{1}{n_{final}^2} - \frac{1}{n_{initial}^2} \right)$$

  - If ΔE_{atom} is positive, the atom is absorbing a photon to go from a lower n level to a higher n level.
  - If ΔE_{atom} is negative, the atom is releasing a photon to go from a higher n level to a lower n level.
- The energy gained or lost by the atom corresponds to the energy of the photon absorbed or released

$$E_{photon} = |\Delta E_{atom}|$$

Line spectra

- A line spectra shows the transition electron energy level transitions which occur in the visible region of light
- Every element has a distinct line spectra



Energy transitions

The first line of the line spectrum of the hydrogen atom emission results from a transition from the $n = 2$ level to the $n = 1$ level. What is the wavelength of the emitted photon?

Energy transitions

Of the following possible transitions of an electron in a hydrogen atom, which emits light of the highest energy?

A. Transition from the n = 1 to the n = 3 level
B. Transition from the n = 1 to the n = 2 level
C. Transition from the n = 3 to the n = 1 level
D. Transition from the n = 2 to the n = 1 level
E. Transition from the n = 5 to the n = 4 level

Multiple Choice

Which of the following statements about a hydrogen atom is false?

A. An electron in the n = 1 level of the hydrogen atom is in its ground state.
B. On average, an electron in the n = 3 level is farther from the nucleus than an electron in the n = 2 state.
C. The wavelength of light emitted when the electron goes from, the n = 3 level to the n = 1 level is the same as the wavelength of light absorbed when the electron goes from the n = 1 level to the n = 3 level.
D. An electron in the n = 1 level is higher in energy than an electron in the n = 4 level.
E. Light of greater frequency is required for a transition from the n = 1 level to n = 3 level than is required for a transition from the n = 2 level to n = 3.

Wave properties of matter

- All matter in motion has a characteristic wavelength as expressed by the de Broglie equation

$$\lambda_m = \frac{h}{mv}$$

- λ_m is the de Broglie wavelength (in m)
- h is Planck's constant
- m is the mass of the particle (in kg)
- v is the velocity (in m/s)

Using the de Broglie equation

What is the wavelength (in m) of a neutron traveling at a speed of 4.15 km/s? The mass of a neutron is 1.675×10^{-27} kg.