Atomic Structure I: Electromagnetic Radiation

1. What are the colors of the visible light spectrum in order from short to long wavelength? What is the approximate wavelength of each color?

Violet	Blue	Green	Yellow	Orange	Red
400 nm	**450**	**500**	**550**	**600**	**700 nm**

2. If the thermonuclear reactor in the center of our sun emits an x-ray photon, how fast will that photon be travelling?

   $c = 3.00 \times 10^8$ m/s

3. What is the wavelength of a 650 nm photon in meters?

   $\lambda = 650 \times 10^{-9}$ m = 6.5×10^{-7} m

4. The "oldies" FM radio station, KRTH, transmits on 101.1 MHz. What is the wavelength of the radiation (in meters)?

$$\nu = 101.1 \times 10^6 \text{ Hz} = 1.011 \times 10^8 \text{ Hz}$$

$$c = \lambda\nu \quad \text{so...} \quad \lambda = \frac{c}{\nu} = \frac{3.00 \times 10^8 \text{ m/s}}{1.011 \times 10^8 \text{ s}^{-1}} = 2.97 \text{ m}$$

5. The Sun emits the highest intensity of light at about 520 nm. What is the color and the energy (in J) of this radiation?

$$c = \lambda\nu$$

$$E = h\nu = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(3.00 \times 10^8 \text{ m/s})}{520 \times 10^{-9} \text{ m}} = 3.82 \times 10^{-19} \text{ J} \text{ (green)}$$

6. A particular star emits light with a λ_{max} of 485 nm. What is the surface temperature of the star? (Stellar emission can be considered to be blackbody.)

$$\lambda_{max} = \frac{0.0029}{T} \quad \text{so...} \quad T = \frac{0.0029}{\lambda_{max}} = \frac{0.0029}{485\times10^{-9}\ \text{m}} = 5980\ \text{K}$$

7. What is the kinetic energy of the electrons ejected from silver metal when it is struck by light with a wavelength of 200 nm?

$$KE_{e^-} = h\nu - \Phi_b$$
$$\Phi_b = 7.58\times10^{-19}\ \text{J}$$
$$KE_{e^-} = \frac{hc}{\lambda} - \Phi_b = \frac{(6.626\times10^{-34}\,\text{J}\cdot\text{s})(3.00\times10^{8}\ \frac{\text{m}}{\text{s}})}{200\times10^{-9}\ \text{m}} - 7.58\times10^{-19}\ \text{J}$$
$$KE_{e^-} = 9.939\times10^{-19}\,\text{J} - 7.58\times10^{-19}\ \text{J} = 2.36\times10^{-19}\ \text{J}$$

Work Functions for Photoelectric Effect

Element	Work Function (eV)	Work Function (J)
Aluminum	4.08	6.54×10^{-19}
Beryllium	5.0	8.01×10^{-19}
Cadmium	4.07	6.52×10^{-19}
Calcium	2.9	4.65×10^{-19}
Carbon	4.81	7.71×10^{-19}
Cesium	2.1	3.36×10^{-19}
Cobalt	5.0	8.01×10^{-19}
Copper	4.7	7.53×10^{-19}
Gold	5.1	8.17×10^{-19}
Iron	4.5	7.21×10^{-19}
Lead	4.14	6.63×10^{-19}
Magnesium	3.68	5.90×10^{-19}
Mercury	4.5	7.21×10^{-19}
Nickel	5.01	8.03×10^{-19}
Niobium	4.3	6.89×10^{-19}
Potassium	2.3	3.68×10^{-19}
Platinum	6.35	1.02×10^{-18}
Selenium	5.11	8.19×10^{-19}
Silver	4.73	7.58×10^{-19}
Sodium	2.28	3.65×10^{-19}
Uranium	3.6	5.77×10^{-19}
Zinc	4.3	6.89×10^{-19}

Adapted from *CRC Handbook of Chemistry and Physics*.

8. The technique of photoelectron spectroscopy (an instrumental method that measures the kinetic energy of electrons produced photoelectrically from metallic targets) was used to identify the metals in an alloy. The electromagnetic radiation source was the Mg K_α x-ray emission at 0.9898 nm. The spectrum showed two photoelectron peaks; the first of which was at 2.0008×10^{-16} J and the other at 2.0014×10^{-16} J. The relative ratios of the two photoelectron emissions was 14:8. What is the composition of the alloy?

$$\nu = \frac{2.9997\times10^{8}\ \frac{\text{m}}{\text{s}}}{0.9898\times10^{-9}\,\text{m}} = 3.0306\times10^{17}\,\text{s}^{-1}$$
$$KE_{e^-} = h\nu - \Phi_b \quad \text{so} \quad \Phi_b = h\nu - KE_{e^-}$$

Photoelectron Peak 1:

$$\Phi_b = (6.626\times10^{-34}\,\text{J}\cdot\text{s})(3.0306\times10^{17}\,\text{s}^{-1}) - 2.0008\times10^{-16}\,\text{J}$$
$$\Phi_b = 7.284\times10^{-19}\ \text{J} \ \text{(possibly Cu, Fe, Hg, or Ag)}$$

Photoelectron Peak 1:

$$\Phi_b = (6.626\times10^{-34}\,\text{J}\cdot\text{s})(3.0306\times10^{17}\,\text{s}^{-1}) - 2.0014\times10^{-16}\,\text{J}$$
$$\Phi_b = 6.684\times10^{-19}\ \text{J} \ \text{(possibly Cd, Pb, Nb, or Zn)}$$

Composition metal 1:metal 2

metal 1: $\frac{14}{22}\times100\% = 64\%$ metal 2: 36%