3) \( E = h \nu \). The energy of radiation is proportional to its frequency.

4) Photons are massless particles of light. The photoelectric effect implied that light (electromagnetic radiation) was characterized by 2 important quantities: its frequency (\( \nu \)), and its intensity (\( I \)). The observation that electrons were ejected from a metal only if light of sufficient frequency were used was consistent with Planck's idea (\( E = h \nu \)): this meant that the light had enough energy to knock an e- away from the metal. Thus, light behaved like a wave. The second observation, that the number of electrons ejected was proportional to the intensity \( I \) of the light, implied that light also behaved like a particle (i.e., more intense light has more "particle" of light). The model that Einstein advanced was this: All electromagnetic radiation (light) has an energy that is proportional to its wave-frequency \( (E_{\text{photon}} = h \nu) \), and that each wave also has a particle nature: particles-like property (i.e., "wave-particle duality").

12) Uncertainty principle: The uncertainty in position. We can determine either the position of an electron, or its energy, to great accuracy. In other words, if we know that the e- as a particle, one can figure out its position \( (\Delta x) \) and that the uncertainty in its position \( (\Delta x) \) is very small. But we consequently lose certainty about the energy of the electron (a wave-particle)

\[ (\Delta E)(\Delta x) \geq h \]

\( \Delta x \) - Planck's constant

\( \Delta E \) - Energy & position

The result is that we never know electron position as a probabilistic function, because we tend to ask first: "What is the energy of an electron?", and then answer "Where is it likely to be found?"
13) $P^2$ is the probability of finding an e- at a given point in space. It has unit volume.

18) 90% bonding $\sigma$ orbital.

24) $\lambda = 5.0 \times 10^{-7}$ m

$\lambda = \frac{c}{v} \Rightarrow E = hv = h \frac{c}{\lambda}$

$$E = \frac{3.00 \times 10^8 \text{ m/s}}{\lambda} \left( \frac{1 \text{ eV}}{5.0 \times 10^{-7} \text{ m}} \right)$$

$$= \frac{3.00 \times 10^8 \text{ eV/m}}{5.0 \times 10^{-7} \text{ m}}$$

$$= 6.0 \times 10^{-19} \text{ J/photom}$$

$$\frac{6.0 \times 10^{-19} \text{ J/photom}}{\text{photom}} = 2.4 \times 10^{-5} \text{ J/mol}$$

28) The energy ordering is:

X-rays > Visible light > Microwaves > FM frequency

b) a) c) d)

30) $E = 2.0 \times 10^2 \text{ eV/mol} \rightarrow 2.0 \times 10^2 \text{ eV/mol} \cdot \frac{3 \text{ mol}}{N_{\text{photons}}} = 3.3 \times 10^{-19} \text{ J/photon}$

$E = hv = h \frac{c}{\lambda} \Rightarrow \lambda = h \frac{c}{E}$

$$\lambda = \frac{6.0 \times 10^{-7} \text{ m}}{1 \text{ eV}} = 602 \text{ nm} \approx 600 \text{ nm}$$

This is the longest wavelength possible to eject e- from Cs.

This is red light (or orange-red)
\( \lambda = 253.65 \text{nm} \text{ UV light (not visible)} \)
\( 365.01 \text{nm} \text{ blue (visible)} \)
\( 404.65 \text{nm} \text{ blue (visible)} \)
\( 435-433 \text{nm} \text{ blue (visible)} \)
\( 1013.975 \text{nm} \text{ infrared (not visible)} \)

52. (a) \( l = \{0, \ldots, n-l\} \). \( l \) cannot be equal to \( n \).
   (b) \( m_l = \{-l, \ldots, 0, \ldots, +l\} \) \(|m_l| \text{ cannot be greater than } l \)
   (c) \( m_l = \{-l, \ldots, 0, \ldots, +l\} \) ditto

53. (a) none \( (|m_l| \neq l) \)
   (b) 3 \( (m_l = -1, 0, 1) \)
   (c) 11 \( (m_l = -5, -4, \ldots, +4, +5) \)
   (d) 1

58. \( 2p \) \( n = 2, l = 1, m_l = 0, \pm 1 \)
   (b) 3d \( n = 3, l = 2, m_l = \pm 2, \pm 1, 0 \)
   (c) 4f \( n = 4, l = 3, m_l = \pm 3, \pm 2, \pm 1, 0 \)

62. (a) 2s has one spherical node, & zero nodal surfaces
   (b) 5d has 2 plane nodes, plus 4 "spherical" nodes
   (c) 5f has 3 plane nodes, plus 4 "spherical" nodes
Bohr's model requires that both the energy and position of an electron be known precisely (at least, assigned to a circular orbit).

Accurately observable phenomena: \( b, e, f, g, h, i, j \)

\( \lambda = 12\text{cm} \quad E = h\nu = \frac{c}{\lambda} \quad n = \frac{c}{\lambda} = 1.7 \times 10^{-19} \text{J/photon} \)

Eyeball: \( mC_P \Delta T = (119)(4.0 \frac{J}{g \cdot K})(3.0K) = 130 \text{J of heat absorbed} \)

\( \frac{1.7 \times 10^{-19} \text{J}}{\text{photon}} \times 130 \text{J} = \frac{7.6 \times 10^5 \text{photons}}{\text{mole of photons}} \)