13.\ Z is the atomic number or number of protons. \Z_{\text{eff}} is the effective nuclear charge or the nuclear charge after taking into account the shielding caused by electrons in the atom.

14.\ The ionization energy is the energy it takes to remove an electron from an atom. As one goes from left to right across the periodic table in one row, electrons are added to the same shell. As each electron is added a proton is also added to the nucleus. Because the electrons are added to the same shell the shielding of these electrons on the nucleus is minimal. This causes the effective nuclear charge to go up. The larger the positive effective nuclear charge the tighter the electrons are held to the nucleus causing a greater amount of energy to be needed to remove an electron. As you go down a period you are adding electrons to a new shell. Each new shell causes substantial shielding of the nucleus. In addition, the electrons are farther away from the nucleus causing less energy to be needed to remove a valence electron.

21.\ \lambda \nu = c \\
\lambda = 1.0~cm \left( \frac{1 m}{100 cm} \right) = 0.010~m \\
\nu = \frac{c}{\lambda} = \frac{2.998 \times 10^8 \frac{m}{s}}{0.010~m} = 3.0 \times 10^{10}~Hz \\
\text{Energy of 1 photon} \\
E = h\nu = (6.626 \times 10^{-34} J \cdot s)(3.0 \times 10^{10}~Hz) = 2.0 \times 10^{-23}~J \\
\text{Energy of Avogadro’s number of photons} \\
N_A\nu = \left( \frac{6.022 \times 10^{23}}{mol} \right) \left( 2.0 \times 10^{-23}~J \right) = 12.0 \frac{J}{mol} \\

22.\ Wave a has a longer wavelength than wave b. \\
Wave b has the higher frequency than wave a. \\
Wave b has the higher energy than wave a. \\
In 1.6 \times 10^{-3}~m wave a completes 4 cycles. \\
\lambda = \frac{1.6 \times 10^{-3}~m}{4} = 4.0 \times 10^{-4}~m \\
\lambda \nu = c \\
\nu = \frac{c}{\lambda} = \frac{2.998 \times 10^8 \frac{m}{s}}{4.0 \times 10^{-4}~m} = 7.5 \times 10^{11}~Hz \\
E = h\nu = (6.626 \times 10^{-34} J \cdot s)(7.5 \times 10^{11}~Hz) = 4.9 \times 10^{-22}~J \\
In 1.6 \times 10^{-3}~m wave b completes 8 cycles. \\
\lambda = \frac{1.6 \times 10^{-3}~m}{8} = 2.0 \times 10^{-4}~m \\
\lambda \nu = c \\
\nu = \frac{c}{\lambda} = \frac{2.998 \times 10^8 \frac{m}{s}}{2.0 \times 10^{-4}~m} = 1.5 \times 10^{12}~Hz \\
E = h\nu = (6.626 \times 10^{-34} J \cdot s)(1.5 \times 10^{12}~Hz) = 9.9 \times 10^{-22}~J \\
All electromagnetic radiation travels at the same velocity, the speed of light. Both waves a and b are infrared radiation.
27. a) \[ \lambda \nu = c \]
\[ \lambda = \frac{c}{\nu} = \frac{2.998 \times 10^8 \frac{m}{s}}{6.0 \times 10^{13} \text{ Hz}} = 5.0 \times 10^{-6} \text{ m} \]
b) Infrared
c) \[ E = h\nu = (6.626 \times 10^{-34} J \cdot s)(6.0 \times 10^{13} \text{ Hz}) = 4.0 \times 10^{-20} J \]
This is the energy per photon, calculate the energy per mol of photons
\[ EN_A = (4.0 \times 10^{-20} J) \left( \frac{6.022 \times 10^{23}}{\text{mol}} \right) = 2.4 \times 10^4 \frac{J}{\text{mol}} \]
d) This bond absorbs radiation with a smaller frequency; therefore, the radiation is less energetic.

29. Calculate the energy needed to remove 1 electron
\[ 279.7 \frac{kJ}{\text{mol}} \left( \frac{1000 J}{1kJ} \right) \left( \frac{1 \text{ mol}}{6.022 \times 10^{23} e^-} \right) = 4.645 \times 10^{-19} J \]
Calculate the wavelength of the photon needed
\[ E = h\nu \]
\[ \lambda = \frac{h\nu}{E} = \frac{(6.626 \times 10^{-34} J \cdot s)(2.998 \times 10^8 \frac{m}{s})}{4.645 \times 10^{-19} J} = 4.277 \times 10^{-7} \text{ m} \]
\[ \lambda = 427.7 \text{ nm} \]

30. Need to determine is 225 nm light can ionize gold (890.1 \( \frac{kJ}{\text{mol}} \))
Determine the energy of 225 nm \( (225 \text{ nm} \left( \frac{1 \text{ m}}{10^9 \text{ nm}} \right) = 2.25 \times 10^{-7} \text{ m} \) light
\[ E = h\nu \]
\[ \lambda = \frac{h\nu}{E} = \frac{(6.626 \times 10^{-34} J \cdot s)(2.998 \times 10^8 \frac{m}{s})}{2.25 \times 10^{-7} \text{ m}} = 8.83 \times 10^{-19} J \]
Calculate the energy per mole of photons
\[ 8.83 \times 10^{-19} J \left( \frac{6.022 \times 10^{23} e^-}{1 \text{ mol}} \right) = 5.32 \times 10^5 \frac{J}{\text{mol}} \left( \frac{1 \text{ kJ}}{1000 \text{ J}} \right) = 532 \frac{kJ}{\text{mol}} \]
Therefore, 225 nm light cannot ionize gold.

31. (total energy)=(energy to remove an e−) + (kinetic energy of e−)
Calculate total energy
\[ E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} J \cdot s)(2.998 \times 10^8 \frac{m}{s})}{254 \times 10^{-9} \text{ m}} = 7.82 \times 10^{-19} J \]
Calculate the energy needed to remove an e− from the surface
\[ 208.4 \frac{kJ}{\text{mol}} \left( \frac{1000 J}{1kJ} \right) \left( \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \right) = 3.46 \times 10^{-19} J \]
Calculate kinetic energy
\[ 7.82 \times 10^{-19} J - 3.46 \times 10^{-19} J = 4.36 \times 10^{-19} J \]

32. Plank studied black body radiation and noted that short wavelength of light were not emitted from hot systems. This is inconsistent with classical theories because there should be no reason that small wavelength of light would not be given off. Therefore, electromagnetic radiation has both wave and matter like properties. In addition, the photoelectric effect showed that it took photons with a minimum frequency before electrons were seen to eject from metal. This held
true even if the intensity (number of photons) was increased but the frequency was below the threshold value.

Matter was shown to have both particle and wave properties using the double slit experiment. When a beam of electrons is forced between two slits a diffraction pattern can be observed which is consistent with matter having wave properties.

The wavelength of matter is calculated by \( \lambda = \frac{h}{mv} \) therefore, the more massive the particle the shorter the wavelength and the less wave like the matter acts. You need to consider the wave properties of a system when the wavelength is greater than the particle size.

34. a) \( \lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34} J \cdot s}{(9.109 \times 10^{-31} kg)(0.10(2.998 \times 10^8 \text{ m/s}))} = 2.4 \times 10^{-11} \text{ m}(\frac{10^9 \text{ nm}}{1 \text{ m}}) = 0.024 \text{ nm} \)

b) \( \lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34} J \cdot s}{(0.055 \text{ kg})(35 \text{ m/s})} = 3.4 \times 10^{-34} \text{ m}(\frac{10^9 \text{ nm}}{1 \text{ m}}) = 3.4 \times 10^{-25} \text{ nm} \)

36. \( 1.0 \times 10^2 \text{ nm}(\frac{1 \text{ m}}{10^9 \text{ nm}}) = 1.0 \times 10^{-7} \text{ m} \)

\[ \frac{h}{mv} = \frac{6.626 \times 10^{-34} J \cdot s}{(9.109 \times 10^{-31} \text{ kg})(1.0 \times 10^{-7} \text{ m})} = 7.300 \frac{m}{s} \]

\( 1.0 \text{ nm}(\frac{1 \text{ m}}{10^9 \text{ nm}}) = 1.0 \times 10^{-9} \text{ m} \)

\[ \frac{h}{mv} = \frac{6.626 \times 10^{-34} J \cdot s}{(9.109 \times 10^{-31} \text{ kg})(1.0 \times 10^{-9} \text{ m})} = 7.3 \times 10^{5} \frac{m}{s} \]

37. \( 3.31 \times 10^{-3} \text{ pm}(\frac{1 \text{ m}}{10^{12} \text{ pm}}) = 3.31 \times 10^{-15} \text{ m} \)

\[ m = \frac{h}{\lambda v} = \frac{6.626 \times 10^{-34} J \cdot s}{(3.31 \times 10^{-15} \text{ m})(0.0100(2.998 \times 10^8 \text{ m/s}))} = 6.68 \times 10^{-26} \text{ kg} \]

Determine molar mass

\[ mN_A = (6.68 \times 10^{-26} \text{ kg})(6.022 \times 10^{23} \text{ mol}^{-1}) = 0.0402 \frac{\text{ kg}}{\text{ mol}} = 40.2 \frac{g}{\text{ mol}} \]

The element is calcium

42. \( \Delta E = -2.178 \times 10^{-18} \text{ J}(\frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2}) \)

a) \( \Delta E = -2.178 \times 10^{-18} \text{ J}(\frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2}) = -1.059 \times 10^{-19} \text{ J} \)

Therefore, the photon emitted would carry 1.059×10⁻¹⁹ J

\( E = hv \) and \( \lambda v = c \)

\[ \lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot s)(2.998 \times 10^8 \text{ m/s})}{1.059 \times 10^{-19} \text{ J}} = 1.876 \times 10^{-6} \text{ m} \]

Infrared
b) \[ \Delta E = -2.178 \times 10^{-18} \left( \frac{1^2}{4^2} - \frac{1^2}{5^2} \right) = -4.901 \times 10^{-20} \text{ J} \]

Therefore, the photon emitted would carry 4.901\times10^{-20} \text{ J}

\[ \lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(2.998 \times 10^8 \frac{\text{m}}{\text{s}})}{4.901 \times 10^{-20} \text{ J}} = 4.053 \times 10^{-6} \text{ m} \]

Infrared

c) \[ \Delta E = -2.178 \times 10^{-18} \left( \frac{1^2}{3^2} - \frac{1^2}{5^2} \right) = -1.549 \times 10^{-19} \text{ J} \]

Therefore, the photon emitted would carry 1.549\times10^{-19} \text{ J}

\[ \lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(2.998 \times 10^8 \frac{\text{m}}{\text{s}})}{1.549 \times 10^{-19} \text{ J}} = 1.282 \times 10^{-6} \text{ m} \]

Infrared

40. The final energy state will be n=\infty, which corresponds to an electron not being associated with the atom anymore, and will result in \( E_f = 0 \).

\[ n \xrightarrow{1} \infty \]

\[ \Delta E = -2.178 \times 10^{-18} \left( \frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2} \right) = -2.178 \times 10^{-18} \left( \frac{1^2}{\infty^2} - \frac{1^2}{1^2} \right) = 2.178 \times 10^{-18} \text{ J} \]

\( E = hv \) and \( \lambda v = c \)

\[ \lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(2.998 \times 10^8 \frac{\text{m}}{\text{s}})}{2.178 \times 10^{-18} \text{ J}} = 9.121 \times 10^{-8} \text{ m} = 91.21 \text{ nm} \]

\[ n \xrightarrow{3} \infty \]

\[ \Delta E = -2.178 \times 10^{-18} \left( \frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2} \right) = -2.178 \times 10^{-18} \left( \frac{1^2}{\infty^2} - \frac{1^2}{3^2} \right) = 2.420 \times 10^{-19} \text{ J} \]

\[ \lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(2.998 \times 10^8 \frac{\text{m}}{\text{s}})}{2.420 \times 10^{-19} \text{ J}} = 8.209 \times 10^{-7} \text{ m} = 820.9 \text{ nm} \]

45. a) This statement is false. The higher the energy orbital the electron is in, the farther away from the nucleus and the easier (the less energy) it is to remove the electron.

b) This statement is true. The greater the value of \( n \), the higher the energy level, and the farther it is away from the nucleus.

c) This statement is false. n=3 \( \rightarrow \n=1 \) is a larger jump than n=3 \( \rightarrow \n=2 \). Therefore, more energy will be released for the n=3 \( \rightarrow \n=1 \) jump. The larger the energy, the greater the frequency of the photon; the greater the frequency of the photon, the smaller the wavelength.

d) This statement is true. In order for an electron transitions from the ground state to the n=3 state the electron must absorb a specific amount of energy. When the electron falls back down to the ground state (n=3 \( \rightarrow \n=1 \)) the electron emits the same amount of energy that it absorbed.

e) This statement is false. The ground state of the hydrogen atoms is n=1 and the first excited state is n=2.

46. n=1 \( \rightarrow \n=5 \)

\[ \Delta E = -2.178 \times 10^{-18} \left( \frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2} \right) = -2.178 \times 10^{-18} \left( \frac{1^2}{5^2} - \frac{1^2}{1^2} \right) \]

\[ = 2.091 \times 10^{-18} \text{ J} \]

\( E = hv \) and \( \lambda v = c \)
\[ \lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(2.998 \times 10^8 \text{ m/s})}{2.091 \times 10^{-18} \text{ J}} = 9.500 \times 10^{-8} \text{ m} = 95.00 \text{ nm} \]

No visible light does not have enough energy to promote an e\(^-\) from n=1 \(\rightarrow\) n=5 state.

n=2 \(\rightarrow\) n=6
\[
\Delta E = -2.178 \times 10^{-18} \text{ J} \left( \frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2} \right) = -2.178 \times 10^{-18} \text{ J} \left( \frac{1^2}{6^2} - \frac{1^2}{2^2} \right)
\]
\[
\lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(2.998 \times 10^8 \text{ m/s})}{4.840 \times 10^{-19} \text{ J}} = 4.104 \times 10^{-12} \text{ m} = 410.4 \text{ nm}
\]

Yes visible light does have enough energy to promote and e\(^-\) from n=2 \(\rightarrow\) n=6 state.

48. \[ E = h\nu = (6.626 \times 10^{-34} \text{ J} \cdot \text{s})(6.90 \times 10^{14} \text{ Hz}) = 4.57 \times 10^{-19} \text{ J} \]
\[ \Delta E = -2.178 \times 10^{-18} \text{ J} \left( \frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2} \right) \]
Light was emitted therefore \(\Delta E\) is negative
\[-4.57 \times 10^{-19} \text{ J} = -2.178 \times 10^{-18} \text{ J} \left( \frac{1^2}{n_f^2} - \frac{1^2}{5^2} \right) \]
\[ n_f = 2 \]

50. When an electron is removed from an atom the final n value is n=\(\infty\)

a) \[ \Delta E = -2.178 \times 10^{-18} \text{ J} \left( \frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2} \right) = -2.178 \times 10^{-18} \text{ J} \left( \frac{1^2}{\infty^2} - \frac{1^2}{1^2} \right) = -2.178 \times 10^{-18} \text{ J} \]
You need 2.178\times10^{-18} \text{ J} in order to remove the e\(^-\) from the ground state of H.

Calculate the energy per mol
\[ N_aE = \left( 6.022 \times 10^{23} \text{ mol}^{-1} \right) \left( 2.178 \times 10^{-18} \text{ J} \right) = 1.312,000 \text{ J/mol} = 1,312 \text{ kJ/mol} \]

b) \[ \Delta E = -2.178 \times 10^{-18} \text{ J} \left( \frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2} \right) = -2.178 \times 10^{-18} \text{ J} \left( \frac{2^2}{\infty^2} - \frac{2^2}{1^2} \right) = -8.712 \times 10^{-18} \text{ J} \]
You need 8.712\times10^{-18} \text{ J} in order to remove the e\(^-\) from the ground state of He\(^+\).

Calculate the energy per mol
\[ N_aE = \left( 6.022 \times 10^{23} \text{ mol}^{-1} \right) \left( 8.712 \times 10^{-18} \text{ J} \right) = 5,246,000 \text{ J/mol} = 5,246 \text{ kJ/mol} \]

c) \[ \Delta E = -2.178 \times 10^{-18} \text{ J} \left( \frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2} \right) = -2.178 \times 10^{-18} \text{ J} \left( \frac{3^2}{\infty^2} - \frac{3^2}{1^2} \right) = 1,960 \times 10^{-18} \text{ J} \]
You need 1.960\times10^{-18} \text{ J} in order to remove the e\(^-\) from the ground state of Li\(^{2+}\).

Calculate the energy per mol
\[ N_aE = \left( 6.022 \times 10^{23} \text{ mol}^{-1} \right) \left( 1,960 \times 10^{-18} \text{ J} \right) = 1.180 \times 10^7 \text{ J/mol} = 1.180 \times 10^4 \text{ kJ/mol} \]

d) \[ \Delta E = -2.178 \times 10^{-18} \text{ J} \left( \frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2} \right) = -2.178 \times 10^{-18} \text{ J} \left( \frac{5^2}{\infty^2} - \frac{5^2}{1^2} \right) = 7.841 \times 10^{-17} \text{ J} \]
You need 7.841\times10^{-17} \text{ J} in order to remove the e\(^-\) from the ground state of C\(^{5+}\).

Calculate the energy per mol
\[ N_aE = \left( 6.022 \times 10^{23} \text{ mol}^{-1} \right) \left( 7.841 \times 10^{-17} \text{ J} \right) = 4.722 \times 10^7 \text{ J/mol} = 4.722 \times 10^4 \text{ kJ/mol} \]
e) \[ \Delta E = -2.178 \times 10^{-18} J \left( \frac{Z_f^2}{n_f^2} - \frac{Z_i^2}{n_i^2} \right) = -2.178 \times 10^{-18} J \left( \frac{26^2}{1^2} - \frac{26^2}{1^2} \right) = 1.472 \times 10^{-15} J \]

You need $1.472 \times 10^{-15}$ J in order to remove the $e^-$ from the ground state of Fe$^{25+}$.

Calculate the energy per mol
\[ N_A E = \left( 6.022 \times 10^{23} \frac{1}{\text{mol}} \right) (1.472 \times 10^{-15} J) = 8.866 \times 10^8 \frac{J}{\text{mol}} \]
\[ = 8.866 \times 10^5 \text{kJ/mol} \]

51. 253.4 nm$\left( \frac{1 \text{m}}{10^9 \text{nm}} \right) = 2.534 \times 10^{-7} \text{ m}$

$\lambda v = c$ and $E = hv$

\[ E = \frac{\hbar c}{\lambda} = \frac{(6.626 \times 10^{-34} J \cdot s)(2.998 \times 10^8 \frac{m}{s})}{2.534 \times 10^{-7} \text{ m}} = 7.839 \times 10^{-19} J \]

\[ \Delta E = -2.178 \times 10^{-18} \left( \frac{Z_f^2}{n_f^2} - \frac{Z_i^2}{n_i^2} \right) \]

Light was emitted therefore $\Delta E$ is negative
\[ -7.839 \times 10^{-19} J = -2.178 \times 10^{-18} \left( \frac{4^2}{n_f^2} - \frac{4^2}{5^2} \right) \]

$n_f = 4$

53. $\Delta x \Delta p \geq \frac{1}{2} \hbar$

$\Delta x \Delta \nu \geq \frac{1}{2} \hbar$

\[ \hbar \frac{h}{2\pi} = \frac{6.626 \times 10^{-34} J \cdot s}{2\pi} = 1.05 \times 10^{-34} J \cdot s \]

a) $\Delta x \Delta \nu \geq \frac{1}{2} \hbar$

\[ \Delta x (9.109 \times 10^{-31} \text{ kg}) (0.100 \frac{m}{s}) \geq \frac{1.05 \times 10^{-34} J \cdot s}{2} \]

$\Delta x = 5.76 \times 10^{-4} \text{ m}$

This is the minimum value of $\Delta x$

b) $\Delta x \Delta \nu \geq \frac{1}{2} \hbar$

\[ \Delta x (0.145 \text{ kg}) (0.100 \frac{m}{s}) \geq \frac{1.05 \times 10^{-34} J \cdot s}{2} \]

$\Delta x = 3.62 \times 10^{-33} \text{ m}$

This is the minimum value of $\Delta x$

The diameter of a hydrogen atom is 74 pm = 7.4×10⁻¹¹ m (pg. 491). Therefore, the uncertainty in the position of the electron is much larger than the diameter of a hydrogen atom.

The diameter of a baseball is ~0.0762 m. Therefore, the uncertainty in the position of a baseball is much smaller than the diameter of a baseball.

57. Energy levels for particle in a box are given by:

\[ E = \frac{n^2 \hbar^2}{8mL} \]

\[ \Delta E = \frac{\Delta n^2 \hbar^2}{8mL^2} = \frac{\hbar^2}{8mL^2} (n_f^2 - n_i^2) \]

$\lambda \nu = c$ and $E = h\nu$

\[ E = \frac{\hbar c}{\lambda} = \frac{(6.626 \times 10^{-34} J \cdot s)(2.998 \times 10^8 \frac{m}{s})}{8080 \times 10^{-9} m} = 2.46 \times 10^{-20} J \]
\[ \Delta E = \frac{\hbar^2}{8mL} \left( n_f^2 - n_i^2 \right) \]
\[ 2.46 \times 10^{-20} \text{J} = \left( \frac{6.626 \times 10^{-34} \text{J} \cdot \text{s}}{8(9.109 \times 10^{-31} \text{kg})L^2} \right) (3^2 - 2^2) \]
\[ L = 3.50 \times 10^{-9} \text{m} = 3.51 \text{nm} \]

58. Energy levels for particle in a box are given by: 
\[ E = \frac{n^2 \hbar^2}{8mL} \]
Calculate the energy of a photon with \( \lambda = 1.523 \times 10^{-5} \text{m} \)
\[ \lambda v = c \text{ and } E = \hbar v \]
\[ E = \frac{\hbar c}{\lambda} = \frac{(6.626 \times 10^{-34} \text{J} \cdot \text{s})(2.998 \times 10^8 \text{m/s})}{1.374 \times 10^{-5} \text{m}} = 1.446 \times 10^{-20} \text{J} \]
\[ \Delta E = \frac{\hbar^2}{8mL} \left( n_f^2 - n_i^2 \right) \]
\[ 1.446 \times 10^{-20} \text{J} = \frac{(6.626 \times 10^{-34} \text{J} \cdot \text{s})^2}{8(9.109 \times 10^{-31} \text{kg})(1.00 \times 10^{-8} \text{m})^2} \left( n_f^2 - 1^2 \right) \]
\[ n_f = 5 \]

59. The energy levels for an electron trapped in a one dimensional box are given by:
\[ E = \frac{n^2 \hbar^2}{8mL} \]
Therefore, as the length of the box is increased the energy per given level will decrease and the separation between energy levels will get closer together.

61. Energy levels for particle in a box are given by:
\[ E = \frac{n^2 \hbar^2}{8mL} \]
Therefore, the smaller the \( L \) the larger the ground state energy. Causing a box with \( L = 10^{-6} \text{m} \) to have a lower ground state energy than a box with \( L = 10^{-10} \text{m} \).

62. Quantum numbers give the allowed solutions of the Schrödinger equation. These allowed solutions are called wave functions.
\( n \) (principle quantum number): Tells us the energy and size of an orbital
\( l \) (angular momentum quantum number): Tells us the shape of the orbital
\( m_l \) (magnetic quantum number): Tells the direction in which the orbital is pointed
We do not know that electrons have a spin. All we know is that electrons in the same orbital cannot have the same set of quantum numbers and each orbital holds 2 electrons. Therefore, the electrons in the orbital must have different intrinsic angular momentum.

66. a) Not allowed, the largest value that \( l \) can be is \( n-1 \)
b) Allowed
c) Allowed
d) Not allowed, \( m_s \) can only have values of \(+\frac{1}{2}\) or \(-\frac{1}{2}\)
e) Not allowed, \( l \) cannot be negative. \( l \) can have values between 0 and \( n-1 \)
f) Not allowed, \( m_s \) can only have values between \( l \) and \(-l\)
68. 5p: Has 3 orbitals 5pₓ, 5pᵧ, 5pₑ
3dₓ²−ᵧ²: Has 1 orbital
4d: Has 5 orbitals: 4dₓₓ, 4dᵧᵧ, 4dₓᵧ, 4dₓ²−ᵧ², 4dₑₑ
n=5: 1 s orbital, 3 p orbitals, 5 d orbitals, 7 f orbitals, and 9 g orbitals
   25 orbitals total
n=4: 1 s orbital, 3 p orbitals, 5 d orbitals, and 7 f orbitals
   16 orbitals total

69. 1p: 0 e⁻ can have the designation 1p. When n=1, l must equal 0. When you have a p orbital l = 1.
   6dₓ²−ᵧ²: This is 1 of the d-orbitals. Each orbital holds 2 electrons. Total = 2e⁻
   4f: There are 7 f-orbitals. Each orbital holds 2 electrons. Total = 14 e⁻
   7pₓ: This is 1 of the p-orbitals. Each orbital holds 2 electrons. Total = 2 e⁻
   2s: There is only 1 s orbital. Each orbital holds 2 electrons. Total = 2 e⁻
   n = 3: When n equals three you have 1 s orbital, 3 p orbitals, and 5 d orbitals. Each orbital holds 2 electrons. Total = 18 e⁻

70. ψ² gives the probability that an electron will be in a certain point.

71. We can only say that an electron has a 90% chance of being in a certain area because electrons are governed by the Heisenberg Uncertainty Principle which states that we cannot know the exact location of light particles.

72. For a g block element l=4. Therefore, 9 possible mᵢ values would be allowed. Since each mᵢ value represents an orbital and each orbital holds 2 electrons the g block would be 18 elements long.
   For an h block element l=5. Therefore, 11 possible mᵢ values would be allowed. Since each mᵢ value represents an orbital and each orbital holds 2 electrons the g block would be 22 elements long.

73. a) n = 4:  2 e⁻ in an s orbital, 6 e⁻ in p orbitals, 10 e⁻ in d orbitals, and 14 e⁻ in f orbitals
    (32 total e⁻)
b) n = 5 and mᵢ=+1:  2 e⁻ in a p orbital, 2 e⁻ in a d orbital, 2 e⁻ in an f orbital, and 2 e⁻ in a g orbital. (8 total e⁻)
c) n = 5 and mₜ₊½: 1 e⁻ in an s orbital, 3 e⁻ in p orbitals, 5 e⁻ in d orbitals, 7 e⁻ in f orbitals, and 9 e⁻ in g orbitals (25 total e⁻)
d) n = 3 and l = 2: 10 e⁻ in d orbitals (10 total e⁻)
e) n = 2 and l = 1: 6 e⁻ in p orbitals (6 total e⁻)
f) n = 0, l=0, and mₜ=0: not allowed (0 e⁻)
g) n = 2, l = 1, mᵢ = -1, mₜ = -½ : (1 e⁻)
h) n = 3 and mₜ = +½ : 1 e⁻ in an s orbital, 3 e⁻ in p orbitals, and 5 e⁻ in d orbitals
    (9 total e⁻)
i) n = 2 and l = 2: not allowed (0 e⁻)
j) n = 1, l = 0, and mₜ = 0:  2 e⁻ in an s orbital (2 total e⁻)

80. Si=[Ne]3s²3p²   Ga=[Ar]4s²3d¹⁰4p¹   As=[Ar]4s²3d¹⁰4p³
    Ge=[Ar]4s²3d¹⁰4p²   Al=[Ne]3s²3p¹   Cd=[Kr]5s²4d¹⁰
\[ S = [\text{Ne}] 3s^2 3p^4 \quad \text{Se} = [\text{Ar}] 4s^2 3d^{10} 4p^4 \]

81. \[ \text{Sc} = [\text{Ar}] 4s^2 3d^1 \quad \text{Fe} = [\text{Ar}] 4s^2 3d^6 \quad \text{Pt} = [\text{Xe}] 6s^2 4f^{14} 5d^6 \] (Do not worry about memorizing exceptions)
\[ \text{Cs} = [\text{Xe}] 6s^1 \quad \text{Eu} = [\text{Xe}] 6s^2 4f^7 \]
\[ \text{Xe} = [\text{Kr}] 5s^2 4d^{10} 5p^6 \quad \text{Br} = [\text{Ar}] 4s^2 3d^{10} 4p^5 \]

84. a) The only 2 elements that have 1 unpaired 5p electrons are indium and iodine. Iodine will form a covalent compound with F.
\[ I = [\text{Kr}] 5s^2 4d^{10} 5p^5 \]
b) element 120= [element 118] 8s^3

c) \[ \text{Rn} = [\text{Xe}] 6s^2 4f^{14} 5d^{10} 6p^6 \]
d) This will be chromium. It turns out that it is lower in energy for chromium to have the following electron configuration
\[ \text{Cr} = [\text{Ar}] 4s^1 3d^5 \] than \[ \text{Cr} = [\text{Ar}] 4s^2 3d^4 \] giving chromium 6 unpaired e⁻.

88. \[ \text{Hg} = [\text{Xe}] 6s^2 4f^{14} 5d^{10} \]
a) \[ n = 3: \] one s orbital, three p orbitals, and five d orbitals have n=3. Each orbital holds 2 e⁻. (18 total e⁻)
b) d orbitals: five 3d orbitals, five 4d orbitals, and five 5d orbitals all of which are filled. Each orbital holds 2 e⁻. (30 total e⁻)
c) p\(_r\) orbital's: The 2p\(_r\), 3p\(_r\), 4p\(_r\), and 5p\(_r\) orbitals are all filled. Each orbital holds 2 e⁻. (8 total e⁻)
d) spin up: For Hg all of the occupied orbitals are full. Therefore, half of the electrons will be spin up and the other half will be spin down. (40 total e⁻)

96. There are 0 unpaired electrons because all orbitals are full.
Yes this is an excited state because the lowest energy state would be 1s\(^2\) 2s\(^2\) 2p\(^x\)\(^2\) 2p\(^y\)\(^2\) 2p\(^z\)\(^2\)\(^1\).
Since the ground state is at a lower energy. Energy will be released when the electron transfers into the lower energy state.

97. a) \[ \text{O} = [\text{He}] 2s^2 2p^4 \]
\[ 2s \quad \uparrow \downarrow \quad 2p \quad \uparrow \downarrow \uparrow \uparrow \]
2 unpaired e⁻

b) \[ \text{O} = [\text{He}] 2s^2 2p^3 \]
\[ 2s \quad \uparrow \downarrow \quad 2p \quad \uparrow \uparrow \uparrow \uparrow \]
3 unpaired e⁻

c) \[ \text{O} = [\text{He}] 2s^2 2p^5 \]
\[ 2s \quad \uparrow \downarrow \quad 2p \quad \uparrow \downarrow \uparrow \uparrow \]
1 unpaired e⁻

\[ \text{Os} = [\text{Xe}] 6s^2 4f^{14} 5d^6 \]
\[ 6s \quad \uparrow \downarrow \quad 4f \quad \uparrow \downarrow \uparrow \downarrow \uparrow \downarrow \uparrow \downarrow \uparrow \downarrow \uparrow \downarrow \uparrow \downarrow \quad 5d \quad \uparrow \downarrow \quad \uparrow \uparrow \uparrow \uparrow \]
4 unpaired e⁻

e) \[ \text{Zr} = [\text{Kr}] 5s^2 4d^2 \]
\[ 5s \quad \uparrow \downarrow \quad 4d \quad \uparrow \uparrow \quad \uparrow \uparrow \quad \uparrow \uparrow \uparrow \]
2 unpaired e⁻
10. All of the trends link back to $Z_{\text{eff}}$, the effective nuclear charge. As you go across the periodic table, electrons are added into shells that already have electrons, therefore, minimal electron shielding occurs. This causes the effective nuclear charge to go up. The larger the effective nuclear charge the tighter the electrons are held to the nucleus, which results in smaller radii and larger ionization energies. The electron affinity is the energy released when an electron is added to a gas phase atom or monatomic ion. The ionization energy is the energy needed to remove an electron from the ground state of a gaseous atom. Electrons are always attracted to the nucleus, therefore, the ionization energy is always positive or energy will always have to be added to remove an electron. When an electron is added to an atom although the electron will be attracted by the nucleus it will be repelled by the other electrons. Therefore, the process could be endothermic or exothermic.

103. Size increases as you go down the periodic table and decreases as you go across.
   a) $\text{S} < \text{Se} < \text{Te}$
   b) $\text{Br} < \text{Ni} < \text{K}$
   c) $\text{F} < \text{Si} < \text{Ba}$
   d) $\text{Be} < \text{Na} < \text{Rb}$
   e) $\text{Ne} < \text{Se} < \text{Sr}$
   f) $\text{O} < \text{P} < \text{Fe}$

104. Ionization energy decreases as you go down the periodic table and increases as you go across.
   a) $\text{Te} < \text{Se} < \text{S}$
   b) $\text{K} < \text{Ni} < \text{Br}$
   c) $\text{Ba} < \text{Si} < \text{F}$
   d) $\text{Rb} < \text{Na} < \text{Be}$
   e) $\text{Sr} < \text{Se} < \text{Ne}$
   f) $\text{Fe} < \text{P} < \text{O}$

106. The smallest radius is the atom that is located closest to the top right hand corner of the periodic table.
   a) $\text{He}$
   b) $\text{Cl}$
   c) element 117
   d) $\text{Si}$
   e) $\text{Na}^+$
   f) $\text{Al}^{3+}$ will have the greatest electron affinity ($\text{Al}^{3+} + \text{e}^- \rightarrow \text{Al}^{3+}$).
   g) $\text{Al}^{3+} < \text{Al}^{2+} < \text{Al}^+ < \text{Al}$
The radius of an atom decreases as you remove electrons because even though electrons are being removed the number of protons stays the same. Therefore, the influence of the protons becomes greater with each removed electron and the radius becomes smaller.

114. Electron affinity: The energy released when an electron is added to a gas-phase atom or monoatomic ion.
The species with the largest (most exothermic) electron affinities are located in the upper right hand corner of the periodic table.
a) I<Br<F<Cl (F is an exception Table 12.8) b) N<O<F

119. The electron affinity is just the opposite of ionization energy. Ionization energies are given on page 486.
a) Mg^{2+} + e^- \rightarrow Mg^+ - 2^{\text{nd}} \text{ ionization energy of Mg} -1445 \text{ kJ/mol}
b) Al^+ + e^- \rightarrow Al - 1^{\text{st}} \text{ ionization energy of Al} -580 \text{ kJ/mol}
c) Cl^- \rightarrow Cl + e^- - \text{electron affinity (pg. 577) of Cl} 348.7 \text{ kJ/mol}
d) Cl \rightarrow Cl^+ + e^- 1255 \text{ kJ/mol}
e) Cl^+ + e^- \rightarrow Cl - 1^{\text{st}} \text{ ionization energy of Cl} -1255 \text{ kJ/mol}

120. a) C, Br, K, Cl (This trend is very irregular you must look at data on pg. 490)
b) N, Ar, Mg, F
c) C, Br, K, Cl

139. Losing the first 2 e^- it is relatively not difficult and then the ionization energy jumps up dramatically. This would be seen with alkaline earth metals.

147. a) The largest energy jump will occur between n=\infty and n=3. The larger the \Delta E the larger the frequency and the smaller the wavelength. Therefore, the lines seen at the highest wavelength are due to the smallest energy jumps.
A n=6 \rightarrow n=3
B n=5 \rightarrow n=3
b) \Delta E = -2.178 \times 10^{-18} \left( \frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2} \right)

Calculate the energy needed to promote an e^- from the n=3 to n=5
\lambda v = c \quad E = \hbar v
E = \frac{\hbar c}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(2.998 \times 10^8 \text{ m/s})}{142.5 \times 10^{-9} \text{ m}} = 1.394 \times 10^{-18} \text{ J}

Calculate the atomic number
1.394 \times 10^{-28} \text{ J} = -2.178 \times 10^{-18} \left( \frac{Z^2}{5^2} - \frac{Z^2}{3^2} \right)
Z=3

Calculate \Delta E of line A
\Delta E = -2.178 \times 10^{-18} \left( \frac{3^2}{6^2} - \frac{3^2}{3^2} \right) = 1.634 \times 10^{-18} \text{ J}
Calculate the wavelength of line A

\[ \lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34} J \cdot s)(2.998 \times 10^8 m/s)}{1.634 \times 10^{-18} J} = 1.216 \times 10^{-7} m = 121.6 nm \]