Sample Photon Energy Problems **Name** ____________________

1) If it takes 3.36 x 10^{-19} J of energy to eject an electron from the surface of a certain metal, calculate the longest possible wavelength, in nanometers, of light that can ionize the metal.

$E = h\nu$

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

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

$\lambda = \frac{(6.626\times10^{-34}\ \cancel{J}\cdot\cancel{s})(2.998\times10^{8}\ \frac{m}{\cancel{s}})}{3.36\times10^{-19}\ \cancel{J}}$

$\lambda = 5.91\times10^{-7}\ m \left|\frac{1\times10^{9}\ nm}{1\ m}\right| = \boxed{591\ nm}$

2) The ionization energy of gold is 890.1 kJ/mol. Is light with a wavelength of 240. nm capable of ionizing a gold atom (removing an electron) in the gas phase?

$\frac{890.1\ KJ}{1\ \cancel{mol}}\left|\frac{1\ \cancel{mol}}{6.022\times10^{23}\ photons}\right|\frac{1000\ J}{1\ KJ}\Big| = 1.478\times10^{-18}\ J$

$\lambda = \frac{hc}{E}$ $\quad \lambda = \frac{(6.626\times10^{-34}\ \cancel{J}\cdot\cancel{s})(2.998\times10^{8}\ \frac{m}{\cancel{s}})}{1.478\times10^{-18}\ \cancel{J}} = 1.344\times10^{-7}\ m = \boxed{134.4\ nm}$

NO, 240 nm is too long (not enough E)

3) What is the energy per photon of the lowest frequency of electromagnetic radiation that can be used to observe a gold atom with a diameter of 280. picometers? (the λ of light must be equal to or smaller than the atom)

$280.\ pm \left|\frac{1\ m}{1\times10^{12}\ pm}\right| = 2.80\times10^{-10}\ m$

$E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\ J\cdot\cancel{s})(2.998\times10^{8}\ \frac{\cancel{m}}{\cancel{s}})}{2.80\times10^{-10}\ \cancel{m}} = \boxed{7.09\times10^{-16}\ \frac{J}{photon}}$

4) DNA consists mainly of (C-H), (C-C), and bonds which have bond energies 413, 348, and 308 kJ/mol, respectively. What is the lowest energy light wave that will break the weakest bond? Determine its wavelength.

$\frac{308\ KJ}{1\ mol}\left|\frac{1\ mol}{6.022\times10^{23}\ photons}\right|\frac{1000\ J}{1\ KJ}\Big| = 5.12\times10^{-19}\ \frac{J}{photon}$

$\lambda = \frac{hc}{E} = \frac{(6.626\times10^{-34}\ \cancel{J}\cdot\cancel{s})(2.998\times10^{8}\ \frac{m}{\cancel{s}})}{5.12\times10^{-19}\ \cancel{J}} = 3.88\times10^{-7}\ m = \boxed{388\ nm}$

UV light will break DNA bonds (violet is about 400 nm)

5) Fluorescent molecules (known as fluorophores) are widely used by chemists and biologists to study sub-cellular molecules, including proteins, DNA, and RNA. In the most straightforward applications, fluorophores are appended to a bio-molecule of interest and used to image the bio-molecule's cellular location. The fluorescence imaging process involves the excitation of a fluorophore with a photon of energy, resulting in a brief (1-10 ns) excited state that is followed by the release of a photon with a second, lower energy.

Imagine that you are studying a protein involved in tumor metastasis (spreading). Based on previous studies, you hypothesize that the protein localizes to the nucleus in tumor cells. To determine the sub-cellular location of your protein, you label it with a fluorophore that can be excited by light in the range of 620. to 674 nm.

The lab's fluorescent microscope is currently set up with a He-Ne laser for excitation. The laser produces a beam of light with a per-photon energy of 3.14×10^{-19} J and an intensity of 13 W (J/s).

(a) Calculate the wavelength of the light emitted by the He-Ne laser.

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

$$\lambda = \frac{(6.626 \times 10^{-34}\ \cancel{J} \cdot \cancel{s})(2.998 \times 10^{8}\ \frac{m}{\cancel{s}})}{3.14 \times 10^{-19}\ \cancel{J}} = \boxed{6.33 \times 10^{-7}\ m}$$

(b) Does the He-Ne laser beam have an appropriate energy to excite your fluorophore (does it fall within the excitation range)?

6.33×10^{-7} m $\rightarrow$ 633 nm

Yes, 633 nm falls between 620. and 674 nm.

(c) Calculate the number of photons emitted by the laser per second.

$$\frac{13\ \cancel{J}}{1\ s} \cdot \frac{1\ \text{photon}}{3.14 \times 10^{-19}\ \cancel{J}} = \boxed{4.1 \times 10^{19}\ \frac{\text{photons}}{s}}$$