Electron Structure
Mrs. Peachee/Chem II

Name: Key 11-12
Date: ______ Hr: ______

1. A photon of violet light has a wavelength of 423 nm. Calculate
   a. the frequency

$$423\,nm \left| \frac{1\,m}{1\times10^{9}\,nm} \right. = 4.23\times10^{-7}\,m$$

$$c = \lambda \nu$$

$$\nu = \frac{c}{\lambda} = \frac{2.998\times10^{8}\,m/s}{4.23\times10^{-7}\,m} = \boxed{7.09\times10^{14}\,\frac{1}{s}}$$

   b. the energy in joules per photon

$$E = \nu h$$

$$= 7.09\times10^{14}\,\frac{1}{s} \cdot 6.626\times10^{-34}\,J\cdot s = \boxed{4.70\times10^{-19}\,\frac{J}{photon}}$$

   c. the energy in kilojoules per mole.

$$\frac{4.70\times10^{-19}\,\cancel{J}}{\cancel{photon}} \cdot \frac{1\,kJ}{1000\,\cancel{J}} \cdot \frac{6.022\times10^{23}\,\cancel{photon}}{1\,mole} = \boxed{283\,\frac{kJ}{mole}}$$

2. Magnetic resonance imaging (MRI) is a powerful diagnostic tool used in medicine. The imagers used in hospitals operate at a frequency of 4.00×10^{2} MHz (1 MHz = 1×10^{6} Hz) Calculate
   a. the wavelength

$$4.00\times10^{2}\,MHz \left| \frac{1\times10^{6}\,Hz}{1\,MHz} \right. = 4.00\times10^{8}\,Hz$$

$$c = \lambda \nu$$

$$\lambda = \frac{c}{\nu} = \frac{2.998\times10^{8}\,J\cdot s}{4.00\times10^{8}\,Hz} = \boxed{0.750\,m}$$

   b. the energy in joules per photon

$$E = h\nu$$

$$= 6.626\times10^{-34}\,J\cdot s \cdot 4.00\times10^{8}\,Hz$$

$$= \boxed{2.65\times10^{-25}\,J/photon}$$

   c. the energy in kilojoules per mole.

$$\frac{2.65\times10^{-25}\,\cancel{J}}{\cancel{photon}} \cdot \frac{1\,kJ}{1000\,\cancel{J}} \cdot \frac{6.022\times10^{23}\,\cancel{photons}}{1\,mole}$$

$$\boxed{1.60\times10^{-4}\,\frac{kJ}{mol}}$$

3. A line in the spectrum of neon has a wavelength of 837.8 nm.

a. In what spectral range does this occur? IR

$$\frac{837.8\,nm}{} \Big| \frac{1\,m}{1\times10^{9}\,nm}$$

$8.38\times10^{-7}\,m$

b. Calculate the frequency of this absorption

$$C = \lambda \nu$$

$$\nu = \frac{c}{\lambda} = \frac{2.998\times10^{8}\,m/s}{8.378\times10^{-7}\,m} = \boxed{3.578\times10^{14}\,\frac{1}{s}}$$

c. What is the energy in kilojoules per mole?

$$E = h\nu$$

$$= 6.626\times10^{-34}\,J\cdot s \cdot 3.578\times10^{14}\,\frac{1}{s} = 2.371\times10^{-19}\,J$$

$$\frac{2.371\times10^{-19}\,J}{} \Big| \frac{1\,kJ}{1000\,J} \Big| \frac{6.022\times10^{23}\,photon}{1\,mole} = \boxed{142.8\,\frac{kJ}{mole}}$$

4. Carbon dioxide absorbs energy at a wavelength of 1498 nm.

a. In what spectral range does this occur? IR

$$\frac{1498\,nm}{} \Big| \frac{1\,m}{1\times10^{9}\,nm} = 1.498\times10^{-6}\,m$$

b. Calculate the frequency of this absorption

$$C = \lambda \nu$$

$$\nu = \frac{c}{\lambda} = \frac{2.998\times10^{8}\,m/s}{1.498\times10^{-6}\,m} = \boxed{2.001\times10^{14}\,\frac{1}{s}}$$

c. What is the energy absorbed by one photon?

$$E = h\nu$$

$$= 6.626\times10^{-34}\,J\cdot s \cdot 2.001\times10^{14}\,\frac{1}{s}$$

$$= \boxed{1.326\times10^{-19}\,J}$$

5. The ionization energy of rubidium is 403 kJ/mole. Do x-rays with a wavelength of 85 nm have sufficient energy to ionize rubidium?

$$\lambda = 85\,nm \qquad \frac{85\,nm}{} \Big| \frac{1\,m}{1\times10^{9}\,nm} = 8.5\times10^{-8}\,m$$

$$E = \frac{hc}{\lambda} = \frac{6.626\times10^{-34}\,J\cdot s \cdot 2.998\times10^{8}\,m/s}{8.5\times10^{-8}\,m}$$

$$= 2.3\times10^{-18}\,J$$

$$\frac{2.3\times10^{-18}\,J}{atom} \Big| \frac{1\,kJ}{1000\,J} \Big| \frac{6.022\times10^{23}\,atoms}{1\,mole} = 1.4\times10^{3}\,\frac{kJ}{mole}$$

[illegible]

6. Energy from radiation can cause chemical bonds to break. To break the nitrogen-nitrogen bond in N_2 gas, 941 kJ/mol is required.
   a. Calculate the wavelength of the radiation that could break the bond.

$$E = h\nu$$

$$\frac{941\ kJ}{mole} \cdot \frac{1\ mole}{6.022 \times 10^{23}\ atoms} \cdot \frac{1000\ J}{1\ kJ} = 1.56 \times 10^{-18}\ \frac{J}{photo}$$

$$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34}\ J\cdot s \cdot 2.998 \times 10^{8}\ m/s}{1.56 \times 10^{-18}\ J/mole} = \boxed{1.27 \times 10^{-7}\ m}$$

   b. In what spectral range does this radiation occur?

$$\frac{1.27 \times 10^{-7}\ m}{} \cdot \frac{1 \times 10^{9}\ nm}{1\ m} = 127\ nm \quad \boxed{UV}$$

7. Microwaves ovens heat food by the energy given off by microwaves. These microwaves have a wavelength of 5.00 X 10^6 nm.
   a. How much energy in kilojoules per mole is given off by the microwave oven?

$$\lambda = \frac{5.00 \times 10^{6}\ nm}{} \cdot \frac{1\ m}{1 \times 10^{9}\ nm} = 5.00 \times 10^{-3}\ m$$

$$E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34}\ J\cdot s \cdot 2.998 \times 10^{8}\ m/s}{5.00 \times 10^{-3}\ m} = 3.97 \times 10^{-23}\ J$$

$$\frac{3.97 \times 10^{-23}\ J}{} \cdot \frac{1\ kJ}{1000\ J} \cdot \frac{6.022 \times 10^{23}\ atoms}{1\ mole} = \boxed{2.39 \times 10^{-2}\ \frac{kJ}{mole}}$$

   b. Compare the energy obtained in (a) with that given off by the ultraviolet rays (λ = 100 nm) of the Sun that you absorb when you try to get a tan.

$$\frac{100\ nm}{} \cdot \frac{1\ m}{1 \times 10^{9}\ nm}$$

$$E_{sun} = \frac{6.626 \times 10^{-34}\ J\cdot s \cdot 2.998 \times 10^{8}\ m/s}{1.00 \times 10^{-7}\ m}$$

$$\frac{1.99 \times 10^{-18}\ J}{} \cdot \frac{1\ kJ}{1000\ J} \cdot \frac{6.022 \times 10^{23}\ photo}{1\ mole} = \boxed{1.20 \times 10^{3}\ \frac{kJ}{mole}}$$

8. Consider the transition from the energy levels n = 4 to n = 2
   a. What is the frequency associated with this transition?

$$E = -2.178 \times 10^{-18}\ J \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$E = -2.178 \times 10^{-18}\ J \left(\frac{1}{4} - \frac{1}{16}\right) = -4.084 \times 10^{-19}\ J$$

$$E = h\nu$$

$$\nu = \frac{E}{h} = \frac{4.084 \times 10^{-19}\ J}{6.626 \times 10^{-34}\ J\cdot s} = \boxed{6.163 \times 10^{+14}\ \frac{1}{s}}$$

   b. In what spectral region does this transition occur?

   c. Is energy absorbed?

$$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34}\ J\cdot s \cdot 2.998 \times 10^{8}\ m/s}{4.084 \times 10^{-19}\ J}$$

$$= 4.864 \times 10^{-7}\ m$$

$$\frac{4.864 \times 10^{-7}\ m}{} \cdot \frac{1 \times 10^{9}\ nm}{} = \boxed{486.4\ nm}$$

c. no

$E = -2.178 \times 10^{-18} J \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$

9. Consider the transition from the energy levels n = 1 to n = 3
   a. What is the wavelength associated with this transition?

$E = -2.178 \times 10^{-18} J \left(\frac{1}{9} - \frac{1}{1} \right) \Rightarrow -2.178 \times 10^{-18} J \left(\frac{1}{9} - \frac{9}{9} \right) = +1.936 \times 10^{-18} J$

$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34} J{\cdot}s \cdot 2.998 \times 10^{8} m/s}{1.936 \times 10^{-18} J} = 1.027 \times 10^{-7} m$

$\frac{1.027 \times 10^{-7} m}{} \Big| \frac{1 \times 10^{9} nm}{1 m}$ $\boxed{102.7 nm}$

   b. In what spectral region does this transition occur?

UV

   c. In energy absorbed?

yes

10. Calculate the wavelength of light emitted when each of the following transitions occur in hydrogen atom. What type of electromagnetic radiation is emitted in each transition? *(Z338.51)*
   a. n = 3 → n = 2

$E = -2.178 \times 10^{-18} J \left(\frac{1}{4} - \frac{1}{9} \right) = -3.025 \times 10^{-19}$

$E = \frac{hc}{\lambda} \quad \lambda = \frac{hc}{E} \Rightarrow \frac{6.626 \times 10^{-34} J{\cdot}s \cdot 2.998 \times 10^{8} m/s}{3.025 \times 10^{-19} J} = 6.567 \times 10^{-7} m$

$6.567 \times 10^{-7} m \Big| \frac{1 \times 10^{9} nm}{1 m} = \boxed{656.7}$

   b. n = 2 → n = 1

$E = -2.178 \times 10^{-18} J \left(\frac{1}{1} - \frac{1}{4} \right) = -1.634 \times 10^{-18} J$

$E = \frac{hc}{\lambda} \quad \lambda = \frac{hc}{E} \Rightarrow \frac{6.626 \times 10^{-34} J \cdot 2.998 \times 10^{8} m/s}{1.634 \times 10^{-18} J} = 1.216 \times 10^{-7} m$

$1.216 \times 10^{-7} m \Big| \frac{1 \times 10^{9} nm}{1 m}$ $\boxed{121.6 nm}$

11. Does a photon of visible light (λ ≈ 400 to 700 nm) have sufficient energy to excite an electron in hydrogen atoms from the n = 1 to the n = 5 energy state?

$E = -2.178 \times 10^{-18} \left(\frac{1}{25} - \frac{1}{1} \right) = 2.091 \times 10^{-18} J$

$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34} J{\cdot}s \cdot 2.998 \times 10^{8} m/s}{2.091 \times 10^{-18} J} = 9.500 \times 10^{-8} m$

$\boxed{95.00 nm}$

no need to be 400nm to 700nm

From the n = 2 to the n = 6 energy state? *(Z338.55)*

$E = -2.178 \times 10^{-18} \left(\frac{1}{36} - \frac{1}{4} \right) = 4.840 \times 10^{-19} J$

$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34} J{\cdot}s \cdot 2.998 \times 10^{8} m/s}{4.840 \times 10^{-19}} = 4.104 \times 10^{-7} m$

$\boxed{410.4 nm}$ yes