AP Chemistry
Atomic Structure – 7 Worksheet

Name: Key Date: ____________ Per: ____

1. At its closest approach, Mars is 56million km from Earth. How long would it take to send a radio message from a space probe on Mars to Earth when the planets are at this closest distance?

$5.6 \times 10^7 km / 3.0 \times 10^5 km/s = 186.6\overline{6}\ s \left(\frac{1\ min}{60\ s}\right) = \boxed{3.1\ min}$

2. The second is defined as the time it takes for 9,192,631,770 wavelengths of a certain transition of the cesium-133 atom to pass a fixed point. What is a) the frequency of this electromagnetic radiation? b) its wavelength?

Frequency = 9,192,631,770 Hz | wavelength$(\lambda) = \frac{3.00 \times 10^8 m/s}{9{,}192{,}631{,}770 Hz} = .0326 m = \boxed{3.26 cm}$

3. The energy required to dissociate the Cl_2 molecule to Cl atoms is 239kJ/mol Cl_2. If the dissociation of a Cl_2 molecule were accomplished by the absorption of a single photon whose energy was exactly the quantity required, what would be its wavelength (in meters)?

$\frac{239\ kJ/mol}{6.022 \times 10^{23}\ molecules/mol} = 3.9688 \times 10^{-19} J/molecule$

$\lambda = \frac{hc}{E} = (6.626 \times 10^{-34} Js)(3.00 \times 10^8 m/s)/3.9688 \times 10^{-19} J$

$\lambda = 5.008 \times 10^{-7} m = \boxed{5.0 \times 10^{-7} m}$

4. In the stratosphere, ultraviolet radiation with a frequency of $1.36 \times 10^{15} s^{-1}$ can break C-Cl bonds in chlorofluorocarbons (CFCs), which can lead to stratospheric ozone depletion. Calculate the energy per quantum of this radiation.

$E = h\nu = 6.626 \times 10^{-34} Js\ (1.36 \times 10^{15} Hz) = \boxed{9.01 \times 10^{-19} J}$

5. Four possible electron transitions in a hydrogen atom are given below:

	$n_{initial}$	n_{final}
(1)	2	5
(2)	5	3
(3)	7	2
(4)	4	6

a) Which transition(s) represent a loss of energy? High to Low (2) & (3)

b) For which transition does the atom gain the greatest quantity of energy?

$2 \rightarrow 5$ (1)

c) Which transition corresponds to emission of the greatest quantity of energy?

$7 \rightarrow 2$ (3)

6. Li^{2+} is a hydrogen-like ion. Such an ion has a nucleus of charge +Ze and a single electron outside this nucleus. The energy levels of the ion are $-Z^2R_H/n^2$, where Z is the atomic number. What is the wavelength of the transition from n = 5 to n = 3 for Li^{2+}? In what region of the spectrum does this emission occur?

$-Z^2 R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ $R_H = 1.0974 \times 10^7 m^{-1}$

$\frac{1}{\lambda} = -3^2(1.0974 \times 10^7 m^{-1})\left(\frac{1}{3^2} - \frac{1}{5^2}\right) = 7{,}023{,}360$ $\lambda = 1.42 \times 10^{-7} m$

$\boxed{142 nm, UV Region}$

7. A microwave oven heats by radiating food with microwave radiation, which is absorbed by the food and converted to heat. Suppose an oven's radiation wavelength is 12.5cm. A container with 0.250L of water was placed in the oven and the temperature of the water rose from 20.0°C to 100.0°C. How many photons of this microwave radiation were required? Assume that all the energy from the radiation was used to raise the temperature of the water. The specific heat of water is 4.184J/gK. 12.5 cm

$q = (250g)(4.184 J/g°C)(80.0°C) = 83,680 J$

$E = \frac{hc}{\lambda} = (6.626 \times 10^{-34} Js)(3.00 \times 10^{8} m/s) / .125 m = 1.590 \times 10^{-24} J/photon$

$83,680 J / 1.590 \times 10^{-24} J/photon = [5.26 \times 10^{28} photons]$

8. Light with a wavelength of 425nm fell on a potassium surface and electrons were ejected at a speed of 4.88×10^5m/s. What energy was expended (the work function) in removing an electron from the metal? Express the answer in joules per electron and in kilojoules per mole of electrons. $KE = \frac{1}{2}mv^2 = \frac{1}{2}(9.11 \times 10^{-31} kg)(4.88 \times 10^5 m/s)^2 = 1.0847 \times 10^{-19} J$

$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} Js)(3.00 \times 10^8 m/s)}{(4.25 \times 10^{-7} m)} = 4.6771 \times 10^{-19} J$

$E_w = 4.6771 \times 10^{-19} - 1.0847 \times 10^{-19} J = [3.59 \times 10^{-19} J/e^-]$

$(3.59 \times 10^{-19} J/e^-)(6.022 \times 10^{23} e^-/mol) / 1000 = 216.3389 = [216 kJ/mol]$

9. When an electron is accelerated by a voltage difference, the kinetic energy acquired by the electron equals the voltage times the charge on the electron. Thus, one volt imparts a kinetic energy of 1.602×10^{-19}volt-coulombs, or 1.602×10^{-19}J. What is the deBroglie wavelength for electrons accelerated by 4.00×10^3 volts?

$E_k = (4.00 \times 10^3 V)(1.602 \times 10^{-19} C) = 6.408 \times 10^{-16} J$

$6.408 \times 10^{-16} J = \frac{1}{2}(9.11 \times 10^{-31} kg)v^2 \quad v = 3.7507 \times 10^7 m/s$

$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34} Js}{(9.11 \times 10^{-31} kg)(3.7507 \times 10^7 m/s)} = [1.94 \times 10^{-11} m] \rightarrow = [19.4 pm]$

10. The term degeneracy means the number of different quantum states of an atom or molecule having the same energy. For example, the degeneracy of the n = 2 level of the hydrogen atom is 4 (a 2s quantum state and the three different 2p states). What is the degeneracy of the n = 5 level? $(l = 0 \rightarrow n-1)$

$n = 5 \quad l = 0 \rightarrow 4$

s: 0 = 1 m_l; p: 1 = 3 m_l; d: 2 = 5 m_l; f: 3 = 7 m_l; g: 4 = 9 m_l [degeneracy = 25]

11. Light of wavelength 1.03×10^{-7}m is emitted when an electron in an excited level of a hydrogen atom undergoes a transition to the n = 1 level. What is the region of the spectrum of this light? What is the principal quantum number of this excited level?

Region @ 103nm $(1.03 \times 10^{-7} m)$ = [Ultraviolet] $\quad R = 1.0974 \times 10^7 m^{-1}$

$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \quad \frac{1}{1.03 \times 10^{-7} m} = 1.0974 \times 10^7 m^{-1}\left(\frac{1}{1^2} - \frac{1}{n_i^2}\right)$

$.11529634 = \frac{1}{n_i^2}$

$n_i = \sqrt{8.6733} = 2.945 \approx [3]$

12. How did the Heisenberg uncertainty principle illustrate the fundamental flaw in Bohr's model of the atom?

By Bohr's model, the electrons orbit is specifically defined so its position/momentum could be determined precisely which is not allowed by the Heisenberg Uncertainty principle

$\Delta x \Delta mv \geq \frac{h}{4\pi}$