Quantum/Nuclear Physics

WORKSHEET #4

Name: ______________________

1. Determine the number of protons, electrons, and neutrons each of these isotopes possesses:
Pu-239, N-14, and Rn-222.

	protons	electrons	neutrons
Pu-239	94	94	145
N-14	7	7	7
Rn-222	86	86	136

2. What is the energy in eV of (a) a microwave photon with a wavelength of 2.00 cm and (b) an x-ray photon with a wavelength of 2.00 nm?

a. $E = hf = hc/\lambda = 4.14\times10^{-15}$ eV·s · 3.00×10^{8} m/s / 0.0200 m = $\boxed{6.21\times10^{-5}\text{ eV}}$

b. $E = hf = hc/\lambda = 4.14\times10^{-15}$ eV·s · 3.00×10^{8} m/s / 2.00×10^{-9} m = $\boxed{621\text{ eV}}$

3. A certain metal is illuminated with light of frequency 9.00 x 10^{14} Hz, the stopping potential is found to be 2.00 V. What is the work function for the metal?

$K_{max} = U_E = qV = 2.00$ eV
$hf = \Phi + K_{max}$
$\Phi = hf - K_{max} = 4.14\times10^{-15}$ eV·s · 9.00×10^{14} Hz - 2.00 eV = $\boxed{1.73\text{ eV}}$

4. Describe the Compton effect. How does it demonstrate the wave/particle nature of light?

When photons have sufficiently high energies (frequencies in the x-ray range and above, for example), they may not just be absorbed by an electron which becomes excited or even absorbed by an electron which becomes ionized and gains some kinetic energy–the photons may have enough energy after colliding with the electron (or nucleus even) to "push" the electron (and change its momentum), and the photon will "scatter" a different direction with a change in its own energy (losing some) and therefore becoming a different wavelength (a longer one). This effect obeys the laws of conservation of momentum and reinforces the idea that a photon of light is a "particle" as was already being proposed as an explanation for the photoelectric effect.

5. A 1.50 kg ball is released from the top of a 135 m tall building. (a) What is its DeBroglie wavelength just before it strikes the earth? (b) What is its kinetic energy?

a. $v^2 = v_0^2 - 2ad$
$v = (-2ad)^{\frac{1}{2}} = (-2 \cdot 9.8\ m/s^2 \cdot 135\ m) = 51.4392846\ m/s$
$\lambda = h/mv = 6.63\text{x}10^{-34}\ J{\cdot}s\ /\ (1.50\ kg \cdot 51.4392846\ m/s) = 8.59265449\text{x}10^{-36}\ m = \boxed{8.59\text{x}10^{-36}\ m}$
b. $KE = \frac{1}{2}mv^2 = 0.5 \cdot 1.50\ kg \cdot (51.4392846\ m/s)^2 = \boxed{1984.5\ J}$

6. Explain how an incandescent light bulb produces light.

Electricity flows through a very thin tungsten filament. The filament has a very high resistance, which means electrons will collide with the material in that part of the circuit losing energy. The majority of that energy is transferred to heating up the molecules of tungsten to a temperature of between two and three thousand kelvins. At those temperatures, the molecules emit blackbody radiation (due to their vibrations/movement). Some of this is in the visible light range, but the majority of it is in the IR range which is why incandescent light bulbs are so hot.

7. An electron has a wavelength of 5.82 x10^{-11}m. (a) What is its kinetic energy? (b) What potential difference is required to accelerate it from rest and give it this much energy in a distance of 5.00 cm?

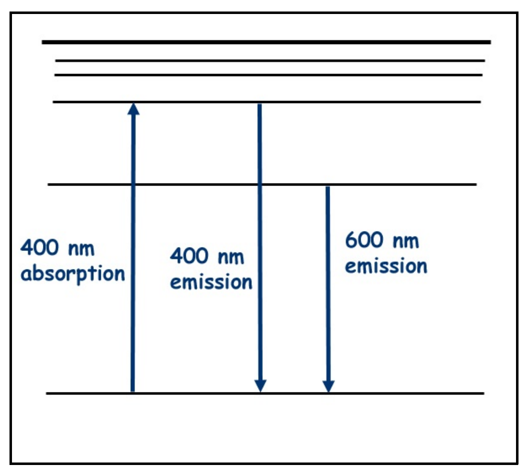
a. $\lambda = h/mv$
$v = h/m\lambda = 6.63\text{x}10^{-34}\ J{\cdot}s\ /\ (9.11\text{x}10^{-31}\ kg \cdot 5.82\text{x}10^{-11}\ m) = 1.2504668\text{x}10^{7}\ m/s = \boxed{1.25\text{x}10^{7}\ m/s}$
b. $v^2 = v_0^2 - 2ad$
$a = v^2/2d = (1.2504668\text{x}10^{7}\ m/s)^2\ /\ (2 \cdot 0.0500\ m) = 1.563667\text{x}10^{15}\ m/s^2$
$F = qE = qV/d$ and since also: $F = ma$ then
$qV/d = ma$
$V = dma/q = 0.0500\ m \cdot 9.11\text{x}10^{-31}\ kg \cdot 1.563667\text{x}10^{15}\ m/s^2\ /\ 1.6\text{x}10^{-19}\ C = 445.1565\ V = \boxed{445\ V}$

or

$\Delta U = \Delta KE$
$qV = \frac{1}{2}mv^2$
$V = \frac{1}{2}mv^2/q = 0.5 \cdot 9.11\text{x}10^{-31}\ kg \cdot (1.2504668\text{x}10^{7})^2/1.6\text{x}10^{-19}\ C = 445.1565\ V = \boxed{445\ V}$

8. A monatomic gas is illuminated with visible light of wavelength 400.0 nm. The gas is observed to absorb some of the light and subsequently to emit visible light at both 400.0 nm and 600.0 nm.

a. In the box at the side, complete an energy level diagram that would be consistent with these observations. Indicate and label the observed absorption and emissions.
b. If the initial state of the atoms has energy *-5.0* eV, what is the energy of the state to which the atoms were excited by the 400.0 nm light?



$E = hf = hc/\lambda$
$= 4.14\text{x}10^{-15}\ eV{\cdot}s \cdot 3.00\text{x}10^{8}\ m/s\ /\ 400.0\text{x}10^{-9}\ m$
$= 3.105\ eV$
$-5.0\ eV + 3.105\ eV = -1.895\ eV = \boxed{-1.9\ eV}$

c. At which other wavelength(s) outside the visible range do these atoms emit radiation after they are excited by the 400.0 nm light?

$E = 4.14\text{x}10^{-15}\ eV{\cdot}s \cdot 3.00\text{x}10^{8}\ m/s\ /\ 600.0\text{x}10^{-9}\ m = 2.07\ eV$
E between 400 nm line and 600 nm line = 3.105 eV - 2.07 eV = 1.035 eV
$\lambda = hc/E = 4.14\text{x}10^{-15} \cdot 3.00\text{x}10^{8}\ m/s\ /\ 1.035\ eV = 1.2\text{x}10^{-6}\ m = \boxed{1200\ nm}$