Solutions to problems (Ch. 3)28, 32, 35 and 53;(Ch. 4)2,6,14,15

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1 Problem 3.28

Problem statement: Compute the threshold frequency for the photoelectric effect with molybdenum. The work function of molybdenum is 4.22 eV. Discuss whether or not yellow light will cause the ejection of electrons.

Solution:
We know that at threshold frequency V_0 is equal to zero. We can then use $\Phi = hc/\lambda$ to solve for the threshold frequency. Because,

$$eV_0 = hf - \Phi$$
$$0 = hf - \Phi$$
$$\Phi = hf$$

And we can substitute $f = \frac{c}{\lambda}$ to get

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

Substituting our numbers into this equation we get,

$$4.22eV = \frac{1240eV * nm}{\lambda}$$

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Solving the equation, we find $\lambda = 293.84$. Rearranging this equation for frequency,

$$f = \frac{3 * 10^8}{293.84 * 10^-9}$$

we find the threshold frequency to be $1.02 * 10^15$.Yes, yellow light would cause the ejection of photons from molybedenum, because $560nm > 294nm$.

2 Problem 3.32

Problem statement: Compute the work function for cesium.Then calculate the energy of electrons ejected by light of 300nm shining on cesium.

Solution:
We know that at threshold frequency $\Phi = \frac{hc}{\lambda}$. Using this equation, we can solve for the work function.

$$\Phi = \frac{1240eV * nm}{653nm}$$

We find the work function to be 1.90eV.

Solving this equation again using 300nm, we find Φ now to be 4.133eV. The kinetic energy of the ejected electrons is equal to the difference between these two values.

$$4.133 - 1.90 = 2.23$$

So the kinetic energy of electrons ejected from cesium due to light of of 300nm is 2.23eV.

3 Problem 3.35

Problem statement: Find the momentum of a photon when ejected due to wavelengths of (a) 400nm, (b) 0.1nm (c) 3cm, and (d) 2nm.

Solution: We know that $E = pc$ and that energy of a photon also is $E = hf$. So $E = pc \rightarrow p = \frac{E}{c}$ Then,

$$p = \frac{hf}{c}$$

.
Substituting $\lambda^{-1} = \frac{f}{c}$ can solve this equation for

$$p = \frac{h}{\lambda}$$

PLugging these numbers in this equation, we find

- (a) $1.6565 * 10^-36$
- (b) $6.626 * 10^-33$
- (c) $2.2087 * 10^-41$
- (d) $3.313 * 10^-34$

4 Problem 3.53

Problem statement: Determine the fraction of the Sun's energy that is radiated through the visible spectrum.
Solution: The percent of radiation through the visble spectrum can be calculated by taking the integral of Plank's radiation law over the range 350nm-700nm, and dividing it by the integral of Plank's radiation law from 0 to infinity.

$$\frac{\int\limits_{300}^{700} \frac{8\pi hc\lambda^{-5}}{e^{(hc/\lambda kT)}-1} d\lambda}{\int\limits_{0}^{\infty} \frac{8\pi hc\lambda^{-5}}{e^{(hc/\lambda kT)}-1} d\lambda}$$

Plugging this equation in to Mathematica, we find the precentage to be about 43%.

5 Problem 4.2

Problem statement: What transition does the wavelength 379.1nm correspond to using the Balmer equation?

Solution: We know that Balmer calculated quantum numbers using the equation

$$\lambda_n = 364.6(\frac{n^2}{n^2 - 4})$$

We can solve this problem by plugging 379.1 into the left side of the equation.

$$379.1 = 364.6(\frac{n^2}{n^2 - 4})$$

$$1.0397n^2 - 4.159 = n^2$$

Solving the equation for n, we find the quantum number to be about 10.

6 Problem 4.6

Problem statement: What fraction of particles with energy 7.0MeV will be scattered at angles greater than 90 degrees in the Rutherford experiment when using gold foil of thickness 2.0μm? What about between the angles of 45 degress and 75 degrees?

Solution: We know that $f = \pi b^2 nt$.

We must first find the number of nuclei per unit volume in gold (n). This can be done using Avogadro's number and the atomic mass of gold in the equation $n = \frac{\rho * N_A}{M}$

So,

$$\frac{(19.3g/cm^3)(6.02 * 10^23atoms/mol)}{197g/mol} = 5.9 * 10^{28}atoms/m^3$$

We must also calculate the impact parameter (b) from the equation $b = \frac{kq_\alpha Q}{m_\alpha v^2}cot\frac{\theta}{2}$. If we ignore $\cot\frac{\theta}{2}$ for the moment, we calculate the rest of the equation with

$$\frac{(2)(79)(1.44ev * nm)}{(2)(7 * 10^6)} = 1.625 * 10^-5m^3$$

Then using the above equation with these calculted values,

$$f = (\pi)(1.625 * 10^-14)(5.9 * 10^{28})(2 * 10^-6) * [\cot\frac{\theta}{2}]^2$$

We find the answer to be $9.789 * 10^-5$.
We solve the second part of the quesiton using $f_{45} - f_{75}$.

$$f = (5.705 * 10^-4) - (1.663 * 10^-4)$$

We can calculate the radius of a gold atom by multiplying

$$\frac{19.3g}{cm^3} \times \frac{mol}{197g} \times \frac{6.02 * 10^23}{mol} = (5.8977 * 10^{22})^{-1}cm^3$$

Setting this value equal to the equation for the volue of a sphere, $V_{sphere} = (4/3)(\pi)(r^3)$ we can solve for radius to be $1.59 * 10^{-8}$.

7 Problem 4.15

Problem statement: Calculate the three longest wavelengths in the Lyman series ($n_f = 1$) in and indicate their position on a horizontal linear scale.
Solution: We can use the equation

$$\frac{1}{\lambda} = R(\frac{1}{n_f^2} - \frac{1}{n_i^2})$$

for n=1,2,3. We calculate the wavelengths to be 122nm, 103nm, and 87nm respectively.

8 Problem 4.16

Problem statement: Calculate the quantum number of earth if its angular momentum were quantized like a hydrogen atom. Would the energy release be detectable in a transition to the next lowest level? What would be the radius of that orbit?

Solution: We know that the mass of Earth is $5.97219 * 10^2 4$. We know the radius of Earth is $1.5 * 10^1 1$. We can calculate the angular velocity of Earth as follows:

$$v = \frac{2\pi r}{(365 days/year)(24 hours/day)(3600 sec/hour} = 29885.774 m/s$$

Based on the equation

$$n = \frac{mvr}{\hbar}$$

we can calculate the Earth's quantum number as $2.5389 * 10^7 4$.
Because the quantum number is so large, and using the equation

$$r_{n-1} = \frac{\hbar}{mv}(n-1)$$

it is impossible the energy change or the radius of the new orbit.