Homework #8: Photons and Conservation

1. You perform a photoelectric effect experiment in which you shine light of different frequencies on a certain material, and you measure the kinetic energies of the electrons emitted by the material.

a) Verify that Einstein's model is not wrong.

I plotted the points with frequency on the x axis and KE on the y axis. I got a figure consistent with a straight line. My best linear fit function was

$$KE = (0.42 \pm 0.02) \ \frac{\text{eV}}{10^{14} \text{ Hz}} \ \nu - (2.2 \pm 0.2) \text{ eV}. \tag{1}$$

Einstein's model predicts that

$$KE = h\nu - \phi \tag{2}$$

where h is Planck's constant and ϕ is the work function of the material. Planck's constant is 6.63×10^{-34} Js in SI units, and if I convert this number into the units of my figure, I get 0.414 (in the units given in Equation 1). This number is not significantly different from my slope, so Einstein's model is not wrong.

b) Predict the maximum wavelength of photons that will eject electrons from the material.

The photon frequency for which the kinetic energy of the ejected electron goes to zero can be predicted from Equation 1:

$$\nu = \frac{KE + (2.2 \pm 0.2) \text{ eV}.}{(0.42 \pm 0.02) \ \frac{\text{eV}}{10^{14} \text{ Hz}}} = (5.2 \pm 0.5) \times 10^{14} \text{ Hz}. \tag{3}$$

To get the wavelength, we simply use $c = \lambda\nu$ and get $(5.7 \pm 0.6) \times 10^{-7}$ m, or 570 ± 60 nm. That's near the green range of visible light.

c) What material do you think you've used as the target in the experiment?

Equation 2 lets me interpret the y-intercept of my fit (Equation 1) as the work function of the material. If you look at the work functions I gave you, there are two materials, sodium and cesium, that are not different from this result. However, iron and copper are more than 10σ off, so I think we can be sure they are not the material here.

2. Give at least two conservation laws violated by each of these decays:

(a) violates Z, muon family number and electron family number

(b) violates baryon number and electron family number

(c) violates muon family number and energy

(d) violates Z number, muon family number, and electron family number