CHM 322/642 Problem Set 1

February 13, 2017

1. Bhopal receives 5.51 kWh/m^2/day of sunlight averaged over a year. The solar spectrum peaks at around 500 nm. Assuming that all the energy received is at this wavelength how many solar photons reach Bhopal per m^2 per second ?

2. The work function of very pure Na is 2.75 eV. (a) Calculate the maximum kinetic energy of photoelectrons emitted from Na exposed to 200 nm UV radiation. (b) Calculate the longest wavelength that will cause the photoelectric effect in pure Na. (c) Impure Na has a workfunction lower than 2.75 eV. In this case, will the maximum kinetic energy of a photoelectron be less than or greater than that for pure Na exposed to 200 nm radiation?

3. A homogenous light beam of wavelength $\lambda = 3000$Å and intensity 5×10^{-2} W m^{-2} falls on a sodium surface. The photoelectric work function W for sodium is 2.3 eV. Calculate :

   (a) the average number of electrons emitted per m^2 and per second (assume that every photon striking the surface ejects an electron); and

   (b) the maximum kinetic energy of the photoelectrons.

4. A certain one-particle, one-dimensional system has a solution to the Schrodinger equation given by $\Psi = ae^{ibt}e^{-bmx^2/\hbar}$ where a and b are constants and m is the mass of the particle. Find the potential energy function $V(x)$ for this system.

5. An X-ray photon of wavelength $\lambda_0 = 1$Å is incident on a free electron which is initially at rest. The photon is scattered at an angle $\theta = 30°$ from the incident direction.

   (a) Calculate the Compton shift $\Delta\lambda$.

   (b) What is kinetic energy T_2 of the recoiling electron and the angle ϕ at which it recoils?

   (c) What fraction of its original energy does the photon lose?

6. A beam of x-rays with wavelength 0.2400 nm is directed toward a sample. The x-rays scatter from the electrons within the sample, imparting momentum to the electrons, which are initially at rest in the lab frame. After scattering, the x-rays are detected at various angles relative to the direction of the incoming beam using a detector that can resolve their wavelengths.

   (a) What is longest scattered wavelength measured by the detector?

   (b) At what scattering angle does this occur?

   (c) If the detector measures a wavelength for the scattered X-rays of 0.2412 nm, what is the X- ray scattering angle?

7. (a) Consider a cricket ball of mass 142 g. Assume that the ball has just been bowled and it is located somewhere between the stumps (take the distance between the stumps to be 20 m). A radar gun has measured the speed of the ball to be 85.0 km.h-1. Show that the spread of velocities caused by the uncertainty principle does not have a measurable consequence.

   (b) What is the kinetic energy of (a) an electron, (b) an alpha particle, and (c) a neutron, having a de Broglie wavelength of 1 Å.

8. A classical electron circling a nucleus in the n^{th} Bohr orbit with velocity $v$and r being the radius of orbit, would radiate electromagnetic energy at the frequency

$$\nu_{class} = \frac{v}{2\pi r} = \frac{m}{2\pi\hbar^3}\left(\frac{Ze^2}{4\pi\epsilon_0}\right)^2 \frac{1}{n^3} \tag{1}$$

   Show that this result agrees with the Bohr transition frequency from the n^{th} to the $(n-1)^{th}$ orbit for large values of n. (This is an illustration of the Bohr correspondence principle.)

9. Use the Heisenberg uncertainty principle to estimate the ground state energy for a particle of mass m in the potential $V(x) = 1/2kx^2$.

10. A particle is in the state described by a wavefunction $\Psi(x) = Ae^{-\alpha x^2/2}$. What is the probability that it has a momentum between p_0 and p_0+dp? What is uncertainty in its momentum?