

Physical Chemistry II

Problem Set I

1. Compute the momentum and speed of a neutron with a wavelength of 3mm. A neutron weighs as much as a proton.
2. Compute the momentum of a photon with a wavelength of 350nm. What speed does a hydrogen molecule (H_2) have to travel at to have the same momentum?
3. The speed of a proton is measured to be $4.5 \times 10^5 \text{ m/s} \pm 1000 \text{ m/s}$. What is the minimum uncertainty in its position?
4. A 500W green laser (525nm) is turned on for 10 sec. How many photons does it emit? How many mols of photons is this?
5. A laser emits photons with a wavelength of 1064 nm with a power output of $5 \times 10^6 \text{ J/s}$
 - a. Compute the energy from a $2 \times 10^{-8} \text{ s}$ pulse.
 - b. Compute the energy of one photon from this laser
 - c. Compute the number of photons in 10 pulses.
6. The work function for metallic cesium is 2.14eV. Compute the KE and speed of an electron hit by a photon of wavelength 300nm. What if the wavelength of the photon is 600nm?
7. The work function for metallic francium is 3.84eV ($1\text{eV} = 1.602677 \cdot 10^{-19} \text{ J}$). Compute the KE and speed of an electron hit by a photon of wavelength 170 pm. What if the wavelength of the photon is $170 \mu\text{m}$?
8. Compute the DeBroglie wavelength of an electron accelerated through a potential of 134V.
9. If the minimum uncertainty in the position of an electron on a straight wire is 150pm compute the minimum uncertainty in its momentum and speed.
10. The Heisenberg uncertainty relation for energy and time is $\Delta E \Delta t \geq h$. If the uncertainty in the lifetime of an excited state is 10^{-9} s what is the uncertainty in the state's energy?
11.
 - a. Explain black body radiation and why it is so important. Sketch a black body curve for $T = 100\text{K}$, 1000K and 10000K . Label the axes.
 - b. Explain the significance of the double slit experiment for electrons
 - c. Explain the significance of the photoelectric effect.

12. The Plank distribution is:

$$\rho = \frac{8\pi hc}{\lambda^5 (e^{hc/(\lambda kT)} - 1)}$$

where k is the Boltzmann constant. What are the units of ρ ?

13. True/False:

- a. A probability density can never be negative
- b. The state function can never be negative
- c. The state function must always be real
- d. The integral of the wave function over "all space" = 1.

14. Compute the momentum eigenvalue of the wave function:

$$\psi(x) = \cos(a)e^{ikx} + \sin(a)e^{-ikx}$$

15. Which of these functions are eigenfunctions of the operator d^2/dx^2 ? Show your work!

e^{ikx} , $\cos(kx)$, kx , $\exp(-ax^2)$

16. A particular wave function is:

$$\psi(x) = \frac{1}{\sqrt[4]{\pi}} \sqrt{2} \left(\frac{m\omega}{\hbar} \right)^{3/4} x e^{-\frac{m\omega}{2\hbar} x^2}$$

Compute the average value of the momentum squared operator. All space for this wave function is $(-\infty, \infty)$.