

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 must a hydrogen molecule (H_2) 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 ($1\text{eV} = 1.602677 \times 10^{-19} \text{ J}$). 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 μm ?
8. Compute the DeBroglie wavelength of an electron accelerated through a potential of 134V. $1\text{V} = 1\text{J/C}$.
9. The fourth fringe of an interference pattern formed by a beam of electrons traveling through a double slit mask appears at 3.3° to incidence. If the slits are 0.5mm apart, compute:
 - a. the wavelength in nm of the particles
 - b. the energy of the particles (mks units!)
 - c. the momentum of the particles (mks units!)
 - d. If the average speed of particles in the beam is 100m/s compute the average particle mass (mks units!).
10. 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.
11. The Heisenberg uncertainty relation for energy and time is

$$\Delta E \Delta t \geq \frac{\hbar}{2}$$

If the uncertainty in the lifetime of an excited state is 10^{-9} s what is the uncertainty in the state's energy?

12.

- a. Explain black body radiation and why it is so important. Sketch a black body curve for $T = 100\text{K}$, 1000K and 10000K (Hint: Think Wein displacement law). Label the axes.
- b. Explain the significance of the double slit experiment for electrons
- c. Explain the significance of the photoelectric effect.

13. The Plank distribution as a function of wavelength is:

$$\rho = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}$$

where k_B is the Boltzmann constant with units of J/K. What are the units of ρ ?

14. 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.

15. Compute the momentum eigenvalue of the wave function:

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

16. Which of these functions are eigenfunctions of the operator d^2/dx^2 ?

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

17. A particular wave function is:

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

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