PH-112 (2023 Spring): Tutorial Sheet 0

Notes:

1. This assignment is a check of your background knowledge. This will not be evaluated.
2. * marked problems will be solved in the Wednesday tutorial class.
3. Please make sure that you do the assignment by yourself. You can consult your classmates and seniors and ensure you understand the concept. However, do not copy assignments from others.

Photoelectric Effect:

1. *In a photoelectric effect experiment, excited hydrogen atoms are used as light source. The light emitted from this source is directed to a metal of work function Φ. In this experiment, the following data on stopping potentials (V_s), for various Balmer lines of hydrogen, is obtained.

$$\begin{aligned} n = 4 \to n = 2, &\text{ transition line : } V_S = 0.43 \text{ V} \\ n = 5 \to n = 2, &\text{ transition line : } V_S = 0.75 \text{ V} \\ n = 6 \to n = 2, &\text{ transition line : } V_S = 0.94 \text{ V} \end{aligned}$$

   a) What is the work function Φ of the metal in eV?
   b) What is the stopping potential (in Volts) for Balmer line of the shortest wavelength?
   c) What will be the photocurrent corresponding to Paschen series (ending in $n = 3$) transitions?

2. In an experiment on photoelectric effect of a metal, the stopping potentials were found to be 4.62 V and 0.18 V for $\lambda_1 = 1850$ Å and $\lambda_2 = 5460$ Å, respectively. Find the value of Planck's constant, the threshold frequency and the work function of the metal.

3. *A monochromatic light of intensity 1.0 μW/cm^2 falls on a metal surface of area 1 cm^2 and work function 4.5 eV. Assume that only 3% of the incident light is absorbed by the metal (rest is reflected back) and that the photoemission efficiency is 100 % (i.e. each absorbed photon produces one photo-electron). The measured saturation current is 2.4 nA.

   (a) Calculate the number of photons per second falling on the metal surface.
   (b) What is the energy of the incident photon in eV ?
   (c) What is the stopping potential ?

4. In a photoelectric experiment, a photocathode is illuminated separately by two light sources of same intensity but different wavelengths, 480 nm and 613 nm. The resulting photocurrent is measured as a function of the potential difference (V) between the cathode and the anode. Observed photocurrent for three values of V is given below

V	current (nA)

	480 nm	613 nm
-0.1	76.3097	64.7039
-0.2	67.6194	44.4078
-0.3	58.9291	24.1118

(a) Using this data, obtain the work function of the photocathode and the cut off wavelength.

(b) What is the maximum kinetic energy of the electron for $\lambda = 480$ nm? What should be the wavelength of light to emit electrons half this kinetic energy?

(c) When the photocathode material is changed, it is found that the cut off frequency is 1.2 times the cut off frequency of the old material. What is the work function of the new material?

5. Light of wavelength 2000 Å falls on a metal surface. If the work function of the metal is 4.2 eV, find the kinetic energy of the fastest and the slowest emitted photoelectrons. Also find the stopping potential and cutoff wavelength for the metal.

Bohr Model:

1. If the nucleus in the Bohr atom is assumed to be of finite mass, show that the equation for angular momentum, orbital radius and the energy will be the same except for the replacement of m by a reduced mass μ.

2. Two similar masses (m) are connected by a spring of spring constant k (neglect the natural length and mass of the spring and any other forces). The masses are made to rotate in a circle about their common centre of mass such that the distance between them is R. Apply Bohr's quantization rule to this system and find the allowed value of r and E_r in terms of m, k and fundamental constants.

3. *If the wavelength λ of the hydrogen atom spectra were to be given by the following expression (instead of the usual one),

$$\frac{1}{\lambda} = R\left(\frac{1}{m^3} - \frac{1}{n^3}\right)$$

where R is a constant and m, n are integers ($n > m$). If the condition for angular momentum quantization can be written as $L = a\hbar$, find the values of a so as to obtain the above spectra. Construct a theory similar to Bohr's using this quantization condition and find an expression of the energy and Bohr's radius.

4. *A muon is an elementary particle of charge $-e$ and mass $m = 207m_e$ (m_e is the mass of the electron). A muonic atom consists of a nucleus of charge Ze with the muon moving in circular oribits about the nucleus. For a muonic atom with $Z = 1$,

(a) calculate the radius of the first Bohr orbit.

(b) calculate the binding energy.

(c) find the wavelength of the first line in the Lymann series.

5. One of the spectral lines in the Hydrogen atom has a wavelength of 4861.320 Å. Along with this, a faint line appears at 4859.975 Ådue to the presence of a small amount of deuterium. Compute the ratio of deuterium mass to the proton mass.

6. *A positronium atom (an electron and a positron revolving about their common centre of mass) is excited from a state with $n = 1$ to $n = 4$. Apply Bohr's theory with suitable modifications and calculate the

   (a) energy that would have been absorbed by the atom

   (b) minimum possible wavelength emitted when such an electron de-excites

   (c) recoil speed and recoil energy of the positronium atom, assumed initially at rest, after the excitation takes place.

7. A hydrogen atom, initially at rest, makes a transition from $n = 4$ to $n =1$.

   (a) Calculate the recoil speed.

   (b) Assuming the gas to be classical, find the temperature at which the hydrogen atoms can achieve this average speed.

   (c) What is the kinetic energy given to the hydrogen atom?

   (d) What would you expect if the hydrogen atoms were in motion instead of initially at rest?

   (e) Can you think of a simple experiment that can be used for cooling a gas?