EASTERN UNIVERSITY, SRI LANKA

SECOND YEAR EXAMINATION IN SCIENCE – 1994/95 & 95/96
(August/September 1997) - REPEAT

PH 201 – ATOMS & GASSES AND QUANTUM MECHANICS

Time: 02 hours

Answer Four questions only, selecting at least Two from each section.

Section A

1. Derive Rutherford's Scattering formula and mention the important features of Rutherford's Scattering of α–particles by gold foil which supported the nuclear model of the atom against Thomson's model.

   A stream of α–particles is bombardered on a mercury nucleus ($Z = 80$) with velocity 1.0×10^7 m/s. If an α–particle is approaching the nucleus in head-on direction, calculate the distance of closest approach. Given mass of α–particle is 6.4×10^{-27} Kg.

2. State the postulate of Bohr's theory and deduce an expression for the energy of the n^{th} orbit of hydrogen atom. What interpretation do you give to the negative sign of the energy value.

   Show that the angular frequency of revolution of an electron in its orbit is given by the Bohr's theory as

$$\omega = \frac{\pi m Z^2 e^4}{2\epsilon_o^2 h^3 n^3}$$

   Where the symbols have their usual meanings.

   Hence, show that when n is very large the frequency of revolution $\frac{\omega}{2\pi}$ is equal to the frequency of the radiation emitted in the transition of an electron from state $n_2 = n + 1$ to state $n_1 = n$.

   Comment on the significance of this result.

3. State the change in assumptions of kinetic theory in the development of the Hirn and Van-der Waals equation of state.

   The critical temperature of CO_2 is 31.1°C and the critical pressure is 73 atm. Assume that CO_2 obeys the Van-der Waals equation.
   Calculate

   (a) the critical density of CO_2.

   (b) the diameter of a CO_2 molecule.

   (Given: molecular weight of CO_2 is 44 amu and 1 atm $= 1.01 \times 10^5$ Nm^{-2}.)

Section B

4. Explain what do you mean by Heisenberg Uncertainity principle with suitable example.

   An atom can radiate at any time after it is excited. It is found that in a typical case the average excited atom has a life time of about 10^{-8} sec. That is, during this period it emits a photon and is deexcited.

   (a) What is the minimum uncertainity $\Delta\nu$ in the frequency of the photon?

   (b) Most photons from Sodium atoms are in two spectral lines at about $\lambda =$ 5890 Å. What is the fractional width of either line, $\frac{\Delta\nu}{\nu}$?

   (c) Calculate the uncertainity ΔE in the energy of the excited state of the atom.

   (d) From the above results determine, to within an accuracy ΔE, the energy E of the excited state of a Sodium atom, relative to its lowest energy state, that emits a photon whose wavelength is centred at 5890 Å.

5. Explain what is photoelectric effect and give Einstein's interpretation for the same. Write down Einstein's photoelectric equation and explain the meaning of the following terms:

   (a) work function.

   (b) threshold frequency.

   (c) stopping potential.

   In an experiment on the photoelectric effect it is observed that for light of wavelength 500 nm a stopping potential of 0.25 V is required to cut off the current of photoelectron, where as, at a wavelength of 375 nm a stopping potential of 1.0 V is required. Calculate the ratio of Planck's constant to the electron charge $\left(\frac{h}{e}\right)$.

6. State the time independent Scrodinger equation for a particle of mass m moving in an one dimensional axis X, subject to a potential $V(x)$.

   What is the probability of finding a particle in a small distance dx centred at the point x where the wavefunction is $\Psi(x)$?

   A particle of mass m is confined to a line and has a wavefunction

$$\Psi = C \exp\left(-\frac{\alpha^2 x^2}{2}\right).$$

(a) Calculate C interms of α.

(b) Obtain an expression for the potential energy at a distance x from the origin if the total energy of the particle is

$$\frac{h^2\alpha^2}{8\pi^2 m}.$$

(c) Write down an integral expression for the probability of finding the particle between the points $x = 4$ and $x = 5$.

You may assume that

$$\int_{-\infty}^{+\infty} \exp\left(-y^2\right) dy = \sqrt{\pi}.$$