Atomic and Molecular Physics, Problem Sheet PHAS2224.1
Issued Thursday 24 January 2008, due Thursday 31 January 2008

1. Explain how Millikan's oil drop experiment can be used to demonstrate that electric charge is quantised in units of $e = 1.6 \times 10^{-19}$ C.

   In a Millikan oil drop experiment a spherical drop of oil fell freely with a terminal velocity of 4.35×10^{-4} ms^{-1} between horizontal plates 5 mm apart. When a potential difference of 3 kV is applied to the plates the drop rose rose at a constant speed of 1.38×10^{-4} ms^{-1}. Given that air has a viscosity of 1.8×10^{-5} Nsm^{-2} and a density of 1.29 kgm^{-3}, and that the density of the oil was 900 kgm^{-3}, find the radius of the oil drop and the electric charge (in coulombs and in multiples of the fundamental charge) on the drop. **[10]**

2. Explain briefly what was observed in the Rutherford scattering experiment and what can be deduced about the structure of the atom from the observations.

   Below is a table containing some of Geiger & Marsden's data from their α-particle scattering experiments of 1913:

angle of deflection ϕ / degrees	number of particles N
30	3.1
22.5	8.4
15	48.2
10	200
7.5	607
5	3320

Table 1: Geiger & Marsden's data

   By plotting a suitable graph, show that the number of particles scattered at angle ϕ is proportional to $\csc^n(\phi/2)$, where the exponent n is to be determined from your graph. **[10]**

3. What two postulates are made about the hydrogen atom in the Bohr model?

   By equating the centripetal force on an electron (charge $-e$) in a circular orbit around a nucleus (charge Ze) with the Coulomb attraction between the electron and the nucleus derive an expression for the allowed energies of the electron.

   The Rydberg constant for hydrogen is $\tilde{R}_{\mathrm{H}} = 109678$ cm^{-1} whereas for singly ionized Helium it is $\tilde{R}_{\mathrm{He}^+} = 109722$ cm^{-1}. Explain why this difference arises, calculate the energy required to completely remove the electron from the ground state of He^+. **[10]**