INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH PUNE

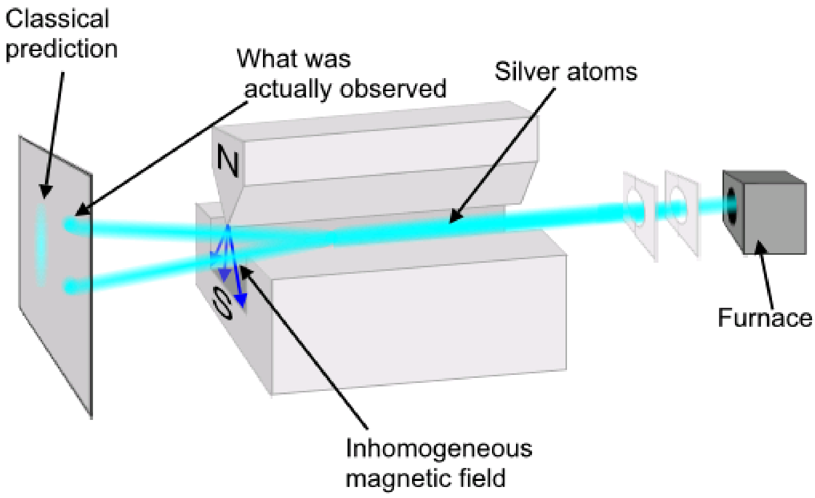
Quiz–1, Spring 2018

Course Name: Atomic and Molecular Physics — Course Code: PHY420
Date: 25.01.2018 — Duration: 08:30–09:30
Instructor: Bhas Bapat — Total Marks 20

Solve any *one* of Q1, Q2 and *three* of Q3–Q6. Questions carry equal marks.

1. The original Rutherford scattering experiment was done using 5 MeV alpha particles incident on a gold target ($Z = 79$). Suppose, that this experiment had been instead done with 10 MeV alpha particles incident on a silver foil ($Z = 47$). Discuss the implications of the outcomes of these experiments on the determination of the size of the nucleus.

2. In the Stern–Gerlach experiment a beam of silver atoms were made to pass through a long, narrow gap which had an inhomogeneous transverse magnetic field. The direction of the field is the same, and perpendicular to the atomic beam, at all points in the gap. The expected and observed images of the beam with the magnetic field are shown here.



   Stern and Gerlach had assumed that the silver atoms were in an $L = 1$ state. In hindsight, is their observation consistent with their assumptions? What is a reasonable conclusion from this experiment?

3. What would be the deuterium equivalent of the 21 cm line in hydrogen? Recall, that the hyperfine splitting of the hydrogen $l = 0$ state is given by

$$\Delta E_{HF} = \frac{4\alpha^4 mc^2 \gamma_p}{3} \frac{m}{M} \frac{f(f+1) - s(s+1)}{n^3}$$

   Write your answer in terms of $4\alpha^4 mc^2\gamma_p/3$. Note also, that the deuterium atom is like the hydrogen atom, the only difference being that the nucleus of deuterium consists of a proton and a neutron, both spin-half particles.

4. What would be the binding energy of the 1s2s and 1s2p configurations of the helium atom, assuming a screening constant that was obtained to match the ground state binding energy (-2.90 a.u.) for a $1s^2$ hydrogen-like configuration?

5. What is the fine structure of the 1s2p configuration of the He atom?

6. Instead of the L-S coupling scheme which we discussed in the class, consider the j-j coupling scheme, in which $\vec{l}$ and $\vec{s}$ of an electron couple to form a new vector $\vec{j}$, and the vectors $\vec{j}_1, \vec{j}_2$ of the two electrons couple to form the net angular momentum $\vec{J}$. The usual angular momentum and spin quantisation rules apply. Show that the *number of terms* in the L-S and j-j coupling schemes is the same (do it for a two electron system).