PHY140Y

Spring Term – Tutorial 23 Discussion

27 March, 2000

1. The "fine structure" of the atom results from the interaction of the magnetic field of the atom itself (generated by the relative orbital motion of the electron and proton) and the electron's magnetic moment

$$\vec{M} \quad = \quad -\frac{e}{m_e}\vec{S}, \tag{1}$$

where $\vec{M}$ is the magnetic dipole moment, e is the charge of the electron, m_e is the electron's mass and $\vec{S}$ is the electron's spin vector. The energy splittings of the different spin states of the electron in an external magnetic field lead to the "Zeeman Effect."

   (a) Calculate the value of the "Bohr magneton" μ_B, defined as the magnitude of the electron's magnetic moment along the z axis.

   (b) In an externally applied magnetic field $B = 1.5$ Tesla, what is the difference in energy between the different spin states of an electron in the same orbital angular momentum and radial quantum state?

   (c) Is this consistent with the data shown in Fig. 40-30 of the text?

   (d) How can this difference in energy be measured?

2. Charles Townes (who will be giving the a special lecture as part of the Department's centennary celebrations in early May) and Arthur Schawlow (a graduate of this Department) developed the laser in the 1950's. The basic idea is that of "stimulated emission," namely that an atom can be goaded to make a transition from a higher energy level to a lower one if a photon of the same energy as that released in the emission process passes by. Einstein discovered this phenomenen in 1917. Thus, if we have a bunch of atoms, all sitting in an excited state and relatively happy there (we call this a metastable state as it has a long lifetime), and we pass by these atoms a few photons of the right energy, this will prompt a chain reaction to occur where all the atoms will deexcite at once, leading to a very bright and coherent burst of light.

   Let's see how this can be used to make a He-Ne laser.

   (a) An electric current passing through a helium gas causes some of the helium atoms to be excited into a metastable state with energy 20.61 eV above the ground state. What would be the minimum kinetic energy of the electron and its minimum velocity in such a collision?

   (b) The helium atoms then collide with neon atoms in their ground state, and occassionally excite the neon atoms into an excited metastable state with energy 20.66 eV. These atoms then deexcite to an intermediate state by stimulated emission by emitting a photon with wavelength $\lambda_e = 632.8$ nm. What is the energy of the intermediate state? What is the colour of the light.

(c) The neon atoms in the intermediate states then decay to the ground state through spontaneous emission. What is the wavelength of that photon and what part of the spectrum is it in?

(d) If we assume all of the electric energy associated with the current flow is transferred into exciting helium atoms, what fraction of this energy is emitted at the wavelength λ_e?

(e) If we wanted to make a 1 mW laser in this way, what would be the current required if we used a 120 V power source?