Fundamentals of Spectroscopy for (Optical) Remote Sensing

Homework #4 (Atomic Spectroscopy)

1. (1) Please summarize the key points for how to study a spectral line and what kind of theories to be used for these studies.
   (2) Please summarize the major interactions inside and outside an atom that determine the energy level structure of this atom. Consider two cases: single electron atom and multi-electron atom.

2. An electron beam enters a homogeneous magnetic field with 1.2T strength. Please calculate the energy difference between the electrons whose spin is parallel to the magnetic field and the electrons whose spin is anti-parallel to the magnetic field.

3. The combination energy of Helium atom is 24.5 eV. In order to ionize the two electrons of a Helium atom one by one, how much energy must be provided?

4. (1) A Helium atomic beam in ground state passes through an inhomogeneous magnetic field (Stern-Gerlach experiment). How many beams will be seen on the screen?
   (2) Under the same conditions, if the atomic beam consists of B atoms (Boron), how many beams will be seen? Why?
   (*Please analyze from the point of view of electron configurations to the atomic state of the ground state, and then to the magnetic field interaction with atomic magnetic moment.*)

5. Assume an atom is in a very strong external magnetic field $\vec{B}$ that is larger than the internal magnetic field of the atom. Thus, the LS coupling of the atom will be broken, and the total orbital angular momentum $\hat{\vec{L}}$ and the total spin angular momentum $\hat{\vec{S}}$ will precess around the external field $\vec{B}$ independently (Paschen-Back effect).
   (1) Write the equation of the atomic total magnetic moment;
   (2) Write the equation of the magnetic interaction energy in the field $\vec{B}$;
   (3) If this atom is a sodium atom (Na), please derive the energy splitting of its ground state and the first excited states, and then draw a diagram of the split energy levels;
   (4) Using selection rules $\Delta m_s = 0, \Delta m_l = 0, \pm 1$, please mark the allowed transitions between the first excited states and the ground state.

6. Laser Isotope Separation (LIS), Electron Paramagnetic Resonance (EPR), Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI) are some important applications of atomic spectroscopy. You are encouraged to choose one of the topics to search on the web or library to find out (1) its working principle, (2) application field, and (3) how it is related to our class contents. Please write a 1-2 page study report for your research results.