Practice Modern Physics II, W2018, Part I

Question 1 Energy Level Diagram of Boron ion B^{2+} For neutral *Be* Z = 5.

(A) Draw the fine-structure diagram of B^{2+} that includes all n = 3 states. Label the states in **spectroscopic notation.**

(B) Using the selection rules of equation 8.8 draw all the allowed transitions of B^{2+} . Such diagrams are called **Grotian diagrams**.

Question 2 Atomic Physics (Fine Structure and Zeeman Effects)

Excited states of atoms, fine-structure, and Zeeman effects. The ground-state configuration of **SODIUM** (Z = 11) is $1s^2 2s^2 2p^6 3s^1$, **in term symbol** is $3^2S_{1/2}$.

A) Write is the **first excited state electronic configuration of Sodium**. Find **the spectroscopic notation** (term symbol) of the **two states** associated with this excited state. **Hint**: find all the total orbital Angular Momentum (L) and total spin (S), and all the **possible** total angular momentum (J). **Also see equation sheet for energy order**!!

B) Write the **second excited state electronic configuration of SODIUM**. Find **the spectroscopic notation** (term symbol) of the **one state** associated with this excited state. Briefly explain why there is **only one state**. **Look at the energy order list in back!**

C) The first excited state of **LITHIUM** (Z = 3) has electronic configuration $1s^2 2p^1$, and is split into two states (doublet) $2^2P_{1/2}$ and $2^2P_{3/2}$. It is estimated that the **internal magnetic field** for this state is $B_{\text{int}} = 0.36T$. Find the **fine-structure** energy difference between the $2^2P_{1/2}$ and $2^2P_{3/2}$ states.

D) Suppose the **LITHIUM** atom is placed in an external magnetic field of magnitude $B = 0.5T$. How many energy levels do the $2^2P_{3/2}$ have? Draw a schematic diagram to illustrate these energy levels. Find the energy spacing between adjacent energy levels. **HINT:** This is the Zeeman Effects! Lande factor is relevant!

Question 3 Molecular Spectroscopy: It is known that the hydrogen molecule H_2 has a vibration absorption (emission) frequency of $v_0 = 1.32 \times 10^{14}\,Hz$.

A) Model the H_2 molecule as two H atoms connected by a spring. Based on the data given calculate the spring constant k. Use m_H = 1u.

B) Now consider a deuterium molecule D_2, where D is a heavy hydrogen with nucleus of one proton and one neutron with a mass m_D = 2amu. Use the data of part A to calculate the vibration frequency of this molecule.

C) Are H_2 and D_2 **infrared active**? Briefly explain your answer.

Question 4 Vibrational Energy Level of oxygen molecule O_2

A) Assume that the O_2 molecule behaves like a harmonic oscillator with a force constant of 210 N/m. Find the energy (in eV) of its **ground** (n = 0) and **first excited** (n = 1) vibrational states. For ^{16}O, $m_o = 16\text{ u}$, where $1\text{ u} = 1.66\times10^{-27}\,kg$.

B) Find the vibration quantum number that approximately corresponds to its 1.5-eV dissociation energy. **Hint:** see dissociation equation on the equation sheet.

C) Is O_2 **infrared active**? Briefly explain your answer.

Question 5 Microwave Spectroscopy: The rotational transition from the $\ell = 2$ to the $\ell = 1$ state in CO is accompanied by the emission of a $9.55\times10^{-4}\,eV$ photon

A) Use this information to find the rotational inertia of the CO molecule.

B) What is the bond length between the C and O atoms. Data: Mass of carbon $m_C = 12\text{u}$; Mass of oxygen $m_O = 16\text{u}$; $1\text{ u} = 1.66\times10^{-27}\,kg$.