4.E: Exercises

Problems

1.	Would you expect the spectrum of magnesium ($Z = 12$) to resemble that of He? Explain your answer.
2.	The boron atom has the electronic configuration $1s^2 2s^2 2p^1$. The single unpaired electron in the $2p$ orbital will possess both orbital and spin angular momentum. Into how many distinct beams will a beam of boron atoms be split when it is passed through an atomic beam apparatus with an inhomogeneous magnetic field directed perpendicular to the direction of travel of the atoms?
3.	When a test tube containing an aqueous solution of Fe^{+3} ions is placed near the poles of a strong magnet, the test tube is attracted and pulled into the magnetic field. When a test tube containing a solution of Zn^{+2} ions is placed near the magnetic field, it is ***not*** attracted into the field. Use the atomic orbital theory to account for the fact that the Fe^{+3} solution is magnetic while the Zn^{+2} solution is not. The atomic number of Fe is 26 and of Zn is 30. (Recall that the $3d$ orbitals are more stable than are the $4s$ orbitals in the ionic forms of the transition elements.)
4.	Suppose you lived in a universe where all of the laws of quantum mechanics applied as they do in ours, but where the spin angular momentum quantum number of the electron had increased from ½ to some larger value. The new value must also be half-integer if the Pauli principle is to apply. Rather than use the general symbol "*l*"to denote an angular momentum quantum number, we shall reserve this symbol for orbital angular momentum and introduce a new symbol "*s*" to denote the spin angular momentum quantum number. In our universe, a beam of hydrogen atoms in their ground state (with $l = 0$) is split in two in an atomic beam apparatus when a magnetic field is applied. The number of quantized components of angular momentum is related to the angular momentum quantum number by the expression $(2l + 1)$ for orbital momentum or $(2s + 1)$ for spin momentum. Thus, since two components are observed, the value of the spin quantum number s in our universe is ½. Recall that the magnetic quantum number m governing the components of angular momentum assumes values from l to � l in steps of unity or from s to � s in the case of spin angular momentum. If we use m_l and m_s to denote the orbital and spin magnetic quantum numbers respectively, then the values of m_s are + ½ and � ½ in our universe.

	(a)	When a beam of hydrogen atoms with $l = 0$ is passed through an atomic beam apparatus in the new universe, the magnetic field causes the beam to split into four (4) separate beams. What is the value of the spin quantum number s in the new universe and what are the possible values for the spin magnetic quantum number m_s ? Since only the spin quantum number has undergone a change in the new universe, the atomic orbital model of electronic structure should still apply and each electron will be assigned to an orbital with some value of n, l and m_l and a given spin quantum number m_s. The statement of the Pauli principle as it applies to the orbital model is "no two electrons in the same atom may have all four quantum numbers the same." How many electrons may occupy an orbital with given values of n, l and m_l in the new universe?
	(b)	Clearly, the periodic table of the elements in the new universe will have a different structure from that in ours. State how many elements would appear in the first, second, third and fourth rows of the new table. What would be the ground state configurations of the elements with atomic numbers Z = 7 and 10 and what would their valencies be? Which element would be the first of the noble gases in the new universe?
5.	When a transition metal ion is place in solution, its magnetic moment generally changes from the value it had in the gas phase, indicating that the number of unpaired electron spins is different in the gas and solution phases. Transition metal ions M^{2+} form a six-coordinated octahedral complex with CN^- ions when placed in solution containing this ligand. The formation of the complex perturbs the d orbitals, changes their energy and partiallly removes their degeneracy. That is, the d-level which is five-fold degenerate in the gas phase is split into two or more levels with different energies. The new sets of levels can be dgenerate, but their degeneracies will necessarily be less than five. By measuring the magnetic moment of solution of the complexes $M(CN)_6^{-4}$ for various metal ions M^{2+}, one can determine the number of unpaired d electrons in the complex. With this information, use the orbital model to determine the number of levels into which the d-level is split and the degeneracy of each of the new levels. The solution of the Fe^{2+} ion showed that no permanent magnetic moment was present - the solution was diamagnetic. The V^{2+} and Ni^{2+} solutions gave moments indicating the presence of three and two unpaired electrons respectively. The atomic numbers of the metal atoms are V:23, Fe:26 and Ni:28. You must show how your final answer is arrived.	