

**Astrophysics — ASTR-4220**  
**Class 25**  
**Atomic Spectra**

**Exercise (30 pts)**

- 1. (5 pts)** — In this exercise we will figure out the spectroscopic term(s) for the ground state of the neutral carbon atom ( $Z = 6$ ). Start by writing down the electronic configuration.
- 2. (5 pts)** — Which of the orbitals in part 1 can be neglected for the purposes of finding the spectroscopic terms? Briefly explain why.
- 3. (5 pts)** — For the remaining electron(s), give all values of  $L$  that are allowed by the rules for adding angular momenta.
- 4. (5 pts)** — For the remaining electron(s), give all values of  $S$  that are allowed.
- 5. (5 pts)** — The table you have just received has all of the possible combinations of  $m_\ell$  and  $m_s$  for electrons that cannot be neglected. In the column headed “Label” write OUT for any combination that violates the Pauli Exclusion Principle.
- 6. (5 pts)** — Now go back through the table and number all of the *distinguishable* states. Indistinguishable state are combinations of quantum numbers that represent the same physical state. For example, rows two and three are indistinguishable and so have received the same label, State 1.

**Solution**

- 1.** —  $1s^2 2s^2 2p^2$
- 2.** — We can neglect the 1s and 2s electrons. These subshells are full and a theorem states that they contribute zero to the total electronic and spin angular momentum of the atom.
- 3.** — The two p electrons have orbital angular momenta  $\ell_1 = \ell_2 = 1$ . The quantum mechanical rules for adding angular momenta say that their sum can be  $L = 2, 1$ , or  $0$ . These correspond respectively to  $D, P$ , and  $S$  states.
- 4.** — The two p electrons have  $s_1 = s_2 = 1/2$ . The total spin can be  $S = 0$  or  $1$ , i.e., the states can be singlets or triplets.

5. and 6. — The filled-in table should be as follows:

$m_{\ell 1}$	$m_{s1}$	$m_{\ell 2}$	$m_{s2}$	Label
+1	+1/2	+1	+1/2	OUT
+1	+	+1	-	1
+1	-	+1	+	1
+1	-	+1	-	OUT
+1	+	0	+	2
+1	+	0	-	3
+1	-	0	+	4
+1	-	0	-	5
+1	+	-1	+	6
+1	+	-1	-	7
+1	-	-1	+	8
+1	-	-1	-	9
0	+	+1	+	2
0	+	+1	-	4
0	-	+1	+	3
0	-	+1	-	5
0	+	0	+	OUT
0	+	0	-	10
0	-	0	+	10
0	-	0	-	OUT
0	+	-1	+	11
0	+	-1	-	12
0	-	-1	+	13
0	-	-1	-	14
-1	+	+1	+	6
-1	+	+1	-	8
-1	-	+1	+	7
-1	-	+1	-	9
-1	+	0	+	11
-1	+	0	-	13
-1	-	0	+	12
-1	-	0	-	14
-1	+	-1	+	OUT
-1	+	-1	-	15
-1	-	-1	+	15
-1	-	-1	-	OUT