Homework for Chapter 5

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1. He 原子的两个电子处在 2p3d 电子组态. 问可能组成哪几种原子态? 用原子态的符号表示之. 已知电子间是 LS 耦合.

$$\begin{cases} s_1 = s_2 = \dfrac{1}{2} \\ l_1 = 1 \\ l_2 = 2 \end{cases} \Rightarrow \begin{cases} L = 3, 2, 1 \\ S = 1, 0 \end{cases}$$

So that the atom has the following 12 states

	S = 0	S = 1
L = 1	$^1P_1$	$^3P_{0,1,2}$
L = 2	$^1D_2$	$^3D_{1,2,3}$
L = 3	$^1F_3$	$^3F_{2,3,4}$

2. 已知 He 原子两电子被分别激发到 2p 和 3d 轨道, 其所构成的原子态为 ^{3}D, 问这两电子的轨道角动量 p_{l_1} 与 p_{l_2} 之间的夹角, 自旋角动量 p_{s_1} 与 p_{s_2} 之间夹角分别是多少?

$$\begin{cases} L = 2 \\ S = 1 \\ l_1 = 1 \\ l_2 = 2 \end{cases} \Rightarrow \begin{cases} p_{l1} = \sqrt{l_1 (l_1 + 1)}\hbar = \sqrt{2}\hbar \\ p_{l2} = \sqrt{l_2 (l_2 + 1)}\hbar = \sqrt{6}\hbar \\ P_l = \sqrt{L (L + 1)}\hbar = \sqrt{6}\hbar \end{cases}$$

$$P_L^2 = p_{l1}^2 + p_{l2}^2 + 2p_{l1}p_{l2}\cos\theta \Rightarrow \cos\theta = \frac{P_L^2 - p_{l1}^2 - p_{l2}^2}{2p_{l1}p_{l2}} \Rightarrow \theta = 106^\circ$$

3. 锌原子(Z=30)的最外层电子有两个，基态时的组态是 4s4s. 当其中有一个被激发，考虑两种情况：

(1) 那电子被激发到 5s 态，

(2) 它被激发到 4p 态.

试求出在 LS 耦合情况下这两种电子组态分别组成的原子状态. 画出相应的能级图. 从(1)和(2)情况形成的激发态向低能级跃迁分别各有几种光谱跃迁?

Q1 When the electrons is in 4s5s

$$\begin{cases} s_1 = s_2 = \dfrac{1}{2} \\ l_1 = 0 \\ l_2 = 0 \end{cases} \Rightarrow \begin{cases} S = 0, 1 \\ L = 0 \end{cases}$$

	S = 0	S = 1
L = 0	$^1S_0$	$^3S_1$
L = 1	$^1P_1$	$^3P_{0,1,2}$

The possible transitions are

$$\begin{aligned} 5^1S_0 &\to 4^1P_1 \\ 5^3S_1 &\to 4^3P_0 \\ 5^3S_1 &\to 4^3P_1 \\ 5^3S_1 &\to 4^3P_2 \\ 4^3P_2 &\to 4^3S_1 \end{aligned}$$

Q2 When the electrons is in 4s5p

$$\begin{cases} s_1 = s_2 = \dfrac{1}{2} \\ l_1 = 0 \\ l_2 = 1 \end{cases} \Rightarrow \begin{cases} S = 0, 1 \\ L = 0, 1 \end{cases}$$

	S = 0	S = 1
L = 0	$^1S_0$	$^3S_1$
L = 1	$^1P_1$	$^3P_{0,1,2}$

The possible transitions are

$$4^1P_1 \to 4^1S_0$$

4. 试以两个价电子 $l_1=2$ 和 $l_2=3$ 为例证明，不论是 LS 耦合还是 jj 耦合都给出同样数目的可能状态.

L-S coupling has 20 states

$$S=0,1$$
$$L=1,2,3,4,5$$

	S = 0	S = 1
L = 1	$^1P_1$	$^3P_{0,1,2}$
L = 2	$^1D_2$	$^3D_{1,2,3}$
L = 3	$^1F_3$	$^3F_{2,3,4}$
L = 4	$^1G_4$	$^3G_{3,4,5}$
L = 5	$^1H_5$	$^3H_{4,5,6}$

jj coupling has 20 states as follows, as well

	$j_1=\frac{5}{2}$	$j_1=\frac{3}{2}$
$j_2=\frac{7}{2}$	$J=6,5,4,3,2,1$	$J=5,4,3,2$
$j_2=\frac{5}{2}$	$J=5,4,3,2,1,0$	$J=4,3,2,1$

6. 已知 He 原子的一个电子被激发到 2p 轨道，而另一个电子还在 1s 轨道. 试作出能级跃迁图来说明可能出现哪些光谱线的跃迁.

$$\begin{cases} s_1=s_2=\frac{1}{2} \\ l_1=1 \\ l_2=0 \end{cases} \Rightarrow \begin{cases} L=1 \\ S=1,0 \end{cases}$$

So that the atom has the following 12 states

	S = 0	S = 1
L = 0	$^1S_0$	$^3S_1$
L = 1	$^1P_1$	$^3P_{0,1,2}$

The possible transitions are

$$2^1P_1 \to 1^1S_0$$
$$2^1P_1 \to 2^1S_0$$
$$2^3P_0 \to 2^3S_1$$
$$2^3P_1 \to 2^3S_1$$
$$2^3P_2 \to 2^3S_1$$

8. Pb 原子基态的两个价电子都在 6p 轨道，若其中一个价电子被激发到 7s 轨道，而其价电子间相互作用属于 jj 耦合。问此时 Pb 原子可能有哪些状态？

jj coupling has 20 states as follows, as well

	$j_1 = \frac{3}{2}$	$j_1 = \frac{1}{2}$
$j_2 = 1/2$	$J = 2, 1$	$J = 1, 0$