Atomic Physics

Summary

1. The basic properties of atom(mass, radius, charge)

2. The atom models

3. Geiger-Marsden experiment

4. Rutherford Scattering formula (Impact parameter, cross section, differential cross section)

5. Nuclear radius

1. The classical atom model

2. Bohr's hydrogen model

3. The spectrum of hydrogen

4. The correspondence principle

5. Alkali atom, penetrating effect and effective nuclear charge

1. Blackbody Radiation
2. Photoelectric Effect
3. Wave properties of matter (Electron scattering)
4. Uncertainty principle
5. Wave Functions, Schrodinger equation with infinite square well
6. Expectation value, operator, orbital angular momentum

1. Electron Spin (Stern-Gerlach Experiment)
2. Magnetic moment (g factor)
3. Spin-orbit coupling (angular moment coupling of single electron)
4. Zeeman effect (Normal and abnormal, polarization, Grotrian Diagram)

Chapter 5

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1. The spectrum of helium
2. The coupling of electrons (electron configuration)
3. The allowed transitions
4. Pauli exclusion principle
5. Periodic Tables (equivalent electrons, shell and subshell, Diagonal rule and Hund's rule)

1. The diffraction of X ray

2. The spectrum of X ray (continuous and characteristic)

3. The production of X ray

4. Moseley formula

5. Compton effect

1. Orbital angular moment

$$\hat{L} = \hat{r} \times \hat{p}$$

The components of orbit angular moment

$$\hat{L}_x = \hat{y}\hat{p}_z - \hat{z}\hat{p}_y = -i\hbar\left(y\frac{\partial}{\partial z} - z\frac{\partial}{\partial y}\right)$$

$$\hat{L}_y = \hat{z}\hat{p}_x - \hat{x}\hat{p}_z = -i\hbar\left(z\frac{\partial}{\partial x} - x\frac{\partial}{\partial z}\right)$$

$$\hat{L}_z = \hat{x}\hat{p}_y - \hat{y}\hat{p}_x = -i\hbar\left(x\frac{\partial}{\partial y} - y\frac{\partial}{\partial x}\right)$$

The square of orbit angular momentum operator

$$\hat{L}^2 = \hat{L}_x^2 + \hat{L}_y^2 + \hat{L}_z^2$$

The eigenstate and eigenvalue of orbit angular moment

$$\hat{L}^2 Y_{lm} = L^2 Y_{lm} = l(l+1)\hbar^2 Y_{lm} \qquad L = \sqrt{l(l+1)}\hbar$$

$$\hat{L}_z Y_{lm} = m_l \hbar Y_{lm}$$

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2. The total magnetic moment is,

$$\vec{\mu}_j = \vec{\mu}_l + \vec{\mu}_s,$$

$$= -g_j \mu_B \vec{J}/\hbar \qquad |\vec{\mu}_j| = -g_j \mu_B \sqrt{j(j+1)}$$

$$\mu_{j,z} = -g_j m_j \mu_B$$

where, g_j is the Lande factor oftotal angular momentum

$$g_j = \frac{3}{2} + \frac{S(S+1) - L(L+1)}{2J(J+1)}$$

$$= \frac{3}{2} + \frac{\hat{S}^2 - \hat{L}^2}{2\hat{J}^2}$$

3. Spin-orbit coupling potential

$$U = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2m_e^2c^2r^3}\vec{L}\cdot\vec{S}$$

energy interval from spin-orbit term

$$\Delta E_{so} = \frac{Z^4e^2\hbar^2}{8\pi\varepsilon_0 m_e^2c^2a_1^3}\frac{1}{n^3l(l+1)}$$

$$= \frac{(\alpha Z)^4}{2n^3l(l+1)}E_0$$

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4. Zeeman effect

The energy in magnetic field is,

$$E_B = g_j m_j \mu_B B$$

The frequency of splitting spectra ,

$$\nu = \nu_0 + (m_2 g_2 - m_1 g_1)\frac{e}{4\pi m}B$$

The selection rules,

$$\Delta m_l = 0, \pm 1$$

Polarizations,

σ^- (ΔM_J = -1) π (ΔM_J = 0) σ^+ (ΔM_J = +1)

5. The coupling of two angular momenta

$$L_1 = \sqrt{l_1(l_1+1)}\hbar$$
$$L_2 = \sqrt{l_2(l_2+1)}\hbar$$
$$L = \sqrt{l(l+1)}\hbar$$

where,

$$l = |l_1 - l_2|, |l_1 - l_2| + 1, |l_1 - l_2| + 2, \ldots, |l_1 + l_2|$$
$$m = m_1 + m_2$$

The letters and numbers used in this notation are called spectroscopic or term symbols.

$$n^{2S+1}L_J$$

For two electrons we have singlet states (S=0) and triplet states (S=1), which refer to the multiplicity 2S+1.

Consider two electrons: One is in the 4p and one is in the 4d subshell. For the atomic states shown

S	*L*	*J*	Spectroscopic Symbol
0 (singlet)	1	1	4^1P_1
	2	2	4^1D_2
	3	3	4^1F_3
1 (triplet)	1	2	4^3P_2
		1	4^3P_1
		0	4^3P_0
1 (triplet)	2	3	4^3D_3
		2	4^3D_2
		1	4^3D_1
1 (triplet)	3	4	4^3F_4
		3	4^3F_3
		2	4^3F_2

The allowed transitions for a single-electron atom are

$$\Delta l = \pm 1 \qquad \Delta m_j = 0, \ \pm 1$$

$$\Delta j = 0, \ \pm 1$$

The choice rules of transitions (for LS coupling scheme) are

$$\Delta L = \pm 1 \qquad \Delta S = 0$$

$$\Delta J = 0, \pm 1 \quad (J = 0 \to J = 0 \ \ \text{forbidden})$$

The choice rules of transitions for jj coupling are

$$\Delta j = 0, \pm 1 \qquad \Delta J = 0, \pm 1$$

$$(J = 0 \to J' = 0 \ \ \text{forbidden})$$

The parity requirement

$$\sum l_i - \sum l_f = \pm 1$$

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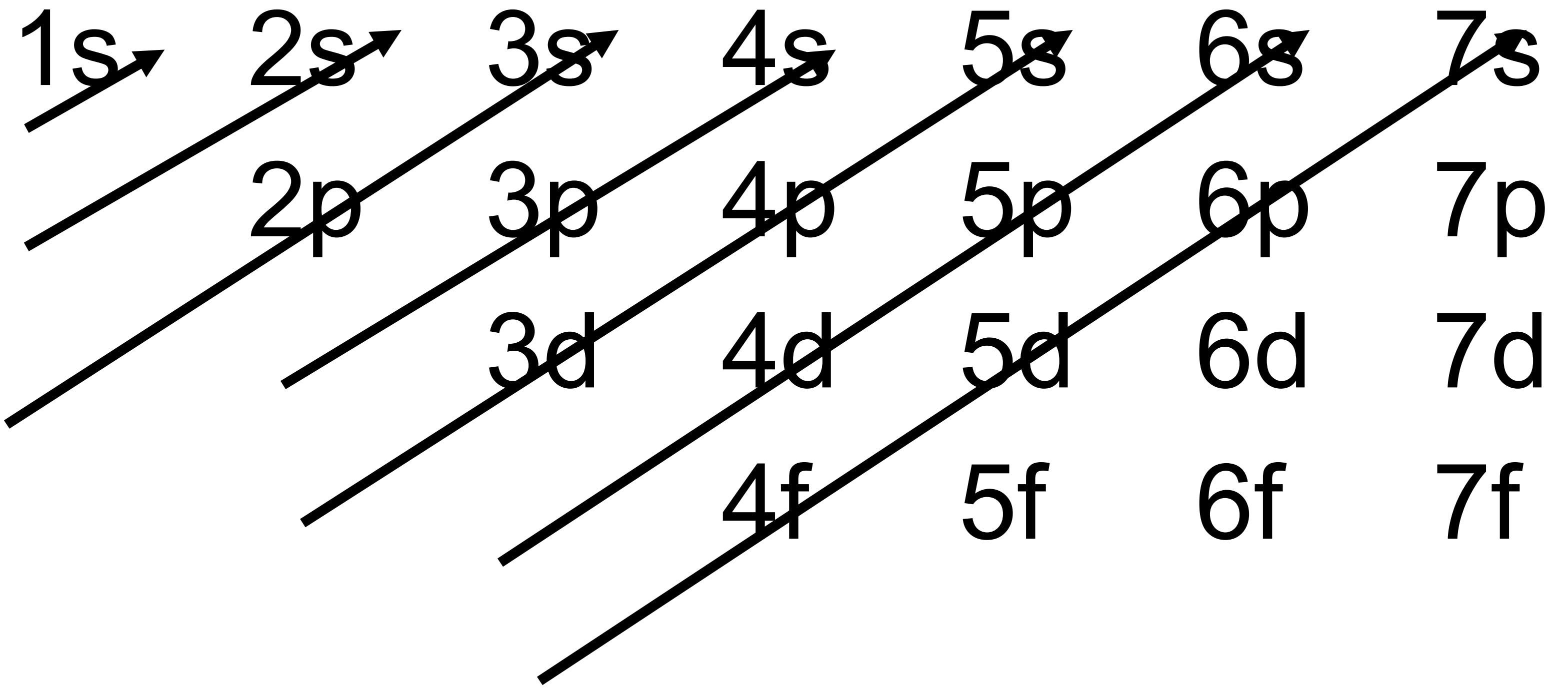
Spectroscopy terms for atoms with equivalent electron configurations

Configuration	Electronic terms	Atoms
$p\ \ p^5$	^2P	B, F
$p^2\ \ p^4$	$^1S\ ^3P\ ^1D$	C, O, N^+
p^3	$^4S\ ^2P\ ^2D$	N, O^+
p^6	^1S	Ne
$d\ \ d^9$	^2D	Sc
$d^2\ \ d^8$	$^1S\ ^3P\ ^1D\ ^3F\ ^1G$	Ti, Ni
$d^3\ \ d^7$	$^2P\ ^4P\ 2^2D\ ^2F\ ^4F\ ^2G\ ^2H$	V, Co
$d^4\ \ d^6$	$2^1S\ 2^3P\ 2^1D\ ^3D\ ^5D\ ^1F$ $2^3F\ 2^1G\ ^3G\ ^3H\ ^1I$	Fe
d^5	$^2S\ ^6S\ ^2P\ ^4P\ 3^2D\ ^4D\ 2^2F$ $^4F\ 2^2G\ ^4G\ ^2H\ ^2I$	Mn
d^{10}	^1S	Zn

Pauli exclusion principle for two electrons

$$L + S = \text{even}$$

The Diagonal Rule for Configurations



If n+l is same, fill the configuration with smaller n first

if n+l are different and n are same, fill smaller l

and n is different, fill larger n

Hund's rules which are empirical state (the first and second) that the term structure with the maximum possible S and the largest possible L for the given S compatible with the Pauli exclusion Principle has the lowest energy.

Hund's third rule (which applies for atoms or ions with a single unfilled shell) states that if the unfilled shell is not more than half-filled the lowest value of J has the lowest energy while if it is more than half-filled the largest value of J has the lowest energy

Good luck!

Examination time: 10:00—11:40, Jan. 18, 2019 (Friday)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