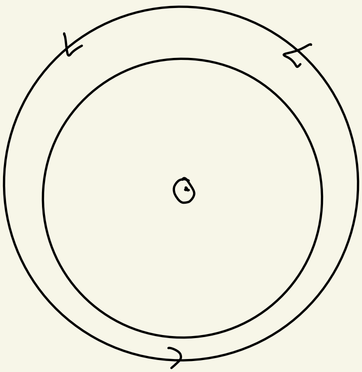
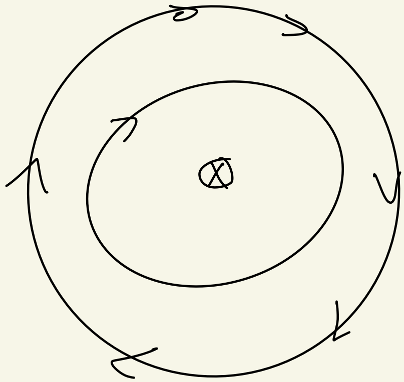
9.1

degenercy | can't distingush between n, l, m_l





R.H.R

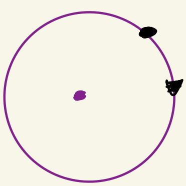
Magnetic dipole moment

the area

$$\vec{\mu} = i\vec{A}$$

the normal vector

what about for $\bar{e}$



H - atom

$$|L| = m_e v r$$

only if it is constant

$$= m_e \frac{2\pi r}{T} r$$

$$= \frac{2m_e}{T} \pi r^2 = \frac{2m_e}{T} A$$

$$L = \frac{2m_e}{T} A \Longrightarrow A = \frac{TL}{2m_e}$$

$$\mu = \frac{q}{T}\frac{TL}{2m_e} \longrightarrow \vec{\mu} = \frac{q}{2m_e}\vec{L}$$

$$\boxed{\vec{\mu} = -\frac{e}{2m_e}\vec{L}}$$

$\vec{\mu}$ opposite to $\vec{L}$

$$|\vec{L}| = \hbar\sqrt{l(l+1}$$

$$l = 0, 1, 2, \ldots n-1$$

$\vec{L}$ is quanized, and $\vec{\mu}$ is quanized.

$$L_z \checkmark = m_l \hbar$$

~~L_x, L_y~~

$$\mu_z = \frac{-e}{2m_e} L_z$$

$$\mu_z = \frac{e\hbar}{2m_e} m_l$$

$$\boxed{\mu_z = \mu_B \; m_l}$$

2.27×10^{-27} J/T = Bohr magneton

$$\mu = -\frac{e\hbar}{2m_L}\sqrt{l(l+l}$$

for $l = 2$

there are 5 orentions for μ.

you can see them when you apply

magnatic field

---

the β will Rotate the μ

tourq!

$$\vec{\tau} = \vec{\mu} \times \vec{\beta}_{ext} = \left|\frac{d\vec{L}}{dt}\right|$$

Larmor Precession

$$|\tau| = \mu \beta_{ext} \sin\theta = L \sin\theta \frac{d\phi}{dt}$$

$$= \frac{e}{2m_e} \cancel{L} B \cancel{\sin\theta} = \cancel{L} \cancel{\sin\theta} \frac{d\phi}{dt}$$

$$\frac{d\phi}{dt} = \frac{eB}{2m_e} = \text{angular velocity}$$

$$w_L = \frac{eB}{2m_e}$$

Larmor frequency

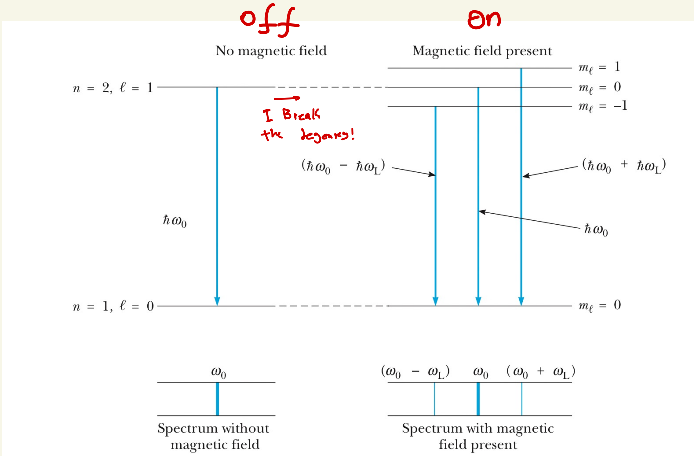
$$U = -\mu \cdot B$$

assuming that only in z axis

$$U = -\frac{e\vec{L}}{2m_e} \cdot \vec{B} = \frac{eL_zB}{2m_e} = \underbrace{\frac{eB}{2m_e}}_{w} \hbar m_\ell$$

$$U = \hbar w_L m_\ell$$

off on



$$E = E_0 + \hbar w_L m_\ell$$

$$\left.\begin{array}{l}\Delta n \geq 1 \\ \Delta \ell = \pm 1\end{array}\right\} \Delta m_\ell = 0, \pm 1$$

You only will see three lines!

for any value of l

How many state you hake?

$l = 5$, then you hake 11 substrate

$2l + 1$ = number of substate

Normal Zeeman Effect

$$\Delta E = \hbar \omega_L = \hbar \frac{eB}{2m_e}$$

increas B to get big $\Delta\lambda$

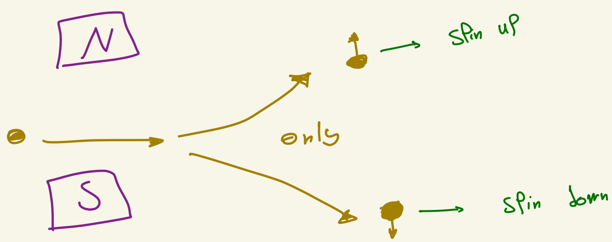
9.2

intrinsic (mass)

e has two motions

 and 

Spin angular momentum



spin up, or spin down only if there is B

this property is called intrinsic property (like the mass)

$\langle l^2 \rangle = \hbar^2 l(l+1) \longrightarrow |\vec{L}| = \hbar\sqrt{l(l+1)}$

the Projection

for z component $\langle L_z \rangle = \hbar m_l$, $m_l = 0, \pm 1, \pm 2 \dots l$

$\langle S^2 \rangle = \hbar^2 S(S+1) \longrightarrow \langle S \rangle = \hbar\sqrt{S(S+1)}$

$S_z = \hbar m_s$, $m_s = -S, -S+1, -S+2 \dots\dots, S$

$m_s \neq 0$

e/P/n $\Longrightarrow$ always $S = \frac{1}{2}$

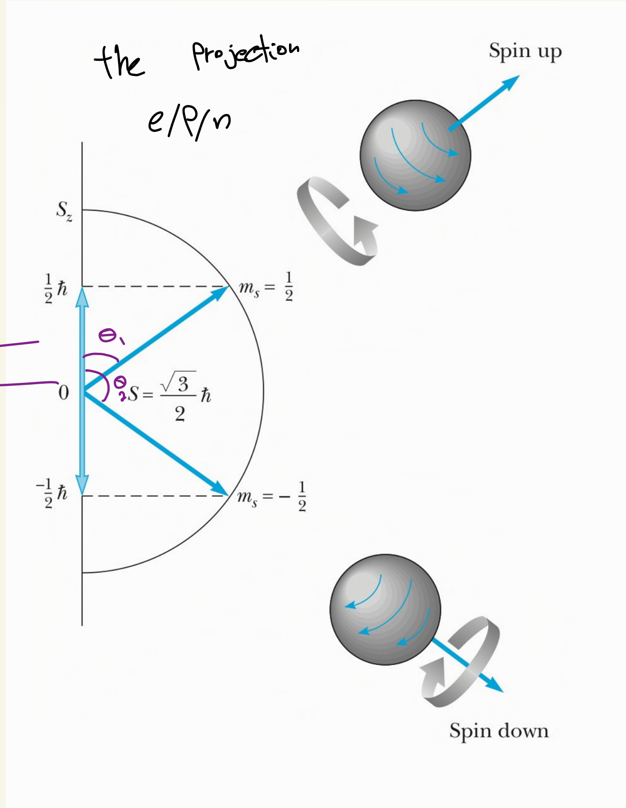
$\langle S \rangle = \hbar\sqrt{\frac{1}{2} \cdot \frac{3}{2}}$

$\langle S \rangle = \hbar\frac{\sqrt{3}}{2}$

$m_s = -\frac{1}{2}, \frac{1}{2}$ only

then

$S_z = \pm\frac{\hbar}{2}$



the angle is qauntized

$$\cos\theta = \frac{S_z}{S} = \pm\frac{1}{\sqrt{3}}$$

$$\theta_1 = 54.7$$

$$\theta_2 = 125.26$$

$$\mu_0 \Longrightarrow B$$

$$\mu = \frac{q}{2m}\vec{L}$$

$$E = E_0 \pm \hbar w_L m_l$$

__Spin__

constant = diffletion of the angle = 2

$$U = -\mu_s \cdot B = -g\frac{q}{2m_e}\vec{S}\cdot B$$

$-e$

$$= \cancel{2}\frac{e}{\cancel{2}m_e}S_z B$$

$\hbar m_s = \pm\frac{\hbar}{2}$

Bohr Magnetron

$$U = \pm\frac{e\hbar}{2m_e}B$$

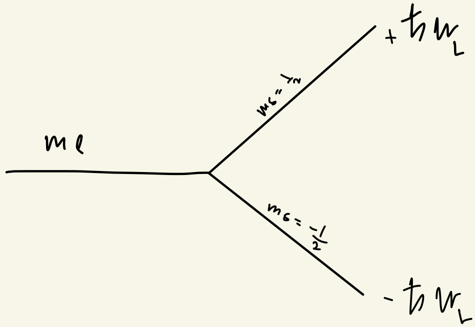
$$= \pm\mu_B B$$

$$= \pm\frac{eB}{2m_e}\hbar$$

$= w_L$!!!

$$\boxed{U = \pm \hbar \omega_L}$$

because of the spin



in the presence of $\vec{B}$:

in genral

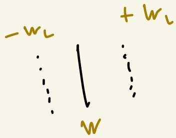
$$\vec{\mu}_{tot} = \vec{\mu}_o + \vec{\mu}_s = \frac{-e}{2m_e}\left(\vec{L} + g\vec{S}\right)$$

$$E = E_0 \pm \overbrace{\hbar \omega_L m_l}^{\text{orbital}} \pm \underbrace{\hbar \omega_L}_{\text{spin}}$$

strong B

Anomolous Zeeman Effect $\equiv$ fine Structre for the atom

↳ Weak B



Without spin:

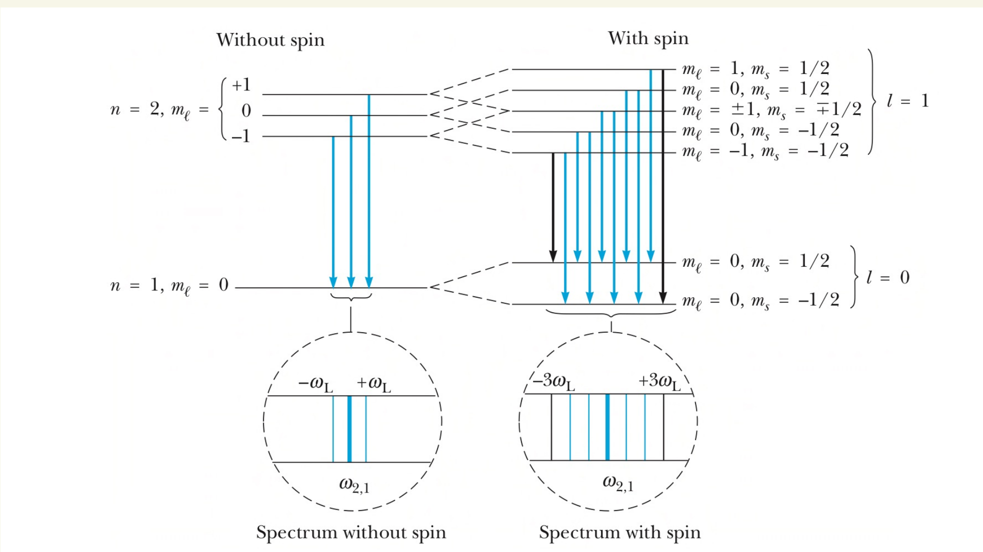
$\Delta l = \pm 1, \quad \Delta m_l = 0, \pm 1$

With spin:

$\Delta l = \pm 1$

$\Delta(m_l + m_s) = 0, \pm 1$

it should be 6, but there is a symmetry so = 5 states



$E = E_0 \pm \hbar w \pm h w$

$E = E_0 \pm \hbar w$, $E = E_0 \pm 2 \hbar w_L$

you have 5 lines in the spectrum

4.3

$\vec{L}$, $\vec{S}$ → spin angular angular momentum

orbital angular momentum

$$\vec{J} = \overset{m_l}{\vec{L}} + \overset{m_s}{\vec{S}}$$

$$|\vec{J}| = \hbar \sqrt{j(j+1)}$$

$$J_z = \hbar m_j$$

for e, $\vec{S} = \frac{1}{2}$

$$\vec{J} = \vec{L} + \vec{\frac{1}{2}}$$

if $\vec{L} = 0$, $J = \frac{1}{2}$ $\longrightarrow$ S State $= nS_{\frac{1}{2}}$

possitive

$m_j = -j, -j+1, \ldots, j-1, j = -\frac{1}{2}, \frac{1}{2} = m_J$

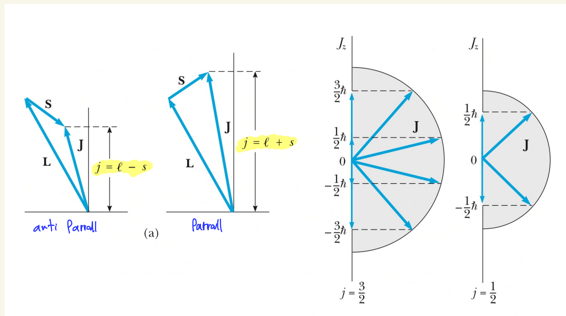
---

if $\vec{L} = 1$, $m_s = \frac{1}{2}$ $\longrightarrow$ P State

$j = \ell - s$ or $j = \ell + s$

$= 1 - \frac{1}{2}$ | $= 1 + \frac{1}{2}$

$j = \frac{1}{2}$ | $j = \frac{3}{2}$



$m_j = -\frac{1}{2}, \frac{1}{2}$ | $m_j = -\frac{3}{2}, -\frac{1}{2}, \frac{1}{2}, \frac{3}{2}$

$nP_{1/2}$ $nP_{3/2}$

$n = 2$, $\ell = 0, 1$

$J = \frac{5}{2}$ $m_j = -\frac{5}{2}, -\frac{3}{2}, -\frac{1}{2}, \frac{1}{2}, \frac{3}{2}, \frac{5}{2}$ $d_{5/2}$

$J = \frac{3}{2}$ $m_j = -\frac{3}{2}, -\frac{1}{2}, \frac{1}{2}, \frac{3}{2}$ $d_{\frac{3}{2}}$

$\ell = 0 \longrightarrow 2$

$\ell = 1 \longrightarrow 6$

$\ell = 2 \longrightarrow 10$

$s, \ell \equiv$ is the projection (distance) along z-axis

j is always +

How many sub state I have for m_j?

$\boxed{m_j = 2j + 1}$

$$J_{total} = \vec{J_1} + \vec{J_2} \ldots \vec{J_n}$$

$\uparrow\uparrow$ or $\downarrow\downarrow$

Summing two vectors, they may be parallel so $(\cdot + \cdot)$, or they might be antiparallel $(\cdot - \cdot)$

$\uparrow\downarrow$

ℓ = is always positive

$$\ell_{max} = 5$$

$$\ell_{min} = 1$$

$\equiv$ 1, 2, 3, 4, 5

Spin - orbit interaction

$B_{ext} = 0$

* there is L

* the Proton is Producing B_{int} at the Position of the electron !!

$$\vec{\mu}_{tot} = \vec{\mu}_l + \vec{\mu}_s = -\frac{e}{2m_e}(\vec{L} + g\vec{S})$$

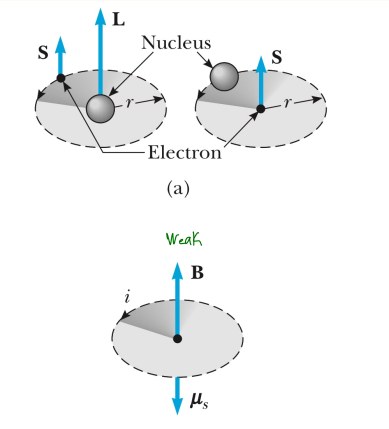
1

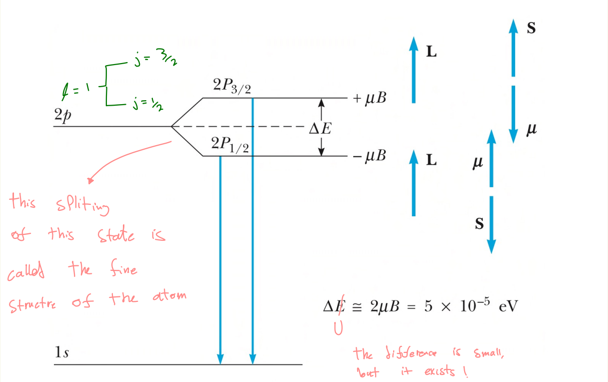
$$U = -\mu_{tot} \cdot B = \frac{e}{2m_e}(\vec{L} + g\vec{S}) \cdot \vec{B}_{int} =$$

when $\vec{L}, \vec{S}, \vec{B}$ all parallel,

$U = \max$

$U = \min$, when S is antiparallel with $\vec{L}, \vec{B}$





this splitting of this state is called the fine structure of the atom

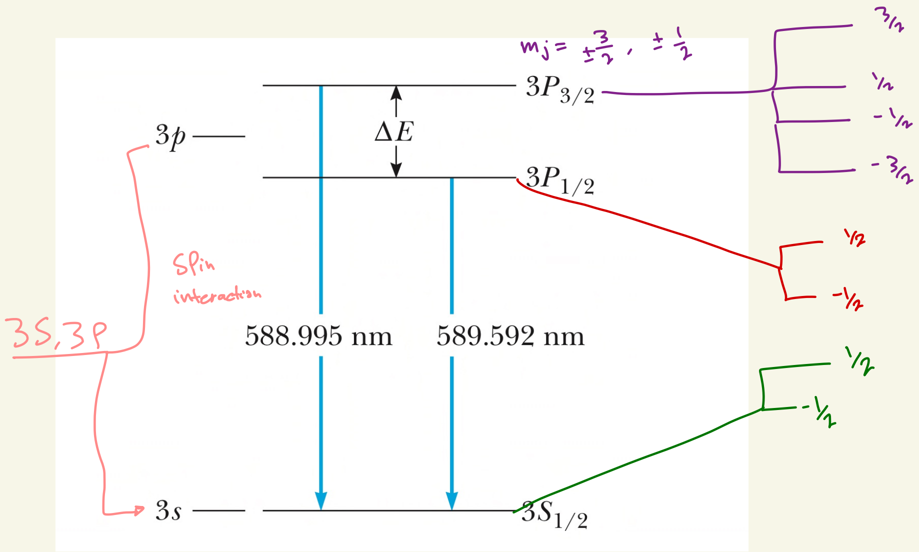
the difference is small, but it exists !

$J = S + L$ is always conserved

S, L: no longer conserved

$3S$, $3P$ are degenerate, but because of the spin, you can see the difference

the Energy of $3S \neq$ the Energy of $3P$



fine Structre of the atom

$B \longrightarrow$ protons weak $=$ you didn't kill them

Weak (anamolus) Zeeman effect

$B \longrightarrow$ Strong (B_{ext})

Normal zeeman effect

it kills the degenercy

4.4

No spin effect

n, l, m_l, m_s 4

there is a spin effect

n, l, j, m_j 4

* No two electrons can have the same four quantum numbers

d $l=2$ $j = 5/2$ $5/2, 3/2, \frac{1}{2}, -\frac{1}{2}, -3/2, -5/2$

$j = 3/2$ $3/2, 1/2, -1/2, -3/2$

Ex

$n = 1 \quad , \quad l = 0$

without spin effect

with spin effect

$m_l = 0$

$m_s = \pm \frac{1}{2}$

always $= \frac{1}{2}$

$j = s + l$

$= \frac{1}{2} + 0$

$j = \frac{1}{2}$

$m_j = \frac{-1}{2}, +\frac{1}{2}$

Total Degeneracy $= 2n^2$

It means that we have $2n^2$ electrons which they have the same E, but different wave functions.

max

$n = 2 \longrightarrow 8 \quad 1 \sim 8$

$n = 3 \longrightarrow 18 \quad 1 \sim 18$

$n = 4 \longrightarrow 32 \quad 1 \sim 32$

electron configuration

$n=1,\ \ell=0$

$H \longrightarrow (1) \longrightarrow 1s$

$He \longrightarrow (2) \longrightarrow 1s^2$

$Li \longrightarrow (3) \longrightarrow 1s^2\, 2s$

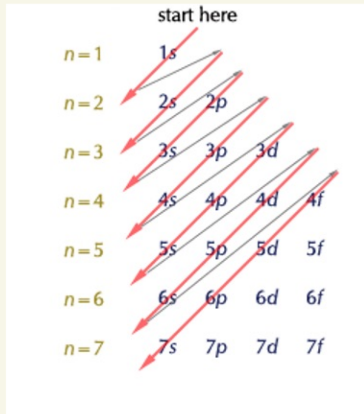
$\ell = 0 \qquad \ell = 1$

$Be \longrightarrow (4) \longrightarrow 1s^2\, 2s^2$

$B \longrightarrow (5) \longrightarrow 1s^2\, 2s^2\, 2p$

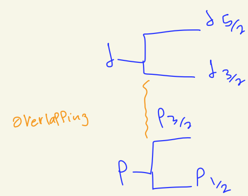
$\ell = 0 \qquad \ell = 1$

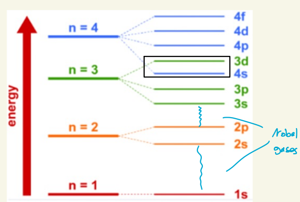
$C \longrightarrow (6) \longrightarrow 1s^2\, 2s^2\, 2p^2$



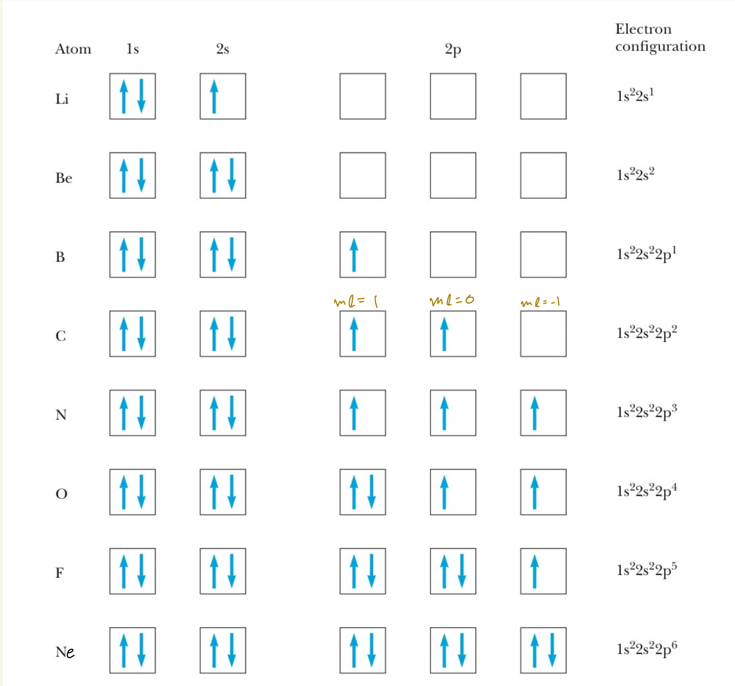
you may fill 3d before 4s. why?

only information

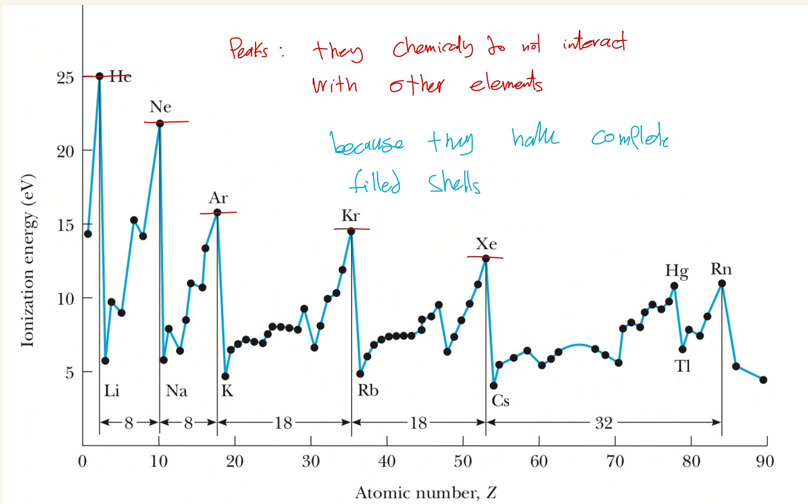




Hund's Rule



Atom
1s
2s
2p
Electron configuration
Li
$1s^2 2s^1$
Be
$1s^2 2s^2$
B
$1s^2 2s^2 2p^1$
$m_l = 1$
$m_l = 0$
$m_l = -1$
C
$1s^2 2s^2 2p^2$
N
$1s^2 2s^2 2p^3$
O
$1s^2 2s^2 2p^4$
F
$1s^2 2s^2 2p^5$
Ne
$1s^2 2s^2 2p^6$



Peaks : they chemically do not interact with other elements
because they have complete filled shells
He
Ne
Ar
Kr
Xe
Hg
Rn
Li
Na
K
Rb
Cs
Tl
8
8
18
18
32
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
Ionization energy (eV)
Atomic number, Z

(a)

9.7

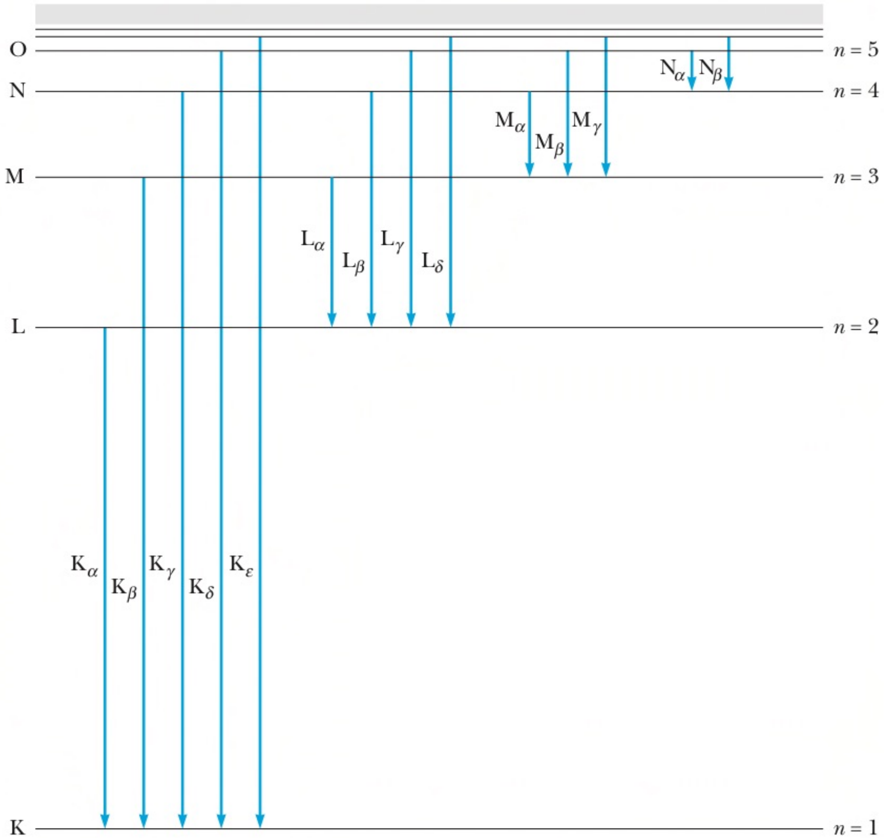


Figure 9.17 Origin of x-ray spectra. The K series (K_α, K_β, K_γ, . . .) originates with electrons in higher-lying shells making a downward transition to fill a vacancy in the *K* shell. In the same way, the filling of vacancies created in higher shells produces the L series, the M series, and so on.

each elemen $\longrightarrow$ x-rays $\longrightarrow$ finger Prints