Shell Model : By. Dmitry Ivanenko.

further developed by Wigner, Maria & Jensen.
(Nobel prize 1963).

→ ① Only applicable in Ground state & not in excited state.

② n & p are filled seperately.

③. Follow the Pauli's Exclusion principle.

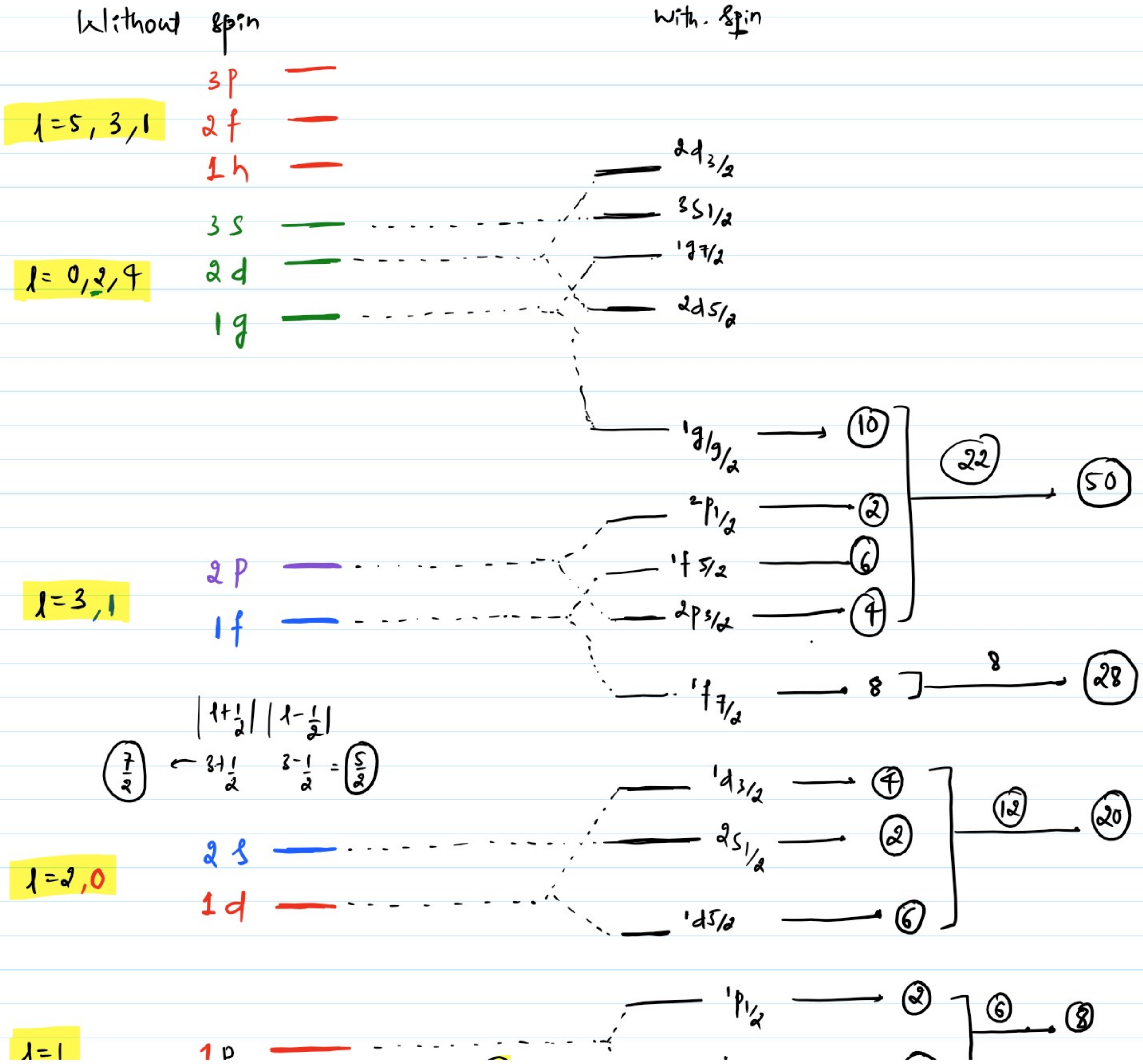
④. Do not follow Hund's rule.

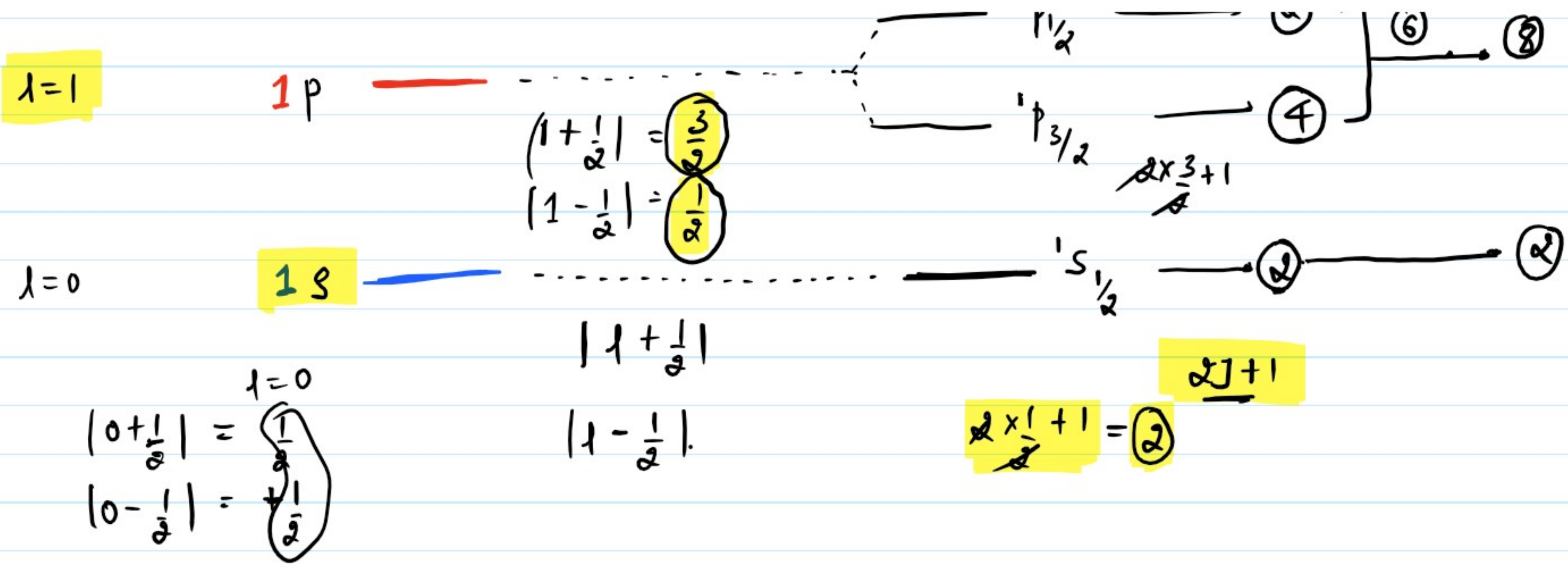
$l = 0 \rightarrow s$

$l = 1 \rightarrow p$

$l = 2 \rightarrow d$

$l = 3 \rightarrow f$





Significance of Nuclear shell model & Consequently Magic Number.

Stability, Abundance, B.E → Expained by using Magic Number.
(2, 8, 20, 28, 50, 82, 126. + 114, 164, 184)

\# Nucleids having magic no. → More stable.

① Significance of these Number : **Nuclear Stability**

Nucleus having double magic no. has heighest stability measured by average nucleus B.E

$^{4}_{2}He_{2}$, $^{16}_{8}O_{8}$, $^{40}_{20}Ca_{20}$, $^{208}_{82}Pb_{126}$

82 → Magic, 126 → Magic

Double Magic No.

Similary the Nucleids with one Magic no. is also stable comparing with neighbouring nuclei.

- Heaviest, non-radioactive nuclei → $^{209}_{83}Bi_{126}$.
- End product of naturally occuring radioactive series is generally $^{208}_{82}Pb_{126}$

② **Nuclear Stability Island :**

Ex: $^{298}_{114}X_{184}$ → Will be stable if discovered.

③. Abundance in Nature :

$^{16}_{8}O_{8}$ ⟶ 48% in earth's crust.

(8 → Magic No. ; 8 → Magic No.)

→ Some ex. $^{88}_{38}Sr_{50}$, $^{89}_{39}Y_{50}$, $^{90}_{40}Zr_{50}$

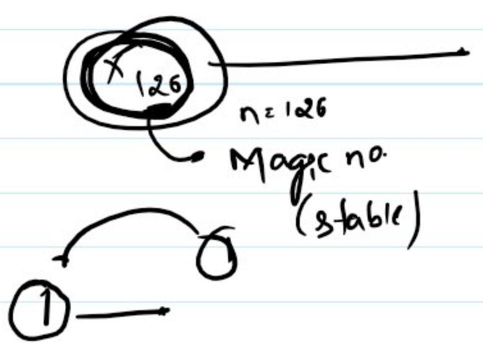
③. Number of stable isotope :

Element with magic No. of proton produce a large no. of isotopes.

$_{20}Ca$ ⟶ 6 isotopes

$_{50}Sn$ ⟶ 10 isotopes.

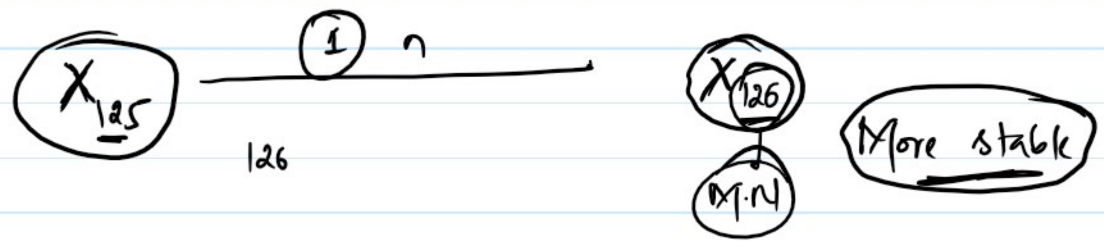
$_{82}Pb$ ⟶ 4 isotopes.



④ Cross Section for Neutron Capture :

Nucleids with Magic No. of neutron show a small cross-section for neutron capture

Nuclei running short by 1 neutron to attain magic number shows very large cross section for neutron capture.



⑤ Tendency of α & β decay

Nuclei which can attain the nearest magic no. through α & β decay are very much unstable in comparision to other nuclei that already have magic no.

Ex: $^{212}_{84}Po_{128}$ ⟶ $^{208}_{82}Pb_{126}$ + $^{4}_{2}\alpha$

Less stable $t_{1/2}$ = 46 sec. More Stable

$^{210}_{84}Po_{126}$ ⟶ $^{206}_{82}Pb_{124}$

Stable $t_{1/2}$ = 136.5 day Unstable

⑥ Nuclear Arrangement & configuration:

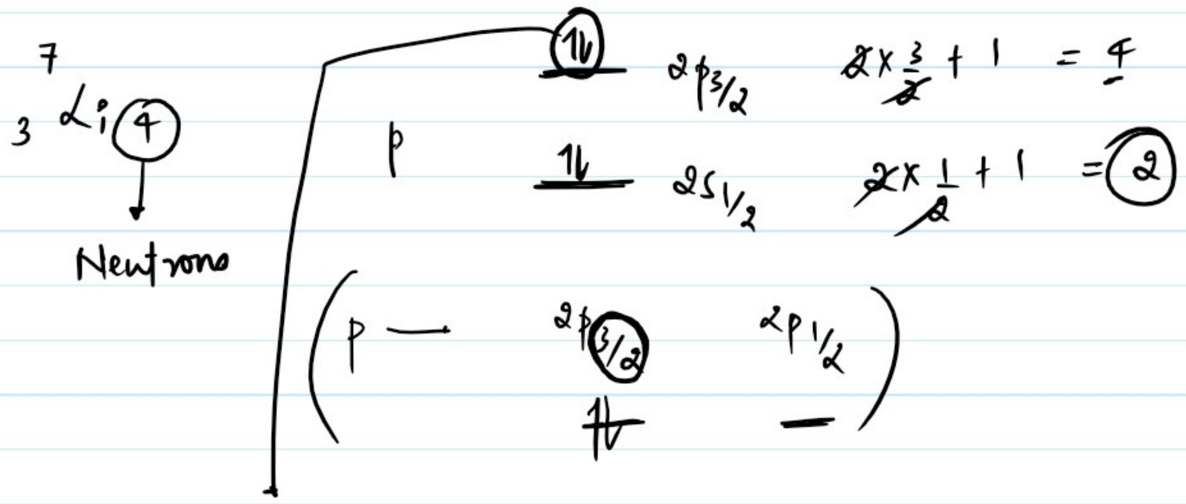
① A particular level can accomodate $(2J+1)$ nucleons.

② The configuration of neutron & proton. are represented seperately.

③ It follows pauli's exclusion principle.

④ In constructing this configuration. Hund's rule of maximum spin multiplicity is not maintained.

Ex: $^{7}_{3}Li$ (4)



These two neutrons are paired.
(Does not follow Hund's rule)

Determination of Nuclear spin, & total nuclear angular momentum. Q.no. & parity is possible.

① **Close shell Nuclei.** (with double magic no)

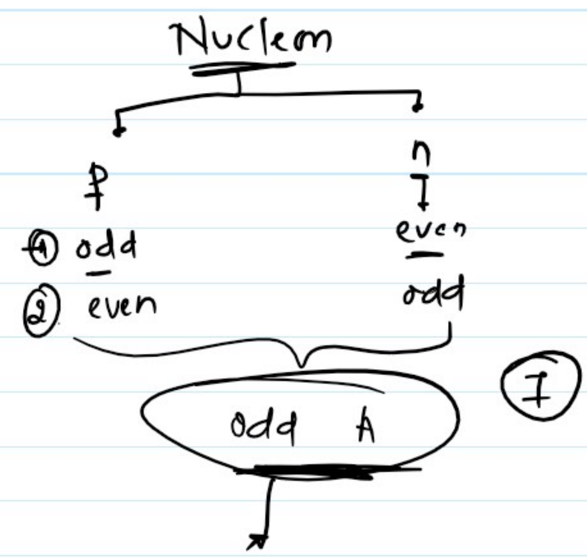
These type of nuclei are extremely stable. & in this case, each kind of nucleons are paired. seperately. & consequently. $(I=0)$

$^{4}_{2}X_{2}$

(I = 0) (I = 0)

② **Nuclei with odd 'A'**

In these type of nuclei, only one kind of. nucleon. (either proton or neutron) is odd. while the other is even. in number & that sublevel. gives the value of I.



A nuclei is of even parity if its orbital is. symmetric. with respect to 'sin' function.

$$\psi(x, y, z) = \psi(-x, -y, -z) \longrightarrow \text{Even parity}$$

$$\psi(x, y, z) = -\psi(-x, -y, -z) \longrightarrow \text{Odd parity}$$

Parity may be determined in the form of 'l'

$(-1)^l = -ve \longrightarrow$ odd parity

$(-1)^l = +ve \longrightarrow$ even parity.

$(-1)^l = +ve$	$(-1)^l = -ve$
$l = 0 \longrightarrow s$	$l = 1 \longrightarrow p$
$l = 2 \longrightarrow d$	$l = 3 \longrightarrow f$
$l = 4 \longrightarrow g$	$l = 5 \longrightarrow h$
even parity	odd parity.

And in such case, nuclear spin is generally determined by J.

Ex: ① $^7_3Li_4$ ⑦ —— odd 'A'

3 → odd; 4 → even

odd ↓ $1s^2_{1/2}$ $1p^1_{3/2}$

(J) → Nuclear spin = $I = \frac{3}{2}$

odd parity

② $^{17}_8O_9$ (17) —— odd 'A'

(8) → even; (9) → odd

$1s^2_{1/2}$ $1p^4_{3/2}$ $1p^2_{1/2}$ $1d^1_{5/2}$

(J) → Nuclear spin ⇒ $I = 5/2$

Even parity

Q.①. For an odd nucleon in 'g' nuclear orbital & parallel to I, spin parity are :

ⓐ $\frac{9}{2}(+)$ ⓑ $\frac{7}{2}(+)$ ⓒ $\frac{9}{2}(-)$ ⓓ $\frac{7}{2}(-)$

→ 1 Nucleon in g

(g) → $l = 4$ . . . . . $(l - \frac{1}{2})$ → $g_{7/2}$; $(l + \frac{1}{2})$ → $g_{9/2}$

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

$|1+\frac{1}{2}|\ |1-\frac{1}{2}|$ $\quad (1+\frac{1}{2}|$ $\frac{9}{2}$

Thus $I = \frac{9}{2}$

π $(-1)^{l} = (-1)^{4} = +1 \rightarrow$ positive (+)

HW

Q. The nuclear & parity corresponding to $^{7}_{3}Li$ in filling of neutron is

(a) $\frac{3}{2}(-)$ (b) $\frac{3}{2}(+)$ (c) $\frac{1}{2}(-)$ (d) $\frac{1}{2}(+)$

Q. In filling of nuclons in shell model. the rule that is followed:

(a) Pauli Exclusion Principle ✓

(b) Hund's rule of maximum multiplicity

(c) Both

(d) None of the above.

Q. Which of the following can not be explained by shell model?

(A). Extra stability of Nuclei.

(B). Nuclear isomerisation.

(C) Energy of first excited state in even even nuclei. ✓

(D) Spin & parities of odd - odd Nuclei.

Thank you ☺