Nuclear Chemistry

Handwritten Notes

for NTA NET-JRF / GATE

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Nuclear Chemistry

(2-6 marks)
GATE → 1 or 2 Ques
BARC → 10-12 Ques

topics

- Nuclear size
- Iso series
- Stability of Nuclei (Very Imp)
  - → Magic Number
  - → $\frac{n}{p}$ ratio + radioactive decay
  - → Nuclear forces
  - → Binding energy
- Kinetics of Radioactive decay
- Radioactive dating
- Threshold energy, B.E, Q-value
- Neutron Activation Analysis

$\boxed{^{A}_{Z}X}$

Proton = Z
Proton + Neutron = A (Mass No.)
∴ $\boxed{\text{Neutron} = A - Z}$

units: Radius of atom = Å (10^{-10} m)
" " Nuclei = fermi (10^{-15} m)

- Distance b/w proton and ~~nucleus~~ neutron in nucleus is 2-3 fermi
- Activation energy non zero for chemical rxn and activation energy zero for nuclear chemistry
- No chemical change, only nuclear change, no $\bar{e}$ involvement

$$\boxed{r = r_0 A^{1/3}}$$

r_0 = constant (1.4×10^{-15} m)
A = mass no.
r = radius of Nuclei

$\boxed{1 \text{ Barn} = 10^{-28} \text{ m}^2}$

Isotope	Isobar	Isotone	Isodiapher	Nuclear Isomer	Iso-electronic
same atomic number $^{2}C, ^{13}C, ^{14}C$	Same mass number $^{40}_{18}Ar$ $^{40}_{19}K$	same neutron number $^{3}_{1}H$ $^{4}_{2}He$	different element have same isotopic number $(n-p)$ $^{19}_{9}F$ $^{39}_{19}K$ $(A-2Z)$ or $(n-p)$ $p+n-p-p=(n-p)$ $\underset{①}{19-2\times9}$ $\underset{①}{39-19\times2}$	Same element but diff nuclear stability $^{60}_{27}Co^{*}$ $^{60}_{27}Co$ ↓ High energy less stable Metastable	H, He^{+} **Isosteric** same no. of $\bar{e}$ + same atomicity CO_2 N_2O $(22\bar{e})$ $(22\bar{e})$

first 5, are involved in nuclear chemistry.

28th Oct, 2016

Stability of Nuclei :-

Proton no. ⇒	Even	Even	odd	odd
Neutron no. ⇒	Even	odd	even	odd
Stability ⇒	59%	20%	19%	2%

Magic no. ⇒ $\boxed{2, 8, 20, 28, 50, 82}$

It represents closed shell of nucleon

Nuclear forces

Attractive forces are stronger than repulsive forces. It means forces involved in the nucleus is not electrostatic. Nuclear forces exist in neutron-neutron, proton-proton, neutron-proton by π Meson exchange

Rate of exchange of π-Meson is 10^{24} sec^{-1} which ~~both~~

holds nucleons together.

Three π Mesons → π^+, π^0, π^-

$$\boxed{\text{Mass of Mesons} = 273 \times \text{Mass of } \bar{e}}$$

$$p \xrightarrow{\pi^+} n \qquad \boxed{p \rightleftharpoons n + \pi^+} \qquad n \xrightarrow{\pi^-} p$$

$$n \xrightarrow{\pi^+} p \qquad p \xrightarrow{\pi^-} n$$

$$\boxed{p \underset{-\pi^0}{\overset{+\pi^0}{\rightleftharpoons}} p} \qquad \boxed{n \underset{\pi^0}{\overset{\pi^0}{\rightleftharpoons}} n} \qquad \Rightarrow \boxed{n \rightleftharpoons p + \pi^-}$$

Radioactivity decay and n/p ratio :

Radioactive discovered by Henry Bacquerell

Unstable nuclei emit sub atomic particle spontaneously until or unless it becomes a stable nuclei.

$$\boxed{\begin{array}{l}\text{Unstable nuclei} \rightarrow \text{Radioactive} \\ \text{Stable nuclei} \rightarrow \text{Not radioactive}\end{array}}$$

$\boxed{\alpha\text{-decay}}$

${}^{4}_{2}He^{++}$ $(2p + 2n)$ [No electron]

$${}^{238}_{92}U = {}^{234}_{90}Th + \alpha \qquad \boxed{{}^{A}_{x}Z \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He}$$

n: n n−2

p: p p−2

$$\frac{n}{p} = \frac{n-2}{p-2}$$

$$\Rightarrow \frac{n-2}{p-2} - \frac{n}{p} = \frac{2(n-p)^{+ve}}{p(p-2)^{+ve}} \Rightarrow \frac{n}{p} \uparrow \text{ses.}$$

$${}^{A}_{x}Z \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

$(A-2Z)$ $\quad A-4-2(Z-2)$

$\quad A-4-2Z+4 = (A-2Z)$ $\quad \therefore$ $\boxed{\text{Isodiapher}}$

$$^{238}_{92}U \longrightarrow {}^{234}_{90}Th + \alpha$$

⇒
- $\frac{n}{p}$ ↑ses
- Isodiaphes (daughter ~~of~~ and parent)
- Nuclear fission
- $\leftarrow\leftarrow$ (2 left shift)

If α-decay occurs in closed vessel, then ideal behaviour of gas is considered, (i.e STP conditions or PV = nRT)

β-decay neutron converts to proton and electron

$$\boxed{^{1}_{0}n \longrightarrow {}^{1}_{1}p + {}^{0}_{-1}e + \bar{\nu}}$$

→ anti neutrino particle to conserve momentum.

→ Mass no. ~~is~~ remains same ∴ Isobar

→ 1 Right shift

$$\underset{0}{^{A}_{Z}X} \longrightarrow \underset{0}{^{A}_{Z+1}X} + \underset{x}{^{0}_{-1}e} + \underset{-x}{\bar{\nu}}$$

$$\frac{n}{p} = \frac{n-1}{p+1} \Rightarrow \frac{n-1}{p+1} - \frac{n}{p} = \frac{-(n+p)}{p(p+1)} \quad \boxed{\frac{n}{p} \downarrow ses}$$

One neutron converts into proton by β-decay. Mass no. remains same. So parent and daughter are isobar. Always associated with emission of anti neutrino particle to conserve momentum. One right shift by daughter element takes place.

ν → Neutrino [Neutral, Mass < M_{e^-}]

$\bar{\nu}$ → Anti Neutrino

Carbon dating

e.g. $^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e$

Positron decay (β^+)

$$\boxed{{}^1_1p \longrightarrow {}^1_0n + {}^0_{+1}e + \nu}$$

0 0 $\underbrace{-x \quad +x}$ equal and opp momentum

$${}^A_Z X \longrightarrow {}^A_{Z-1}Y$$

$$\frac{n}{p} \quad \frac{n+1}{p-1} \qquad \frac{n+1}{p-1} - \frac{n}{p} = \frac{n+p}{p(p-1)} \begin{matrix} +ve \\ -+ve \end{matrix} \qquad \boxed{\frac{n}{p} \uparrow ses}$$

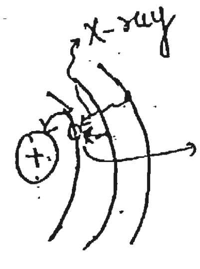
eg $${}^{15}_8O \longrightarrow {}^{15}_7N + {}^0_{+1}e$$

→ ~~Is~~ Isobar (d|p)

K-capture

electron from filled shell falls over nucleus, If proton is converted into neutron. If ē belongs to K shell, then it is called K-capture. If ē belongs to L shell then it is called L-capture.

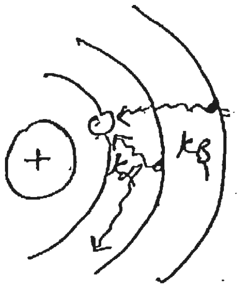
$$\boxed{{}^1_1p + {}^0_{-1}e \longrightarrow {}^1_0n + X\text{-ray}}$$



hole created by falling of ē into nucleus. then other ē from other shell fulfills this vacancy and X-ray is emitted.

$${}^A_Z X \quad {}^A_{Z-1}X \qquad \frac{n+1}{p-1} - \frac{n}{p}$$

$$\frac{n}{p} \quad \frac{n+1}{p-1} \qquad = \frac{n+p}{p(p-1)} \; +ve \qquad \boxed{\frac{n}{p} \uparrow ses}$$



- → Isobars (d|p)
- → One left shift ←
- → X-ray emitted.

K-capture is happening because nucleus is unstable.

Radioactivity is a spontaneous process.

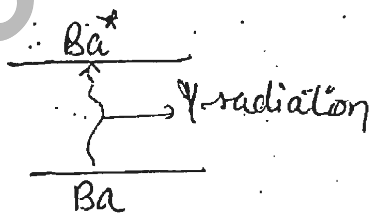
γ-decay

γ-decay never occur independently. It always occurs in association with α or β decay.

By α or β decay, atom gets excited, then come back by emission of quanta of light in the form of EMR

e.g. $$^{137}_{57}Cs \xrightarrow{\beta} \underbrace{{}^{137}_{58}Ba^* \longrightarrow {}^{137}_{58}Ba + {}^{0}_{0}\gamma}_{\gamma\text{-decay}}$$

- → $\frac{n}{p}$ ratio do not change
- → Nuclear isomer (d/p)
- → No shift in periodic table
- → γ-radiation ...



Neutron emission

(Very rare) $$^{87}_{36}Kr \longrightarrow {}^{86}_{36}Kr + {}^{1}_{0}n$$

$$\frac{n}{p} \qquad \frac{n-1}{p} \qquad \frac{n-1}{p} - \frac{n}{p} = \frac{-1}{p}$$

$\boxed{\frac{n}{p} \downarrow \text{ses}}$

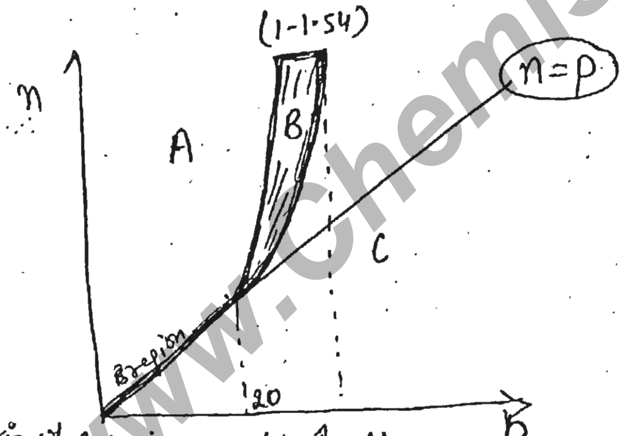
- → $\frac{n}{p}$ ↓ses
- → d/p are p isotopes
- → Neutron emit
- → No shift

Decay	d/p relation	Z	A	shift	n/p ratio	Associated product
α	Isodiapher	-2	-4	←←	+ (↑ses)	Nil
β	Isobar	+1	0	→	– (↓ses)	$\bar{\nu}$
β^+	Isobar	-1	0	←	+	ν
K-capture	Isobar	-1	0	←	+	X-ray
γ	Isomer	0	0	No shift	No change	γ-ray
Neutron	Isotope	0	-1	Noshift	–	Nil

$\frac{n}{p}$ ratio → Minimum value = 0 $\;^1_1H \;\; \frac{0}{1} = ⓪$

$\frac{n}{p}$ ratio → Maximum value = 2 $\;^3_1H \;\; \frac{2}{1} = ②$

if $\frac{n}{p}$ ratio lies b/w $\boxed{1 - 1.54}$ then stable



$\frac{n}{p} = 1$

A region (unstable region)

$\left(\frac{n}{p}\right)_A > \left(\frac{n}{p}\right)_B$

⇒ All isotope undergo β- decay.

B region (stable region)

$\frac{n}{p} = 1 - 1.54$ Stable Belt

C region (Unstable region)

$\left(\frac{n}{p}\right)_C < \left(\frac{n}{p}\right)_B$

$\frac{n}{p}$ ratio of C region can be ↑sed by,

α-decay → radioisotope of natural heavy nuclei

β^+ → radioisotope of lighter element

K-capture → radioisotope of Artificial Heavy element.

Kinetics of Radioactive decay

Acc to Law of Radioactive decay, rate of radioactive decay is directly proportional to the no. of radioactive atom. i.e $\boxed{r \propto N}$

$\boxed{r = \lambda N}$ λ = Decay constant

λ does not depend on temp, pressure, external field, depends only on nature of nuclei.

Activity = r = $-\frac{dN}{dt}$ = $\cancel{\lambda t}\lambda N$

↓

No. of radioactive atom decaying per unit time

⇒ $\boxed{N = N_0 e^{-\lambda t}}$

... $\boxed{\ln \frac{N_0}{N} = \lambda t}$

$$\boxed{\text{Specific Activity} = \frac{\text{Activity}}{\text{Mass}}}$$

for stable isotope, $\boxed{\lambda = 0}$
e.g (^{12}C)

No. of Half lives $\boxed{\lambda t = \ln \frac{N_0}{N}}$ — ①

$A \longrightarrow$ product
$t=0, N_0$
$t=t, N$
$t=t_{1/2}, \frac{N_0}{2}$

$$\lambda t_{1/2} = \ln \frac{N_0}{N_0/2}$$

$\boxed{\lambda t_{1/2} = \ln 2}$ — ②

$\frac{①}{②}$ $\frac{\lambda t}{\lambda t_{1/2}} = \frac{\ln N_0/N}{\ln 2}$

$$\boxed{\text{No. of half lives } (n) = \frac{\text{total time}}{\text{Half life time}}}$$

$$\underset{\text{initial sample}}{16g} \xrightarrow[①]{t_{1/2} = 5min} 8g \xrightarrow[②]{5min} 4g$$

$$\text{No. of half lives } (n) = \frac{\text{total time}}{t_{1/2}} = \frac{10}{5} = ②$$

Dividing eqn ① by ② we get $\boxed{n} = \frac{t}{t_{1/2}} = \frac{\ln N_0/N}{\ln 2}$

$$n \ln 2 = \ln \frac{N_0}{N}$$

$$\ln 2^n = \ln \frac{N_0}{N} \Rightarrow \boxed{2^n = \frac{N_0}{N}}$$

$$\Rightarrow \boxed{\frac{N}{N_0} = \left(\frac{1}{2}\right)^n}$$

Average life (τ)

Species reduce to 37% of its original ~~life~~ value

$$\lambda t = \ln \frac{N_0}{N} \Rightarrow \lambda . \tau = \ln \frac{100}{37} = 1$$

$$\therefore \boxed{\tau = \frac{1}{\lambda}}$$

$\lambda, \tau, t_{1/2} \Rightarrow$ Intensive property.

In duration $\boxed{\lambda(t_2 - t_1) = \ln \frac{N_1}{N_2}}$

Radioactive decay

$\boxed{{}^{238}U}$ → used for detecting age of rock etc. (rock and mountain)

$\boxed{{}^{14}C}$ (Wood and Mummy)
↓ $t_{1/2} = 5730$ years

$${}^{238}U \longrightarrow {}^{206}Pb$$

$t = 0$ 1 mole

$t = t$ 0.1 mole 0.9 mole

$$N_0 = (U^{238} + Pb^{206})_t$$

$$N = ({}^{238}U)_t$$

$$\lambda t = \ln \frac{N_0}{N} \Rightarrow \boxed{\frac{0.693\,t}{t_{1/2}} = \ln \frac{(U^{238} + Pb^{206})_t}{({}^{238}U)_t}}$$

^{14}C carbon dating

In atmosphere, $${}^{14}_{7}N + \underset{\text{cosmic ray}}{{}^{1}_{0}n} \longrightarrow \underset{{}^{14}CO_2 + {}^{12}CO_2}{{}^{14}_{6}C} + {}^{1}_{1}H$$

$\boxed{\frac{{}^{14}C}{{}^{12}C} = \text{constant}}$ → In atmosphere / plant

At $t = 0$ $\quad {}^{12}C = x \quad {}^{14}C = y \quad \frac{y}{x} = \text{constant}$

$t = t \quad {}^{12}C = x \quad {}^{14}C = y' \quad \frac{y'}{x} = \text{constant}$ Here $\boxed{y' < y}$

∵ ^{12}C is stable, uska decay nhi hota

↓ after death of plant $\quad {}^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta + \bar{\nu}$

$\boxed{\text{Decay of } {}^{14}C \text{ is } \beta \text{ decay}}$

$\frac{n}{p} = \frac{8}{6} = 1.3 \qquad \frac{n}{p} = \frac{7}{7} = ①$

$\frac{n}{p}$ ratio of ${}^{14}_{7}N$ < n/p ratio of ${}^{14}_{6}C$ ⇒ β decay

Now $\ln \frac{N_0}{N} = \lambda t \Rightarrow \ln \frac{\left(\frac{y}{x}\right)_{t=0}}{\left(\frac{y'}{x}\right)_{t=t}} = \lambda t \qquad \boxed{\ln \frac{y}{y'} = \lambda t}$

Here $\lambda = 0.693 / t_{1/2}$
and $t_{1/2}$ (^{14}C) = 5730 yrs.

In atmosphere, cosmic ray smash into normal ^{12}C atoms (in atmosphere $^{12}CO_2$) and create ^{14}C isotopes (in atmosphere $^{14}CO_2$) this process occur for a long time and constantly, so there is fairly constant ratio of $^{14}C/^{12}C$ ~~by~~ ~~^{12}C~~ in atmosphere. Now living plants breathe CO_2 indiscriminately and so while they are living and have constant ratio of $\frac{^{14}C}{^{12}C}$ in ~~of ^{14}C and ^{12}C in~~ them as atmosphere.

humans also consume plants so they have same ratio of $\frac{^{14}C}{^{12}C}$ as present in atmosphere as in living plants. When they ~~are~~ die, ratio does not remain constant ∵ of β-decay and amount of ^{14}C loses and hence ratio of $^{14}C/^{12}C$ also loses. No change in amount of ^{12}C (∵ no disintegration) and finally we can evaluate the age of wood or ~~mummy~~ mummy.

Q 16 g of radioactive sample have $t_{1/2}$ = 4 hours. How much sample remain after 10 hours.

Soln $16g \xrightarrow{4hrs}$

Specific Activity → Intensive
Activity → Extensive

$$\lambda t = \ln \frac{N_0}{N}$$

$$\frac{0.693}{4} \times 10 = \ln \frac{16}{N} \Rightarrow 1.7325 = \ln \frac{16}{N}$$

$\boxed{2.82g}$

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{n}$ no. of Half lives $(n) = \frac{10}{4}$ — α ⇒ $\frac{N}{16} = \left(\frac{1}{2}\right)^{n}$

$\boxed{N = 2.82g}$.

Que A radioactive nuclei A undergo α decay to produce B, Half life of decay of A is 69.32 yrs. After what time $\frac{\text{weight of A}}{\text{weight of B}}$ becomes $\frac{0.204}{1}$

Soln $^{204}A \longrightarrow {}^{200}B + {}^{4}_{2}He$

$\lambda t = \ln\frac{N_0}{N}$

$$\cancel{\frac{0.693}{69.32}t} = \cancel{\ln\left(\frac{n_A/M_A}{n_B/M_B}\right)}$$

$$= \cancel{\ln\left(\frac{0.204 \times 200}{1 \times 204}\right)}$$

∵ $w_A = 0.204$
$w_B = 1$
$M_A = 204$
$M_B = 200$

$$\frac{n_A}{n_B} = \frac{w_A/M_A}{w_B/M_B} = \frac{w_A}{w_B}\cdot\frac{M_B}{M_A}$$

$$= \frac{0.204}{1} \times \frac{200}{204 \times 1000} = \frac{0.2}{10} = \boxed{\frac{1}{5}}$$

$^{204}A \longrightarrow {}^{200}B + {}^{4}_{2}He$

t = 0 6
t = t 1 5

⇒ $\frac{N_0}{N} = \frac{6}{1}$ ⇒ $\lambda t = \ln\frac{N_0}{N}$ ⇒ $\frac{0.693}{69.32} \times t = \ln\frac{6}{1}$

$t = \frac{1.791}{0.0099}$ ~~t =~~

$\boxed{t = 180 \text{ years}}$

Units of radioactivity

$$\boxed{\begin{array}{l} 1\ \text{Bq} = 1\ \text{dps}\ (\text{S.I}) \\ 1\ \text{Rd} = 10^6\ \text{dps} \\ 1\ \text{Curie} = 3.7 \times 10^{10}\ \text{dps} \end{array}}$$

Difference b/w physical and chemical adsorption is classified by the behaviour of N_2 on iron surface. At the temp. of liquid $N_2 = 190°C$, N_2 is adsorbed physically on the iron surface. Amount of Nitrogen adsorbed loses rapidly as the Temp. raises. At R.T, Fe does not adsorb nitrogen at all. At high temp. i.e 500°C Nitrogen is chemically adsorbed on the Fe surface.

Binding Energy

Energy released when a nucleus is formed by the combination of proton and neutron is called binding energy.

$$\boxed{B.E = \Delta m c^2}$$

$$\downarrow$$

$$kg\ (ms^{-1})^2$$

$$kg\,m^2 s^{-2}$$

$$\underbrace{kg\,m\,s^{-2}\cdot m}$$

$$\underbrace{Nm}$$

Joule

$$B.E = \underset{\substack{\downarrow \\ amu}}{\Delta m} \times 931.5\ MeV$$

$$1\ a.m.u = \frac{1}{12} \times \text{Mass of } 1C \text{ atom}$$

$$= \frac{1}{12} \times \frac{12}{N_A}$$

$$= \frac{1}{N_A} = 1.66 \times 10^{-27}\ kg$$

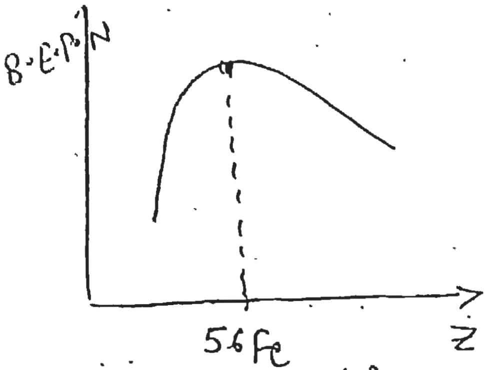
$\boxed{1\text{ Mev} = 1.6 \times 10^{-13}\text{ J}}$

Na atom = 1 mole - 1 g

1 atom = $\frac{12}{N_A}$

Δm = mass defect.

Binding energy per nucleon :-



(Most stable) due to high B.E.P.N

Q-value of Nuclear Rxn expressed in term of incoming and outgoing kinetic energy.

$\boxed{\begin{array}{ll} Q = +ve & \text{exoergic} \\ Q = -ve & \text{endoergic} \end{array}}$

* ⟶ Bethe's Notation

A(a, b) B

heavy atom (target) ← $A + a \longrightarrow b + B$ → composite nuclei

projectile, lighter atom

$$\boxed{Q = (E_B + E_b) - (E_A + E_a)}$$

Nucleon capture ⟶

$A({}^{1}_{0}n, \gamma)B$

Target ← T (P, L.E) C.N

Projectile, lighter element, Composite nuclei

$T + P \longrightarrow C.N + E^*$

${}^{208}_{82}Pb + {}^{7}_{3}Li \longrightarrow {}^{215}_{85}At + \gamma$ ← this really act as L.E

Q = 5.58

Since value comes -ve, it means supply of energy must be converted into mass for a reaction to occur.

$Q = +ve$ exoergic => mass convert into K.E

$Q = -ve$ endoergic => K.E convert into mass

Threshold energy (E_{th})

minimum kinetic energy of the projectile needed to initiate the reaction is called threshold energy. In other words, minimum projectile energy necessary to satisfy mass energy and momentum conservation in nuclear rxn, to form products in their ground state.

i.e. energy necessary to compensate for a -ve Q value.

Excitation energy (E^*) →

It is the excess energy above the ground state for ~~which~~ the product of nuclear rxn.

T is at rest
∴ its E_T (i.e K.E) is zero.

$$P + T \longrightarrow C.N + E^*$$

(I) Mass Energy Conservation

$$E_p + m_p c^2 + m_T c^2 = E_{C.N} + m_{C.N} c^2 + E^*$$

$$E_p + \underbrace{(m_p + m_T - m_{C.N})c^2}_{Q} = E_{C.N} + E^*$$

$$\therefore \boxed{E_p + Q = E_{C.N} + E^*} \quad - ①$$

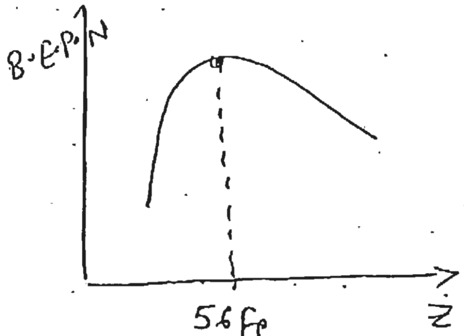
$$\boxed{1\ MeV = 1.6 \times 10^{-13}\ J}$$

Na atom = [illegible]

$$1\ atom = \frac{12}{N_A}$$

Δm = mass defect.

Binding energy per nucleon :-



(Most stable) due to high B.E.P.N

Q-value of Nuclear Rxn

expressed in terms of incoming and outgoing kinetic energy.

$$\boxed{\begin{array}{ll} Q = +ve & \text{exoergic} \\ Q = -ve & \text{endoergic} \end{array}}$$

Bethe's Notation

* ⟶ Bethe's Notation

$A(a, b)B$

heavy atom (Target) $\leftarrow A + \underset{\text{Projectile}}{a} \longrightarrow \underset{\text{lighter atom}}{b} + B \rightarrow$ composite nuclei

$$\boxed{Q = (E_B + E_b) - (E_A + E_a)}$$

Neutron capture ⟶

$A({}^{1}_{0}n, \gamma)B$

Target ← $T(P, L.E)\ \underline{C.N}$ Composite nuclei

Projectile

lighter element

$$T + P \longrightarrow C.N + E^*$$

$${}^{208}_{82}Pb + {}^{7}_{3}Li \longrightarrow {}^{215}_{85}At + \gamma$$

this radiⁿ act as L.E

$$\boxed{Q = -5.589}$$

$$(T + P) \longrightarrow (C\cdot N) + E^*$$

mass m_1 mass m_2

If (i) $m_1 > m_2$ i.e reactant mass is more, its and converting into K.E.

∴ $Q = +ve$

(ii) $m_2 > m_1$; ie product mass is more

∴ K.E is converting into mass

∴ $Q = -ve$

When $m_1 > m_2$

$$\boxed{Q = \Delta m c^2} = (m_1 - m_2)c^2 \quad Q = +ve$$

(II) Momentum conservation

momentum of projectile, P_P = momentum of C.N

$$\boxed{P_P = P_{C\cdot N}}$$

from non-relativistic Quantum, i.e time independent Quantu

$$\sqrt{2A_P E_P} = \sqrt{2A_{C\cdot N} E_{C\cdot N}}$$

$$A_P E_P = A_{C\cdot N} E_{C\cdot N}$$

$$\boxed{E_{C\cdot N} = \frac{A_P \cdot E_P}{A_{C\cdot N}}}$$

$P = \sqrt{2mE}$

$K.E = \frac{P^2}{2m}$

$$E_{P+Q} = \frac{A_P}{A_{C\cdot N}} E_P + E^*$$

$$E_P\left[1 - \frac{A_P}{A_{C\cdot N}}\right] + Q = E^*$$

$$\boxed{A_{C\cdot N} = A_P + A_T}$$

$$E_P\left[\frac{A_P + A_T - A_P}{A_{C\cdot N}}\right] = E^* - Q$$

$$E_P \frac{A_T}{A_{C\cdot N}} = E^* - Q$$

$^{208}Pb + ^{7}Li \rightarrow ^{215}At$

T P C.N

$$\boxed{E_p = (E^* - Q)\frac{A_{C.N}}{A_T}}$$

(i) When $E^* = 0$ ⇒ $\boxed{E_p = E_{th}}$

$$\boxed{E_p = E_{th} = -Q\frac{A_{C.N}}{A_T}}$$

(ii) When $E^* \neq 0$ $\quad E^* = E_p\frac{A_T}{A_{C.N}} + Q$

Hence threshold energy is ~~greathe~~ greater than Q value with opposite sign always.

Excitation energy is then dissipated by emission of photon or nuclear particles.

Ques Calculate threshold energy and K.E. of ^{215}At

$^{208}_{82}Pb + ^{7}_{3}Li \longrightarrow ^{215}_{85}At \quad Q = -5.589$ MeV

(i) 5.589 (ii) -5.77 ✓(iii) 5.77 (iv) 5.377

Q & K. opposite and greater value

$$E_{th} = -Q\frac{A_{C.N}}{A_T} = -(-5.589) \times \frac{215}{208} = \underline{5.777 \text{ MeV}}$$

$$E_{C.N} = E_p\frac{A_p}{A_{C.N}} \qquad \boxed{E_p = -Q}$$

i.e. K.E of ^{215}At $\quad 5.58 \times \frac{7}{215}$ → mass of projectile

$= 0.18$ MeV

if we consider E^*,

$$\boxed{E_p = (E^* - Q)\frac{A_{C.N}}{A_T}}$$

By putting E^* we get $(E_p = -Q)$

In this Reaction, 5·58 MeV of K·E is converted into mass, overcome the -ve Q value and 0·18 MeV goes into the K·E of composite nuclei.

$$\boxed{E^* \propto T^2}$$

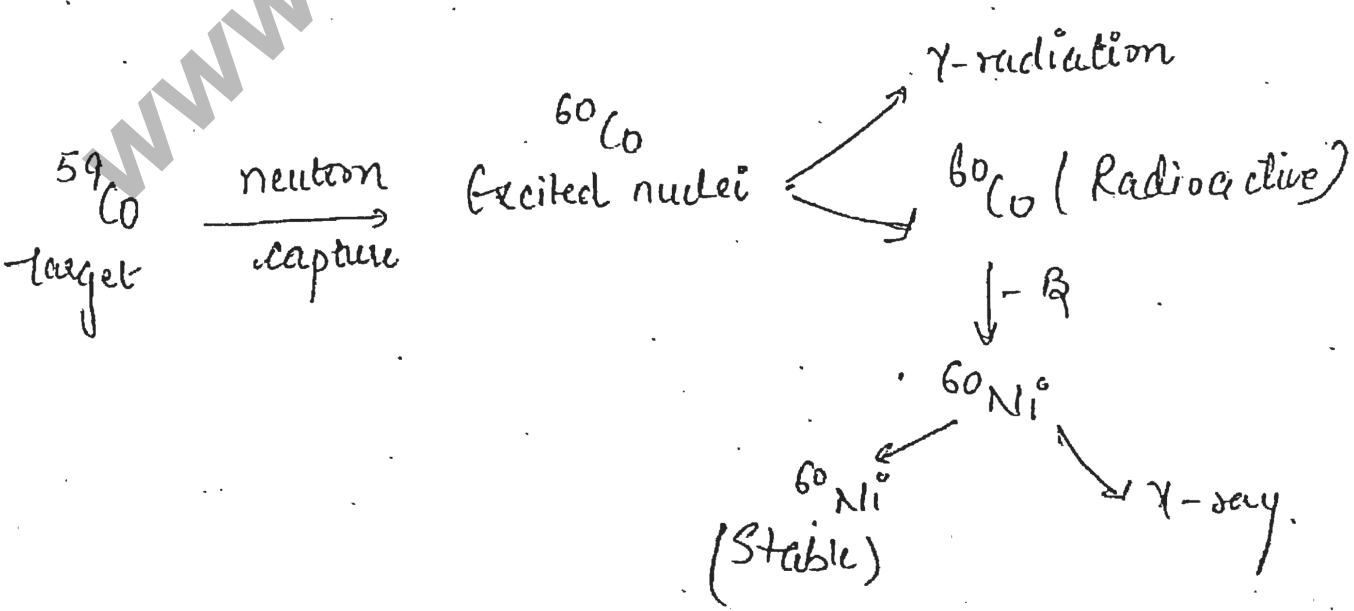
$$\boxed{E^* = \underset{\downarrow}{a}T^2} \rightarrow \text{level density parameter.}$$

Neutron activation Analysis :-

- Instrumental NAA (Direct sample is used)
- Radioactive NAA (sample used after removal of interfering substance)

Nuclear process used to determine concentration of element. Sample is bombarded with neutron causing the element to form radioactive isotope. Radioactive emission and radioactivity decay path for each element are well known.

By this information ~~we~~ are it is possible to study emission spectra of radioactive sample and determine the conc. of element.



:= Projectile $^{12}C(P, P)^{12}C \Rightarrow$ Elastic scattering
light dala, light nikla

$^{12}C(P, P)^{12}C^{*} \Rightarrow$ Inelastic scattering

$^{54}Fe(^{32}S, ^{28}Si)^{58}Ni \Rightarrow$ Rearrangement rxn.
heavy dala, heavy nikla

Area of cross section (σ)

Cross section area is related to probability that a rxn will takes place.

$$\boxed{\gamma = \phi_i n A t \sigma}$$

γ = yield (no. of rxn per unit time)

n = particle density (no. of target particle per unit volume)

A = Area of beam spot

ϕ_i = Incidence flux $\left[\frac{\text{Beam particle}}{\text{Time} \times \text{Area}}\right]$

t = thickness of target

σ also depends on half life of product

Nuclear fission (α-decay is nuclear fission)

Nucleus splits into two roughly equally sized fission fragments

$\left.\begin{array}{l} \frac{Z^2}{A} > 48 \\ A > 220 \end{array}\right] \longrightarrow$ Spontaneous Nuclear fission

Spontaneous fission have low rate then α-decay.

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