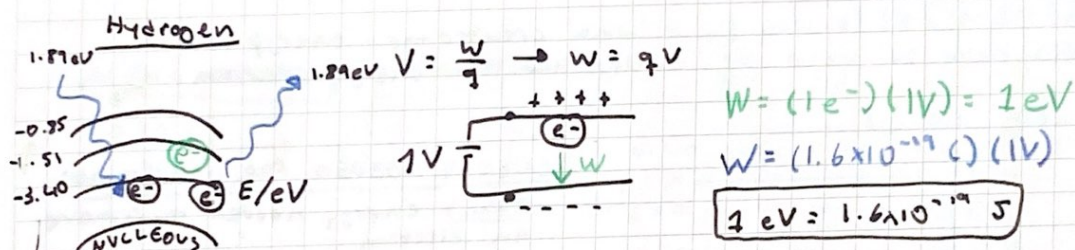


Calculation of Energy into and out of electron

$E = hf$ h : Planck's constant
 f : frequency (Hz)

$E = h \left(\frac{c}{\lambda} \right) \rightarrow c = \lambda f \rightarrow f = \frac{c}{\lambda}$
 $\lambda = \frac{hc}{E}$



The values are negative because you need to provide POSITIVE energy in order to move e^- up

In order to move 1 electron up one energy level...

$E = E_f - E_i = -1.51 - (-3.40) = 1.89 eV$

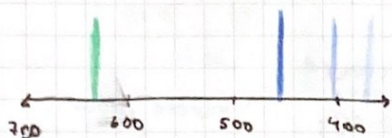
6. emitted by e^-
 1.89 eV

$\lambda = \frac{hc}{E}$

$1.89 eV \left| \frac{1.6 \times 10^{-19} J}{1 eV} \right| = 3.024 \times 10^{-19} J$

$\lambda = \frac{(6.63 \times 10^{-34})(3 \times 10^8)}{3.024 \times 10^{-19}} = 6.577 \times 10^{-7} m$

$6.577 \times 10^{-7} \rightarrow 657.7 nm$ on EM spectrum



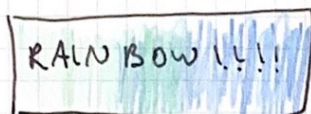
Emission spectrum: The set of possible λ s that can be emitted from the electron returning to its energy level

↳ Every element has its own unique emission spectrum!!

WHITE LIGHT



CONTINUUM SPECTRUM



↳ white is ALL the colors combined

HOT GAS



EMISSION SPECTRUM



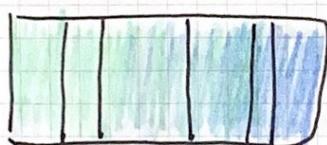
↳ produced from moving e^- to $n=2$!!!



COLD



GAS

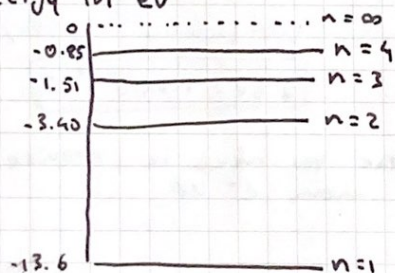


When the full spectrum of light is transmitted through a gas but photons are ABSORBED

ABSORPTION SPECTRUM

REMEMBER! It was Bohr who created the energy levels diagram to help us understand the energy spectrum

Energy in eV



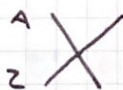
ENERGY NEEDED FOR IONIZATION:

Exact energy needed to remove an electron

Ex. Highest energy photon emitted from $n=4$ (in eV and λ)

$$\begin{aligned} E_{\text{photon}} &= 12.75 \text{ eV} \\ &= 9.73 \times 10^{-8} \text{ J} \\ &= 97.3 \text{ nm} \end{aligned}$$

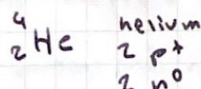
Nuclear Structure Review



X = element
 A = nucleon number
 Z = protons



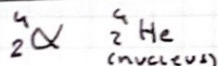
lead
82 p^+
128 neutrons



Nuclear Structure and Radioactive Decay

The emission of particles and energy from a nucleus is called radioactivity. There are 3 types!

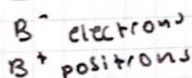
ALPHA DECAY



The energized molecule throws out "daughter" protons in the form of simpler element's isotopes.

MORE MASS RELEASED
LESS KE WHEN RELEASED

BETA DECAY



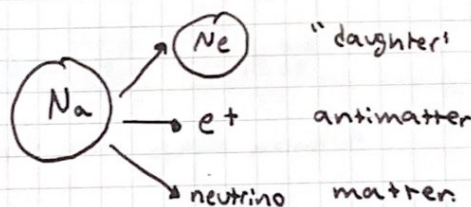
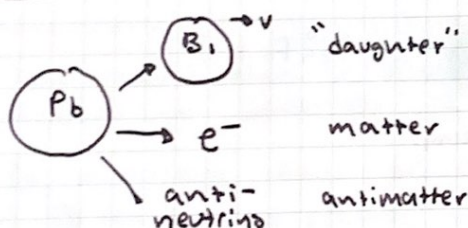
The energized molecule throws out daughter electrons or positrons to decrease its overall energy.

LESS MASS RELEASED
MORE KE WHEN RELEASED

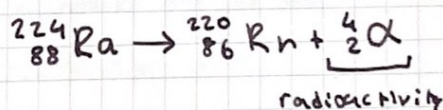
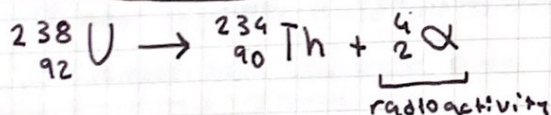
GAMMA RAYS



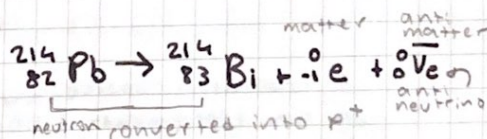
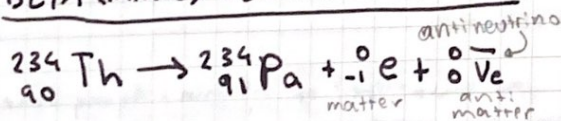
The energized molecule throws out energy in the form of photons. No physical change, just less energy. EM energy. NO CHANGE IN MASS
RELEASED EM ENERGY



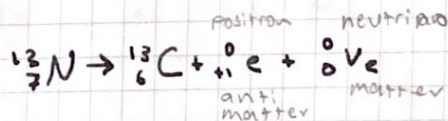
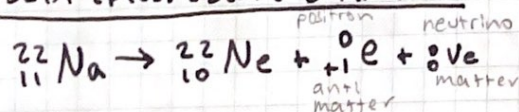
ALPHA DECAY EXAMPLES



BETA (minus) DECAY EXAMPLES



BETA (plus) DECAY EXAMPLES



RADIOACTIVE DECAY (GAMMA) EXAMPLES

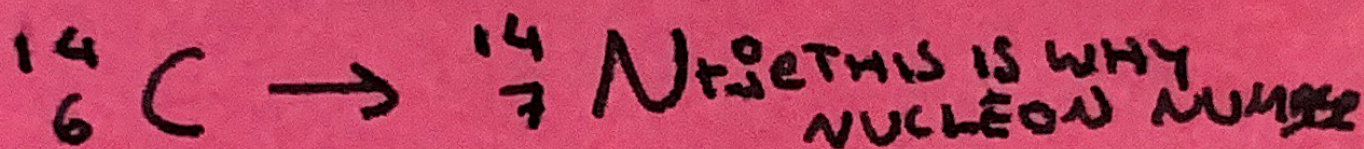
$$\lambda = \frac{hc}{E}$$



release of the extra energy with no losses

NOTES ON BETA DECAY:

- neutrons turn into protons, creating beta particles (e^-), in beta MINUS decay.



n: 8
p: 6



n: 7
p: 7

STAYS THE SAME

- in beta PLUS decay, protons turn into neutrons and electron with POSITIVE charge (positron).



n: 9
p: 9

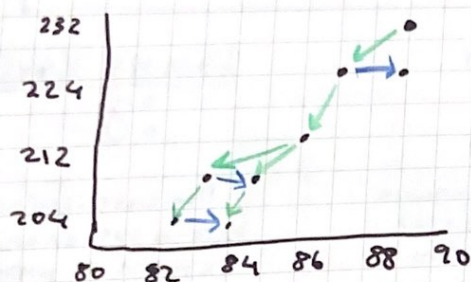


n: 10
p: 8

NUCLEON NUMBER
STILL STAYS THE
SAME.

Remember that all radioactive decay is RANDOM and SPONTANEOUS

Decay series

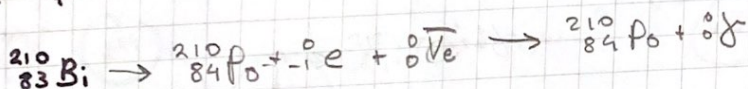


The Decay series of a nucleus shows the varying changes this element goes through.

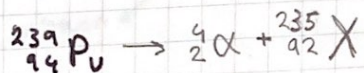
Alpha decay
Beta minus decay.

Examples.

Bismuth decays w/ Beta decay and then Gamma emission. Write the equation



Polonium decays with alpha decay.



When a tree was still living, it had 100% of its carbons. The half life of the carbon is 5700 years. 0.8% is left.

$$100\% \xrightarrow{\text{HL}} 50\% \xrightarrow{\text{HL}} 25\% \xrightarrow{\text{HL}} 12.5\% \xrightarrow{\text{HL}} 6.25\% \xrightarrow{\text{HL}} 3.125\% \xrightarrow{\text{HL}} 1.5625\% \xrightarrow{\text{HL}} 0.78125\%$$

7 total Half lives

$$5700 \times 7 = 39900 \text{ years}$$

A radioactive source had a half-life of 3.0 min. At the start of an experiment 32.0 mg. How much will be left after 18 mins.

$$32 \text{ mg} \xrightarrow{3} 16 \text{ mg} \xrightarrow{3} 8 \xrightarrow{3} 4 \xrightarrow{3} 2 \xrightarrow{3} 1 \xrightarrow{3} 0.5$$

$3 \times 6 = 18 \text{ mins}$ 0.5 mg left

State what is meant by activity of a sample
rate of decay of the sample

Mass Defect and Binding Energy

p^+ p^+
 n^0 n^0
 e^- e^-
 CONSTITUENT
 PARTICLES

→ ATOMS

weight of added up constituents

IS NOT EQUAL TO

weight of the atom.

MASS IS "LOST"
(mass defect).

He atom = 4.002603 u

$p^+ = 1.007276 \text{ u}$ $n^0 = 1.008664 \text{ u}$ $e^- = 0.000549 \text{ u}$

4.002603 u

+

4.032974

MASS DEFECT = 0.030375 u

This mass defect is actually the binding energy, the energy needed to SEPARATE the atom.

to calculate mass defect:

- ① identify the protons, electrons, and neutrons in the element
- ② multiply the standard weight of these by the amount present
- ③ add together these multiplied values
- ④ subtract this new value to the "real" weight

BINDING ENERGY: The energy released when a nucleus is assembled from its constituent parts.

$$E = mc^2$$

$\downarrow$ eV or J
 $\downarrow$ mass defect u or kg
 $\downarrow$ ms⁻¹
 $\frac{\text{MeV}}{c^2}$

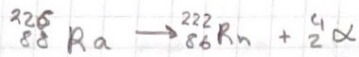
E = binding energy
 m = mass
 c = speed of light

→ mass turns into energy!
This is why stars have light, heat, etc.

1 u = 1 atomic mass unit

1 u = 931.5 $\frac{\text{MeV}}{c^2}$

Radium undergoes alpha decay to give radon.



How much energy is released during this process?

$$R_a = 226.0254 \text{ u}$$

$$R_n = 222.0176 \text{ u}$$

$$\text{Alpha} = 4.0026 \text{ u}$$

$$226.0254 \text{ u} \rightarrow 222.0176 \text{ u} + 4.0026 \text{ u}$$

$$226.0254 - 226.0202 \text{ u}$$

$$\text{mass defect} = 0.0052 \text{ u}$$

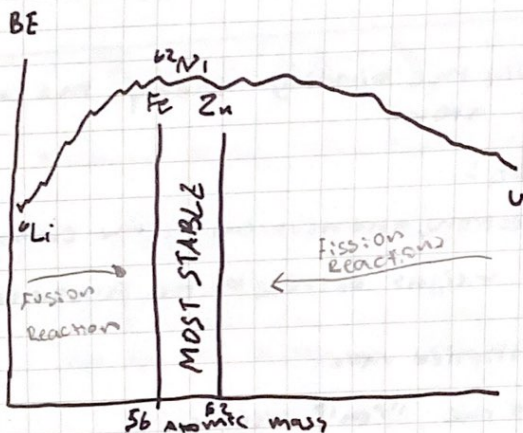
$$E = mc^2$$

$$E = 0.0052 (931.5 \frac{\text{MeV}}{\text{u}}) c^2$$

$$E = 0.0052 (931.5 \text{ MeV})$$

$$E = 4.8438 \text{ MeV}$$

plug in the unit for u
in order to cut back on
converting values to eV and
having to square c.



Relationship between BE
and A-A.

FISSION NUCLEAR REACTION

• Splitting one large nucleus and getting 3 products:

↳ 2 smaller nuclei

↳ 3 neutrons

↳ energy

• Alpha decay

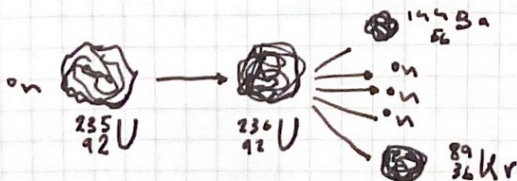
• Beta decay

• Gamma rays

• Done by firing a neutron to a large nucleus

• Nucleus becomes unstable

• Forces make a nuclear reaction to release excess energy



NUCLEAR FUSION REACTION

- Joining 2 small nuclei and getting 3 products:
 - ↳ a larger nucleus
 - ↳ a neutron
 - ↳ Energy released.
- ALWAYS Gamma Rays
- Requires a lot of energy to join them
- Two small nuclei must be at extremely high temp
- key process in stars



Binding Energy: The energy needed to separate the nucleons from the nucleus.

= mass defect (c^2)

$\frac{BE}{A}$ → Binding energy per nucleon.

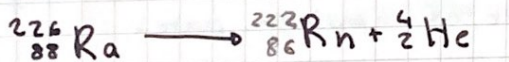


$$E_{\text{released}} = \Delta m \cdot c^2$$

$$\Delta m = \sum m_{\text{reactants}} - \sum m_{\text{products}}$$

($m_{\text{reactants}} \rightarrow m_{\text{products}}$)

$$E_{\text{released}} + \sum BE_{\text{reactants}} = \sum BE_{\text{products}}$$



energy released = 4.84 MeV

$$\text{Ra-226} = 226.0254 \text{ u}$$

$$\text{Rn-222} = 222.0176 \text{ u}$$

$$\text{Helium-4} = 4.0026$$

What type of energy is released? Which product would likely get the highest energy?

$$E_r = \Delta m \cdot c^2$$

$$226.0254 - (222.0176 + 4.0026)$$

$$\text{mass defect} = 0.0052$$

$$E_r = 0.0052 \text{ u} (931.5)$$

$$E_r = 4.8438 \text{ MeV}$$

A stationary Uranium-238 undergoes alpha decay to form Thorium-234

$$E_{\text{released}} = 4.27 \text{ MeV}$$

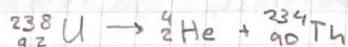
$$BE/A \text{ He} = 7.07 \text{ MeV}$$

$$BE/A \text{ Th} = 7.60 \text{ MeV}$$

Show that BE/A for U-238

is equal to $1.2 \times 10^{-12} \text{ J}$

$$E_{\text{released}} + \sum BE_{\text{react}} = \sum BE_{\text{products}}$$



$$4.27 \text{ MeV} + (x) = 1806.68$$

$$x = 1802.41 \text{ MeV}$$

$$BE/A = 7.07$$

$$BE/A = 7.60$$

$$BE = 7.07(4)$$

$$BE = 7.60(234)$$

$$BE = 28.28$$

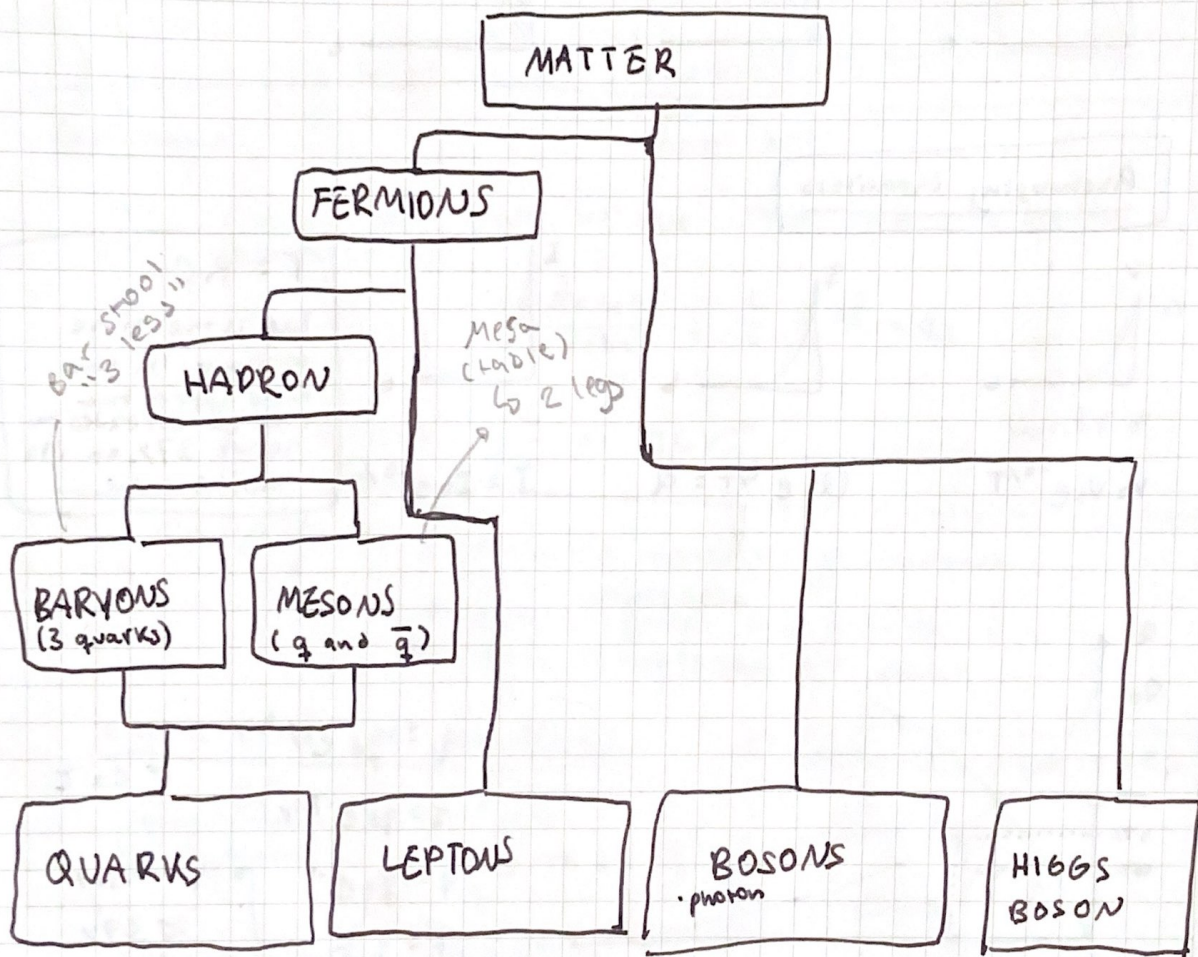
$$BE = 1778.4$$

$$1802.41 \cdot \frac{1.60 \times 10^{-13} \text{ J}}{1 \text{ MeV}} = BE \text{ of Uranium}$$

$$\frac{BE}{A} = \frac{2.883856 \times 10^{-10}}{238}$$

$$= 1.21 \times 10^{-12} \text{ J per nucleon}$$

THE STANDARD MODEL



CHARGE	QUARKS			BARYON NUMBER
$+\frac{2}{3}$ elementary particle	UP	CHARM	TOP	$\frac{1}{3}$
$-\frac{1}{3}$ elementary particle	DOWN	STRANGE	BOTTOM	$\frac{1}{3}$
STRANGENESS NUMBER: $S = -1$				

FERMIONS (QUARKS and leptons)					
Name:	up	charm	top		
Symbol:	u $\bar{u}$	c $\bar{c}$	t $\bar{t}$		
charge:	$+\frac{2}{3}e$ $-\frac{2}{3}e$	$+\frac{2}{3}e$ $-\frac{2}{3}e$	$+\frac{2}{3}e$ $-\frac{2}{3}e$		
Baryon:	$\frac{1}{3}$ $-\frac{1}{3}$	$\frac{1}{3}$ $-\frac{1}{3}$	$\frac{1}{3}$ $-\frac{1}{3}$		
Strangeness:	0	0	0		
Lepton:	0	0	0		

Name:	down	strange	bottom
Symbol:	d $\bar{d}$	s $\bar{s}$	b $\bar{b}$
charge:	$-\frac{1}{3}e$ $\frac{1}{3}e$	$-\frac{1}{3}e$ $\frac{1}{3}e$	$-\frac{1}{3}e$ $\frac{1}{3}e$
Baryon:	$\frac{1}{3}$ $-\frac{1}{3}$	$\frac{1}{3}$ $-\frac{1}{3}$	$\frac{1}{3}$ $-\frac{1}{3}e$
Strangeness:	0	-1 +1	0
Lepton:	0	0	0

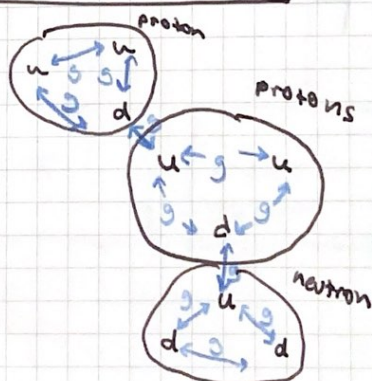
LEPTONS			
charge			
-1e	electrons	muon	tau
0	electron neutrino	muon neutrino	tau neutrino
LEPTON # = 1			

TIT3 LEPTONS			
Name:	electron	muon	tau
Symbol	$e \bar{e}$	$\mu \bar{\mu}$	$\tau \bar{\tau}$
Charge	-1e +1e	-1e +1e	-1e +1e
Baryon	0 0	0 0	0 0
Strangeness	0 0	0 0	0 0
Lepton	1 -1	1 -1	1 -1

Name	electron neut.	muon neut.	tau neut.
Symbol	$\nu_e \bar{\nu}_e$	$\nu_\mu \bar{\nu}_\mu$	$\nu_\tau \bar{\nu}_\tau$
Charge	0 0	0 0	0 0
Baryon	0 0	0 0	0 0
Strangeness	0 0	0 0	0 0
Lepton	1 -1	1 -1	1 -1

FUNDAMENTAL FORCES

Name	strong nuclear force
particles experiencing	quarks, gluons
particles mediating	gluons
relative strength	
range	
role in universe	



FUNDAMENTAL FORCES

Name:	Strong nuclear force	EM (E) Force	Weak Nuclear Force w.n.f	gravitational Force
experiencing:	quarks, gluons	All charged particles	Quarks, Leptons	masses
mediating:	gluon	photon (BOSON)	W^+, W^-, Z^0	"graviton"
relative strength				
range	$\times 10^{-15} \text{ m}$	∞	$\times 10^{-18} \text{ m}$	∞

HADRONS { Baryons: Any 3 quarks
Mesons: a quark and an anti-quark

HADRONS differ from other subatomic particles, because:

- They are only made of quarks
- We cannot see leptons
- Hadrons are always composed of at least 2 quarks

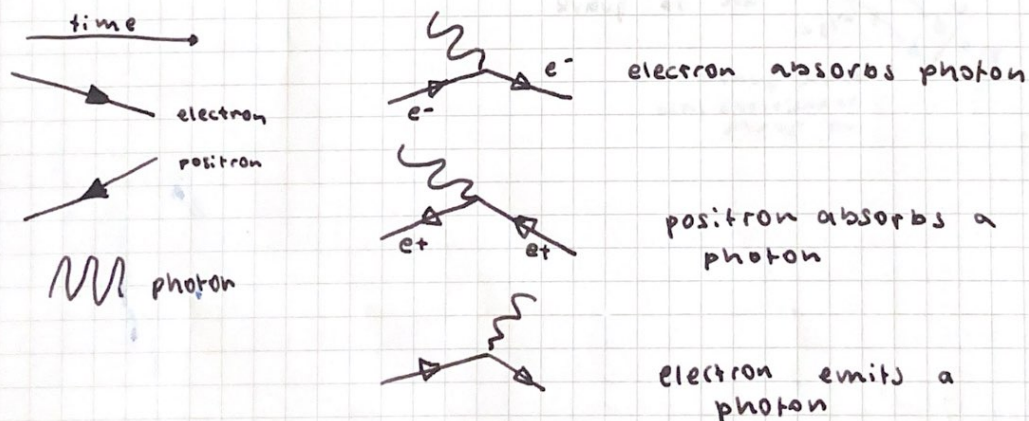
PROTON: $u u d$

ANTI-PROTON: $\bar{u} \bar{u} \bar{d}$

NEUTRON: $d d u$

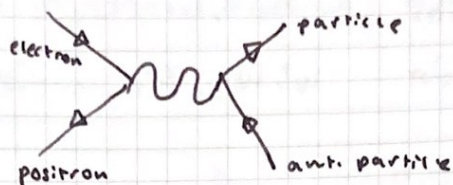
ANTI-NEUTRON: $\bar{d} \bar{d} \bar{u}$

FEYNMANN DIAGRAMS: are a way of visualizing any elementary particle interaction using a vertex.

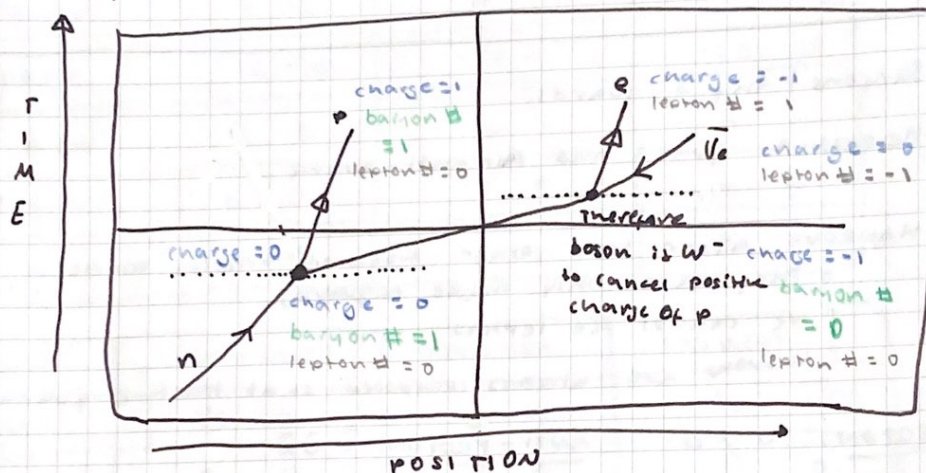


When matter collides with its anti-matter, ANNIHILATION happens

↳ In some cases a photon materialises into an electron and a positron



β^- decay: $n \rightarrow p + e + \bar{\nu}_e$



in terms of quark transformation:

