Particle Physics =

In nuclear reactions, energy, momentum and charge are conserved.

Energy released in nuclear reaction is called Disintegration energy Q

* When they looked at mass/energy before and after for β decay they noticed Enegy before was greater that energy after – Pauli proposed that there must be an extra chargeless particle to carry the excess energy. Eventually detected in 1956.

Neutrino → no charge → mass way smaller than $\bar{e}$ (given in tables as a fraction of m_e)

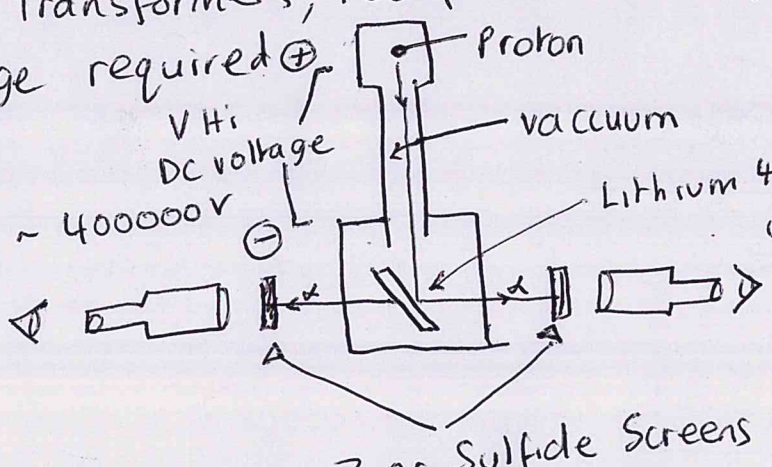
First artificial transmutation done by Rutherford 1919

$$^{4}_{2}He + ^{14}_{7}N \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

First artificial transmutation using Proton accelerator done by Cockcroft & Walton in 1932 – Also verified Einstein's $E = mc^2$ for 1st time experimentally. Nobel prize winners(1951)

$$^{3}_{7}Li + ^{1}_{1}H \rightarrow ^{4}_{2}He + ^{4}_{2}He + \text{Kinetic Energy}$$

Proton accelerator used large dc voltages to accelerate Protons that had been produced in a Hydrogen discharge tube. Transformers, rectifiers and capacitors produced hi dc voltage required



Proton has energy of approx 1 meV

α particles strike Zinc Sulfide screens and produce flashes of light – these are viewed through microscopes

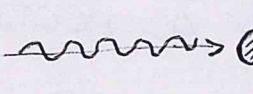
Mass often expressed in a.m.u or u. formula in log table to convert mass in u to mass in kg ($u = 1.66 \times 10^{-27}$ kg)

Antimatter Paul Dirac (GB), predicted antimatter (positrons etc) in 1920's. Carl Anderson discovered positron by looking at tracks in a cloudchamber ↺ same as $\bar{e}$ but opp direction in MField same mass, same size charge

Pair production: A hi energy gamma ray produces two particles identical but of opposite sign. when it collides with the nucleus of an atom. Some of the energy of γ ray goes into the mass of the 2 particles, some goes into k.Energy.

lead plate in a cloud chamber bombarded with hi-energy γ rays produces positron + electron → seen ↻

photon/gamma ray $hf = 2mc^2 + E_{k1} + E_{k2}$



charge, momentum, energy Conserved (γ ray has momentum despite no mass)

Antiparticle usually has ¯ on top eg ν, $\bar{\nu}$.

Pair annihilation: Particle + antiparticle if near and not moving (low in energy) will join together and turn into pure energy in the form of photons. $e^+ + e^- \rightarrow 2hf$

The reason two photons are produced is because mom. must be conserved → can't have one photon going in one direction because momentum before is zero. $\bar{e} \rightarrow \leftarrow e^+$

PARTICLE ACCELERATORS hi energy particles collide → energy released in form of new particles. Energy turns into matter

Need v. High Energies → cyclotron (1929-39) in U.S.

Magnetic/Electric fields used to accelerate particles. MF confines EF accelerates

New particles produced were unstable → $t_{1/2}$ between $10^{-6} \rightarrow 10^{-23}$ s

e.g. $p + p$ + energy → $p + p$ + additional particles.

Bigger energy ⇒ bigger particles, more particles

PARTICLES

LEPTONS – fundamental can't break into smaller particles

$\bar{e}$	e^+	ν_e	$\bar{\nu}_e$
τ	$\bar{\tau}$	ν_τ	$\bar{\nu}_\tau$
μ	$\tilde{\mu}$	ν_μ	$\bar{\nu}_\mu$

Hadrons – made of quarks

100's of them

Baryons (Heavy)

3 Quarks

QQQ or $\bar{Q}\bar{Q}\bar{Q}$

	$(\frac{2}{3})(\frac{2}{3})(\frac{1}{3})$	Charge	Anti
PROTON	uud	(+1)	$\bar{u}\bar{u}\bar{d}$ (-1)
NEUTRON	udd	(0)	$\bar{u}\bar{d}\bar{d}$ (0)
LAMBDA	uds	(0)	$\bar{u}\bar{d}\bar{s}$ (0)
SIGMA	uus	(+1)	$\bar{u}\bar{u}\bar{s}$ (-1)

Mesons

2 Quarks

$Q\bar{Q}$

Pion	$u\bar{d}$	(+1)
Kaon	$u\bar{s}$	(+1)
$\overline{\text{Pion}}$	$\bar{u}d$	(-1)

QUARKS

Up	(u)	$+2/3$	$\bar{u}$	$-\frac{2}{3}$
Down	(d)	$-1/3$	$\bar{d}$	$+1/3$
Strange	(s)	$-1/3$	$\bar{s}$	$+1/3$
Charmed	(c)	$+2/3$	$\bar{c}$	$-2/3$
Bottom	(b)	$-1/3$	$\bar{b}$	$+1/3$
Top	(t)	$+2/3$	$\bar{t}$	$-2/3$

1911 Rutherford – atom mostly empty space
– neucleus ⊕ charge concentrated
– electrons ⊖ charge "orbit" nucleus

1932 Neutron discovered – exists in nucleus
– same ~~charge~~ mass as ⊕ proton
– neutral – no charge

– implied existance of strong nuclear force with very short range of less than diameter of nucleus ← (P) (P) →

FUND. FORCES OF NATURE :

	STRENGTH	ACTS ON	Occurance	Range
STRONG NUCLEAR	1	P, N	Binds Nucleus	10^{-15}
ELECTROMAGNETIC	10^{-2}	charged particles	Binds atoms molecules	∞
WEAK NUCLEAR	10^{-7}	ALL	β - decay	10^{-18}
GRAVITATIONAL	10^{-38}	ALL	keeps universe togeher	∞