*Important examples

E

undecayed atom

potential barrier comes from nuclear forces + Coulomb potential

lower energy state: decayed atom

α-particle emission: think of α-particle as initially confined by a nucleus' potential.

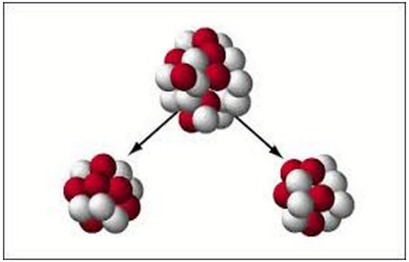
- Nuclear fission.

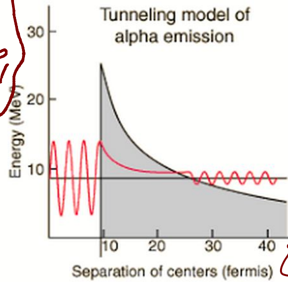
Tunnelling prob ≈ decay prob per unit time.

V sensitive to details of the potential and the initial state energy

⇓

wide range of half-lives for different unstable nuclei



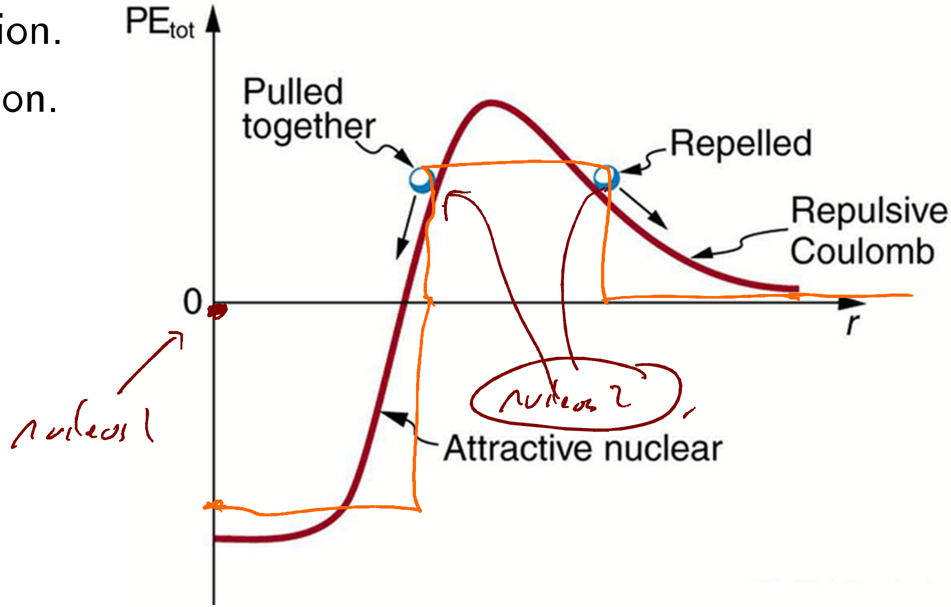


α particle "bounces" between potential barriers created by nuclear "shell" for a long time but eventually tunnels through and escapes

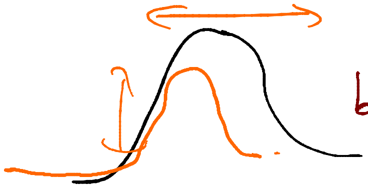
could (we won't) model α-particle tunnelling by directly calculating a consistent solution to the SE.

*Important examples

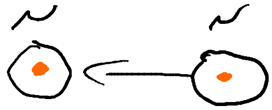
- Nuclear fission.
- Nuclear fusion.



*Important examples

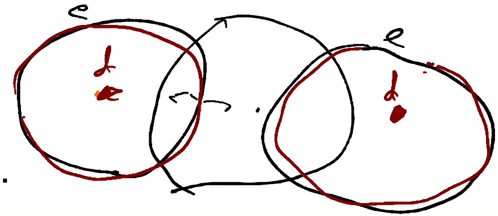


muon μ has -ve charge (like electron) but higher mass.
but unstable.



Get muonium atoms much closer before potential barrier becomes relevant.
fusion rate is much greater for muonic hydrogen.

- Nuclear fission.
- Nuclear fusion.
- Muon-catalysed nuclear fusion.



Bohr radius ~ 1/ m_e
m_mu ~ 207 m_e

Prob of fusing two hydrogen isotopes is low because the relevant potential scale is ≈ Bohr radius of electron orbit.

muon catalyzed fusion (μCF) - principle and motivations

After injection of muons into D/T mixture (or other hydrogen isotopes)

Formation of muonic atoms and muonic molecules

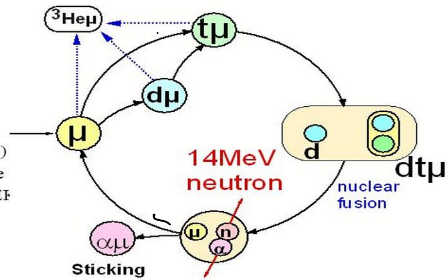
In small dtμ molecule, Coulomb barrier shrinks and d-t fusion follow

Muon released after d-t fusion

- muon works as catalyst -

History

1947 Hypothesis of μCF (Frank)
1957 observation of pdμ fusion (Alvarez)
1966 observation of resonant ddμ formation
1967 hypothesis of resonant formation Vesman)
1979-82 observation of large dtμ formation rate
1987 observation of x-rays from (αμ)⁻ (PSI,KEK
1993 large ddμ formation rate in solid
1995 study with eV beam of (tμ)
1996 systematic study starts at RIKEN-RAL

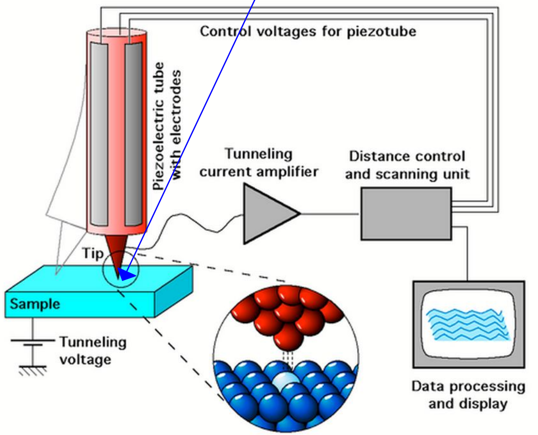


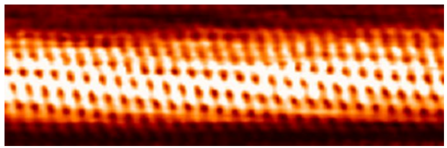
Alas: muon catalysed fusion doesn't (quite) give net energy gain.

*Important examples

$$|T|^2 \approx \exp(-\frac{2a}{\hbar}\sqrt{2m(U-E)}). \qquad (5.39)$$

- Nuclear fission.
- Nuclear fusion.
- Muon-catalysed nuclear fusion.
- Scanning tunnelling electron microscopy. *





Scanning tunnelling microscopy image of a carbon nanotube.

(Source of images: Wikipedia)