# Fusion

# Nuclear fusion

- Two or more atomic nuclei are combined to form a larger nucleus plus other atomic particles.
- Nuclear fusion will result in a mass difference between the reactants and the products
- This mass difference will result in either the emission or absorption of energy

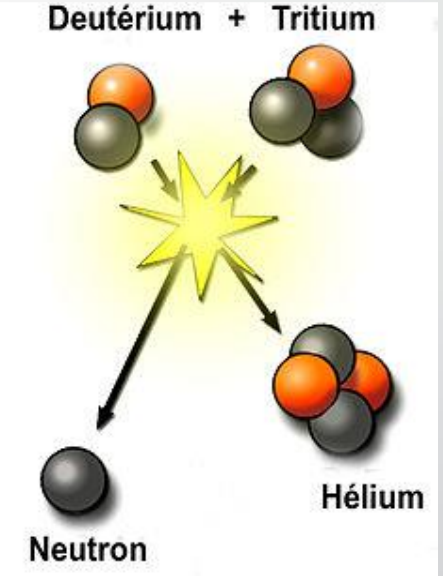


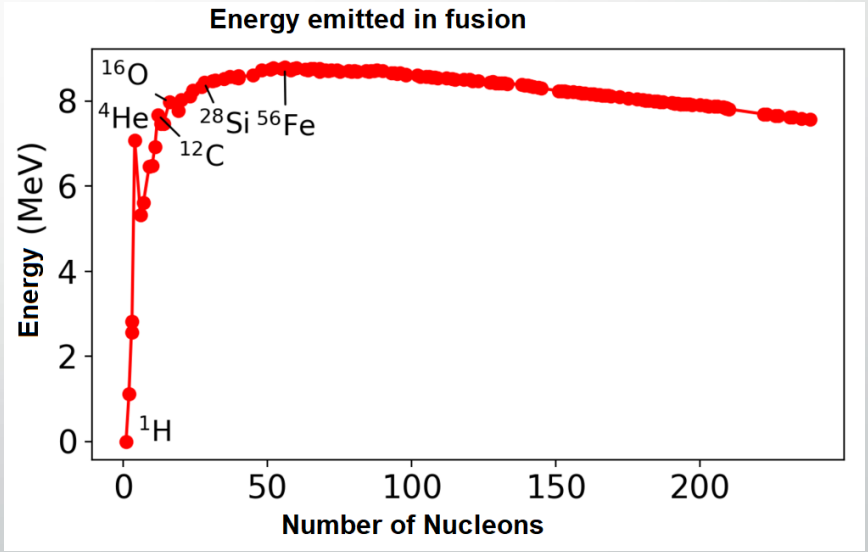

*Image courtesy Lamiot*

# $E = mc^2$

- In both Fusion and Fission the extra energy is a result of what Einstein called a 'Mass defect'
  - A difference between the mass of reactants and the products
- If the products have less mass than the reactants, that change in mass will be seen as energy
- If the reactants have more mass than the products, then an amount of energy is required to make the reaction occur

# Fusion reactants

- In general all elements up to the creation of Iron (Fe) as a product are lighter than their reactants
- Thus in each fusion energy is given out
- Up till the creation of Iron, where no excess energy is available




- Aside
  - It is for this reason that stars continue to fuse until they end up with an iron core. At this stage no energy is available to drive the next level of fusion.

# Lets go back a step

- Fusion, like fission, is a random or probabilistic process and therefore, there is no 'one way' that fusion takes place.

- The ultimate example of fusion is a star
  - Stars are big, really, really, really big
  - Thus the forces at the centre of a star are also really, really, really big
  - Big force results in 'big' heat, but more on that later
  - In the beginning a star is just a mass of Hydrogen, much of it $H^+$
  - The centre of a star starts as just Hydrogen, but then there is lots of pressure
  - The Hydrogen is forced together

# In a star

- So two Hydrogen atoms get forced together and become helium $He_2^2$
  - Well **NO**! sorry, not that simple
- Stage 1 – two Protons fuse, however, being unstable they immediately decay to Deuterium (1 Proton,1 Neutron), a Positron and a Neutrino ($\beta^+$decay)
- Stage 2 – the Deuterium fuses with another Proton. The mass of products is smaller than the mass of reactants and the excess mass is ejected as energy ($\gamma$ radiation). We now have $He^3$.
- Stage 3 – two $He^3$ fuse together forming $He^4$ and two $H^1$ and Gamma radiation (not shown)

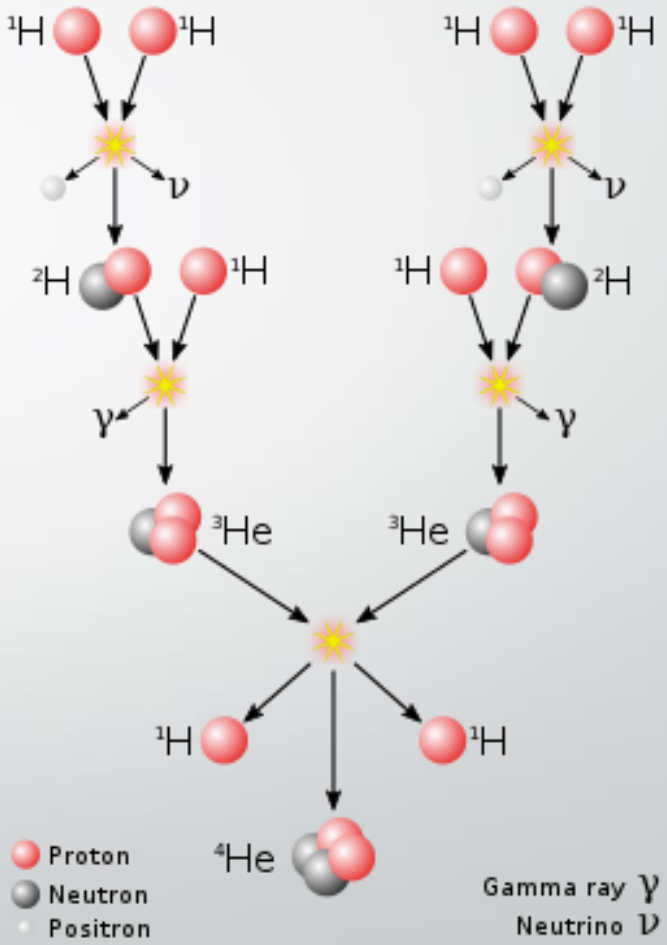
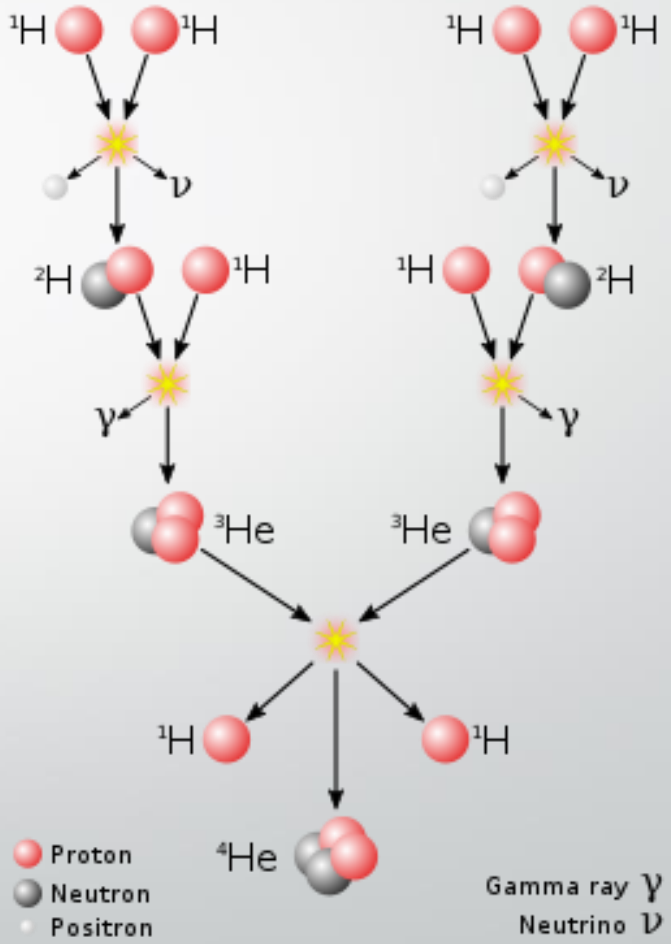



*Image courtesy Sarang*

# Note

- Because the centre of a star is under massive pressure AND with fusion happening there is a massive amount of heat and excess Neutrinos there are two things happening
  - Everything is being pushed into everything else
  - Everything is being 'disassociated' due to the high heat and extremely high kinetic energy
  - By 'disassociated', there are electrons in there, but the heat/kinetic energy is so high that they cannot sit in their 'normal' energy levels.



# And

- Thus, this is a path to Helium and not the only one.