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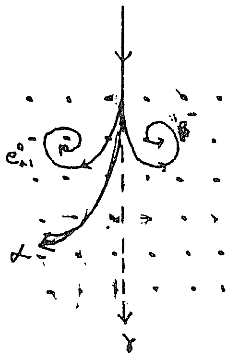

1. Spontaneous nuclear fission is the process in which a very large nucleus splits into two smaller nuclei.

Induced fission is caused by the capture of a nucleon (neutron) that causes instability and the eventual split of the large nucleus. (ie forced fission)

2. See text

3. Mass reactants:

$n = 1.675 \times 10^{-27}$ kg

$U = 3.9017 \times 10^{-25}$ kg

$\therefore$ mass $= 3.91845 \times 10^{-27}$ kg

mass products:

$Ba = 2.28922 \times 10^{-25}$

$Kr = 1.57534 \times 10^{-25}$

$3n = 5.025 \times 10^{-27}$

$\therefore$ mass $= 3.91481 \times 10^{-27}$ kg

$\therefore$ mass defect $= m_R - m_P$

$= 0.00364 \times 10^{-27}$

$= 3.64 \times 10^{-30}$ kg

$\therefore E = \Delta m c^2$

$= 3.64 \times 10^{-30} \times (3 \times 10^{8})^2$

$= 3.276 \times 10^{-13}$ J.

En of gamma photon

$= 3.276 \times 10^{-14}$ J.

$\therefore E = hf$

$\therefore f = E/h = \frac{3.276 \times 10^{-14}}{6.63 \times 10^{-34}}$

$= 4.9 \times 10^{19}$ Hz.

4. $n^{1}_{0} + U^{235}_{92} \rightarrow Sn^{132}_{50} + Mo^{101}_{42} + 3n^{1}_{0}$

Conserved: (1) mass / Energy
(2) nucleons
(3) charge
(4) momentum

5. The fission of a U^{235} nucleus produces about 230 MeV.
230 MeV is equivalent to 3.7×10^{-11} Joules.
This is about 10^{7} times the amount of chemical energy given out by the combustion of methane.

6. Fission gives out huge amounts of energy for small amounts of mass compared with methane burnt in oxygen.
Fossil fuels use too much mass & produce too much waste (CO/CO_2).
The amount of waste produced by fission is very much less.

7. $n_0^1 + U_{92}^{235} \rightarrow Xe_{54}^{140} + Sr_{38}^{94} + 2n + \gamma$

$n_0^1 + U_{92}^{235} \rightarrow Sn_{50}^{132} + Mo_{42}^{101} + 3n + \gamma$

Could be different because of the energy of the neutrons. If the neutron energies are different, different fissions are likely ∴ it is important to control the energy of neutrons in reactors.

8 (1) All the nuclei have an excess of neutrons ∴ They will decay by β^- emission which is neutron decay.

(2) $[{}_0^1n \rightarrow {}_1^1p + e^- + \bar{\nu}]$

∴ ${}_{56}^{141}Ba \rightarrow {}_{57}^{141}La + e^- + \bar{\nu}$

${}_{36}^{92}Kr \rightarrow {}_{37}^{92}Rb + e^- + \bar{\nu}$

etc
etc.

9. If they have low energy they are more likely to be captured ∴ upsetting the n/p ratio & promoting fission. High energy neutrons are likely to collide & shatter nuclei, or reflect off.

b) The moderator slows the neutrons down to thermal energies so that effective neutron capture can occur.

10. When high energy neutrons collide with D_2O molecules they transfer more of their energy & momentum to the D_2O. ∴ it only takes a few collisions between a neutron & D_2O molecules to reduce the neutron energy to a level that will ensure capture. Larger moderator molecules will cause the neutrons to collide & 'bounce off' with most of their energy & momentum retained. ∴ many more collisions are necessary to ensure capture. ∴ D_2O is more effective as a moderator.

11. Naturally occurring uranium ore does not have enough U^{235} to maintain a chain reaction. ∴ The fuel is enriched to ensure that enough neutrons can collide with U^{235} nuclei to promote fission & the chain reaction.

12.

mass reactants:

$m\,H_1^2 = 3.34357 \times 10^{-27}$

$m\,H_1^2 =$ "

∴ mass total $= 6.68714 \times 10^{-27}$ kg

mass products:

$m\,He_2^3 = 5.00683 \times 10^{-27}$

$m\,n_0^1 = 1.675 \times 10^{-27}$

∴ mass total $= 6.68183 \times 10^{-27}$ kg

∴ mass defect Δm

$= 0.00531 \times 10^{-27}$

$= 5.31 \times 10^{-30}$ kg.

∴ $E_n = \Delta m c^2$

$= 5.31 \times 10^{-30} \times (3 \times 10^8)^2$

$= 4.78 \times 10^{-13}$ J.

13. To fuse the nuclei we need to overcome the coulombic repulsion of the nuclei (positive charges) & this is usually done by giving the nuclei large kinetic (thermal) energy.

14. Energy $= \Delta V q$

∴ $E_n = 100{,}000 \times 1.6 \times 10^{-19}$

$= 1.6 \times 10^{-14}$ J.

(2) $E_n = K = \frac{1}{2}mv^2$

∴ $1.6 \times 10^{-14} = \frac{1}{2} \times 3.34357 \times 10^{-27} \times v^2$

∴ $v^2 = \frac{1.6 \times 10^{-14} \times 2}{3.34357 \times 10^{-27}}$

$v = 3.1 \times 10^6\ ms^{-1}$

15. mass reactants:

$m\,H_1^2 = 3.34357 \times 10^{-27}$

$m\,H_1^1 = 1.673 \times 10^{-27}$

mass $= 5.01657 \times 10^{-27}$ kg

$m\,He_2^3 = 5.00683 \times 10^{-27}$ kg

∴ mass defect Δm

$= 0.00974 \times 10^{-27}$ kg

$= 9.74 \times 10^{-30}$ kg

∴ max. energy of the gamma photon

$E = \Delta m c^2$

$= 9.74 \times 10^{-30} \times (3.0 \times 10^8)^2$

$E_n = 8.766 \times 10^{-13}$ J.

16. 400 Mega watts

$\equiv 400\times10^6$ watts

$= 400\times10^6$ Joules / sec.

$= 400\times10^6 \times 60\times60\times24$ Joules / day.

$= 3.456\times10^{13}$ Joules / day

$\therefore$ Using $E = \Delta m c^2$

$3.456\times10^{13} = \Delta m \times (3\times10^8)^2$

$\therefore \Delta m = \dfrac{3.456\times10^{13}}{(3\times10^8)^2}$

$= 3.84\times10^{-4}$ kg.

$\equiv 0.38$ g.

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17. (1) Energy generation
(2) manufacture of radio-isotopes
(3) nuclear research.

18. (1) Core:
Contains the fuel rods and control rods. Where fission occurs. Basically a group of fuel rods in a high flux of neutrons. Where energy is produced.

(2) Rods of enriched uranium – U^{235} is the fission material U^{238} is the fertile fuel.

(3) The moderator – D_2O (heavy water) – reduces the energy and momentum of the neutrons so that capture can occur to promote fission.

(4) Control rods – typically Boron & Cadmium – They 'soak up' neutrons so that the number of neutrons (slow) colliding with the fuel can be controlled $\therefore$ controlling the chain reaction & hence the energy output.

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19. The energy output is controlled by moving the control rods in & out of the core. The further the rods are inserted the more neutrons are absorbed $\therefore$ the reaction chain is reduced & so is the energy. The reverse gives more energy.

20.

$n_0^1 + Li_3^6 \rightarrow H_1^3 + H_1^3 + H_1^1$

$He_2^3 + He_2^3 \rightarrow He_2^4 + H_1^1 + H_1^1$

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21. $E_n = \Delta m c^2$

$\therefore 4.3\times10^{-12} = \Delta m c^2$

$\therefore \Delta m = \dfrac{4.3\times10^{-12}}{(3.0\times10^8)^2}$

$\therefore \Delta m = 4.8\times10^{-29}$ kg

(2)(a) $E_n = \Delta m c^2$

$= 4\times10^9 \times (3\times10^8)^2$

$\therefore E_n = 3.6\times10^{26}$ J / second.

(b) # of reactions

$= \dfrac{3.6\times10^{26}}{4.3\times10^{-12}}$

$= 8.4\times10^{38}$ reactions per second!

(c) Time $= \dfrac{\text{total mass}}{\text{mass lost / s.}}$

$T = \dfrac{2.0\times10^{30}}{4\times10^9}$

$T = 5\times10^{20}$ seconds.

$= 1.6\times10^{13}$ years. !!