SPH3U 7.4 Nuclear Fission

1. Mass-energy equivalence

Mass-energy equation:	$E = mc^2$ (Einstein).
c	speed of light, 3.0×10^8 m/s.
Law of conservation of mass-energy:	Mass can transform into energy, and energy into mass. The total mass-energy in a closed system is conserved.

Particle	Mass (kg)	Mass (u)
proton	$1.672\ 6014 \times 10^{-27}$	1.007 276
neutron	$1.674\ 920 \times 10^{-27}$	1.008 665
electron	$9.109\ 56 \times 10^{-31}$	0.000 549

Atomic mass unit (u):	$1\ u = 1.66 \times 10^{-27}$ kg.
Mega-electron volt:	$1\ MeV = 1.602 \times 10^{-13}$ J.

Mass defect: Δm	Difference between the calculated mass of an ~~nucleus~~ atom and its actual mass.
Binding energy:	Amount of energy needed to separate a nucleus.

Determine the mass defect and binding energy of a lithium-7 nucleus, given that its actual atomic mass is 7.016 00 u, and using the particle mass table above.

^7_3Li: $3p^+ + 4n^0 + 3e^-$

$= 3(1.007276) + 4(1.008665) + 3(0.000549) = 7.058135$.

$\Delta m = 7.058135 - 7.01600 = 0.042135\ u$.

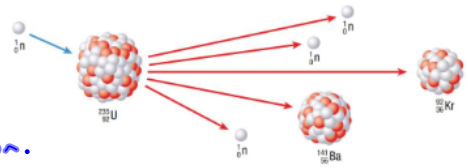
$E = \Delta m c^2 = (0.042135)(3.0 \times 10^8)^2 (1.66 \times 10^{-27}\ \frac{kg}{u})$

$= 6.29 \times 10^{-12}$ J.

$= (6.29 \times 10^{-12})(\frac{1\ MeV}{1.602 \times 10^{-13}\ J}) = 39$ MeV.

2. Nuclear fuel

U-235 fission:	$^{235}_{92}U + {}^1_0n \rightarrow {}^{92}_{36}Kr + {}^{141}_{56}Ba + 3({}^1_0n)$
Chain reaction:	repeated series of reactions where the products of a reaction create a new reaction.



Other nuclear fuels:	Plutonium-239, Thorium-232, Uranium-233.

What is the energy yield of the following fission reaction? Use the given masses below.

$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{140}_{55}Cs + {}^{93}_{37}Rb + 3({}^{1}_{0}n)$

mass of U (m_U) = 235.044 u
mass of Cs (m_{Cs}) = 139.909 u
mass of Rb (m_{Rb}) = 92.922 u
mass of neutron (m_n) = 1.009 u

$m_U + m_n = m_{Cs} + m_{Rb} + 3m_n + \Delta m$.

$\Delta m = m_U + m_n - (m_{Cs} + m_{Rb} + 3m_n)$

$= 235.044 + 1.009 - 139.909 - 92.922 - 3(1.009)$

$= 0.195$ u.

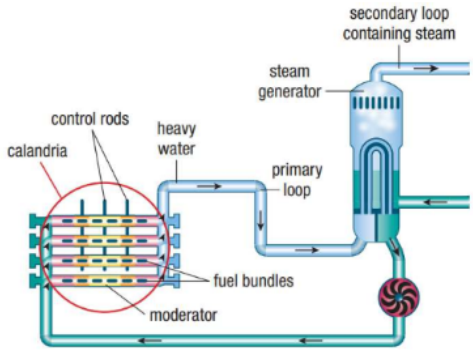
$= (0.195)(1.66 \times 10^{-27}\ kg) = 3.237 \times 10^{-28}\ kg$

$E = \Delta m c^2 = (3.237 \times 10^{-28})(3.00 \times 10^8)^2 = 2.913 \times 10^{-11}$ J

$= 181.9$ MeV.

3. CANDU Reactors

Neutron moderation:	Neutrons are slowed down by heavy water for chain reaction.
Natural uranium:	99.27% U-238 (not fuel), 0.72% U-235 (radioactive).
Radiation badges:	Wear them, they show how much radiation you've been exposed to.
Waste disposal:	Very little pollution, but nuclear (radioactive) waste needs to be stored safely for 100s of years.



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