Fission and Energy Release

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Einstein's Law of Special Relativity led to Mass-Energy Equivalence

where E = energy, m = mass and c = speed of light

= m/s

Mass-Energy Equivalence

One gram (1/1000 of a kg) of mass is equivalent to:

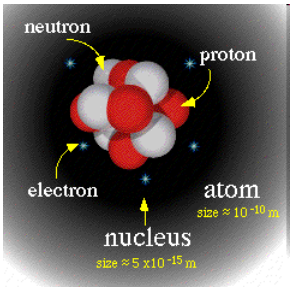
- 89.9 terajoules (89,900,000,000,000 Joules)
- 25.0 million kilowatt-hours (≈ 25 Gigawatt·hours)

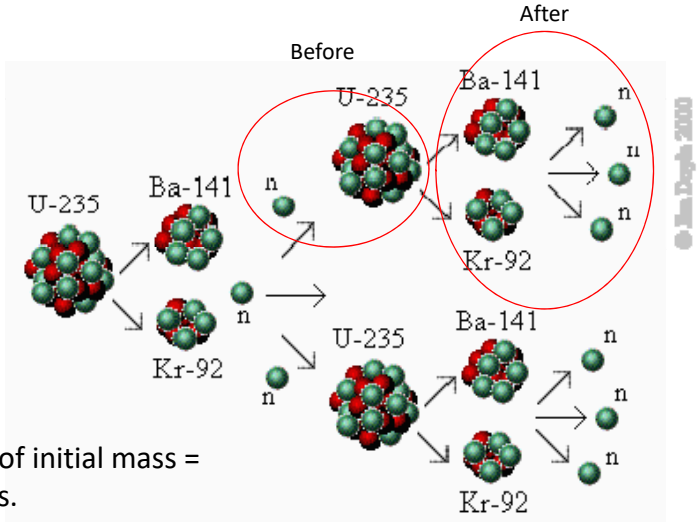
or the energy released by

- 21.5 kilotons (21,500,000 kg) of

- combustion of 568,000 gallons of

Fission and Fission Products



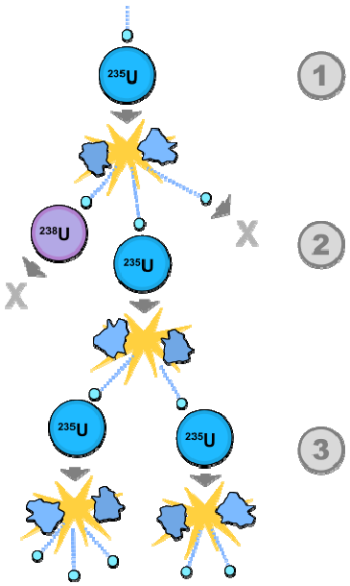


Difference in mass per fission = 0.1% of initial mass = 3.27×10^{-11} Joules = kW-hrs.

1 gram of pure Uranium-235 has atoms (= 2.56×10^{21}). So, fissioning 1 gram of U-235 produces kW-hrs (equivalent to kg of coal).

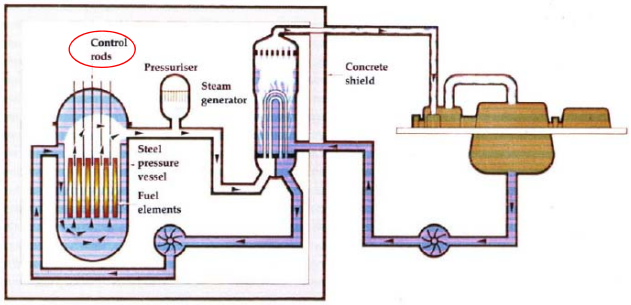
Fission Chain Reaction

- Nuclear reactors utilize chain fission reactions in a sustained and controlled manner.
- Each fission reaction produces ~ MeV of energy.
- In contrast, most chemical reactions (such as burning coal or TNT) release at most a few eV per reaction.
- So, per unit mass, nuclear fuel contains at least times more usable energy than does chemical fuel.
- In nuclear reactors, 1 gram of U-235 fuel can produce kW-hours of electricity at 30% efficiency. Note an electric kettle uses ~1 kW-hr in 1 hr.



Nuclear Reactors

- Feed: Fresh fuel assemblies
- Process: Nuclear chain reaction
- Product: Heat (and electricity)
- "Waste:" Irradiated fuel assemblies
  - Uranium + plutonium + fission products



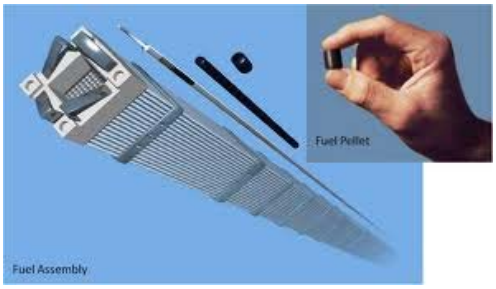


Figure 1.3a Schematic: Pressurised Water Reactor (PWR)

URANIUM ENRICHMENT

- Feed: UF_6 gas
  - Natural uranium, U-235 concentration %
- Process: Gaseous diffusion or gas centrifuge
- Product: Enriched UF_6
  - Low-enriched uranium (LEU), U-235 enrichment %
  - Highly enriched uranium (HEU), U-235 enrichment %