Introduction to Physical Science

Nuclear Energy

Presented by Robert Wagner

Nuclear Transmutation

- The conversion of one nuclide to another
- Example:
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- Requires very high energies
  - Particle accelerators can be used

Transuranium Elements

- Uranium (Z=92) is the heaviest naturally occurring element
  - Heavier elements can be produced artificially
- Bombard uranium-238 with neutrons:
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  - Decays
    - Half life = 23.5min
    - Half life = 2.36 days

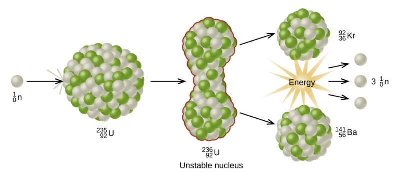
Transuranium Elements (2)

Preparation of Some of the Transuranium Elements

Name	Symbol	Atomic Number	Reaction
americium	Am	95	${}^{239}_{94}\text{Pu} + {}^{1}_{0}\text{n} \longrightarrow {}^{240}_{95}\text{Am} + {}^{0}_{-1}\text{e}$
curium	Cm	96	${}^{239}_{94}\text{Pu} + {}^{4}_{2}\text{He} \longrightarrow {}^{242}_{96}\text{Cm} + {}^{1}_{0}\text{n}$
californium	Cf	98	${}^{242}_{96}\text{Cm} + {}^{4}_{2}\text{He} \longrightarrow {}^{245}_{98}\text{Cf} + {}^{1}_{0}\text{n}$
einsteinium	Es	99	${}^{238}_{92}\text{U} + 15{}^{1}_{0}\text{n} \longrightarrow {}^{253}_{99}\text{Es} + 7{}^{0}_{-1}\text{e}$
mendelevium	Md	101	${}^{253}_{99}\text{Es} + {}^{4}_{2}\text{He} \longrightarrow {}^{256}_{101}\text{Md} + {}^{1}_{0}\text{n}$
nobelium	No	102	${}^{246}_{96}\text{Cm} + {}^{12}_{6}\text{C} \longrightarrow {}^{254}_{102}\text{No} + 4{}^{1}_{0}\text{n}$
rutherfordium	Rf	104	${}^{249}_{98}\text{Cf} + {}^{12}_{6}\text{C} \longrightarrow {}^{257}_{104}\text{Rf} + 4{}^{1}_{0}\text{n}$
seaborgium	Sg	106	${}^{206}_{82}\text{Pb} + {}^{54}_{24}\text{Cr} \longrightarrow {}^{257}_{106}\text{Sg} + 3{}^{1}_{0}\text{n}$ ${}^{249}_{98}\text{Cf} + {}^{18}_{8}\text{O} \longrightarrow {}^{263}_{106}\text{Sg} + 4{}^{1}_{0}\text{n}$
meitnerium	Mt	107	${}^{209}_{83}\text{Bi} + {}^{58}_{26}\text{Fe} \longrightarrow {}^{266}_{109}\text{Mt} + {}^{1}_{0}\text{n}$

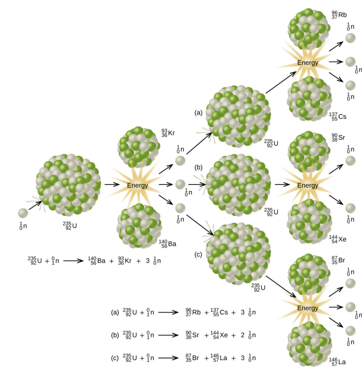
Nuclear Fission

- Heavier elements can decompose into more stable elements with lower masses
  - Usually does not occur naturally
  - Bombardment with neutrons
- Mass difference between products and reactants yields energy



Critical Mass

- Free neutrons are produced in a fission reaction
  - These can cause fission of other nuclei
- Fissile or fissionable material is material that is capable of sustaining a nuclear chain reaction
- A critics mass of material is needed
  - Number of neutrons produced exceeds the number of neutrons absorbed



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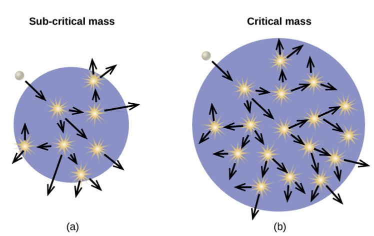
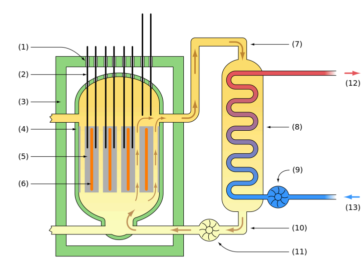


Fission Reactors

- Controllable chain reactions
- Nuclear fuel
  - Example: Uranium-235 (<1% of naturally occurring)
  - Enriched to 5% or so
    - Allows a chain reaction
    - Does not allow for a supercritical mass - no explosion
- Control rods - absorb neutrons to control rate of reaction



Fusion Reactions

- Converting light nuclei into heavier nuclei
- Energy source of our Sun
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- The mass difference is converted to energy:
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- Requires very high temperatures
  - 10-15 million Kelvin
- Nuclear weapon - Hydrogen bomb
- Nuclear power - need a way to contain the material - magnetic fields? Focused laser beams? Current research is ongoing…

Summary

- The transmutation of elements can produce energy
- Nuclear fission splits heavier elements into lighter ones
- Nuclear fusion combines lighter elements into heavier ones