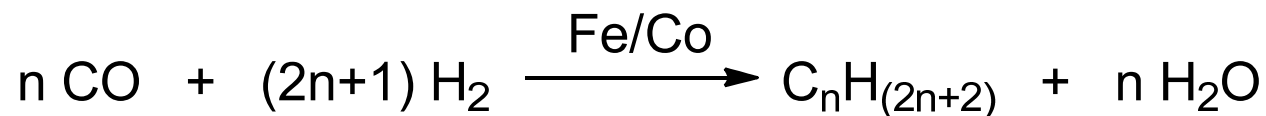
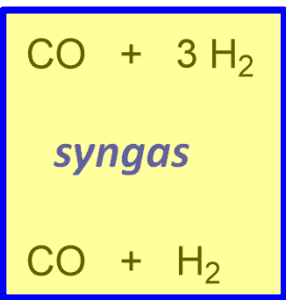
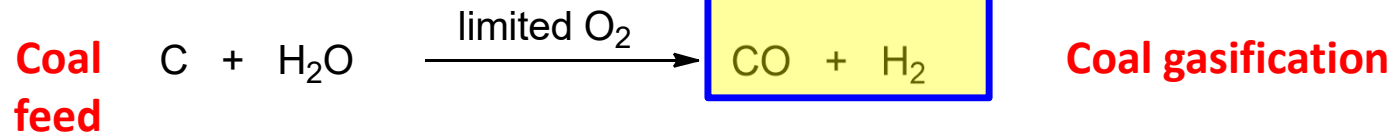
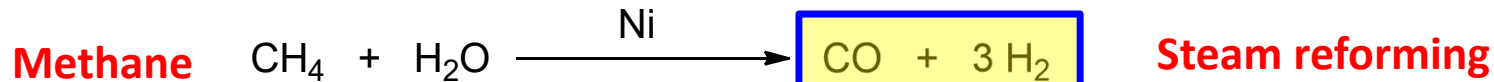
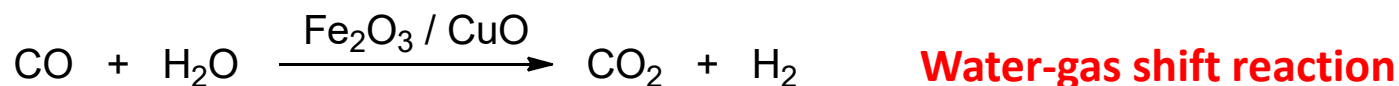


Alternatives to Petroleum

'Synthetic' gasoline: Fischer-Tropsch (or C_1) Chemistry

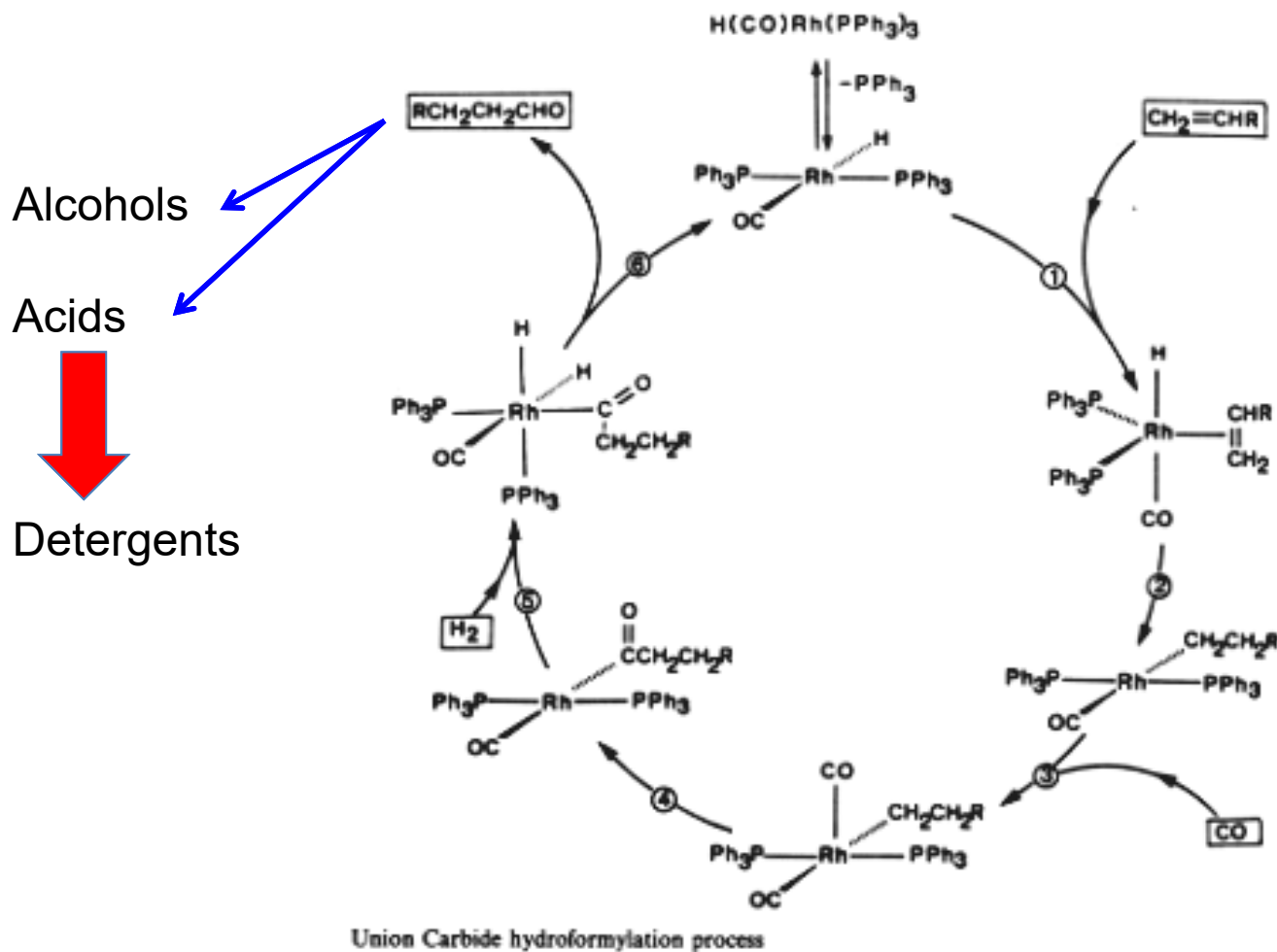


Other reactions relevant to this chemistry:



Syngas: A versatile starting material for synthesis

Hydroformylation: converting alkenes to functionalized products



Sasol: played an important role in 'synthetic' gasoline development

S. Africa: limited oil but abundant coal reserves



From the Sasol corporate website: www.sasol.com

GTL = gas to liquid

Oil Shale: rebirth of US petroleum production

Oil shale: actually organic matter known as **kerogen** that produces a low grade crude oil when heated to **450-500 C**. (*In contrast, 'oil-bearing shales' actually DO contain oil*)

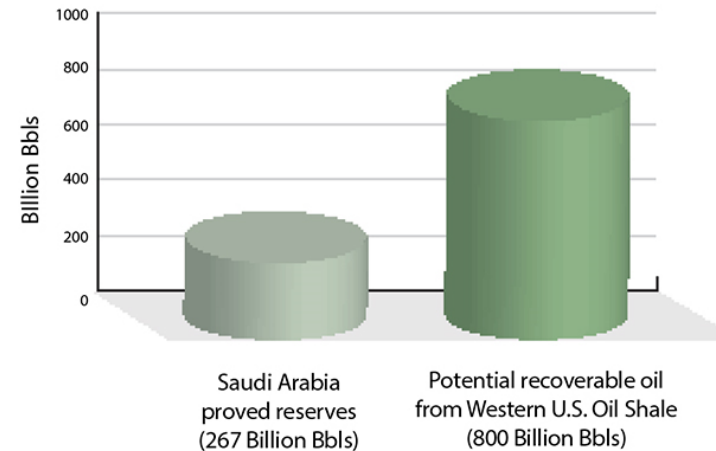
Largest oil shale deposit in the world:

Eocene Green River Formation of Colorado, Utah, and Wyoming is estimated to contain about **800 billion barrels of oil**

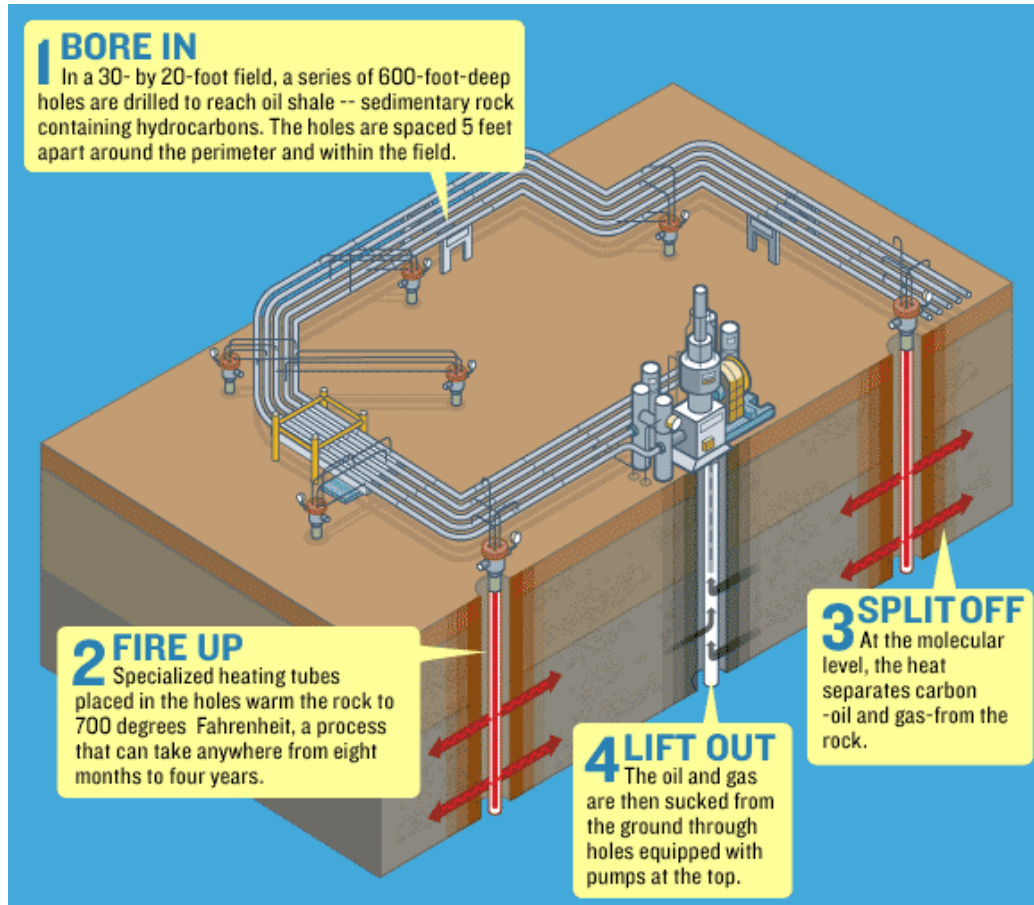


From: API – US Oil Shale Factsheet

Figure 2. Oil reserves of Saudi Arabia vs. Western U.S. oil shale potential.



In situ extraction of oil from Oil Shale deposits (kerogen):



from www.evsroll.com

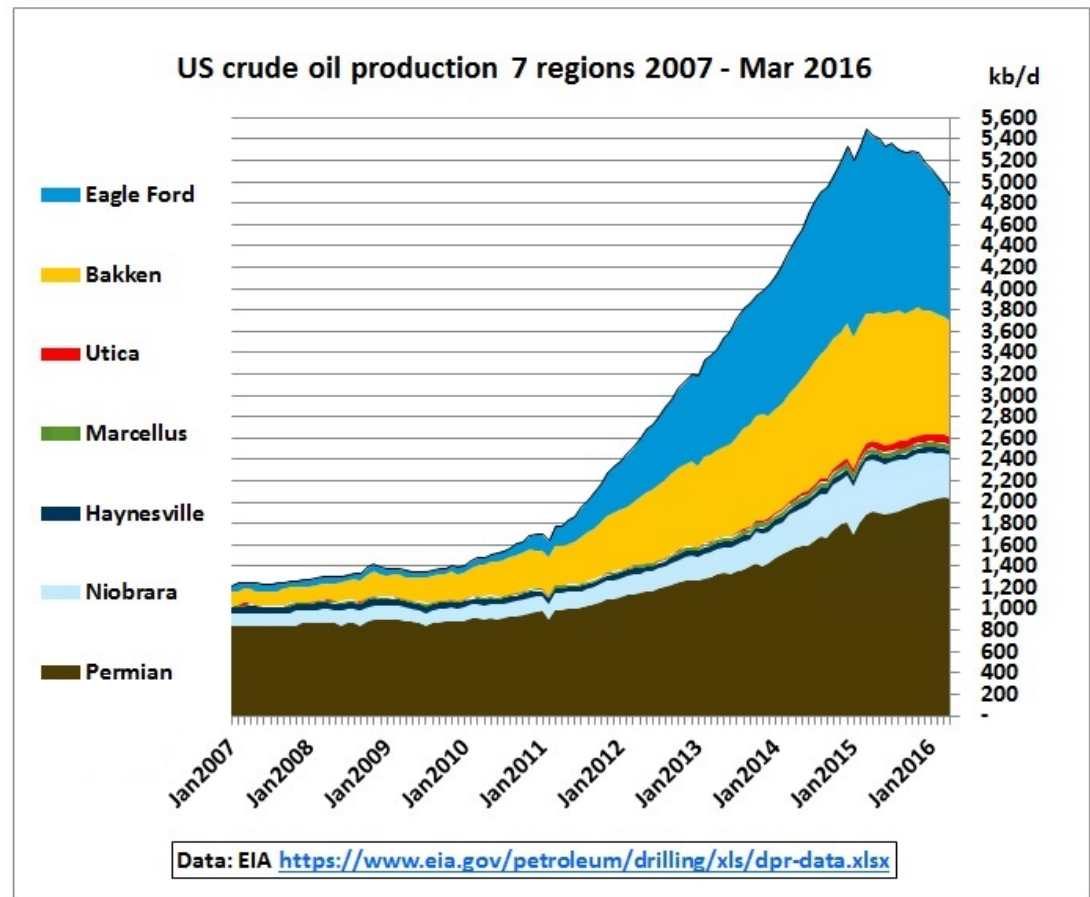
from Permanent Culture Now

Shale (*Tight*) Oil: fracking R Us

This **IS** actually oil trapped in shale formations: many large deposits in US and Russia

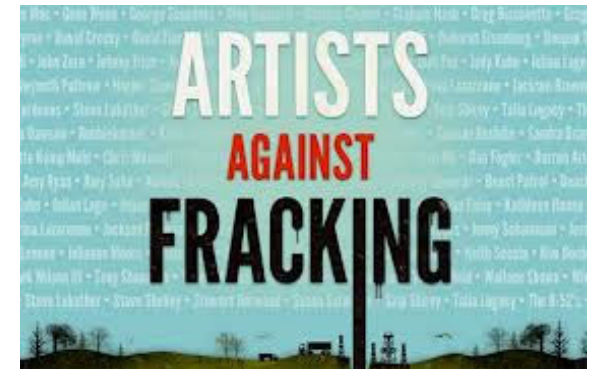
Technique based on extraction by **fracking:** *hydraulic fracturing of the surrounding rock*

Fracking fluid:
90% water
9.5% sand/ceramic
and
0.5% chemical additives that can include:
HCl, gums, ethylene glycol, isopropanol, methanol or gelling agents



Fracking concerns?

- Consumes large quantities of water
 - True, but water is not 'lost' in the process
- Fracking fluid generally not recovered so environmental contamination
 - True, but most components are water and sand plus organic gums
- **Groundwater contamination**
 - Aquifer depths are far closer to the surface than frack zone so less likely that contamination will occur
- Release of trapped gases to air
 - Volume levels insignificant
- Increased seismic activity: micro-quakes
 - True but is this good or bad?



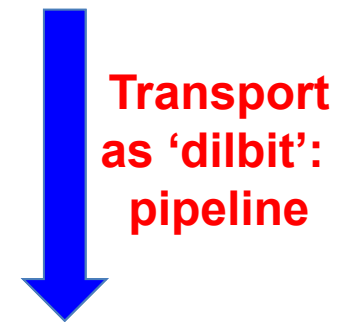
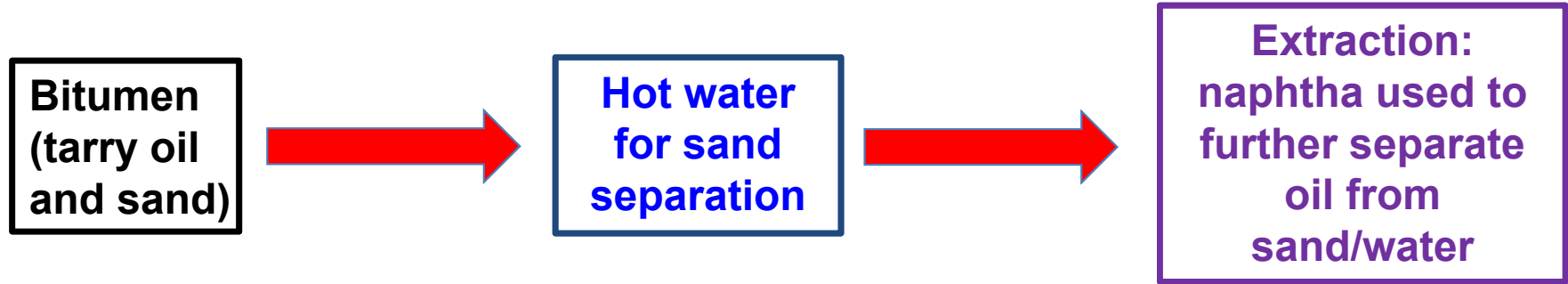
Video (from American Petroleum Institute):

<https://www.api.org/oil-and-natural-gas/wells-to-consumer/exploration-and-production/hydraulic-fracturing/fracking-safe-oil-gas-extraction>



Tar Sands: Oil Recovery

Athabasca tar sands deposits are largest in the world and close to surface



Tar Sands: **Issues**

- **Dirty process**
- **Very energy intensive**
- **Uses a huge amount of water**
- **Strip mining defaces environment**
- **Located far from ports and refineries: pipelines (Keystone XL, Northern Gateway)**



from the Huffington Post

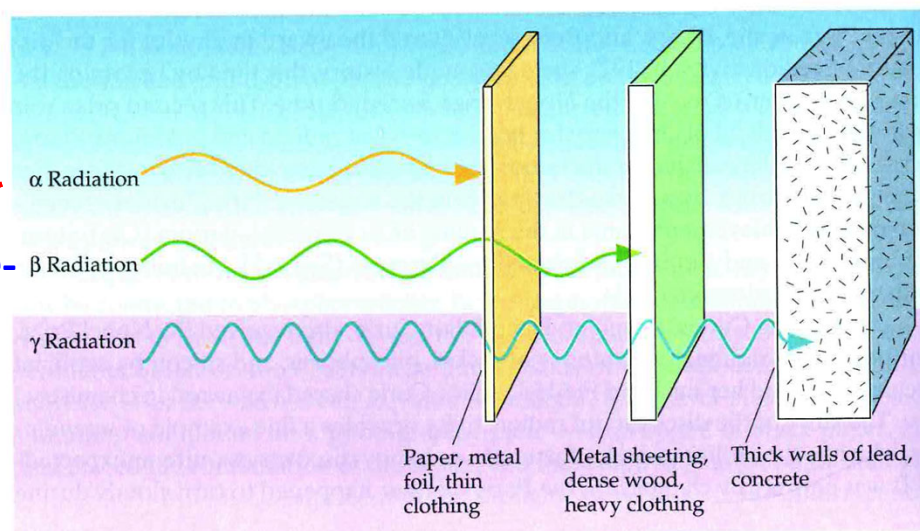
Nuclear Energy

Notation => mass number, atomic number and charge

39 Mass number
19 Atomic number
1+ Charge

Protium	$\begin{matrix} 1 \\ 1 \end{matrix} \text{H}$
Deuterium	$\begin{matrix} 2 \\ 1 \end{matrix} \text{H}$
Tritium	$\begin{matrix} 3 \\ 1 \end{matrix} \text{H}$
Helium atom	$\begin{matrix} 4 \\ 2 \end{matrix} \text{He}$
Helium nucleus	$\begin{matrix} 4 \\ 2 \end{matrix} \text{He}^{2+}$
Uranium-235	$\begin{matrix} 235 \\ 92 \end{matrix} \text{U}$
Potassium atom	$\begin{matrix} 39 \\ 19 \end{matrix} \text{K}$
Potassium cation	$\begin{matrix} 39 \\ 19 \end{matrix} \text{K}^{1+}$

Radioactive decay



The Extraordinary Chemistry of Ordinary Things, 4th Ed.

Nuclear reactions

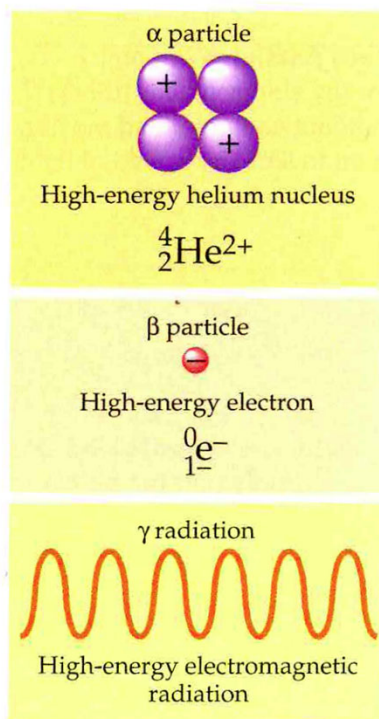
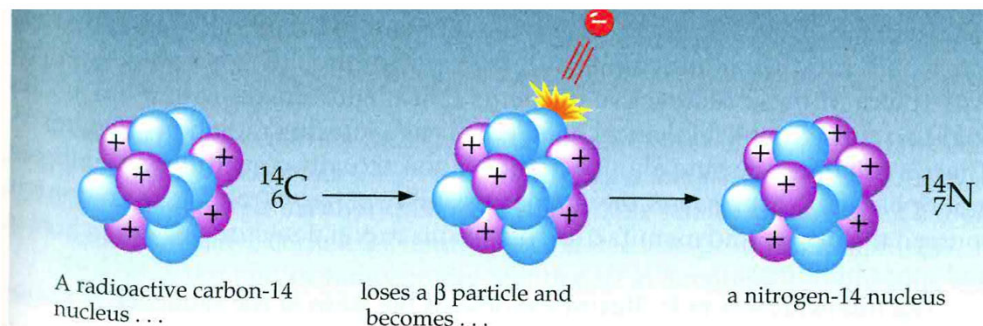
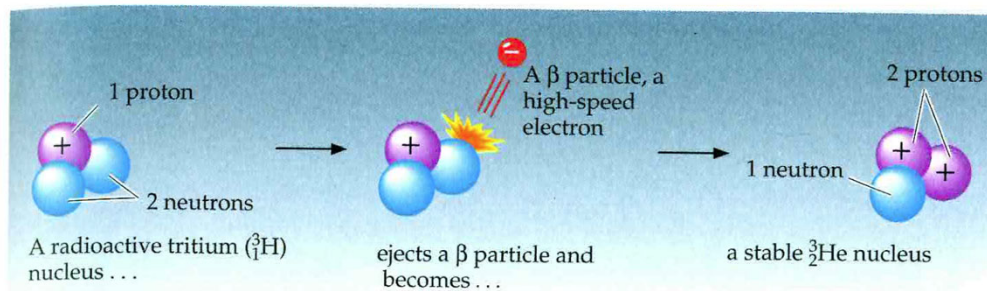
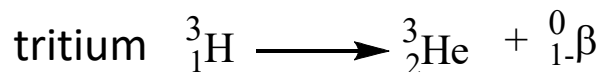
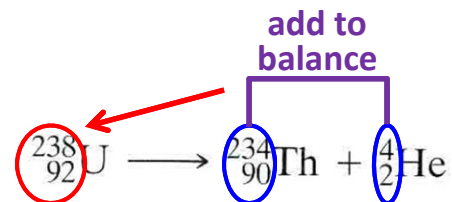


Figure 4.4 The components of α rays, β rays, and γ rays.

Beta decay: neutron converts to a proton and an electron (ejected):



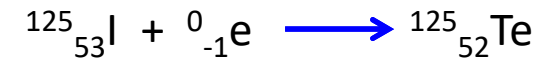
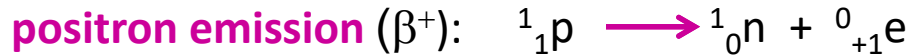
Alpha emission: ejection of a helium nucleus



The Extraordinary Chemistry of Ordinary Things, 4th Ed.

Nuclear reactions (cont)

Things that happen to protons...



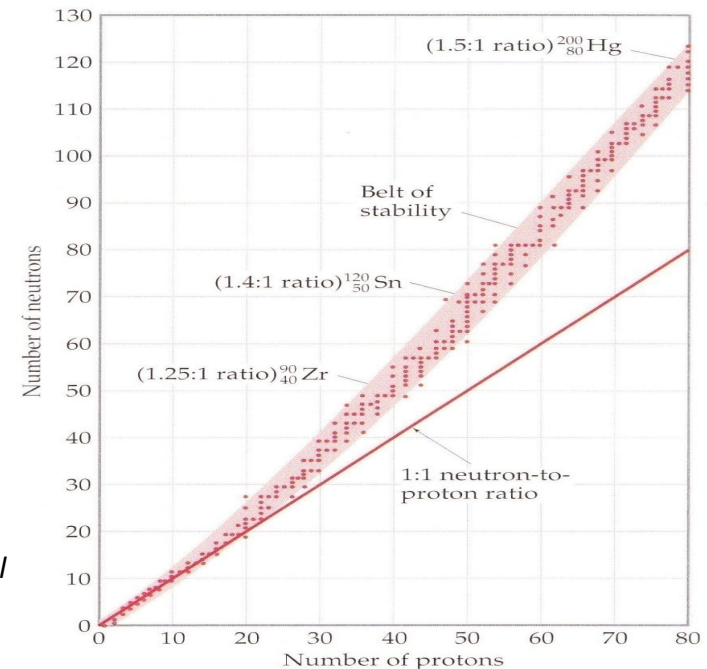
And also note:



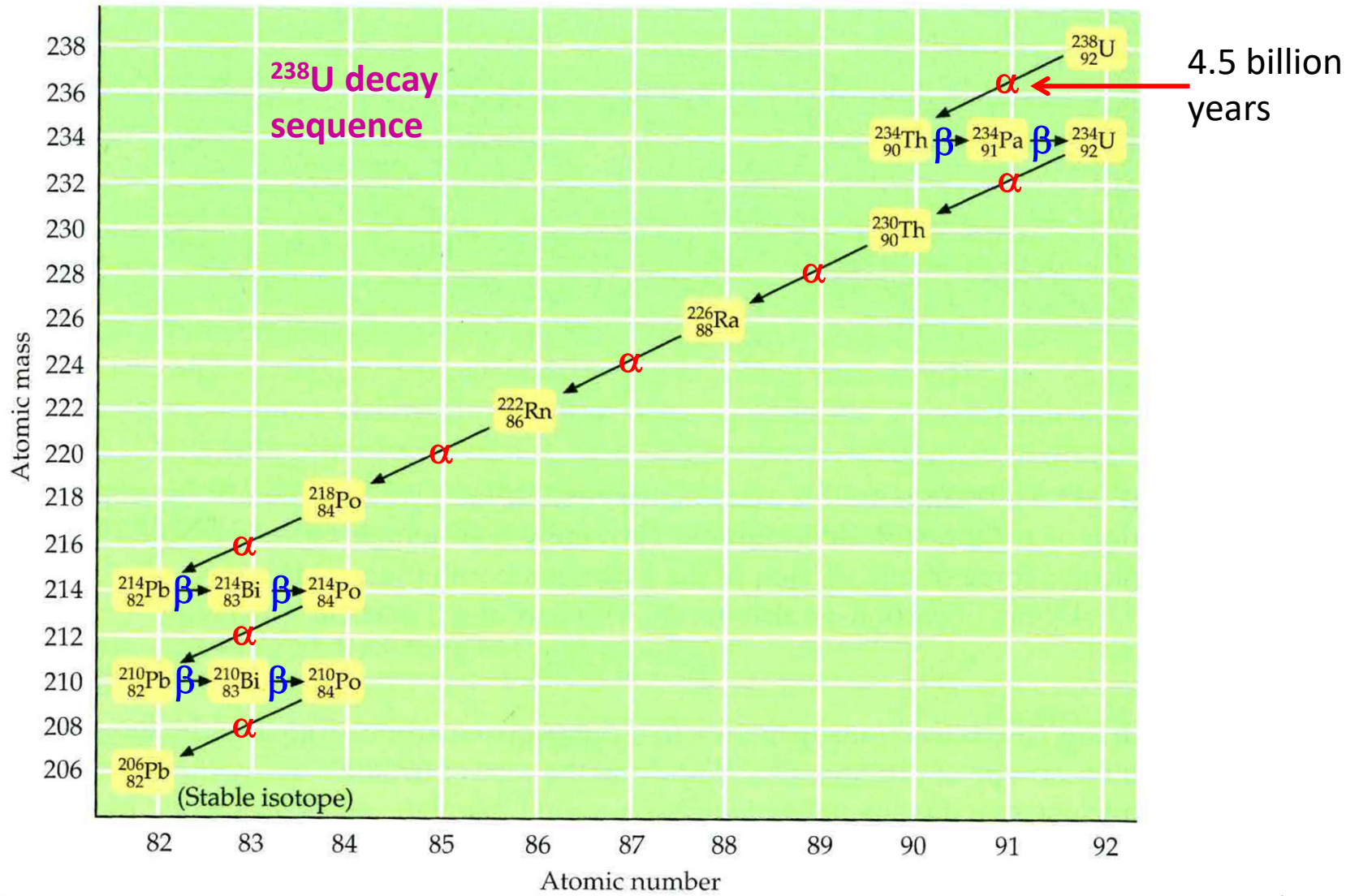
positrons and electrons annihilate one another
producing two gamma rays
(that travel in exactly opposite directions)

Belt of stability: only certain ratios of
neutrons and protons are stable

*from Westlake, OH school
resources website*

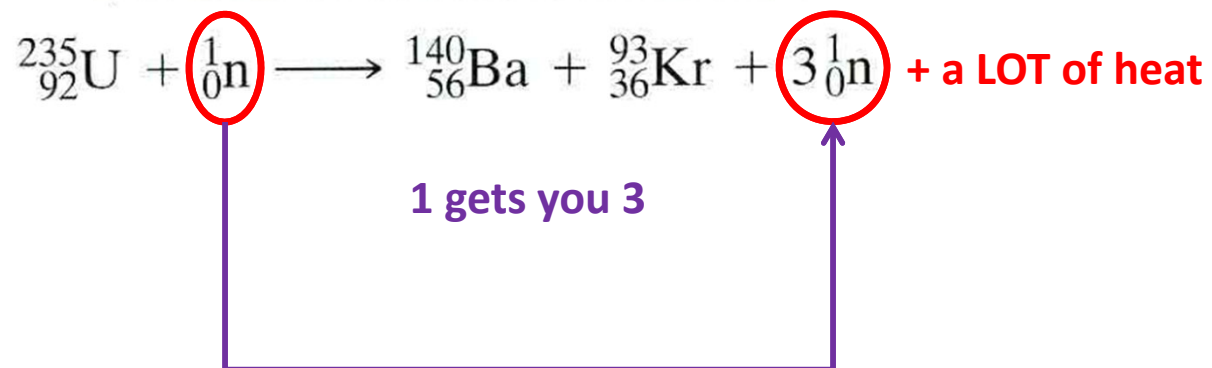


Decay occurs through many steps until a stable atom is formed



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Why is there energy released – nuclear fission



$$E = mc^2$$

$$M_{\text{U}235} + M_{\text{n}} = 236.053 \text{ amu}$$

$$M_{\text{Ba}140} + M_{\text{Kr}93} + 3M_{\text{n}} = 235.869 \text{ amu} \text{ so-called 'mass defect'}$$

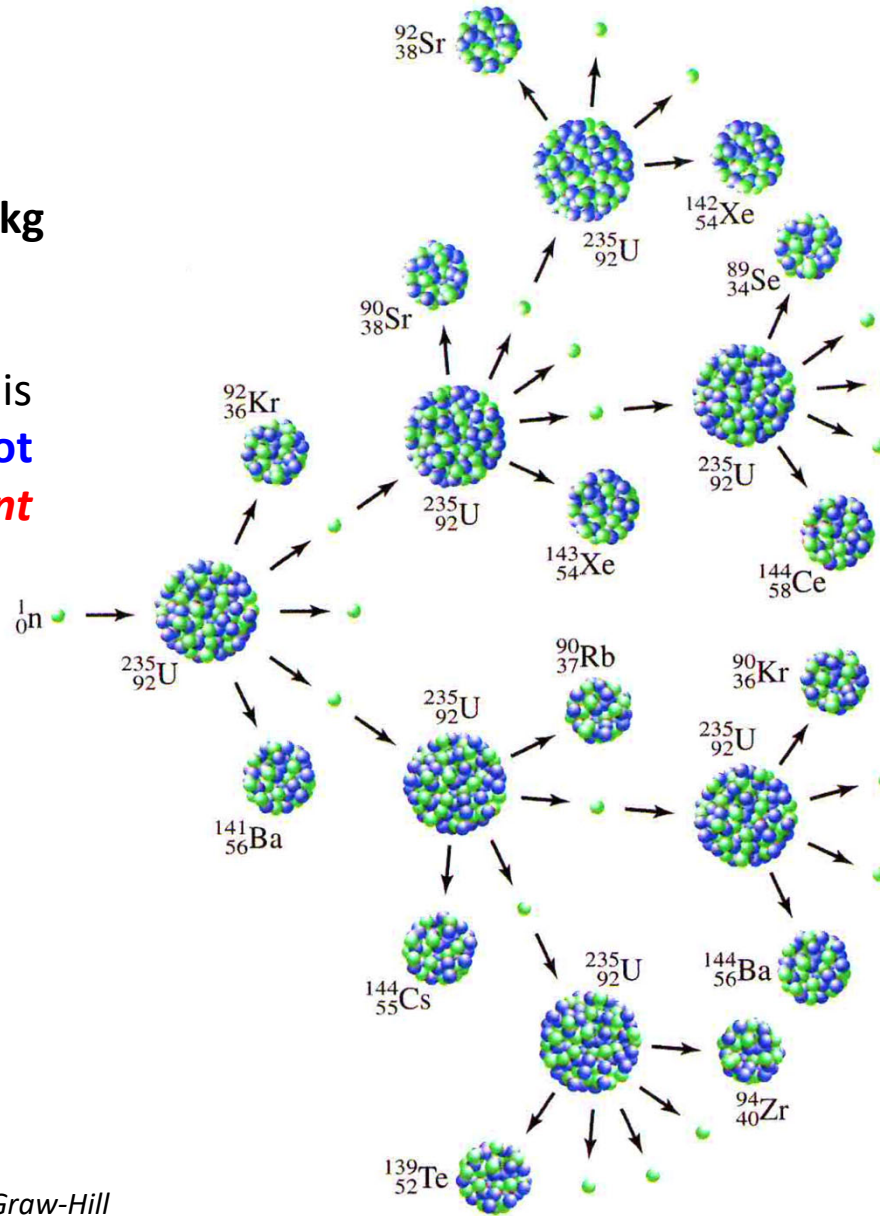
Mass lost = 0.184 amu or 0.078% of U235 mass is **converted to energy**

1kg of U235 = 9.0×10^{10} kJ equivalent to 33,000 tons of TNT

Chain reaction

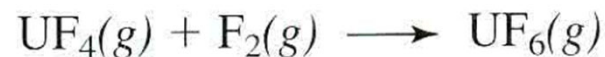
^{235}U critical mass is ca. 4 kg

Most U is ^{238}U which is radioactive but not fissionable so enrichment is required



Enrichment in ^{235}U required for:

- Reactors: 3-5%
- Bombs: 90%



- Membrane diffusion
- Centrifugation

Plutonium production and breeder reactors



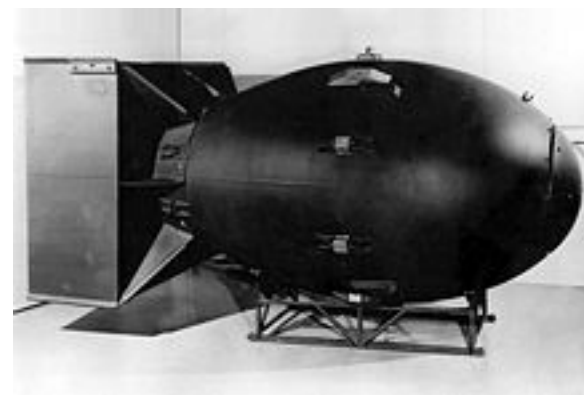
^{239}Pu is fissile:

Core of ^{239}Pu surrounded by ^{238}U gives *in situ creation (breeding)* of ^{239}Pu from non-fissile ^{238}U

Concerns about breeder reactors:

- plutonium is low melting so cooling is critical (core meltdown is a major risk)
- ^{239}Pu has a long half life (25,000y) and is v. toxic
- reactor grade ^{239}Pu easily used in bombs

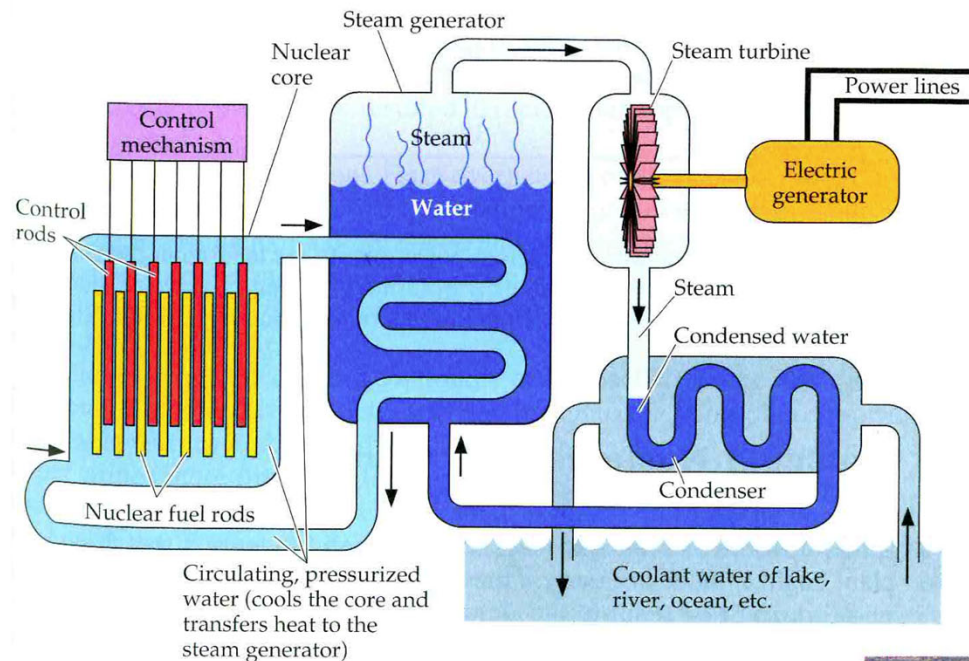
*from Chemistry in Context 6th Edition, ACS, McGraw-Hill and
Chemistry for Changing Times, 9th Ed., Prentice-Hall*



'Fat Man' ^{239}Pu bomb dropped on Nagasaki, Japan

Nuclear Reactors

Pressurized water reactor

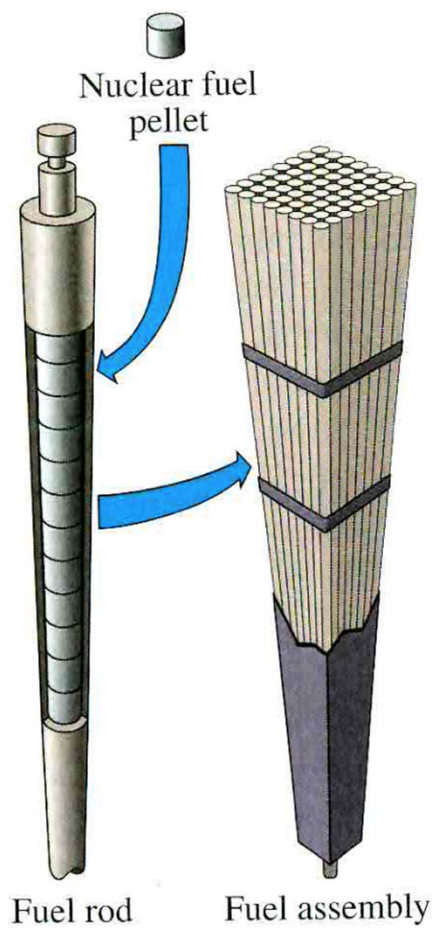
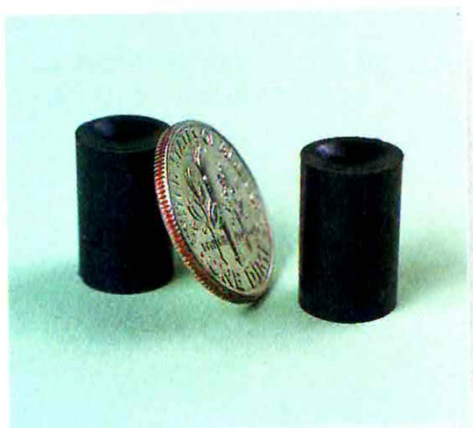


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Chemistry in Context 6th Edition, ACS, McGraw-Hill

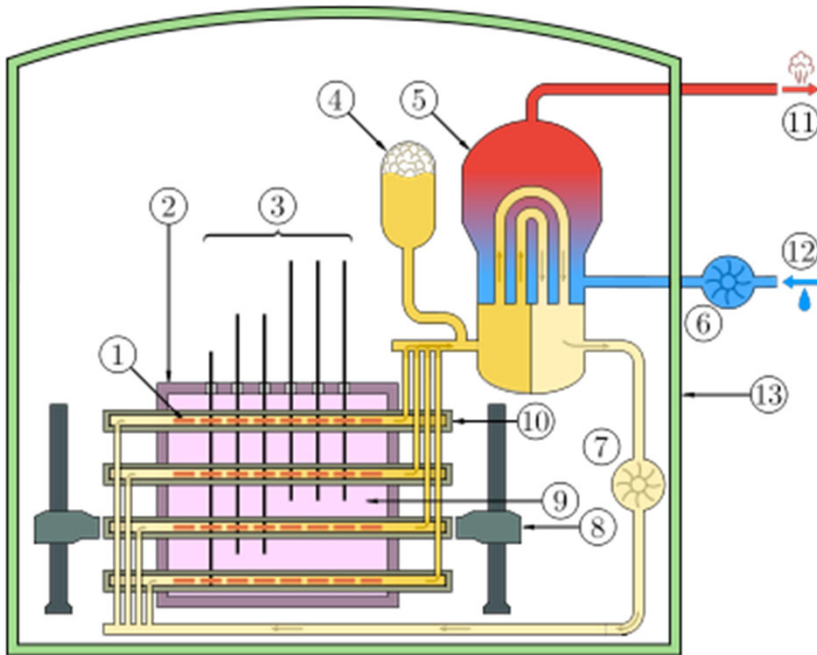
Fuel pellets and rods



Chemistry in Context 6th Edition, ACS, McGraw-Hill

CANDU Reactor

D₂O as moderator: low neutron capture cross section allows use of natural uranium fuel



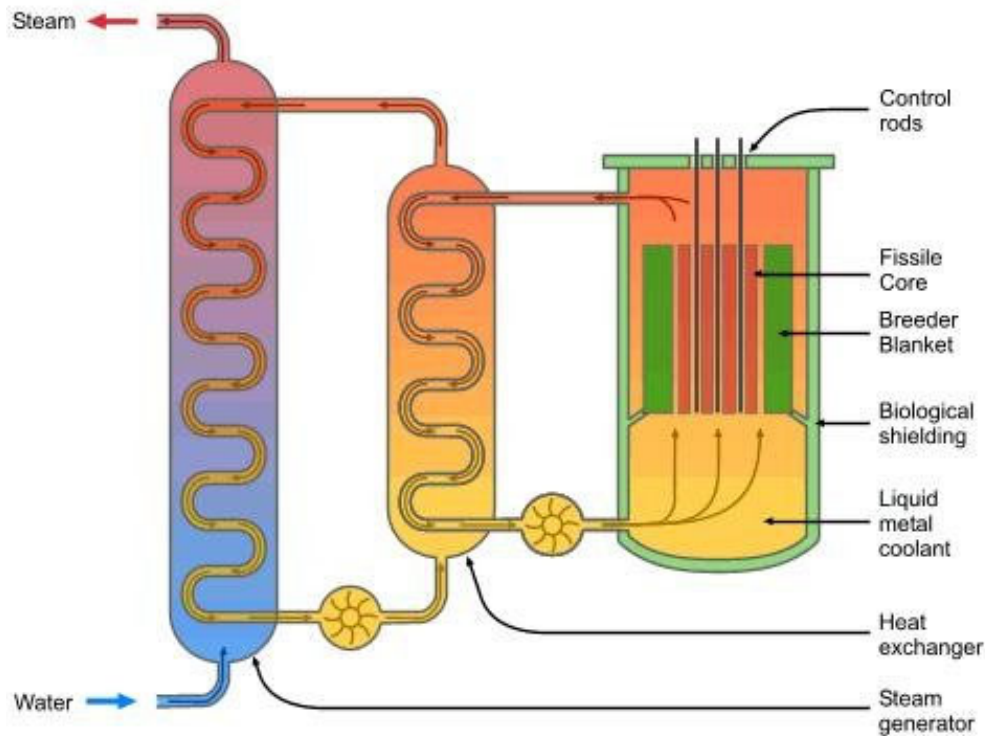
wikipedia

Pickering – 8 units of 540 MW each



<http://www.nucleartourist.com/world/canada.htm>

Breeder Reactors: generate their own fuel (sort of...)



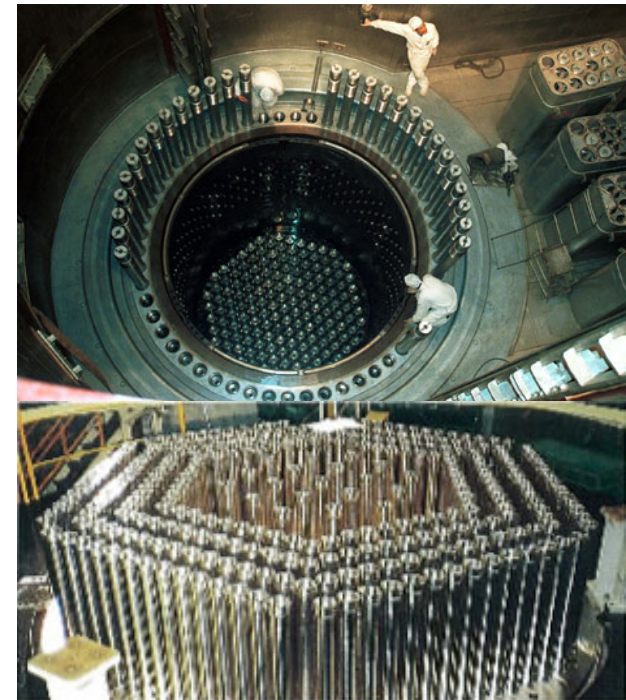
From: universe-review.ca

Monju: liquid Na cooled breeder reactor:
decommissioned after liquid Na leak and fire
 Cost: ca. \$11B (US)

Why Na?

- Not pressurized
- Good thermal conductor
- Does not absorb neutrons well

From: Mitsubishi Heavy Industries



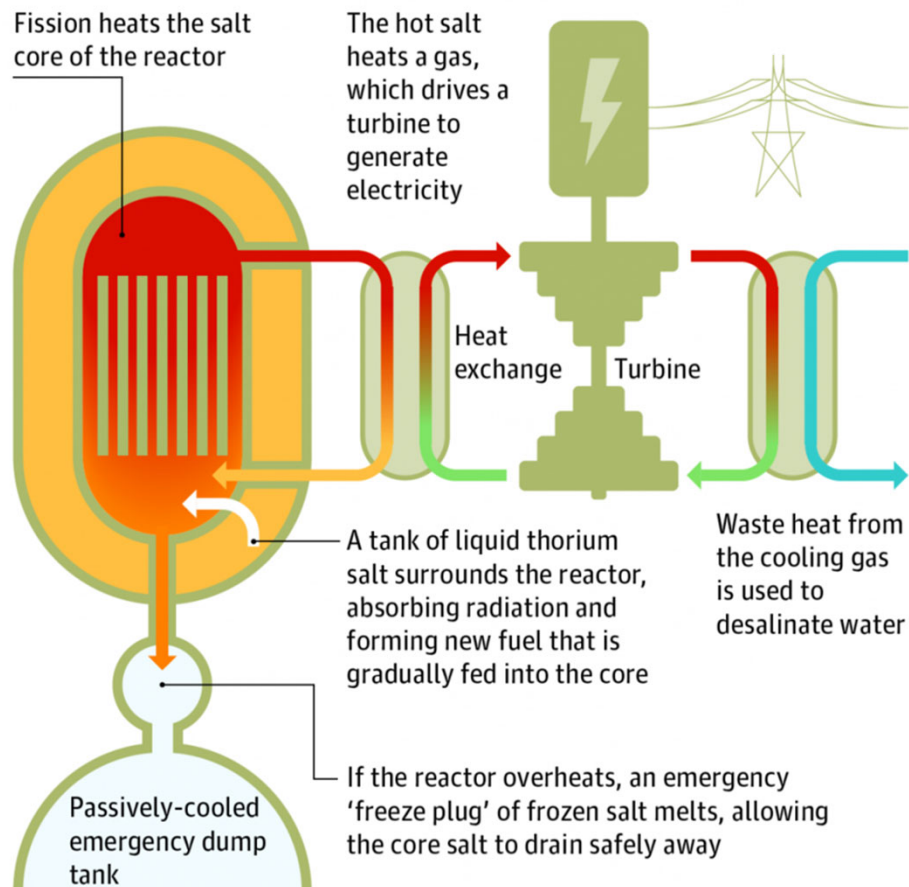
Core internals of Monju
 – Core support plate and connecting pipes –



Monju

LFTRs: Future of Nuclear Reactors?

Liquid-fluoride thorium reactor



Uses less expensive Th fuel, not weaponizable, not pressurized

First new LFTR in 40 years started operation in 2017 (Netherlands)

Risks of nuclear energy

Risk is of **explosions (non-nuclear)** and **escape of radioactive materials**

Three Mile Island – Harrisburg, PA, Mar '79
partial meltdown, stuck control valve

From: www.atomicarchive.com



Chernobyl – Ukraine, Apr '86
total meltdown, power surge, steam explosion
31 direct fatalities, long term effects on
hundreds of thousands

For some other remarkable photos like this see Timm Seuss' article in businessinsider:
<http://www.businessinsider.com/chernobyl-disaster-photos-timm-suess-2012-4?op=1>



Fukushima – Japan, Mar '11
partial meltdown of multiple reactors,
power failure caused by tsunami,
Hydrogen and pressure explosions released
gases

from: <http://www.sciencemediacentre.co.nz>



Sources:

Eubanks, L.P., Middlecamp, C.H. Hetzel, C.E. and Keller, S.W. "Chemistry in Context: Applying Chemistry to Society" 6th edition (2009), A Project of the American Chemical Society, McGraw Hill Higher Education

Snyder, C.H. "The Extraordinary Chemistry of Ordinary Things" (2003), Wiley.

For examples of the process used in the tar sands see: www.syncrude.ca web site

The Economist: see the January 20, 2011 article, 'Muck and Brass' at:
<http://www.economist.com/node/17959688>

Waldron, K. "The Chemistry of Everything" (2009), Prentice-Hall.

Hill, J.W., Kolb, D.K. "Chemistry for Changing Times", 9th Ed. (2001), Prentice-Hall.