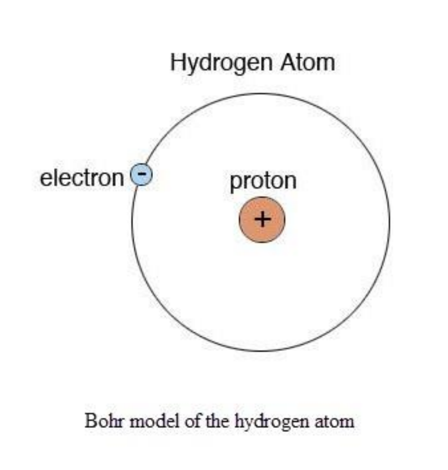
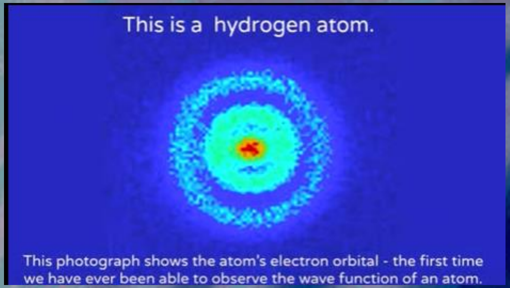
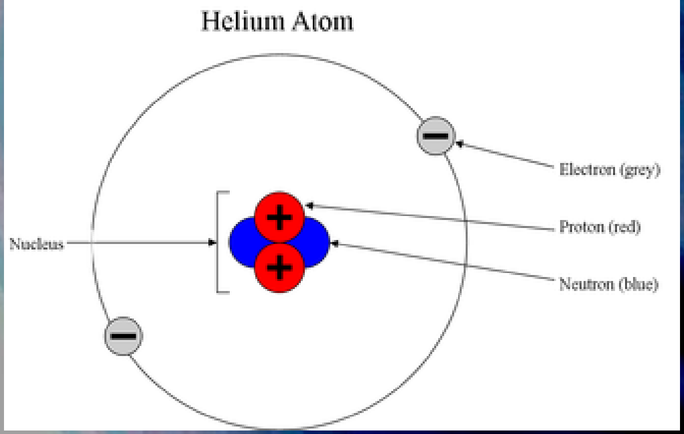
Background: The ATOM



Bohr model of the hydrogen atom





The ATOM:

1. Smallest unit of all matter
2. Basic building block for everything around us
3. Atom size about 1/100,000th the width of a hair

ATOMS consist of:

1. Protons (+) and Neutrons (0) in NUCLEUS
2. Electrons (-) orbiting the nucleus

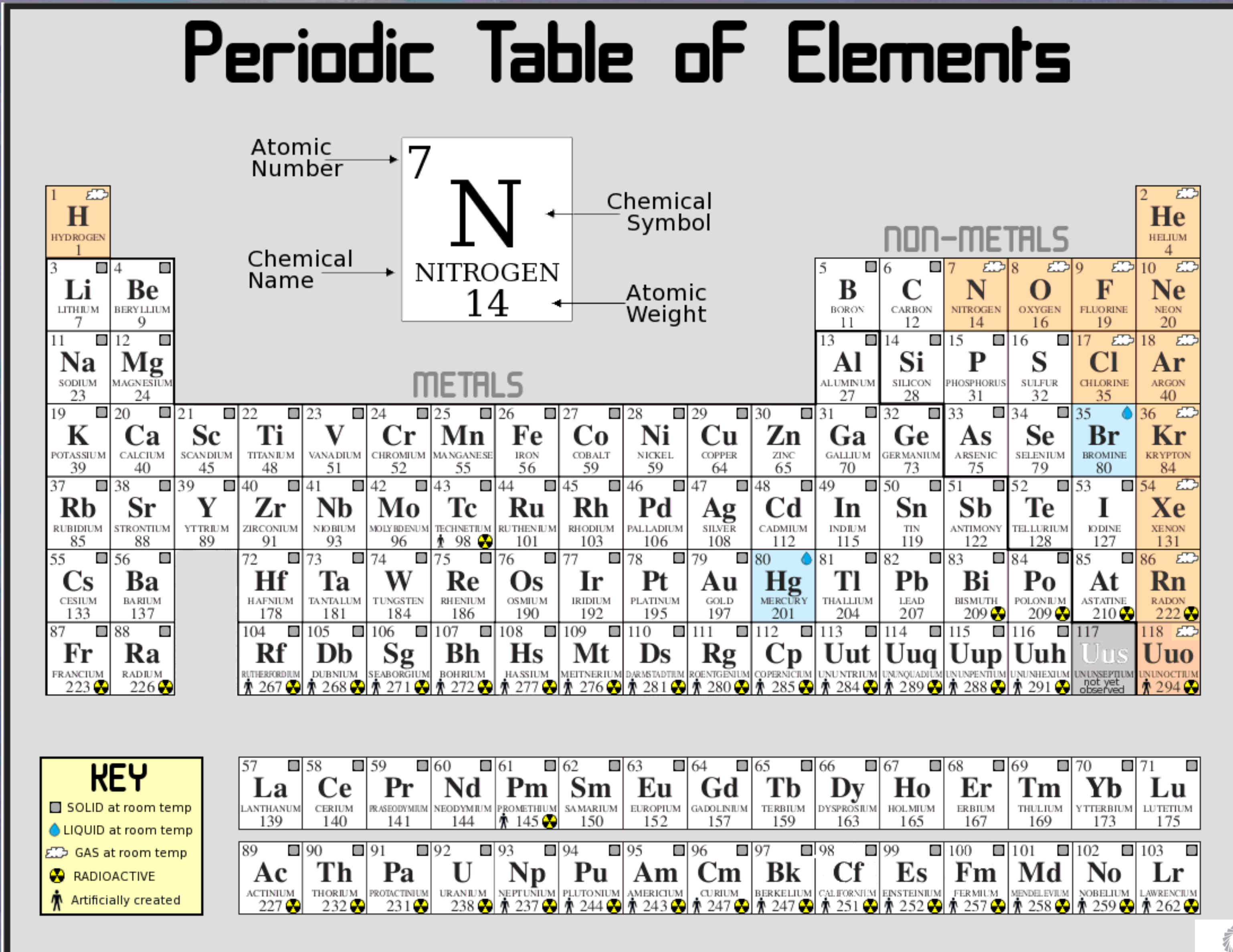
WHAT HOLDS the ATOM TOGETHER?

1. 4 FORCES
   1. Gravitational (all subatomic particles)
   2. ELECTROMAGNETIC – Electrons & Protons
   3. STRONG FORCE – Nucleus Protons & Neutrons
   4. WEAK FORCE – within the proton and the neutron

= each FORCE is associated with ENERGY

Background: Elements

- Element = atoms all contain the same number of protons



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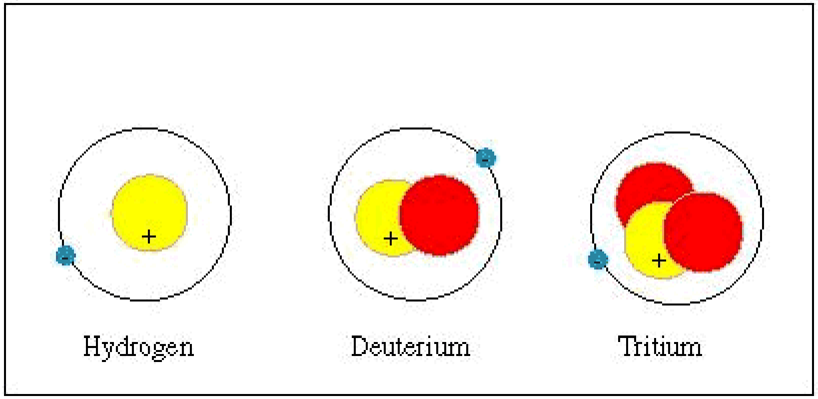
Background: Isotopes

- **Isotopes** = variations of a chemical element
  - Isotopes of an element have the same number of protons in each atom but different numbers of neutrons.



Bohr model of the hydrogen isotope atoms

Isotope	a.k.a	Atomic Weight	=	# Protons	+	# Neutrons
H (Protium)	^{1}H	1	=	1	+	0
H-2 (Deuterium)	^{2}H	2	=	1	+	1
H-3 (Tritium)	^{3}H	3	=	1	+	2

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Background: Isotopes

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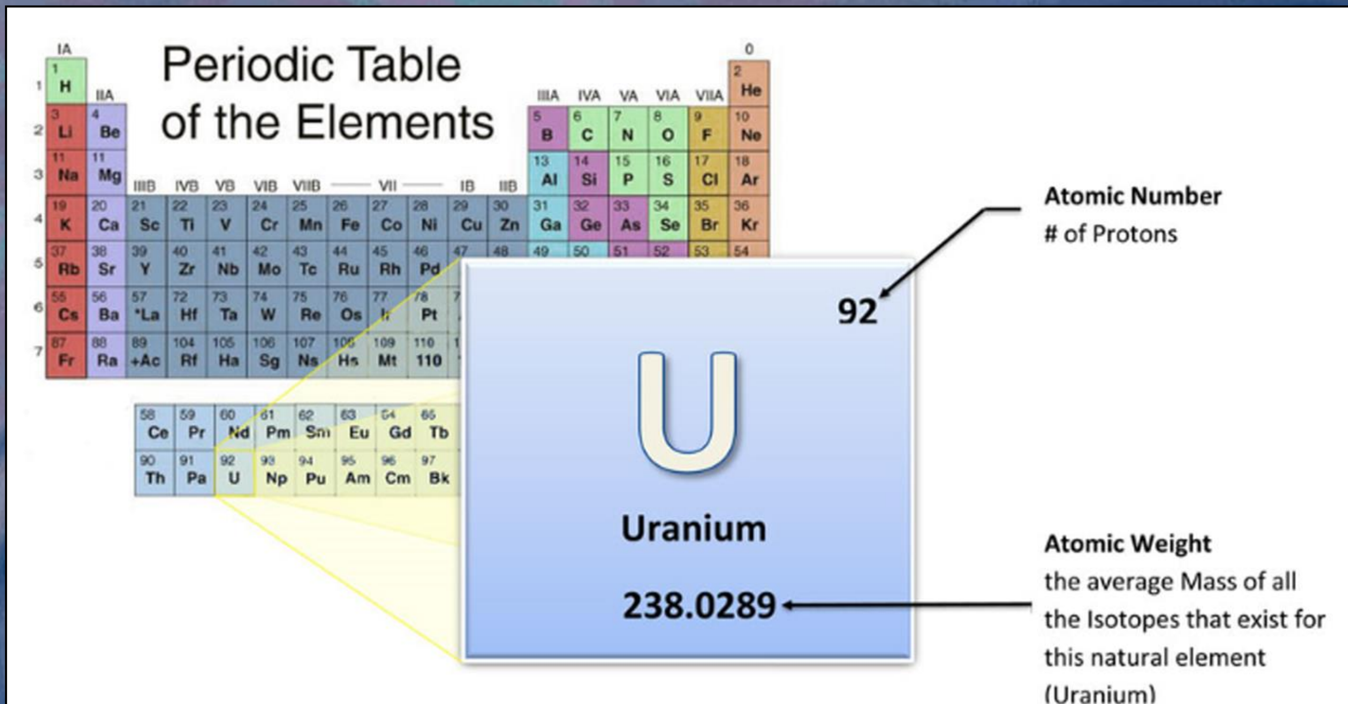

Isotope	a.k.a	Atomic Weight	=	# Protons	+	#Neutron s
U-238	^{238}U	238	=	92	+	146
U-235	^{235}U	235	=	92	+	143
U-234	^{234}U	234	=	92	+	142

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Background: Radiation

- **Radiation** = ENERGY that is emitted or transmitted in the form of rays, electromagnetic waves, and/or particles.
- Radiation can be either non-ionizing (low energy) or IONIZING (high energy)

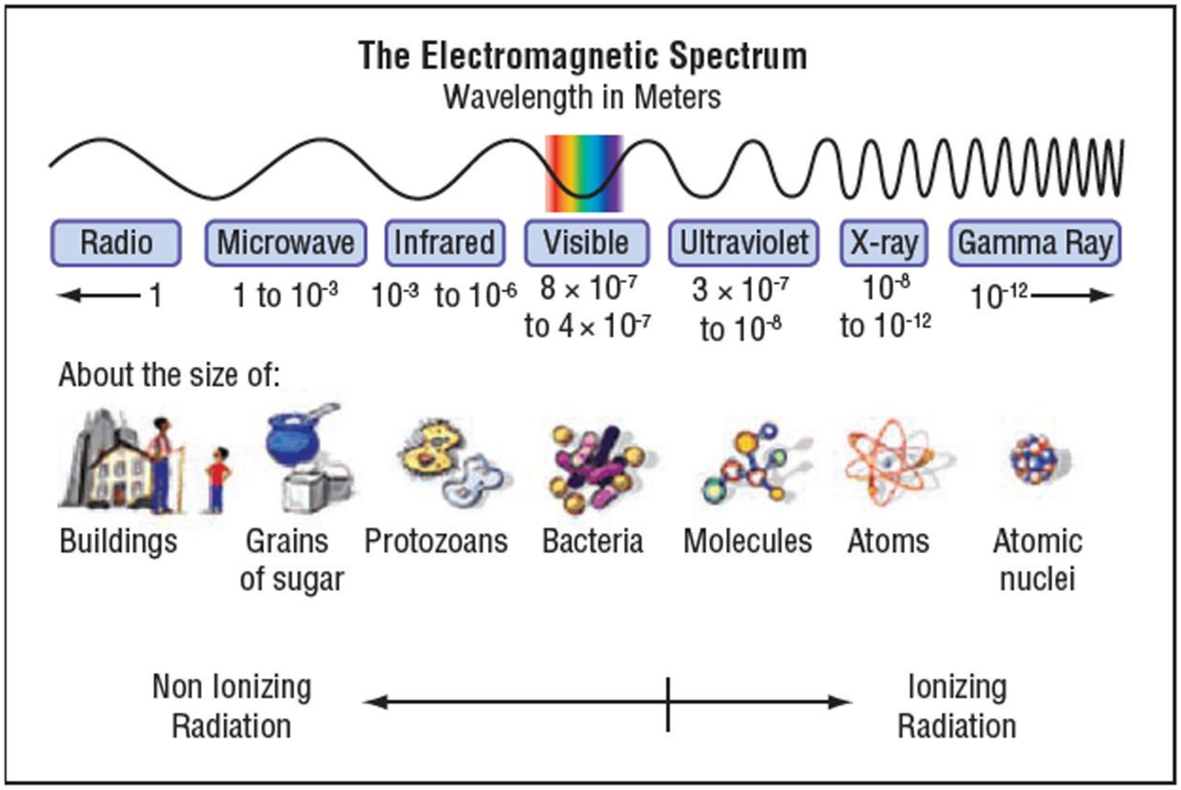


Image Credit: NASA.

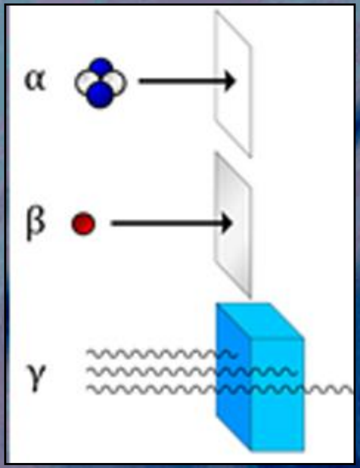
http://www.nasa.gov/pdf/284273main_Radiation_HS_Mod1.pdf

Background: Radioactive Materials

- An atom is STABLE if the forces among the particles in the nucleus are balanced.
- An atom is UNSTABLE if the forces among the particles in the nucleus are unbalanced.
- When an atom is UNSTABLE, it will lose particles or energy to become STABLE.

- <u>**Radioactive decay, radioactivity**</u> - process by which the nucleus of an unstable atom loses ENERGY by emitting particles of IONIZING RADIATION.

- **IONIZING RADIATION** includes alpha particles, beta particles, and gamma rays



Paper stops an alpha particle (a Helium nucleus of 2p + 2n)

Aluminum sheet stops a beta particle (an electron)

Lead & Dense Materials stop gamma rays (a photon)

A Material that contains unstable atoms which undergo radioactive decay is **Radioactive Material**

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Background: Isotopes & Half-Life

- The **CHEMICAL PROPERTIES** of an elements ISOTOPES are similar and do not differ significantly. *
- The **NUCLEAR PROPERTIES** of an elements ISOTOPES do differ significantly.
- STABLE ISOTOPES do not undergo radioactive decay
- UNSTABLE ISOTOPES undergo radioactive decay - are "radioactive"
  - Referred to as "radionuclides"

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Background: Isotopes & Half-Life

- STABLE ISOTOPES do not undergo radioactive decay
- UNSTABLE ISOTOPES undergo radioactive decay - are "radioactive"
  - Referred to as "radionuclides"
- Each UNSTABLE ISOTOPE has:
  - A unique HALF-LIFE
    - The HALF-LIFE ($t_{1/2}$) of an isotope refers to the amount of time required for one-half of the atoms to undergo radioactive decay.
  - A unique DECAY CHAIN
    - = a series of ISOTOPES (daughter products) that are created as radioactive decay progresses.
  - A unique set of ENERGY emissions
    - Observed or measured as keV - meV emission spectra.
    - Alpha, Beta, Gamma, etc.
  - Measurement of emission spectra used to identify specific ISOTOPES in lab and field

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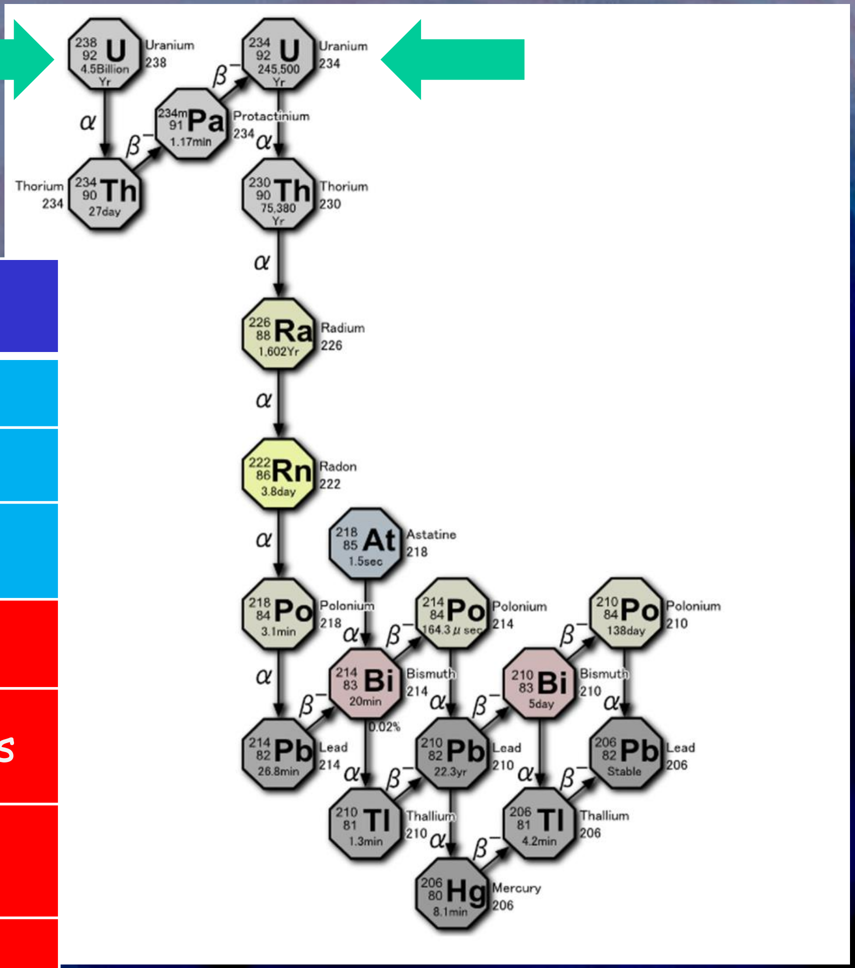
Background: Isotopes & Half-Life

- Complete U-238 DECAY CHAIN



Isotope	Half-Life
Iodine-131 (^{131}I)	8.0197 days
Tritium (^{3}H)	12.32 years
Technetium-99m*	6.6 hours
Technetium-99	211,000 years
U-238	4.468 billion years
U-235	703 million years
U-234	246,000 years

- Half-lives of Natural, Medical, Man-made Radionuclides

Red Shading indicates PGDP Radionuclides

* "m" for metastable – a very short half life (used for medical diagnostics)

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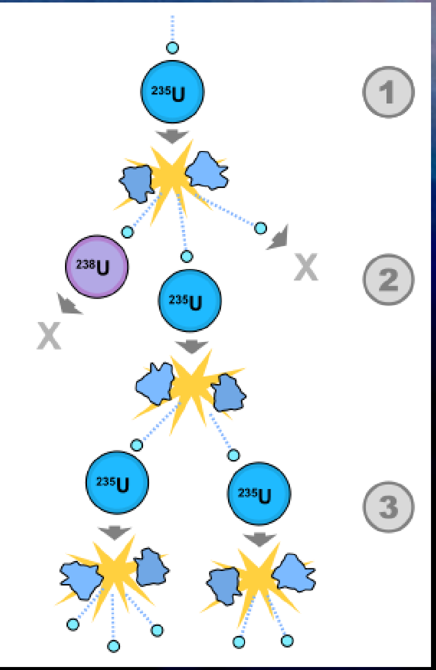
Background: Fission for Energy

- **FISSION** is a self-sustaining nuclear reaction caused by radioactive decay or induced, for example, by bombardment with neutrons
  - Results in the nucleus of a particle splitting into smaller parts (lighter nuclei) which are ejected along with ENERGY
  - Releases very large amounts of ENERGY
- **Nuclear power reactors harness the energy and heat** from nuclear **FISSION** to produce the steam that runs turbines which, in turn, generate electricity
- The amount of available ENERGY contained in nuclear fuel is millions of times the amount of available ENERGY contained in a similar mass of chemical fuel such as petroleum or natural gas.
- One kilogram of enriched uranium-235 has the capacity to produce as much energy as 1,500,000 kilograms (1,500 tons) of coal



Background: Uranium Enrichment

- Naturally Occurring Uranium has 3 isotopes with similar chemical but different nuclear properties
  - **U-238** The most plentiful/abundant; over 99% of natural U
  - **U-235** The only **FISSILE** naturally occurring U isotope; approximately 0.72% of natural U
  - **U-234** Less plentiful U isotope; approximately 0.0055% of natural U
- **FISSION** is a self-sustaining nuclear reaction caused by radioactive decay or induced, for example, by bombardment with neutrons
  - Results in the nucleus of a particle splitting into smaller parts (lighter nuclei) which are ejected along with ENERGY
  - Releases very large amounts of ENERGY
- **FISSILE** material can sustain a nuclear reaction which results in a release of ENERGY as HEAT
- The HEAT from **FISSION** is used to drive turbines and generate electricity
- PGDP MUST INCREASE (ENRICH) THE NATURAL ABUNDANCE OF FISSILE U-235 FOR USE AS A FUEL SOURCE (from 0.7% to 5%)

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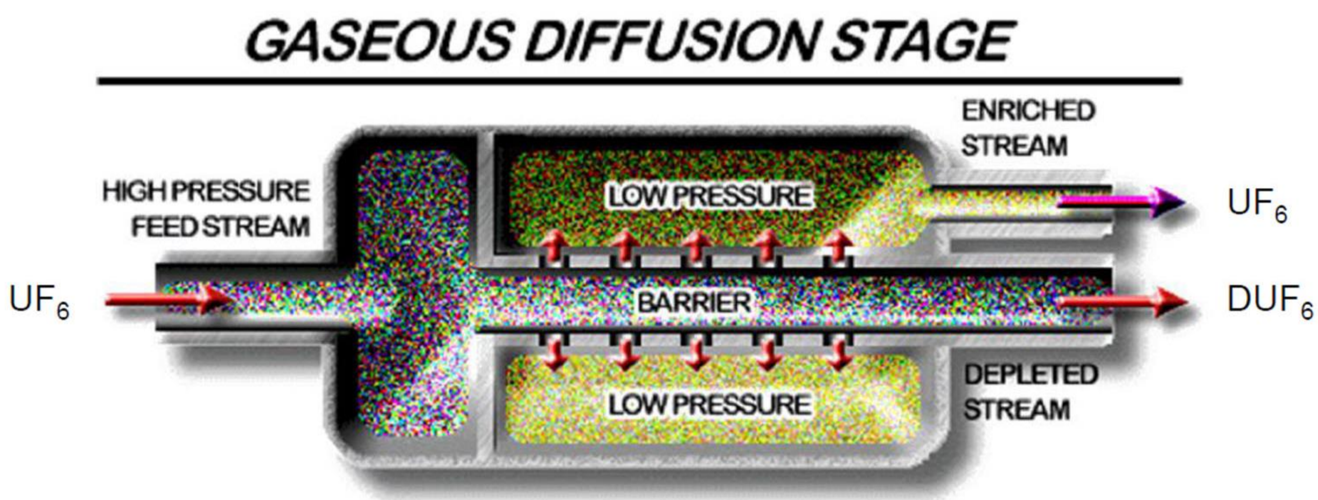
Background: Uranium Enrichment

- The GASEOUS DIFFUSION PROCESS was used at PGDP to increase the abundance of U-235 in URANIUM.
- URANIUM is blended with FLUORINE GAS at high temperature and pressure to produce URANIUM HEXAFLUORIDE GAS (UF6)
- U-235 separated from U-238 by DIFFUSION thru membranes (a STAGE)
- A volume of UF6 gas is passed thru > 1,800 STAGES before enrichment is complete



This process of uranium enrichment increases the concentration of U-235 from 0.7% up to 5.0%

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This process of uranium enrichment increases
the concentration of U-235 from 0.7% up to 5.0%

Enrichment

The 8th Stage Convertor (of 1,760) from PGDP's diffusion process

Citations

http://www.ukrcee.org/Outreach/Education/gaseous_diffusion.aspx

http://en.wikipedia.org/wiki/Half-life

http://en.wikipedia.org/wiki/Radioactive_decay

http://www.nasa.gov/pdf/284273main_Radiation_HS_Mod1.pdf

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