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Reply all |

Hello. I think I've attached most of the information you requested. I'll be away at a conference for the next several days so in case you require further information I've included some links that might be helpful. Have a nice day.

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Nuclear Fission and Mass-Energy Equivalence

Fission is the process by which a large nucleus exothermically splits into two fragments of approximately equal size and neutrons upon being bombarded with an initial neutron. A typical fission reaction is:

$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\ {}^{1}_{0}n $$

The energy released is far greater than the energy released by exothermic chemical reactions. Chemical reactions involve the arrangement of electrons and the electrostatic force. Nuclear reactions involve the nuclei of atoms, the strong and weak nuclear force.

The binding energy of a nucleus is the energy change for the reaction in which that nucleus is broken into its constituent protons and neutrons. Einstein's theory of special relativity states that mass is a form of energy. Mass and energy are related by the following relationship where *c* is the speed of light in m/s and energy is measured in joules (J):

$$ \Delta E = c^2 \Delta m $$

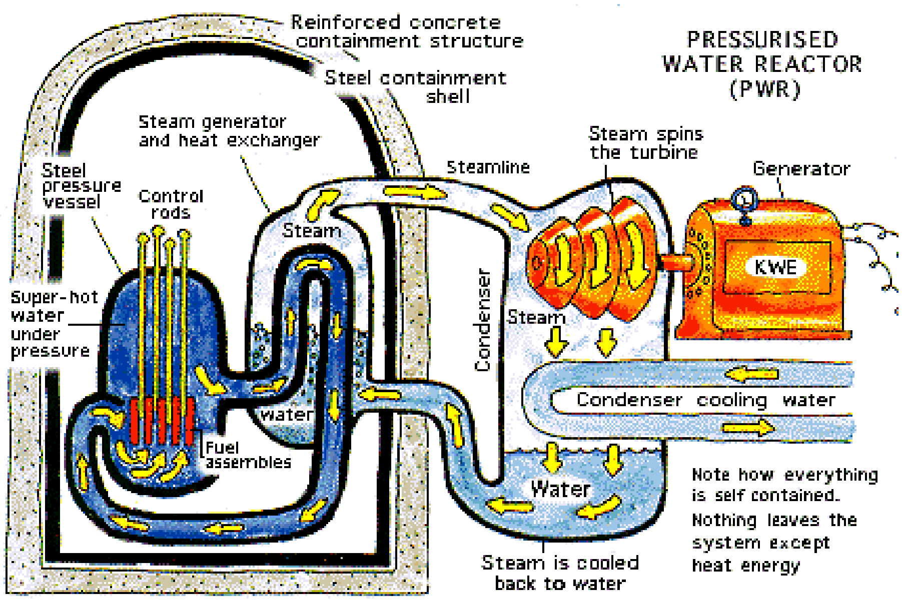
In nuclear reactions the mass difference between products and reactants results in the large amounts of energy released. A convenient means of expressing this energy is the million electron volts or MeV. The electron volt is the energy given to an electron when it is accelerated through a potential difference of one volt.

$$ 1\ eV = 1.602x10^{-19}\ J $$

By Einstein's mass-energy equivalence, the energy equivalent of one atomic mass unit is 931.494 MeV. The enthalpy change for a nuclear reaction can be calculated by finding the mass defect of the products and converting from atomic mass units into joules. In equations of nuclear reactions, the mass and charge numbers on each side must balance but elements need not be conserved.

Nuclear Reactors

Nuclear reactors use the exothermic nature of fission reactions to produce electricity. There are three main designs in North America, the Pressurized-water nuclear power reactor (PWR), the boiling-water nuclear power reactor (BWR), and the CANada Deuterium Uranium nuclear power reactor (CANDU). The BWR and PWR are very similar in design while the CANDU reactor differs significantly from the two. Each model has certain advantages and disadvantages, but all operate on the same basic idea. The heat released by the nuclear fission is used to produce steam which drives a turbine. In turn, this turbine operates a generator which produces electricity.



(Image courtesy of Uranium Information Center)

A key difference between a PWR/BWR reactor and a CANDU reactor is the fuel used. A PWR or BWR reactor requires enriched uranium. Enriched uranium is uranium in which the concentration of the isotope U-235 is elevated above natural levels. CANDU reactors do not require enriched uranium as fuel. This difference is a result of the moderators used in the design.

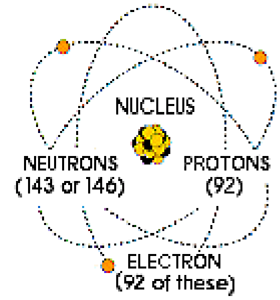
Moderators are substances which slow down neutrons. The fission yield is dependent on the speed of the incident neutrons. Effective moderators include water and heavy water. Control rods absorb neutrons, are used to control the rate of fission in the reactor and are made of cadmium.

For more information on Nuclear reactors, the following resources may prove useful:

- The Nuclear Tourist
- University of Wisconsin Nuclear Reactor Tour
- Canadian Nuclear FAQ

Uranium Enrichment

Natural Uranium consists of 99.3% uranium-238, and 0.7% uranium-235. Uranium-235 undergoes fission upon absorbing both fast and slow neutrons while uranium-238 only undergoes fission after absorbing fast neutrons. PWR and BWR nuclear reactors require uranium fuel which has been enriched so that the concentration of U^{235} is approximately 3%.



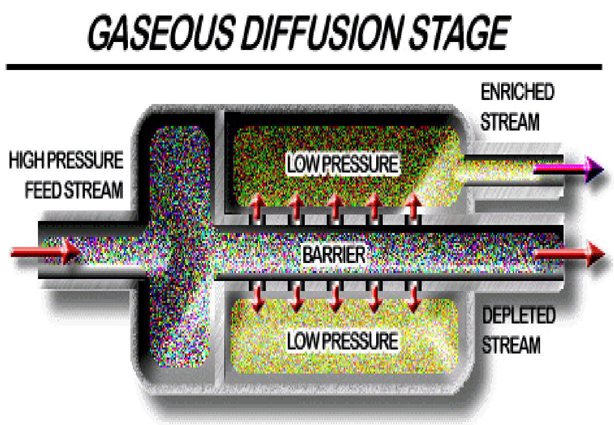
Uranium ores, in which uranium is frequently in the form of Uranite (U_3O_8) are first mined. The uranium ore undergoes a complex series of chemical reactions in addition to physical processing. After this, uranium trioxide is converted to uranium hexaflouride gas by the following sequence of reactions:

$$UO_{3(s)} + H_{2(g)} \rightarrow UO_{2(s)} + H_2O_{(g)}$$

$$UO_{2(s)} + 4\ HF_{(g)} \rightarrow UF_{4(s)} + 2\ H_2O_{(g)}$$

$$UF_{4(s)} + F_{2(g)} \rightarrow UF_{6(g)}$$

Uranium hexaflouride undergoes a gaseous diffusion process which uses Graham's law to increase the concentration of ^{235}U in a sample of the gas. Gaseous diffusion is a long and expensive process. It accounts for approximately one third of the total cost of reactor fuel.



Useful Links:

- [Kennesaw State Unviersty: Chem Cases - Uranium Production]
- [United States Nuclear Regulatory Commission – Uranium Enrichment]

(Uranium atom image courtesy of Uranium Information Center)
(Diffusion image courtesy of USEC)