Lecture 7 Feb 10, 2012.
Environmental science FFY471, Env physics FYP350

Elements from lecture 2 on
Nuclear energy

On the first lecture on Nuclear energy we introduced some basic aspects of nuclear energy and emphasized the nuclear fuel cycle as the backbone for further discussions.
When it concerns environmental science and environmental physics there are three points in the nuclear fuel cycle of special importance
- the resources
- the reactor operation (and safety)
- the waste disposal

What we want to find out, or analyse, in the associated Problem package 4, is the ability to use the resources more efficiently, to operate the reactors more safe and to manage the nuclear waste with less problems.

Nuclear reactors

The present commercial reactors in the world can be divided into light water reactors and heavy water reactors. Water is then the cooling medium and the moderator.
Another more differentiated division of present day nuclear reactors is into

Pressurised Water Reactor (PWR)
Boiling Water Reactor (BWR)
Pressurised Heavy Water Reactor
Gas-cooled Reactor (AGR & Magnox)
Light Water Graphite Reactor
Fast Neutron Reactor (FBR)

The light water reactors use uranium enriched to about 3-4 % of U-235 as fuel. The enrichment is necessary in order to maintain the chain reaction. It is possible to run a reactor on natural uranium, but the one has to have heavy water as cooling and moderator material. The decisive difference between heavy water and light water is that heavy water has a much lower absorption of neutrons. When there are more neutrons in the reactor one does not need so many uranium-235 fuel atoms. (This is a different explanation compared to the one on the lecture.)

The existing reactors belong to what is called generation I- III. About ten years ago, around 2002-2003, several countries in the world established a forum for working with generation IV reactors. There are some main types of gen IV reactors

Very-high-temperature reactor (VHTR)
Supercritical-water-cooled reactor (SCWR)
Molten-salt reactor (MSR)
Gas-cooled fast reactor (GFR)
Sodium-cooled fast reactor (SFR)
Lead-cooled fast reactor (LFR)

Some major aims with the development of these reactors are to
- improve the use of the fuel for nuclear reactors
- to make the reactors more safe under normal operation and to prevent meltdown in case of emergency
- to reduce the amount of produced high level waste

Most generation IV reactors are in an early state of development and no commercial reactor of this type is expected before 2020-2025.

There are several different possibilities to increase the efficiency of the reactor. The most effective, and maybe the most complicated one, is to breed the fuel. Fast neutrons then convert fertile isotopes like U-238 and Th-232 to fissile isotopes Pu-239 and U-233.
Pu-239 or U-233 then produce energy when split into fission products and the production of Pu-239 and U-233 can be larger than the consumption of U-235.

Radioactive waste

One divides the waste according to their different level of activity.

The real problem is the high-level waste containing of
-fission products (Cs-137, Sr-90 and a lot of other isotopes)
-transuranium elements (Pu-239 and several others)

Theses elements must be in safe storage for a very long time, some of the elements up the order of 100 000 years.

The waste can be stored without any measures taken with the fuel elements (the waste) or they can be reprocessed. When reprocessed it is possible to extract the majority of the transuranium elements and use them again in a reactor or convert them to less harmful elements.

The reprocessing is a somewhat delicate business and few countries have entered that business.

Accelerator driven systems (ADS)

This is a completely different type of reactor and is based upon external production of a high energy proton beam. The beam enters the wall of reactor in which, there is a spallation target, giving rise to neutron production when hit by the proton beam.

Besides being used as a power producing reactor it can also be used for transmutation.
By transmutation one can transform long lived transuranium elements to less dangerous and more short lived transuranium elements (or other lighter elements).