# Nuclear Power Generation

1. Name a material that can be used for the fuel rods in a reactor.

Uranium(-235 or -238 in fast breeders) ( plutonium(-239)) (1)

1. Name a material that can be used for control rods in a reactor.

**Boron**/ **Silver-indium-cadmium** alloys/ **Hafnium/** [**Dysprosium titanate**](http://en.wikipedia.org/wiki/Dysprosium_titanate) (1)

Chemical elements with a sufficiently high capture cross section for neutrons include [silver](http://en.wikipedia.org/wiki/Silver), [indium](http://en.wikipedia.org/wiki/Indium) and [cadmium](http://en.wikipedia.org/wiki/Cadmium). Other elements that can be used include [boron](http://en.wikipedia.org/wiki/Boron), [cobalt](http://en.wikipedia.org/wiki/Cobalt), [hafnium](http://en.wikipedia.org/wiki/Hafnium), [dysprosium](http://en.wikipedia.org/wiki/Dysprosium), [gadolinium](http://en.wikipedia.org/wiki/Gadolinium), [samarium](http://en.wikipedia.org/wiki/Samarium), [erbium](http://en.wikipedia.org/wiki/Erbium), and [europium](http://en.wikipedia.org/wiki/Europium), or their alloys and compounds,

1. What is the purpose of the control rods?

They are used **regulate the rate of reaction by absorbing excess neutrons** so that

Only one of the extra neutrons produced goes on to fission another nucleus. (1)

1. Name a material that can be used as a coolant.

Water/sodium (1)

A [nuclear reactor coolant](http://en.wikipedia.org/wiki/Nuclear_reactor_coolant) — usually water but sometimes a gas or a liquid metal or [molten salt](http://en.wikipedia.org/wiki/Molten_salt)

1. What is meant by the critical mass of the fuel?

The minimum mass required for the chain reaction to be sustainable (1)

1. Here is the nuclear equation for a typical fission process:

What is required to balance the equation? 3 neutrons (1)

1. In what form will the bulk of the energy from fission be in?

Kinetic energy of the fission fragments/thermal energy (1)

1. How is this energy used in a power plant so that electricity can be generated?

It is used to heat water to produce steam. (1)

1. Why is the reactor made of thick steel?

This is to ensure it can withstand the high pressure and temperature developed. (1)

1. Which kind of radiation is most difficult to stop?

Gamma (1)

1. What kind of radiation is most likely to be emitted by a neutron rich isotope produced by fission?

Beta minus (1)

1. Why does gamma emission often occur after alpha or beta emission?

Because the nucleus **has excess energy/ is in an excited state after particle emission**. This excess energy is given out as the gamma emission. (1)

1. Why are the fuel rods likely to be more dangerous after use than before use?

**The fission products** are not alpha emitters like the original uranium and will therefore **emit the more penetrating beta and gamma.** (1)

1. Because the fission fragments have a relatively high fraction of neutrons, they are unstable, and decay with short half-lives. They form the ‘high-level’ radioactive waste that cannot be simply disposed of; it has to be stored somewhere for a minimum of 20 half lives.

By what factor will the activity fall after 20 half lives?

By ½20 /9.5 x 10-7/approximately a millionth (1)

1. If 137Cs has a half life of 30.23 years how long is 20 half lives? If the initial activity is 100,000 Bq, what will be the activity after 20 half lives?

20 half-lives is 30.23 x 20 = 604.6 years. (1)

½20 x 100,000 = 0.095… i.e. 0.1 Bq (1)

1. What is the difference between high level waste and low level waste?

High level waste is the waste that is directly radioactive i.e. unused fuel and the fission products. (1)

Low level waste is the waste that consists of items that are contaminated by the radioactive material such as clothing and the material the reactor itself is made of. (1)

1. Where does depleted uranium come from?

The enrichment process that is used to manufacture the fuel rods in which the U-235 has been removed to leave mostly U-238 (1)

1. How can high level waste be reduced?

By reprocessing - recovering the uranium and plutonium from the spent nuclear fuel and reusing in a mixed oxide fuel (1)

1. How do nuclear power plants prevent radiation escaping into the surroundings?

The core is inside a building with very thick concrete walls (1)

1. Where are spent fuel rods stored initially?

They are stored underwater in specially constructed shielded pools (1)