RADIOACTIVITY SUMMARY

Radioactivity

The atomic number of an atom is the number of protons in the nucleus.
The mass number of an atom is the total number of protons and neutrons in the nucleus.
The atoms of an element have the same number of protons in their nuclei but the number of neutrons can vary.
Atoms with the same number of protons but different numbers of neutrons are called isotopes.
An atom is radioactive if its nucleus has an unstable proton to neutron ratio.
An unstable proton to neutron ratio causes an elevated energy level in the nucleus.
When a nucleus undergoes radioactive decay it lowers its energy level by giving off radiation.
The radiation given off by atoms that are naturally radioactive can be either alpha particles, beta particles or gamma rays.
Alpha particles are helium nuclei - two protons and two neutrons.
When an alpha particle is released, a new nucleus is formed with two less protons and two less neutrons.
Beta particles are electrons formed when a neutron in the nucleus changes to a proton and an electron.
When a beta particle is released, a new nucleus is formed with one more protons and one less neutron.
Gamma rays are short bursts of very high frequency electromagnetic waves.
When a gamma ray is released, the same number of neutrons and protons are present but they have settled to a lower energy level.

Properties of Radiation

Alpha particles are stopped by air molecules in a few centimeters.
Beta particles are stopped by air molecules in a few meters.
Gamma rays can travel very long distances through the air.
Alpha particles are good ionizers - they can easily knock electrons from atoms during collisions.
Beta particles have medium ionizing ability.
Gamma rays are poor ionizers.

Mathematics of Radioactive Decay

Radioactive decay is a random event.
If a nucleus is very unstable there is a high probability it will decay soon and a sample of the substance undergoes a large number of radioactive decays each second.
If a nucleus is slightly unstable there is a low probability it will decay soon and a sample of the substance undergoes a small number of radioactive decays each second.
The time it takes for half of the radioactive nuclei to decay, is called the half life of the isotope.
The half life of an isotope is a constant.
Very unstable isotopes have half lives of fractions of seconds.
Slightly unstable isotopes have half lives of thousands of years or longer.

If a nucleus is slightly unstable it has a large decay constant. If very unstable a small decay constant.
The number of nuclei remaining in unstable form after time t is equal to the number when timing started times e to the power minus the decay constant times t.

Doses

Doses are measured by determining the number of joules of energy absorbed per kg of the body by radiation that has been absorbed.
If ionizing radiation transfers 1 Joule of energy to 1 kg of body tissue, the Absorbed Dose is 1 Gray.
Doses are usually around millionths of Grays.
The amount of damage to the body depends on the type of radiation.
The Absorbed Dose Equivalent equals the Absorbed Dose in Gray times the Quality Factor of the radiation absorbed. e.g. α particles x 20 β particles x 1
The unit of Absorbed Dose Equivalent is called the Sievert Sv.

1,000,000 μSv	Nausea, vomiting, not lethal but cancers likely in future years.
5,000,000 μSv	Serious illness and 50% chance of imminent death.
10,000,000 μSv	All people die.

Organs vary in the way they are affected by ionizing radiations. Each organ has a risk factor.
The Effective Absorbed Dose Equivalent an organ receives equals the Absorbed Dose Equivalent times the Risk Factor of the organ. e.g. bones x 0.03 lungs x 0.12

Nuclear Transformations

The mass number of a nucleus is the total number of protons and neutrons.
The atomic number of a nucleus is the number of protons.
For the radioactive nucleus $^{x}A_{y}$ x is the mass number and y is the atomic number.
A proton is $^{1}p_{1}$ a neutron is $^{1}n_{0}$ and an electron is $^{0}e_{-1}$.
The general equation for a transformation is Parent nucleus decays to Daughter nucleus plus emitted particle.
If several generations of daughter nuclei are radioactive, a decay chain is formed that finishes at a stable isotope of lead.
The mass number of the parent nucleus is equal to the mass number of the daughter nucleus plus the mass number of the emitted particle. (superscripts add up)
The atomic number of the parent nucleus is equal to the atomic number of the daughter nucleus plus the atomic number of the emitted particle. (subscripts add up)
The mass of the parent nucleus is greater than the mass of the daughter nucleus plus the mass of the emitted particle.
The energy released in the transformation equals the mass lost times the square of the speed of light.
1 electronVolt of energy is equal to the energy transfer when 1 electron moves through a Potential Difference of 1 Volt.
1 eV equals 1.6 times 10 to the minus 19 Joules.
Energy transfers during transformations are about 10 million eV.

Fission

If a nucleus with an even atomic number 92 or greater and an odd mass number absorbs a neutron, it can be split into two smaller nuclei with about 3 neutrons set free.
The total mass of the particles after fission is less than before fission so energy is released.
If the neutrons set free are absorbed by other nuclei, then a chain reaction can occur.
If the sample is less than the critical size, it has a small mass to surface area ratio and too many neutrons lost from the sample to sustain a chain reaction.
Detonation of a bomb is achieved by ramming together two pieces smaller than critical size.
In a nuclear reactor, for each fission only one of the free neutrons cause another fission. Control rods absorb the rest.

Nuclear Force

The nuclear force of attraction is the same for proton/proton, neutron/neutron and neutron/proton combinations.
The force acts over very short distances. A particle in the nucleus is only attracted to its immediate neighbours.
The nuclear force is about 100 times stronger than the repulsion between protons at the same distance apart, and holds the nucleus together.

Fusion

Fusion is the joining together of the isotopes of hydrogen called deuterium $^{2}H_{1}$ and tritium $^{3}H_{1}$.
A deuterium nucleus has one proton and one neutron. A tritium nucleus has one proton and two neutrons.
The fusion reaction is $^{2}H_{1}$ plus $^{3}H_{1}$ gives $^{4}He_{2}$ plus $^{1}n_{0}$.
More energy is released in this process than in the fission process because more mass is lost.
To get the deuterium and the tritium nuclei to stick together, the nuclei must come very close so the nuclear force overcomes the repulsion between the protons.
The nuclei must be moving very fast if they are to get close enough to stick together and this means the temperature has to be as high as in the sun.
In the fusion reactors being developed, the super high temperature gas is held away from the walls of the container by a very strong magnetic field.