Chapter Four: Atomic Structure

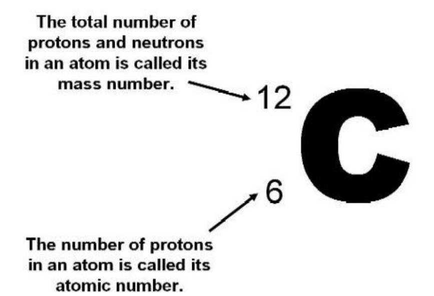
Atomic Structure

Particle	Where is it?	Charge	Mass
Neutron	Nucleus	0	1
Proton	Nucleus	+1	1
Electron	Electron shells	-1	0

-The number of protons in an atom will determine which element the atom is

-A differing number of electrons will determine whether or not the atom is an ion

-A differing number of neutrons will determine whether the element is an isotope or not



Mass number - atomic number = number of neutrons

-The atomic number can also be called the proton number as it is easier to remember this is the number of protons

-In an element, the number of protons will be the same as the number of electrons, so for example in carbon above, there is 6 protons and also 6 electrons

-Having the same number of protons and electrons will mean that there is the same number of negatives and positives, meaning there is no overall charge on the atom

Radioactive Decay

-An atom with an unstable nucleus is known as a radioisotope, this will emit particles in an attempt to become stable

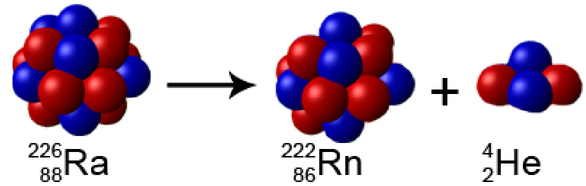
-Radioactive decay is a random process, it is not possible to predict when an atom will decay

-When representing nuclear decay equations, the total mass on each side must be equal

-Alpha decay consists of two protons and two neutrons being emitted (a helium nucleus)

-When an alpha particle is emitted:

- The atomic number decreases by two
- The mass number decreases by four
- A new element is formed



-Beta decay consists of one of the neutrons in the nucleus decaying into a proton and a neutron, then an electron is emitted

-In beta decay:

- The atomic number increases by one
- The mass number remains the same
- A new element is formed

-Gamma decay has no effect on the mass or the charge of the nucleus, gamma radiation is high energy electromagnetic waves

Types of radiation

	Alpha (α)	Beta (β)	Gamma (γ)
What is it?	Two protons, two neutrons (A helium nucleus)	An electron	An electromagnetic wave
What is it stopped by?	Paper	Aluminium	Lead / Concrete
Distance travelled in air?	5 centimètres	1 meter	Infinite
Deflected by a field?	Deflected by both types of fields, towards the negative side of an electric field	Deflected the most by both types of fields, towards the positive side of an electric field	No
Ionising	Yes	Weak	Yes
Uses	Smoke alarms	Radioactive tracers	Killing cancer cells

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Background Radiation

-Background radiation is ionising radiation that is around us all of the time, this is measured in sieverts (Sv)

-Natural sources include:

- Rocks
- Cosmic rays from space

-Human / artificial sources include:

- Waste products from hospitals
- Waste products from nuclear power
- Manufactured isotopes

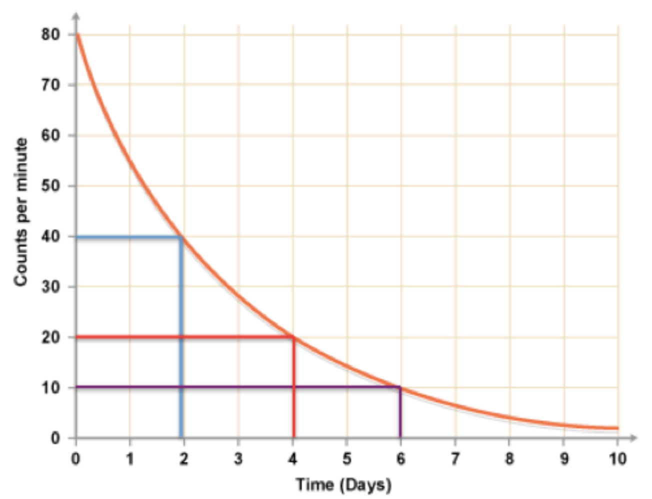
-The levels of background radiation vary from place to place depending on what is in the locality

Radioactive Half-Life

-Half life is the time that it takes for the amount of nuclei (or mass) in an isotope to half or the amount of emissions to fall by half

-It is a random process, but for every period of time that is the half life, half of the isotope will decay

-Graphs or logic can be used:



Half life = 4 days

Original = 80 cpm

1 half life(2 days) = 40 cpm

2 half lives (4 days) = 20 cpm

3 half lives (6 days) = 10 cpm

Hazards and Uses of Radiation

-Radioactive contamination is the unwanted presence of materials containing radioactive atoms

-The most unstable atoms have the shortest half-life, but they can give out a lot of radiation in that time

-Alpha particles have the most ionising power, but the least penetrating power, whereas gamma has the most penetrating power, but the weakest ionising power

-Medical tracers are radioisotopes that are put into the body either by injection or eating

-They can check the function of internal organs or for blockages in a patient's blood vessels

-The radiation needs to emit radiation to be detected externally but not with an ionising power to damage the patient's tissue, also it must have a short enough half life that it will not be exist long enough to damage the patient's cells

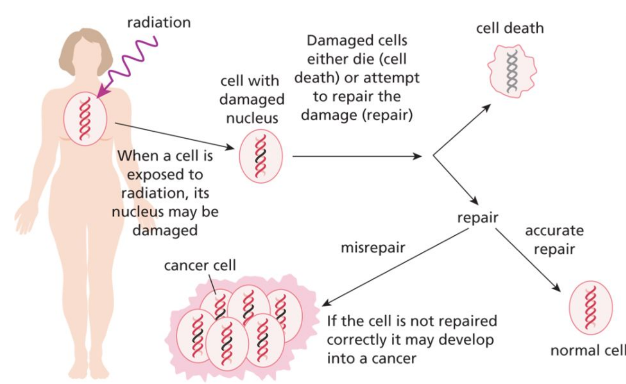
Irradiation

-Irradiation is the exposure of an object to nuclear radiation

-Irradiation can occur through background radiation, or artificially in situations such as sterilising food with gamma radiation

-Ionisation can occur within DNA, this can cause mutations in cells, such as uncontrollable division, which can lead to cancer

-A cell can be repaired if the damage is realised, but this can go wrong, and secure the mutation within the DNA, possibly making the mutation worse



Uses of Radiation in Medicine

-X-rays and gamma rays are both electromagnetic waves with similar wavelengths, but x-rays are produced by x-ray machines and gamma rays emitted by radioactive isotopes

-Radioisotopes in medicine must:

- -Emit gamma rays
- -Have a suitable half life
- -Not be toxic to humans

-Radiotherapy is a method of destroying cancer cells by exposure to high levels of radiation

-In this situation x-rays can be preferential because:

-They are only produced when needed

-Energy can be changed and controlled

-When this is being used, the targeted area is very small, and the x-rays are aimed from three directions to minimise damage to other healthy cells

-Brachytherapy involves planting a 'seed' of a radioactive isotope directly within a tumour to give the tumour a high dose of radiation

-This is preferential for cancers in the prostate gland, cervix and womb

Using Nuclear Radiation

-The use of nuclear radiation can only be justified if the benefits outweigh the risks

-Side effects of the use of nuclear radiation include:

-Vomiting

-Pain and redness of the skin

-Greater risk of infection

-Tiredness

-Benefits include:

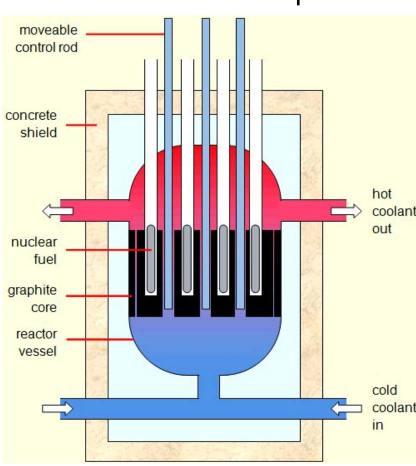
-Treatment of cancers

-Investigating the internal body without invasive treatments (uses of tracers)

Nuclear Fission

-Is the splitting of a nucleus upon a collision with a neutron to release energy from the nucleus, this releases three more neutrons, creating a chain reaction as these collide with three more atoms

-The most common isotopes used in the fission reactor are uranium-235 or plutonium-239



-The reactor has to be specially designed with a number of features:

-Control rods made of boron, these absorb excess neutrons, controlling the reaction, when the reaction needs to be slowed down, these rods are lowered into the reactants

-Water as a coolant, this is used to absorb the energy released in the fission reaction, meaning that this can be used as steam to turn the turbines, this also stops Uncontrollable heating

-**Steel and concrete surround**, this is to withstand the high temperatures given off, but also to stop the radiation from escaping the vessel

-**Graphite moderator** which slows down the fast moving neutrons which means that other collisions are more likely

Nuclear Fusion

-Is the coming together of two light nuclei to form a heavier nucleus and release energy, it is the type of reaction that occurs in the sun, lots of heat energy is needed for this to occur

$$^{1}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He$$

$$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2^{1}_{1}H$$

-At the moment fusion reactors are not used successfully on earth as it requires more energy to get the high temperature needed, than what it gives out through the nuclear fusion process, also the nuclei that are needed for fusion are hard to obtain

-In a fusion reactor, plasma would be heated by passing a large electric current across it, and this would be contained by a magnetic field, so it doesn't touch the side of the reactor and cool down

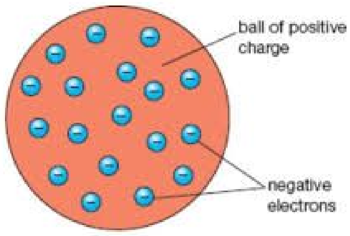
-Fusion releases more energy than fission, heavy hydrogen is readily available and the products of the reaction are harmless

Changing Ideas about the Atom

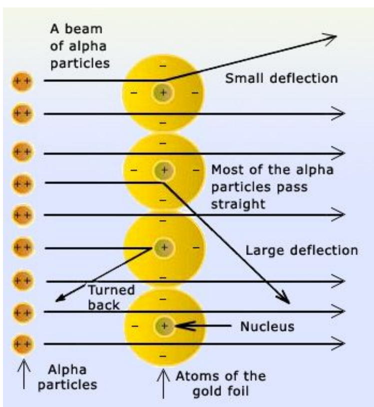
-400BC Democritus described materials as being made of small particles known as atoms

-1803 John Dalton described the atom as a billiard (snooker) ball, this meant that it was a solid ball of mass

-1897 JJ Thomson discovered the electron, he described this as a 'plum pudding' model, meaning that the majority of the atom was a positive mass, but with negatively charged electrons scattered randomly like currents in a pudding



-1909 Geiger, Marsden and Rutherford found that the atom had a nucleus, they used gold leaf and fired positive alpha particles at it, most passed straight through, a few were deflected and some were repelled straight back
-This experiment showed that the nucleus had a lot of space around it, and also that it was positively charged as it had repelled positive particles



-1913 Niel Bohrs stated that electrons orbited the nucleus in electron shells
-1932 James Chadwick discovered the neutron through mathematical analysis of atoms