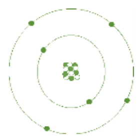
EDEXCEL TOPIC 6 RADIOACTIVITY.

Atom Structure



Small molecules (ie: Oxygen) typical size of 10^{-10}m.	
Diameter of an atom 1 X 10^{-10}m.	
Diameter of nucleus is 10,000 times smaller.	

Neutral charge	Equal numbers of protons and electrons.

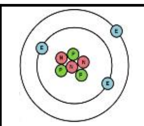
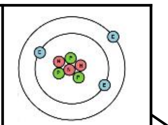
Atom		
Positively charged nucleus, surrounded by negatively charged electrons	Nuclear radius is much smaller than the atom.	Almost all of the atom's mass is in the nucleus.

Electrons	
Orbit the nucleus at set distances	Absorbing or emitting EM radiation causes change in orbit.

Electrons lost	Positive ion.

Atomic number = 3 protons Mass number = 6 (3 neutrons + 3 protons).

Atomic number = 3 protons Mass number = 7 (4 neutrons + 3 protons).

Isotope	^6_3Li		^7_3Li	

Different forms of an element with the same number of protons but different number of neutrons

Mass number	*Number of protons and neutrons*
Nucleon	*Smaller particles in the nucleus*
Atomic number	*Number of protons*
Ion	*Unequal number of electrons to protons*

Particle	*Relative Charge*	*Relative mass*	*Found*
Proton	*+1*	*1*	*In the nucleus*
Neutron	*None*	*1*	
Electron	*-1*	*1/1835 Or 0.0005*	*Orbits the nucleus*
Positron	*+1*		

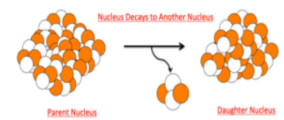
Detecting		
	Use Geiger-Müller *tube*	Radiation passes into tube, ionising gas causing a short pulse of current to flow.
	Photographic film	Film becomes darker when radiation reaches it.

Count rate	*Number of clicks per second*
Dose	*Amount of radiation*

Background radiation

Background radiation
Low level ionising radiation from space and naturally occurring radioactive substances in the environment
Radon gas (49%), Medical (15%), Ground and buildings (13%), Cosmic rays (12%), Food and Drink (10%), Nuclear and other (1%).

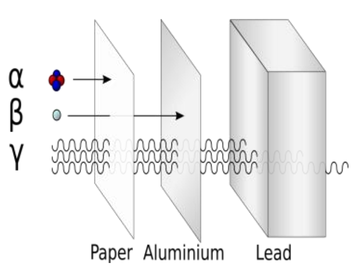
Types of radiation and radioactive decay



J J Thomson (1897)	Discovered electrons could be removed from atoms. Suggested 'plum-pudding' model – atoms were spheres of positive charge with tiny negative electrons stuck in them.
Rutherford and Marsden (1909)	Fired a beam of alpha particles (He^{2+}) at thin gold foil. They expected particles to pass straight through or be slightly deflected. They found some travelled through, some were deflected more than expected and some bounced back.
Rutherford (1911)	Used above evidence to suggest most of the mass of atom was concentrated at the centre in a tiny nucleus, most of atom was empty space and the nucleus had a positive charge since positive alpha particles were repelled. The nuclear model was created.
Bohr (1913)	Tweaked Rutherford's idea, and suggested modern model of atom – electrons in fixed orbits at set distances from nucleus. The distances were called energy levels. He suggested electrons can only exist in these energy levels. This Bohr model is the currently accepted model of the atom.

Radioactive decay	*Unstable atoms randomly emit radiation to become stable*
Ionisation	*Radiation that 'knocks' electrons from atoms*

Decay	Alpha (α)	Beta (β-)	Positron (β+)	Gamma (γ)	Neutron
Emitted from nucleus	Helium nuclei (^4_2He)	High energy, high speed electron ($^0_{-1}e$)	High energy, high speed particle ($^0_{+1}e$)	High frequency Electromagnetic wave	Neutron
Mass number	4	0	0	0	+1
Atomic number	+2	-1	+1	0	0
Charge	+2	-1	+1	0	0
Ionising	Strongly	Moderately.	Moderately.	Weakly.	Not.
Penetrating	Few cm	Few metres.	Smaller range.	Few kilometres.	
Stopped by	Paper or skin.	Aluminium.	When they hit an electron they destroy each other.	Concrete or lead.	



To balance nuclear equations the total mass and atomic numbers must be equal on both sides.

$^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^4_2\alpha$

$^{14}_6C \rightarrow ^{14}_7N + ^0_{-1}\beta$

$^{18}_9F \rightarrow ^{18}_8O + ^0_{+1}\beta$

$^{99}_{43}Tc \rightarrow ^{99}_{43}Tc + \gamma$

$^{13}_4Be \rightarrow ^{12}_4Be + ^1_0n$

When nuclei undergo radioactive decay, nuclear rearrangement and loss of energy as gamma radiation often occurs.

β- a neutron becomes an proton and an electron.

β+ a proton becomes an neutron and a positron.

Gamma rays do not change the charge or the mass of the nucleus.

EDEXCEL TOPIC 6 RADIOACTIVITY.

Using radiation

Beta	*Gauging thickness*	Paper is passed between rollers connected to a detector, which measures the amount of Beta particles passing through. Too thin, pressure reduced, too thick, pressure increased.
Beta or Gamma	*Tracing leaks*	Radioactive tracer leaks out of damaged area and is detected using Geiger-Müller tube.
Gamma	*Diagnosis of cancer.*	Cancer cells are very active so take up glucose quicker than normal cells. Using radioactive glucose will detect cancer cells.
Gamma	*Treatment of cancer.*	Cancer cells divide more quickly and are more susceptible to be killed by radiation.
Alpha	*Household smoke alarms*	Alpha particles ionise molecules in air. Ions are attracted to charged plates allowing a small current to flow. Smoke gets in the way of ions and current decreases setting off alarm.
Gamma	*Irradiating food*	Kills bacteria.
Gamma	*Sterilising medical equipment*	Kills bacteria.
Uses	*Different isotopes have different half lives*	Household smoke alarms, irradiating food, sterilising medical equipment, tracing and gauging thicknesses, diagnosis and treatment of cancer.

PHYSICS ONLY

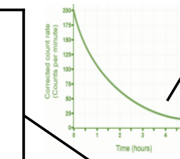
To prevent activity decreasing, isotope made close to scanner.

PET scanners	*Positron emission tomography – used to diagnose conditions.*
	Short half=life tracers injected into patient. Positron meets electrons in organ and annihilates emitting high energy gamma rays in opposite direction. Gamma rays used to locate tumour.

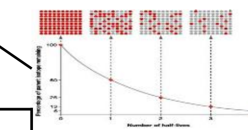
Treating tumours	*Internally – short half-life alpha emitters placed inside body in or near tumour.*	Alpha is strongly ionising so damages cells. Have a short range so damage to normal tissue is limited.
	Internally – short half-life beta emitters (implants) placed inside body in or near tumour.	Beta penetrates case of implant and damages tumour cells. Range is longer so more damage to healthy can occur.
	Externally – long half-life gamma rays aimed at tumour	Gamma penetrates into body, some damage to surrounding cells occurs.

Half-life

Decay	*When a nucleus will decay cannot be predicted - it is a random process*	An unstable nucleus changes and emits particles changing the atom.
Half life	*The time taken for the activity of a radioactive source to decay by half*	A period of time, constant for each isotope for half of the un-decayed nuclei to decay.
Unit of activity	*Becquerel*	The number of nuclear decays per second.



Radioactive activity of a source decreases over a period of time.



Dangers

Low doses cause minor damage, cells divide rapidly (cancer).

High doses kills cells causing radiation sickness.

Alpha cannot penetrate the body.

Beta and gamma penetrate the body.

Ionisation
Radiation ionises atoms leads to tissue damage

Reduce the risk	Reduce length of exposure time.
	Reduce distance from source.

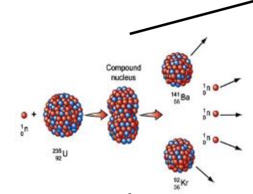
Irradiation
Person is in exposed to radioactive source

Contamination
Unwanted presence of radioactive atoms in body or ground

Nuclear energy

PHYSICS ONLY

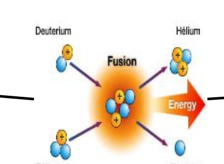
Nuclear power	*Thermal energy released from nuclear fission*	Produces radioactive products.
Nuclear fission	*One large unstable nucleus splits to make two smaller nuclei*	Neutron hits U-235 nucleus, nucleus absorbs neutron, splits emitting two or three neutrons and two smaller daughter nuclei. Process also releases energy.



Process repeats, chain reaction formed.

Used in nuclear power stations.

Nuclear fusion
Two small nuclei join to make one larger nucleus
Difficult to do on Earth – huge amounts of pressure and temperature needed.
Occurs in stars.



Strong electrostatic repulsive forces from positively charged nuclei have to be overcome, using lots of heat and pressure so is uneconomical.

Advantages	*Very reliable, 'clean' fuel - does not release greenhouse or acid rain gases, produces huge amounts of energy*
Disadvantages	*People see it as dangerous, nuclear waste has very long half life and needs to disposed of safely, risk of leaking and explosions*

Fuel rods	Made of U-238, 'enriched' with U-235 (3%). Long and thin to allow neutrons to escape, hitting nuclei.
Control rods	Made of Boron. Controls the rate of reaction. Boron absorbs excess neutrons.
Moderator	Water slows down fast moving neutrons.
Concrete	Neutrons hazardous to humans – thick concreate shield protects workers.

Controlled reaction	*Steady rate of nuclear fission*	1 neutron produces another fission.

Nuclear energy store in fuel.	Thermal energy. →	Thermal energy store in moderator.
Thermal energy store in moderator.	Thermal energy. →	Thermal energy store in water.
Thermal energy store in water.	Kinetic energy. →	Kinetic energy store in steam.
Kinetic energy store in steam.	Kinetic energy. →	Kinetic energy store in turbine.
Kinetic energy store in turbine.	Kinetic energy. →	Kinetic energy store in generator.
Kinetic energy store in generator.	Electrical energy. →	To the National Grid.

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EDEXCEL TOPIC 6 RADIOACTIVITY.

Atom Structure

Small molecules (ie: Oxygen) typical size of 10^{-10}m.

Diameter of an atom 1 X 10^{-10}m.

Diameter of nucleus is 10,000 times smaller.

	Neutral charge	Equal numbers of protons and electrons.

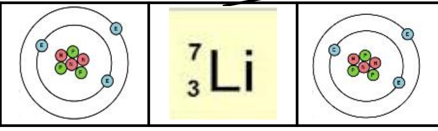
	Positively charged nucleus, surrounded by negatively charged electrons	Nuclear radius is much smaller than the atom.
		Almost all of the atom's mass is in the nucleus.

	Orbit the nucleus at set distances	Absorbing or emitting EM radiation causes change in orbit.

Electrons lost	Positive ion.

Atomic number = 3 protons
Mass number = 6 (3 neutrons + 3 protons).

Atomic number = 3 protons
Mass number = 7 (4 neutrons + 3 protons).

	$^{6}_{3}Li$		$^{7}_{3}Li$	

Different forms of an element with the same number of protons but different number of neutrons

	Number of protons and neutrons
	Smaller particles in the nucleus
	Number of protons
	Unequal number of electrons to protons

	Relative Charge	Relative mass	Found
	+1	*1*	*In the nucleus*
	None	*1*	
	-1	*1/1835 Or 0.0005*	*Orbits the nucleus*
	+1		

	Use Geiger-Müller *tube*	Radiation passes into tube, ionising gas causing a short pulse of current to flow.
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	Number of clicks per second
	Amount of radiation

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	Fired a beam of alpha particles (He^{2+}) at thin gold foil. They expected particles to pass straight through or be slightly deflected. They found some travelled through, some were deflected more than expected and some bounced back.	
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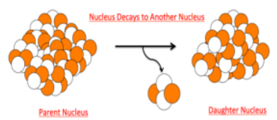

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	Radiation that 'knocks' electrons from atoms

Background radiation

Low level ionising radiation from space and naturally occurring radioactive substances in the environment
Radon gas (49%), Medical (15%), Ground and buildings (13%), Cosmic rays (12%), Food and Drink (10%), Nuclear and other (1%).

Types of radiation and radioactive decay

Emitted from nucleus	Helium nuclei ($^{4}_{2}He$)	High energy, high speed electron ($^{0}_{-1}e$)	High energy, high speed particle ($^{0}_{+1}e$)	High frequency Electromagnetic wave	Neutron
Mass number	4	0	0	0	+1
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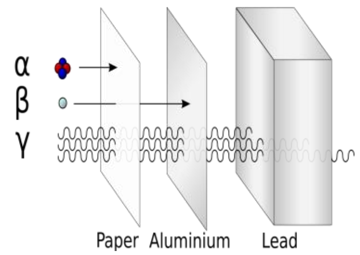

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EDEXCEL TOPIC 6 RADIOACTIVITY.

Using radiation

PHYSICS ONLY

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Tracing leaks	Radioactive tracer leaks out of damaged area and is detected using Geiger-Müller tube.
Household smoke alarms	Alpha particles ionise molecules in air. Ions are attracted to charged plates allowing a small current to flow. Smoke gets in the way of ions and current decreases setting off alarm.
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Half-life

When a nucleus will decay cannot be predicted - it is a random process	An unstable nucleus changes and emits particles changing the atom.
The time taken for the activity of a radioactive source to decay by half	A period of time, constant for each isotope for half of the un-decayed nuclei to decay.
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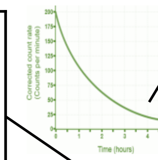

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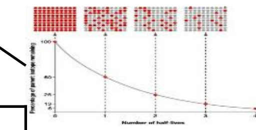


Dangers

Radiation ionises atoms leads to tissue damage

- Low doses cause minor damage, cells divide rapidly (cancer).
- High doses kills cells causing radiation sickness.
- Alpha cannot penetrate the body.
- Beta and gamma penetrate the body.

Person is in exposed to radioactive source

- Reduce length of exposure time.
- Reduce distance from source.

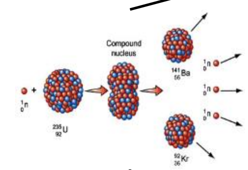
Unwanted presence of radioactive atoms in body or ground

Nuclear energy

PHYSICS ONLY

Thermal energy released from nuclear fission	Produces radioactive products.
One large unstable nucleus splits to make two smaller nuclei	Neutron hits U-235 nucleus, nucleus absorbs neutron, splits emitting two or three neutrons and two smaller daughter nuclei. Process also releases energy.
Steady rate of nuclear fission	1 neutron produces another fission.

- Made of U-238, 'enriched' with U-235 (3%). Long and thin to allow neutrons to escape, hitting nuclei.
- Made of Boron. Controls the rate of reaction. Boron absorbs excess neutrons.
- Water slows down fast moving neutrons.
- Neutrons hazardous to humans – thick concreate shield protects workers.



- Process repeats, chain reaction formed.
- Used in nuclear power stations.

Nuclear energy store in fuel.	Thermal energy. →	Thermal energy store in moderator.
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Very reliable, 'clean' fuel - does not release greenhouse or acid rain gases, produces huge amounts of energy	
People see it as dangerous, nuclear waste has very long half life and needs to disposed of safely, risk of leaking and explosions	

Two small nuclei join to make one larger nucleus

- Difficult to do on Earth – huge amounts of pressure and temperature needed.
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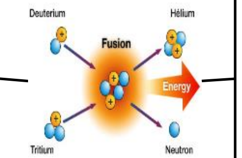

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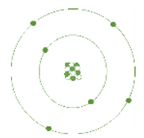
Atom Structure



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Atom	
	Nuclear radius is much smaller than the atom.
	Almost all of the atom's mass is in the nucleus.

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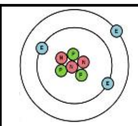
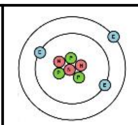
Isotope	$^{6}_{3}Li$		$^{7}_{3}Li$	

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Nucleon	
Atomic number	
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Particle			
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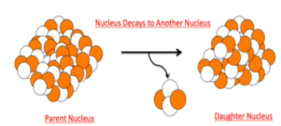

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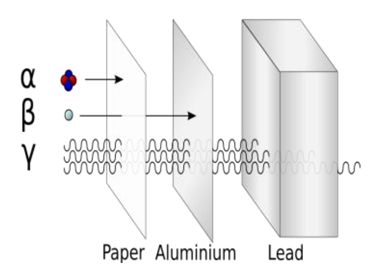

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	Film becomes darker when radiation reaches it.

Count rate	
Dose	

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Using radiation

PHYSICS ONLY

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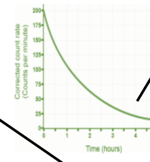
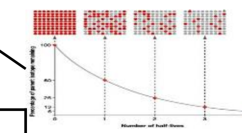
Half life		A period of time, constant for each isotope for half of the un-decayed nuclei to decay.
Unit of activity		The number of nuclear decays per second.

Radioactive activity of a source decreases over a period of time.





Dangers

Low doses cause minor damage, cells divide rapidly (cancer).

High doses kills cells causing radiation sickness.

Alpha cannot penetrate the body.

Beta and gamma penetrate the body.

Ionisation

Irradiation

Reduce the risk	Reduce length of exposure time.
	Reduce distance from source.

Contamination

Advantages	
Disadvantages	

Nuclear energy

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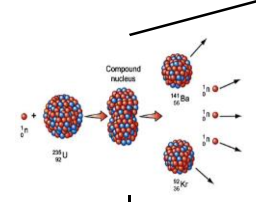
Nuclear power		Produces radioactive products.

Fuel rods	Made of U-238, 'enriched' with U-235 (3%). Long and thin to allow neutrons to escape, hitting nuclei.
Control rods	Made of Boron. Controls the rate of reaction. Boron absorbs excess neutrons.
Moderator	Water slows down fast moving neutrons.
Concrete	Neutrons hazardous to humans – thick concreate shield protects workers.

Controlled reaction		1 neutron produces another fission.

Nuclear fission		Neutron hits U-235 nucleus, nucleus absorbs neutron, splits emitting two or three neutrons and two smaller daughter nuclei. Process also releases energy.

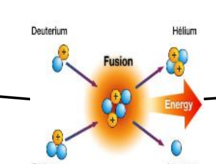


Process repeats, chain reaction formed.

Used in nuclear power stations.

Nuclear energy store in fuel.	Thermal energy. →	Thermal energy store in moderator.
Thermal energy store in moderator.	Thermal energy. →	Thermal energy store in water.
Thermal energy store in water.	Kinetic energy. →	Kinetic energy store in steam.
Kinetic energy store in steam.	Kinetic energy. →	Kinetic energy store in turbine.
Kinetic energy store in turbine.	Kinetic energy. →	Kinetic energy store in generator.
Kinetic energy store in generator.	Electrical energy. →	To the National Grid.

Nuclear fusion
Difficult to do on Earth – huge amounts of pressure and temperature needed.
Occurs in stars.



Strong electrostatic repulsive forces from positively charged nuclei have to be overcome, using lots of heat and pressure so is uneconomical.

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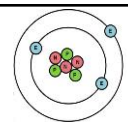
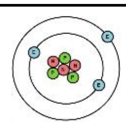
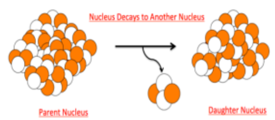
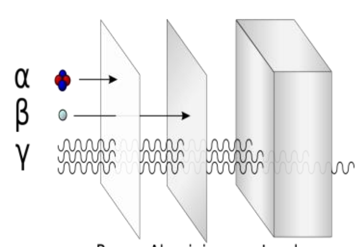
Atom Structure

	$^{6}_{3}Li$		$^{7}_{3}Li$	



Background radiation

Types of radiation and radioactive decay



$^{226}_{88}Ra \rightarrow$

$\rightarrow\ ^{14}_{7}N +\ ^{0}_{-1}\beta$

$\rightarrow\ ^{18}_{8}O +$

$^{99}_{43}Tc \rightarrow\ ^{99}_{43}Tc + \gamma$

$^{13}_{4}Be \rightarrow$

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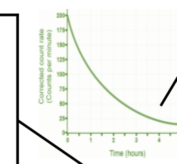
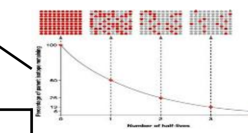
Using radiation

Half-life





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Dangers

Nuclear energy

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