Isotopes and Nuclear Radiation

Isotopes and ionisation. They sound similar, but they're totally different, so read this page carefully.

Isotopes are Different Forms of the Same Element

1) Each element has a set number of protons (so each nucleus has a given positive charge). The number of protons in an atom is called its atomic number or its proton number.
2) The mass (nucleon) number of an atom (the mass of the nucleus) is the number of protons + the number of neutrons in its nucleus.

Every oxygen atom has 8 protons.

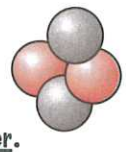
Mass number — $^{16}_{8}O$ — Element symbol (oxygen)

Atomic number

3) Elements (usually isotopes) can be written as, e.g. carbon-14. This means that the mass number is 14.
4) Isotopes of an element are atoms with the same number of protons (the same atomic number) but a different number of neutrons (a different mass number). E.g. $^{18}_{8}O$ and $^{16}_{8}O$ are two isotopes of oxygen.
5) All elements have different isotopes, but there are usually only one or two stable ones.
6) The other unstable isotopes tend to decay into other elements and give out radiation as they try to become more stable. This process is called radioactive decay.
7) Radioactive substances spit out one or more types of ionising radiation when they decay: alpha, beta, gamma. Neutrons (n) can also be emitted.

Alpha Particles are Helium Nuclei

1) Alpha radiation is when an alpha particle (α) is emitted from the nucleus. An α-particle is two neutrons and two protons (like a helium nucleus).
2) They don't penetrate very far into materials and are stopped quickly — they can only travel a few cm in air and are absorbed by a thin sheet of paper.
3) Because of their size they are strongly ionising.



Beta Particles can be Electrons or Positrons

1) A beta-minus particle (β^-) is simply a fast-moving electron released by the nucleus. Beta-minus particles have virtually no mass and a relative charge of –1.
2) A beta-plus particle (β^+) is a fast-moving positron. The positron is the antiparticle of the electron. This just means it has exactly the same mass as the electron, but a positive (+1) charge.
3) They are both moderately ionising. Beta-minus particles have a range in air of a few metres and are absorbed by a sheet of aluminium (around 5 mm thick).
4) Positrons have a smaller range, because when they hit an electron the two destroy each other and produce gamma rays — this is called annihilation and it's used in medical imaging.

Gamma Rays are EM Waves with a Short Wavelength

1) After a nucleus has decayed, it often undergoes nuclear rearrangement and releases some energy. Gamma rays (γ) are waves of EM radiation (p.168) released by the nucleus that carry away this energy.
2) They penetrate far into materials without being stopped and will travel a long distance through air.
3) This means they are weakly ionising because they tend to pass through rather than collide with atoms. Eventually they hit something and do damage.
4) They can be absorbed by thick sheets of lead or metres of concrete.

Isotopes of an outfit — same dress, different accessories...

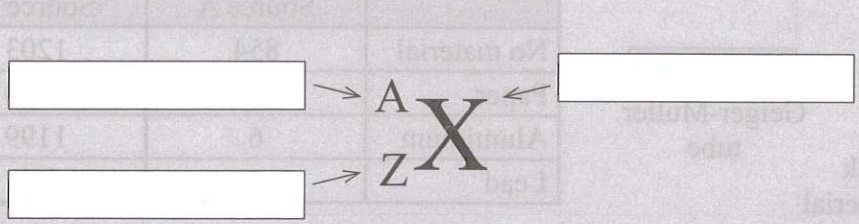
Knowing different kinds of radiation and what can absorb them could bag you a few easy marks in an exam.

Q1 For each of alpha, beta-minus and gamma radiations, give an example of a material that could be used to absorb it. Refer to the material's thickness in your answer. [3 marks]

Isotopes and Nuclear Radiation

Warm-Up

The standard notation used to represent atoms is shown. Use the words below to correctly fill in the labels. You don't have to use every phrase, but each phrase can only be used once.



electron number
neutron number
mass number
element symbol
charge
atomic number

1 **Figure 1** shows a smoke detector. Smoke detectors contain radioactive isotopes. These isotopes are unstable and undergo radioactive decay to become more stable. They do this by emitting nuclear radiation.

Grade 4-6

Figure 1

a) State what is meant by isotopes of an element.

.....

.....

[2]

b) Some nuclear radiation is ionising.
State **three** types of ionising radiation emitted by radioactive decay.

.....

.....

[3]

c) The unstable isotope in the smoke detector releases a particle made up of two protons and two neutrons from its nucleus.

i) State the name of this type of decay.

.....

[1]

ii) State and explain the range in air of the released particle.

.....

.....

[2]

[Total 8 marks]

2 A student carries out an experiment to investigate two different radioactive sources. Her experiment is shown in **Figure 2**. She changes the material between the source and the Geiger-Muller tube and measures the count rate. **Figure 3** shows her results.

Grade 6-7

Figure 2

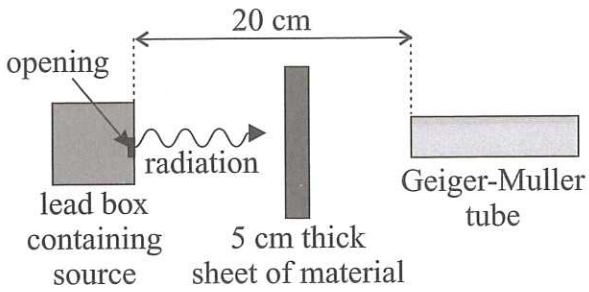


Figure 3

Material	Count rate (counts per minute)	
	Source A	Source B
No material	854	1203
Paper	847	1200
Aluminium	6	1199
Lead	5	280

a) Deduce the type of radiation source A emits.

.....

[1]

b) State what kind of radiation source B emits. Explain your answer.

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.....

.....

[3]

[Total 4 marks]

3 One isotope of sodium is $^{23}_{11}Na$.

Grade 6-7

a) Write down the nucleon number of this isotope.

.....

[1]

b) Calculate the number of neutrons in the sodium nucleus.

Number of neutrons = ...

[1]

c) Which of the following is another isotope of sodium?

☐ **A** $^{11}_{23}Na$ ☐ **B** $^{11}_{24}Na$ ☐ **C** $^{23}_{12}Na$ ☐ **D** $^{24}_{11}Na$

[1]

d) An isotope of neon is $^{23}_{10}Ne$. State whether or not the charge on the neon isotope's nucleus is different to the charge on the nucleus of the sodium isotope. Explain your answer.

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[2]

[Total 5 marks]