Level 2 Physics: Atoms & Radioactivity – Types of Radioactivity - Answers

Prior to 2012, this was an external standard - AS90256. It is likely to be assessed using an internal test from 2012 onwards (although teachers can select from a range of assessment techniques). There were only minor changes to this standard when it became AS91172. The old external examinations may be useful revision for an internal test.

The Mess that is NCEA Assessment Schedules….

Level 2 Physics: **AS 91172** replaced **AS 90256.**

In 90256, from **2004 to 2011**, there was an Evidence column with the correct answer and Achieved, Merit and Excellence columns explaining the required level of performance to get that grade. Each part of the question (row in the Assessment Schedule) contributed a single grade in either Criteria 1 (Explain stuff) or Criteria 2 (Solve stuff). From 2003 to 2008, the NCEA shaded columns that were not relevant to that question (Sorry haven't had time to do 2004 yet).

Question	Evidence	Achievement	Merit	Excellence
2011(2) (a)	Alpha particles are deflected up the page. Beta particles are deflected down the page. Gamma rays go straight through.	Correct diagrams showing alpha going up, beta going down and gamma going straight through. **OR** Incorrect diagrams showing alpha going down, beta going up and gamma going straight through AND Beta curving more than alpha.	Correct diagrams showing alpha going up, beta going down and gamma going straight through. **AND** Beta curving more than alpha.	

(b)	**Alpha:** Alpha **goes up** because: • Flemings left hand rule (or other suitable hand rule) predicts this Alpha **has a small / smaller deflection** because • Alpha has much **greater mass** (8000 × compared with beta) so it affected less by the force produced by the magnetic field. • Alpha has a much **smaller charge / mass ratio** (x 1 / 4000 compared with beta) and so is affected less by the force produced by the magnetic field. **Beta:** Beta **changes direction** because • Flemings left hand rule (or other suitable hand rule) predicts this Beta **has a large / larger deflection** because • Beta has much **smaller mass** (1 / 8000 × compared with alpha) so it affected more by the force produced by the magnetic field. • Beta has a much **larger charge / mass ratio** (x 4000 compared with alpha) so it affected more by the force produced by the magnetic field. An acceptable alternative for alpha **and** beta: • Positive particles are deflected up and negative particles are deflected downwards by the magnetic field (because of opposite charge). **Gamma:** Gamma **does not change direction / it is unaffected** because gamma rays have **no charge / neutral** so are **unaffected** by a **magnetic field**. "Direction does not change / it is unaffected by *electric* field" not accepted.	ONE correct reason for alpha OR ONE correct reason for beta. OR Correct comparison of alpha and beta based upon opposite charges. OR The correct reason for gamma.	TWO correct reasons including two of: • ONE correct reason for alpha. • ONE correct reason for beta. • Correct comparison of alpha. and beta based upon opposite charges. • The correct reason for gamma.	Correct reasons for all THREE radiations including all of: • Correct reason for direction for alpha. • Correct reason for direction for beta (or correct comparison of alpha and beta based upon opposite charges). • Correct reason for shape for alpha. • Correct reason for shape for beta (or correct comparison of alpha and beta based upon mass or charge / mass). • Correct reason for gamma.

(c)	Alpha: • Alpha particles are helium nuclei / two protons and two neutrons. • During alpha decay, the nucleus loses two protons and two neutrons (this may be implied from above) • The atomic number of the nucleus decreases by two and its mass number decreases by four. Beta: • Beta particles are **electrons** (from the nucleus). • During beta decay a neutron changes to a proton and an electron and the electron is emitted. • The **atomic number** of the nucleus increases by one, and its **mass number** stays the same. Gamma: • Gamma is electromagnetic radiation / waves / rays / photons. • During gamma decay, energy is released from the nucleus. • The atomic number and mass number of the nucleus are not affected / stay the same.	THREE of nine descriptions are correct.	SIX of nine descriptions are correct.	EIGHT of 9 descriptions are correct.
2011(3) (a)	$^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\alpha$ (allow a as well as α)	Correct answer including numbers for Alpha.		
2010(1) (a)	Electrons (emitted from nuclei – NOT from orbiting electrons around the nucleus).	Electrons (emitted from nucleus is neutral but do not accept if refers to orbiting electrons).		
(b)	A = 54 Z = 131	BOTH correct.		

(c)	Conservation of charge / atomic number (conservation of mass number is neutral).	Correct principle / law named (not an explanation).		
(d)	• Beta are particles, gamma are photons / waves / electromagnetic radiation. • Beta has mass and gamma has no mass. • Beta travel slower than gamma. • Beta are less penetrating than gamma. • Beta are more ionising than gamma. • Beta emission changes value of Z / structure of the nucleus, gamma does not. • Beta are charged and gamma are not charged. • Beta changes the element and gamma does not change the element. Do not accept energy comparison	ONE correct difference.	TWO correct differences.	

(e)	• The Technetium 99m has a **6 hr / short half- life,** which means it **won't remain in the body very long** therefore there is less chance of damage. • The Technetium 99m has a 6 hr / short half-life, which means it will **have a long enough half-life to remain active during diagnosis** to make an image. • The Technetium 99m has a 6 hr / short half-life, which means it will **decay with enough intensity** to make an image. • The Technetium 99m has a 6 hr / short half life, which means it will **decay quickly enough** that after a **short time / some time, eg after 24 hr** it is almost harmless / all gone / will not remain active after use. • Technetium 99m emits gamma rays that are **very penetrating** and **so can pass through the body to the detector**. • Technetium 99m emits gamma rays that are **not very ionising** and so can pass **through the body without causing damage**. • Technetium 99m decays to Technetium 99 that has a **very long half-life** so will **produce very low levels of radiation / is non-harmful**. • Technetium 99m decays to Technetium 99 which then **emits low energy beta particles that will not damage tissue**.	One concept explained using Physics. (Explanation links correct **physics** to the statement made) (An example of an insufficient link is "the Technetium 99m are not in the body very long therefore do not cause any harm" because there is no physics in this statement – needs to be a link to short half-life.)	TWO or more concepts explained using Physics. (Explanations link correct **physics** to the statements made.)	

2010(2) (c)	X… alpha / α Y… gamma / γ Z… beta / β X is alpha because its **direction changes** because • Fleming's left hand rule (or other suitable hand rule) predicts this • Alpha has much **greater mass** (8000 × compared with beta) so it affected less by the force produced by the magnetic field. • Alpha has a much **smaller charge/mass ratio** (× 1/4000 compared with beta) and so is affected less by the force produced by the magnetic field. Y is gamma because its **direction does not change / it is unaffected** because gamma rays have no charge/neutral (so are unaffected by a magnetic field). Do not accept are "unaffected by electric field". Z is beta because its **direction changes** because • Flemings left hand rule (or other suitable hand rule) predicts this. • Beta has much **smaller mass** (1/8000 × compared with alpha) so it affected more by the force produced by the magnetic field. • Beta has a much **larger charge/mass ratio** (× 4000 compared with alpha) so it affected more by the force produced by the magnetic field. Note: A third reason may be stated as because two of the three types of radioactivity have already been identified so the remaining type must be the third type.	ALL correctly identified as: X… alpha / α Y… gamma / γ Z… beta / β **OR** ONE correct reason.	ALL correctly identified as: X… alpha / α Y… gamma / γ Z… beta / β **AND** ONE correct reason.	ALL correctly identified as: X… alpha / α Y… gamma / γ Z… beta / β **AND** THREE correct reasons.

(b)	${}^{4}_{2}\mathrm{He} + {}^{14}_{7}\mathrm{N} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$ (p or proton instead of H is also correct)	Nuclear equation correctly interpreted from words (i.e. helium + nitrogen goes to oxygen + one other particle). Accept just + Can accept α symbol for alpha particle in the equation.	Nuclear equation correctly interpreted from words (i.e. helium + nitrogen goes to oxygen + one other particle) (Accept just +, accept α symbol for alpha particle in the equation). **AND** Atomic and mass numbers correct (ignore symbol for proton / hydrogen).	
(c)	Proton or hydrogen nucleus / ion or protonium nucleus / ion.	Correct answer.		
(d)	1. Conservation of charge / atomic number. 2. Conservation of mass number / nucleon number.	**Both** conservation laws stated correctly. (do not accept atomic mass number)		
(e)	P – alpha particle as it is stopped (not absorbed) by paper Q – gamma ray as it has greater penetrating power and goes through lead as well.	Correct identification of both alpha AND gamma emissions. **OR** One emission correctly identified and specific reason given in context (e.g. alpha stopped by paper / gamma can pass through lead – do not accept “alpha has low penetrating power” etc.).	**Both** emissions correctly identified and specific reasons given in context (e.g. alpha stopped by paper / gamma can pass through lead – do not accept “alpha has low penetrating power” etc.).	

2009(3) (a)	${}^{241}_{94}\text{Pu} \rightarrow {}^{0}_{-1}\beta + {}^{241}_{95}\text{Am}$ Can also accept alternative symbol for beta particle (but not b or B). The inclusion of gamma is neutral ${}^{0}_{-1}e$	Correct equation. (A correct subtraction with plutonium minus beta goes to Americium is acceptable but the equation must have + or – and $\rightarrow$ but don't accept =.)		
(c)	When an alpha particle is emitted, the nucleus loses 2 protons and 2 neutrons. Hence the atomic number reduces by two and the nucleon number reduces by 4. There is no change to number of protons or neutrons in the nucleus when a gamma ray is emitted. However, energy is lost in the form of gamma rays as these carry high energy. These changes make a more stable nucleus.	1 OF: For alpha decay, the atomic number reduces by 2 and the mass number reduces by 4 / the nucleus loses 2 protons and 2 neutrons. **OR** For gamma rays, there is no change to number of protons or neutrons in the nucleus / excess energy is lost from the nucleus by the emission of the gamma ray. **OR** These changes make a more stable nucleus.	2 OF: For alpha decay, the atomic number reduces by 2 and the mass number reduces by 4 / the nucleus loses 2 protons and 2 neutrons. **OR** For gamma rays, there is no change to number of protons or neutrons in the nucleus / excess energy is lost from the nucleus by the emission of the gamma ray. **OR** These changes make a more stable nucleus.	ALL 3 OF: For alpha decay, the atomic number reduces by 2 and the mass number reduces by 4 / the nucleus loses 2 protons and 2 neutrons. **AND** For gamma rays, there is no change to number of protons or neutrons in the nucleus / excess energy is lost from the nucleus by the emission of the gamma ray. **AND** These changes make a more stable nucleus.

(d)	$^{241}_{95}\mathrm{Am} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{237}_{93}\mathrm{Np}$ Can accept α symbol for alpha particle in the equation.	Correct equation. (A correct subtraction with americium minus alpha goes to neptunium is acceptable but the equation must have + or – and $\rightarrow$ but don't accept =.) **AND** Correctly identifies neptunium as daughter product. (The inclusion of gamma is neutral.)		
2008(1) (a)	Helium nucleus / He^{2+} / Helium 2+ ion (but not Helium positive ion).	**Helium nucleus / He^{2+} / Helium 2+ ion** (but not Helium positive ion).		
(b)	Removing an electron from air / atom / molecule to produce a positive ion / atom / molecule.	**Removing** an **electron** from **air / atom / molecule.**	**Removing** an **electron** from **air / atom / molecule** to produce a **positive ion / atom / molecule.**	
(c)	Alpha particles are not very penetrating and could not pass through the case / alpha could only travel a few cms through air / alpha cannot pass through skin so would not be harmful.	Alpha particles are not **very penetrating / only travel a few cms through air /** alpha cannot **pass through skin**.		
(d)	**95** protons **146** neutrons	Both correct		

(e)	$^{241}_{95}\mathrm{Am} \rightarrow {}^{237}_{93}\mathrm{Np} + {}^{4}_{2}\mathrm{He}$ A correct subtraction with Am minus alpha goes to Np (equation to follow) but must have + or – and → (don't accept =)	**Correct equation** accept He or He^{2+} or α (but not a or A).		
(f)	Conservation of charge.	Conservation of **charge** (references to conservation of mass are neutral).		
(h)	When the Americium decays, it doesn't disappear, but changes into a slightly smaller nucleus (Np). The Neptunium is still there so the **mass is virtually unchanged.**		Correct answer.	
(i)	**Out of the page** (not up).	Correct answer – accept circled answers (if both answers, they must match to be awarded grade).		
(j)	Diagram shows **Bends to the left**, **significantly greater curvature.** ends to the left because • the beta particle is **opposite (negative) charge** or use of the / **right hand slap / left hand rule** (no details required regarding digits etc). • Greater curvature because the beta particle has much less mass / smaller mass / lighter.(The fact that force on beta is less is not required).	Correct diagram OR Correct direction (but not sufficiently significant) with correct explanation for this.	Correct diagram and one explanation.	Correct diagram and both explanations.

2008(2) (a)	$^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\beta$ OR A correct subtraction with Cobalt minus beta goes to Nickel (equation to follow) but must have + or – and → (don't accept =) Named particle: beta particle / electron Accept β or e (but not b or B).	Beta correctly named OR Correct equation.	Beta correctly named AND Correct equation.	
(b)	A neutron has decayed into a proton and an electron. The electron (accept beta for emitted electron) is emitted.	A **neutron** has decayed into a **proton** and an **electron**.	A **neutron** has decayed into a **proton** and an **electron**. AND The **electron is emitted**. (Also accept – a neutron decays into a proton and releases an electron in the process)	
(c)	$^{99}_{43}\text{Tc} \rightarrow {}^{99}_{43}\text{Tc} + \gamma$ Don't accept: λ, Y Accept: γ ,gamma, ɣ	Correct except for one error (e.g. omitting gamma completely, wrong gamma symbol, one wrong number)	**Correct equation**.	
(d)	Gamma rays are (high frequency or high energy) waves / photons (of electromagnetic radiation). (accept gamma are not particles) They have no mass number and no charge, so they do not change the number of protons or neutrons.	Gamma rays are (high frequency or high energy) **waves / photons** (of electromagnetic radiation). OR They have **no mass** and **no charge**	Gamma rays are (high frequency or high energy) **waves / photons** (of electromagnetic radiation). AND They have **no mass** and **no charge**	Gamma rays are (high frequency or high energy) **waves / photons** (of electromagnetic radiation). AND They have **no mass** and **no charge** AND so they do **not change the number of protons or neutrons** of Tc

2007(2) (a)	Different number of neutrons / 3 more neutrons in Pt-195 / 3 less neutrons in Pt-192 / different mass number / Pt-195 has greater mass. (They have the same number of protons.)	One correct difference (don't accept nucleons).		
(b)	The 78 represents the atomic number / number of protons. The 195 represents the mass number / number of nucleons / number of protons and neutrons / relative atomic mass (not "atomic mass").	Both identified correctly (don't accept number of electron instead of protons).		
(c)	$^{192}_{77}Ir \rightarrow {}^{192}_{78}Pt + {}^{0}_{-1}e$ Particle is Beta particle / β or electron e^-	Correct equation – accept β instead of e (If γ as well, ignore. Irrelevant whether numbers to left or right –but not diagonals). **OR** Beta particle / electron produced (must be stated not inferred from equation). Don't accept: b, B.	Correct equation – accept β instead of e (If γ as well, ignore. Irrelevant whether numbers to left or right –but not diagonals). **AND** Beta particle / electron produced (must be stated not inferred from equation). Don't accept: b, B.	
(d)	Conservation of mass / mass number / nucleon number. **AND** Conservation of atomic number / charge number / charge.	Both correct.		
(e)	Half-life should be long enough in order for the doctors to be able scan the patients (assuming being used as tracer). Half-life should not be too long in the patient as radioactivity could harm the patient.	One correct reason.	Both correct reasons.	

(f)	Alpha particles are highly ionising and could harm cells in the human body. Gamma radiation has very low ionising ability and hence is safer for use.	Alpha particles are highly **ionising.** **OR** Gamma rays are poor **ionisers** (do not accept gamma rays do NOT ionise).	Alpha particles are highly ionising as **compared** with gamma rays. **AND** Human cells could be harmed by ionisation / cause cancer.	
(g)	(i) For alpha decay, the atomic number reduces by 2 and the mass number reduces by 4. An alpha particle consists of two neutrons and two protons. (ii) For beta decay, the atomic number increases by one, but the mass number remains the same. A beta particle is a fast-moving electron. It is emitted when a neutron changes to a proton and an electron.	ONE of THREE from: For alpha decay, the atomic number reduces by 2 and the mass number reduces by 4. **OR** For beta decay, the atomic number increases by one, but the mass number remains the same. **OR** ONE of: (During beta decay, a beta particle is emitted when a neutron changes to a proton and an electron / beta particle. **OR** An alpha particle is emitted consisting of two neutrons and two protons.)	TWO of THREE from: For alpha decay, the atomic number reduces by 2 and the mass number reduces by 4. **OR** For beta decay, the atomic number increases by one, but the mass number remains the same. **OR** ONE of: (During beta decay, a beta particle is emitted when a neutron changes to a proton and an electron / beta particle. **OR** An alpha particle is emitted consisting of two neutrons and two protons.)	THREE of THREE from: For alpha decay, the atomic number reduces by 2 and the mass number reduces by 4. **AND** For beta decay, the atomic number increases by one, but the mass number remains the same. **AND** ONE of: (During beta decay, a beta particle is emitted when a neutron changes to a proton and an electron / beta particle. **OR** An alpha particle is emitted consisting of two neutrons and two protons.)

2006(2) (a) (b)	$^{4}_{2}\mathrm{He}$ or $^{4}_{2}\alpha$ Alpha particle. Irrelevant whether numbers to left or right (but not diagonals). Don't accept: a, A. $^{0}_{-1}e$ or $^{0}_{-1}\beta$ Beta particle Irrelevant whether numbers to left or right (but not diagonals). Don't accept: b, B	Correct numbers and symbols **OR** correct particles.	Correct numbers and symbols **AND** correct particles.	
(c)	$^{1}_{1}p + {}^{0}_{-1}e$ Irrelevant whether numbers to left or right (but not diagonals). Don't accept: H instead of p	Correct numbers **OR** one correct particle.	Correct numbers **AND** correct particles.	
(d)	$^{60}_{27}\mathrm{Co} \rightarrow {}^{60}_{28}\mathrm{Ni} + {}^{0}_{-1}e + {}^{0}_{0}\gamma$ Atomic Number = 27 Mass Number = 60 Don't accept: λ, Y Accept: γ , γ	Correct Atomic and Mass numbers **OR** Correct equation (treat zeros on gamma as neutral and numbers on Cobalt in equation as neutral).	Correct Atomic and Mass numbers **AND** Correct equation (treat zeros on gamma as neutral and numbers on Cobalt in equation as neutral).	

2006(3) (a) (b) (c)	*Red source emits gamma rays.* 1. Gamma rays are **very penetrating** 2. Gamma rays **have no charge**, so are **not deflected by a magnetic field**. *Blue source emits alpha particles.* 1. Alpha particles are **easily absorbed/don't penetrate** paper 2. Alpha particles are **charged**, so they are **deflected by a magnetic field.** *Green source emits beta particles.* 1. Beta particles **penetrate paper** 2. Beta particles are **charged** so they are **deflected by magnetic fields**.	Three sources correct. **AND** at least 2 of explanations correct	Three sources correct. **AND** at least 4 of explanations correct	Three sources correct. **AND** ALL 6 of explanations correct
2006(4) (a)	The lead stops beta particles/radioactivity escaping. Allow to stop gamma only if candidate explains gamma may be by product of beta decay	Correct answer.		
2005(3) (a)	Alpha/ α Gamma/ γ Beta/β If students give Name and symbol: If Name correct but accompanying symbol incorrect accept answer as correct If Name incorrect but accompanying symbol correct do NOT accept answer	All correctly named.		

(b)	Downwards particle's mass (beta) is much less than the other particle (alpha) because it is an electron whereas the other particle consists of a helium nucleus (or 2 protons + 2 neutrons)/beta is 1/8000th of the mass of the alpha particle Deflection is actually a consequence of charge/mass ratio so accept charge/mass ratio also Do not accept particles changing speed since question states speed is same	Mass is less/charge to mass ratio is greater	Achievement ***plus*** reason for smaller deflection in terms of relative mass or charge/mass ratio	
2005(4)	*X* are beta particles/β. *Y* is gamma radiation/γ. If students give Name and symbol: If Name correct but accompanying symbol incorrect accept answer as correct If Name incorrect but accompanying symbol correct do NOT accept answer	Correct identification of both types of radioactivity.		
2005(5)	a = 1, b = 1, *X* = proton or hydrogen or H.	Correct values for *a* and *b*.	Achievement ***plus*** correct identification of *X*.	

2005(8) (a)	$^{241}_{95}\mathrm{Am} \rightarrow {}^{4}_{2}\alpha + {}^{237}_{93}\mathrm{Np}$ (Americium and alpha particle must be on opposite sides of arrow) or equivalent equation (including numbers) showing Americium minus alpha particle goes to Np Accept He as replacement for α	Correct answer including Np.		
(b)	• Alpha particles cause more ionisation then beta or gamma because they are more massive particles. • The range of alpha particles is much less than that of beta or gamma so an alpha source is safer to use.	Alpha particles cause greater ionisation Alpha particles have a shorter range.	Achievement ***plus*** benefit of shorter range.	.
(c)	A long half-life means that the source would last longer/ not need replacing/activity of source roughly constant	Correct answer.		