National 5 Chemistry
Unit 3.4 Nuclear Chemistry

Lesson	Content	Traffic Light: Red	Amber	Green

40 Radioactive decay involves changes in the nuclei of atoms. Unstable nuclei (radioisotopes) can become more stable nuclei by giving out alpha, beta or gamma radiation.

41, 44a, 46a

Alpha particles (α) are helium nuclei

- alpha particles have a mass number = 4 and an atomic number = 2
- alpha particles have a double positive charge as they have no electrons
- deflected by an electric field towards the negatively charged plate
- stopped by piece of paper and travel only a few centimetres

$${}^{4}_{2}He$$

Alpha decay of ${}^{210}Po$ can be written as: $${}^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$$

42, 44b, 46b

Beta particles (β) are electrons ejected from a nucleus

- beta particles have a mass number = 0 and an atomic number = -1
- beta particles have a negative charge
- deflected by an electric field towards a positively charge plate
- stopped by thin sheet of aluminium and travel over a metre in air

$${}^{0}_{-1}e$$

Beta decay of ${}^{99}Mo$ can be written as: $${}^{99}_{42}Mo \rightarrow {}^{99}_{43}Tc + {}^{0}_{-1}e$$

43

Gamma rays (γ) are electromagnetic waves emitted from within the nucleus of an atom.

- Gamma radiation is able to travel great distances in air.
- They can be stopped by barriers made of materials such as lead or concrete.
- Gamma rays are not deflected by an electric field.

45 In nuclear equations alpha, beta, protons and neutrons are written as:

Alpha particle	Beta Particle	Proton	Neutron
${}^{4}_{2}He$	${}^{0}_{-1}e$	${}^{1}_{1}p$	${}^{1}_{0}n$

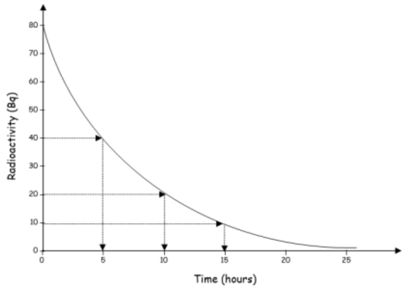
47 Half-life is the time for half of the nuclei of a particular isotope to decay.

48 The half-life of an isotope is a constant. Half-life is unaffected by temperature, chemical conditions (compound form or element) or physical conditions (solid, liquid, gas or solution). Radioactive isotopes can be used to date materials e.g. carbon dating of ${}^{14}C$.

49

The half-life of an isotope can be determined from a graph showing a decay curve.

- Find a halving of the quantity on the y-axis e.g. 100% to 50% or 2g to 1g
- Measure the time taken for the halving to take place on the x-axis



50 The quantity/proportion of radioisotope, half-life or time elapsed from the other variables:

Calculate the half-life of the radioisotope if it takes 45 days for 2g of radioisotope to decay into 0.1g or the radioisotope.

Mass (g)	No of Half Lives
3.2	0
1.6	1
0.8	2
0.4	3
0.2	4
0.1	5

5 x $t_{½}$ = 45day ∴ $t_{½}$ = **9days**

How long did it take for 80g of a radioisotope with a half-life of 17 days 0.625g of radioisotope?

Mass (g)	Time Taken (days)
80	0
40	17
20	34
10	51
5	68
2.5	85
1.25	102
0.625	**119 days**

A radioisotope has a half-life of 3hours. How much of 64g of the radioisotope will remain after 15 hours?

Time (hrs)	Mass (g)	Proportion
0	64	1
3	32	1/2
6	16	1/4
9	8	1/8
12	4	1/16
15	**2g**	1/32

51, 52

Radioisotopes have a range of uses in medicine and in industry.

- Radioisotopes can be used to release gamma radiation to kill cancer cells
- Radioisotopes used must take account of type of radiation released and half-life
  - Gamma radiation is too penetrating to be used as medicines in the body
  - Medicines with very long half-lives are unsuitable for use in the body.

Nat5
Traffic Lights

Past Paper Question Bank
Unit 3.4 Nuclear Chemistry

JABchem

Outcome	Original Specimen Paper	New Specimen Paper	Nat5 2014	Nat5 2015	Nat5 2016	Nat5 2017	Nat5 2018	Nat5 2019	Nat5 2020	Nat5 2021						
40								L4a								
41 44a 46a			L1a L5a	L2a L2b			mc22 L12a									
42 44b 46b	L12c	L14c			mc18	L5b	L12c									
43							mc22									
45			L5c					L8e								
47								L4b(i)								
48								L4b(iii)								
49						L5a(i)										
50	L12a	L14a	L5b	L2c(i)	mc19	L5a(ii)	L12b	L4b(ii)								
51 52	L12b	L14b		L2c(ii)	mc17											

Nat5	Answer	% Correct	Reasoning
2016 MC 17	A	70	☑A a radioisotope which is alpha emitting and has a long half life ☒B gamma rays are too penetrating to be stopped by a smoke ☒C a smoke detector with a short half-life would need to be replace too often ☒D gamma rays are too penetrating to be stopped by a smoke
2016 MC 18	A	50	$^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}e$
2016 MC 19	C	45	Time (years) / % ^{14}C Content: 0 / 100; 5600 / 50; 11200 / 25
2018 MC 22	D	-	☒A beta particles bend towards the positive electrode ∴ Y is not a beta particle ☒B alpha particles bend towards the negative electrode ∴ Y is not a alpha particle ☒C beta particles bend towards the positive electrode ∴ X is not a beta particle ☑D X is alpha (bends towards to negative electrode) & Y is gamma (does not bend)

Time (years)	% ^{14}C Content
0	100
5600	50
11200	25

<table>
<tr><th>Nat5</th><th>Answer</th><th>Reasoning</th></tr>
<tr><td>2014
1a</td><td>Repulsion/deflection by (positive) nucleus</td><td>Positive (alpha) particles mainly travel straight through the layer of gold. Some of the positive (alpha) particles travel close to the nuclei of the gold atoms. The nuclei of the gold atoms are also positive and deflect the passing positive (alpha) particles by repulsion of positives charges.</td></tr>
<tr><td>2014
5a</td><td>Alpha</td><td><table>
<tr><th>Radiation</th><th>Stopped by</th><th>Charge</th><th>Atomic Number</th><th>Mass Number</th></tr>
<tr><td>Alpha</td><td>Paper</td><td>Positive</td><td>2</td><td>4</td></tr>
<tr><td>Beta</td><td>Aluminium</td><td>Negative</td><td>-1</td><td>0</td></tr>
<tr><td>Gamma</td><td>lead</td><td>No charge</td><td colspan="2">Gamma radiation is a wave not a particle</td></tr>
</table></td></tr>
<tr><td>2014
5b</td><td>$\frac{1}{4}$</td><td><table>
<tr><th>Time (days)</th><th colspan="2">Fraction</th></tr>
<tr><td>0</td><td>1</td><td>100%</td></tr>
<tr><td>8</td><td>$\frac{1}{2}$</td><td>50%</td></tr>
<tr><td>16</td><td>$\frac{1}{4}$</td><td>25%</td></tr>
</table></td></tr>
<tr><td>2014
5c</td><td>Sodium</td><td>Mass number of X = 28 – 4 = 24
Atomic number of X = 13 – 2 = 11 ∴ Element 11 = sodium</td></tr>
<tr><td>2015
2a</td><td>Neptunium</td><td>$^{241}_{95}Am \rightarrow ^{4}_{2}He + ^{237}_{93}Np$</td></tr>
<tr><td>2015
2b</td><td>alpha</td><td><table>
<tr><th>Radiation</th><th>Stopped by</th><th>Charge</th><th>Atomic Number</th><th>Mass Number</th></tr>
<tr><td>Alpha</td><td>paper</td><td>Positive</td><td>2</td><td>4</td></tr>
<tr><td>Beta</td><td>aluminium</td><td>Negative</td><td>-1</td><td>0</td></tr>
<tr><td>Gamma</td><td>lead</td><td>No charge</td><td colspan="2">Gamma radiation is a wave not a particle</td></tr>
</table></td></tr>
<tr><td>2015
2c(i)</td><td>1g</td><td><table>
<tr><th>Time (hr)</th><th>Mass (g)</th></tr>
<tr><td>0</td><td>8</td></tr>
<tr><td>16</td><td>4</td></tr>
<tr><td>32</td><td>2</td></tr>
<tr><td>48</td><td>1</td></tr>
</table></td></tr>
<tr><td>2015
2c(ii)</td><td>Longer half-life</td><td>Americium-242 has too short a half-life to be effective in a smoke-detector as the amount of Americium would half every 16 hours. It would not be operational within days of manufacture. Americium-241 has a half-life of 432years and will be working for many lifetimes but must be disposed of carefully.</td></tr>
<tr><td>2017
5a(i)</td><td>14 days</td><td>phosphorus-32 content = 100%, Time= 0days
phosphorus-32 content = 50%, Time= 14days } half-life = 14 days</td></tr>
<tr><td>2017
5a(ii)</td><td>42days</td><td><table>
<tr><th>Mass (g)</th><th>No of half lives</th></tr>
<tr><td>20</td><td>0</td></tr>
<tr><td>10</td><td>1</td></tr>
<tr><td>5</td><td>2</td></tr>
<tr><td>2.5</td><td>3</td></tr>
</table>
If 1 half-life = 14 days
3 half-lives = 42 days</td></tr>
<tr><td>2017
5b</td><td>Beta β</td><td>$^{32}_{15}P \rightarrow ^{32}_{16}S + ^{0}_{-1}e$</td></tr>
<tr><td>2018
12a</td><td>Alpha Particles are stopped by paper</td><td><table>
<tr><th>Radiation</th><th>Alpha</th><th>Beta</th><th>Gamma</th></tr>
<tr><td>Mass</td><td>4</td><td>0</td><td>No mass</td></tr>
<tr><td>Charge</td><td>2</td><td>-1</td><td>No charge</td></tr>
<tr><td>Stopped by</td><td>Paper</td><td>Aluminium</td><td>Thick lead</td></tr>
<tr><td>Deflection</td><td>Towards negative</td><td>Towards positive</td><td>No defection</td></tr>
<tr><td>Use</td><td>Smoke detectors</td><td>Measuring thickness of paper in paper mill</td><td>Radiotherapy cancer treatment</td></tr>
</table></td></tr>
</table>

2018 12b	14.8	<table><tr><th>Number of half-lives</th><th>Fraction</th></tr><tr><td>0</td><td>1</td></tr><tr><td>1</td><td>$^{1}/_{2}$</td></tr><tr><td>2</td><td>$^{1}/_{4}$</td></tr><tr><td>3</td><td>$^{1}/_{8}$</td></tr><tr><td>4</td><td>$^{1}/_{16}$</td></tr></table> 1 half-life = 3.7 years 4 half-lives = 4x3.7years = 14.8years
2018 12c	increases stays the same	$^{204}_{81}Tl \rightarrow ^{204}_{82}Pb + ^{0}_{-1}e$
2019 4a	nucleus	All nuclear reactions take place in the nucleus.
2019 4b(i)	One answer from:	The time for half of the mass to decay / The time for half of the (radio)activity to decay / The time for half of the nuclei to decay
2019 4b(ii)	87.5%	<table><tr><th>Time (days)</th><th>Percentage Remaining</th></tr><tr><td>0</td><td>100%</td></tr><tr><td>8</td><td>50%</td></tr><tr><td>16</td><td>25%</td></tr><tr><td>24</td><td>12.5%</td></tr></table> 12.5% remaining after 24 days 87.5% must have decayed by 24 days
2019 4b(iii)	Stays the same	Half-life is independent of concentration, temperature and state of matter (solid, liquid, gas or solution)
2019 8e	$^{1}_{0}n$	<table><tr><th>Particle</th><th>Proton</th><th>Neutron</th><th>Electron</th><th>Alpha</th><th>Beta</th></tr><tr><td>Symbol</td><td>$^{1}_{1}p$</td><td>$^{1}_{0}n$</td><td>$^{0}_{-1}e$</td><td>$^{4}_{2}He$</td><td>$^{0}_{-1}e$</td></tr></table>

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Past Paper Question Bank
Unit 3.4 Nuclear Chemistry

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Outcome	H 2000	H 2001	H 2002	H 2003	H 2004	H 2005	H 2006	H 2007	H 2008	H 2009	H 2010	H 2011	H 2012	H 2013	H 2014	H 2015
40			mc29					mc39		L17a		L12a				mc40
41 44a 46a				L3b			L14a(i)	mc40	mc39	L16a L16b					mc40	
42 44b 46b		L1b	L2b	mc39	L2a		mc40	mc40 L3a	L5a	mc39	mc40	L12b	L4a		mc40 L7b	L8a
43	mc29							mc40		mc39					mc40	
45	L4a	L1a				mc39				mc40	L6a			L12a	L7a	
47																
48		mc30 g32b	L2c	mc38		L6b(ii)					L6c		L4b(i)	mc39	L7c(ii)	L8c(ii)
49			L2a	L3a					L5b(i)			L12c(i)			L7c(i)	
50	mc30	L1c			L2b(ii)	mc40	mc39	L3b(ii)	mc40	L16c	L6b		L4c	L12b		L8c(i)
51 52							L14a(ii)		L5b(ii)			mc40				L8b

<table>
<tr><th>H</th><th>Answer</th><th>% Correct</th><th>Reasoning</th></tr>
<tr><td>2000
Higher
MC
29</td><td>C</td><td>69</td><td>On β–emission, the mass number stays the same and the atomic number increases by one. This would turn a group 4 element into a group 5 element</td></tr>
<tr><td>2000
Higher
MC
30</td><td>C</td><td>83</td><td><table><tr><td>Time (years)</td><td>0</td><td>21</td><td>42</td><td>63</td></tr><tr><td>Fraction</td><td>1</td><td>$\frac{1}{2}$ = 0.5</td><td>$\frac{1}{4}$ = 0.25</td><td>$\frac{1}{8}$ = 0.125</td></tr></table></td></tr>
<tr><td>2001
Higher
MC
30</td><td>C</td><td>37</td><td>Half life is the same as the nucleus splitting is the same with the same half-life.
The intensity of the radiation is different as 1g of radium metal contains more radium nuclei than 1g of radium oxide</td></tr>
<tr><td>2002
Higher
MC
29</td><td>D</td><td>46</td><td>Strontium has atomic number of 38 (date booklet) → 38 protons.
Number of neutrons = mass number – atomic number = 90 – 38 = 52 neutrons
∴ratio of neutrons:protons = 52:38 = 1.37:1</td></tr>
<tr><td>2003
Higher
MC
38</td><td>C</td><td>58</td><td>☒A Half-life must be the same for the same isotope of lead
☒B Half-life must be the same for the same isotope of lead
☑C Same lead isotope means same half life & different intensity due to concentration
☒D Intensity of radiation will be different as there is less radioactive lead in the solution</td></tr>
<tr><td>2003
Higher
MC
39</td><td>A</td><td>69</td><td>β-emission: neutron splits into proton (stays in nucleus) and electron (ejected from nucleus)
β-emission: atomic number increases +1 and Mass number stays same</td></tr>
<tr><td>2005
Higher
MC
39</td><td>B</td><td>70</td><td>Neutron capture involves changing the number of neutrons so there is no change of atomic number (ie number of protons). Answer B is the only answer with the same atomic number as ^{32}P.</td></tr>
<tr><td>2005
Higher
MC
40</td><td>B</td><td>57</td><td>α-emission → loss of mass of 4 ∴ mass no.=200 is starting isotope.
25% of starting isotope (200) remains so 2 half-lives have passed
2 half-lives = 8 days ∴ 1 half-life = 4 days</td></tr>
<tr><td>2006
Higher
MC
39</td><td>C</td><td>66</td><td>25% of ^{14}C left → 2 half-lives have passed.
1 half-life = 5600 years ∴ 2 half-lives = 2x5600 = 11200 years</td></tr>
<tr><td>2006
Higher
MC
40</td><td>B</td><td>70</td><td>β-emission: atomic number increases by 1 & mass number remains constant
∴ mass number remains at 231 during β-emission</td></tr>
<tr><td>2007
Higher
MC
39</td><td>C</td><td>57</td><td>Number of protons = atomic number = 38
Number of neutrons = mass number – atomic number = 90 – 38 = 52
Neutron : Proton
52 : 38
1.37 : 1</td></tr>
</table>

<table>
<tr><td>2007
Higher
MC
40</td><td>D</td><td>72</td><td>Alpha Particles are positive ∴ attracted towards negative plate (Path X)
Beta Particles are negative ∴ attracted towards positive plate (Path Z)
Gamma Rays have no charge ∴ travel straight through (Path Y)</td></tr>
<tr><td>2008
Higher
MC
39</td><td>C</td><td>92</td><td>$^{227}_{90}Th \rightarrow {}^{223}_{88}Ra \rightarrow {}^{219}_{86}Rn \rightarrow {}^{215}_{84}Po \rightarrow {}^{211}_{82}Pb$
∴ 4 alpha particles removed</td></tr>
<tr><td>2008
Higher
MC
40</td><td>C</td><td>83</td><td><table><tr><th>Fraction</th><th>Time (years)</th></tr><tr><td>1</td><td>0</td></tr><tr><td>0.5</td><td>21</td></tr><tr><td>0.25</td><td>42</td></tr><tr><td>0.125</td><td>63</td></tr></table></td></tr>
<tr><td>2009
Higher
MC
39</td><td>A</td><td>35</td><td><table><tr><th>Radiation Type</th><th>Alpha</th><th>Beta</th><th>Gamma</th></tr><tr><td>Deflection</td><td>Down to bottom</td><td>Up to top</td><td>Straight through</td></tr><tr><td>Size of deflection</td><td>Nearer centre as Alpha are heavy</td><td>Nearer top as Beta are light</td><td>(No deflection)</td></tr></table></td></tr>
<tr><td>2009
Higher
MC
40</td><td>C</td><td>49</td><td>$^{31}_{15}P + {}^{1}_{0}n \rightarrow {}^{32}_{15}P$</td></tr>
<tr><td>2010
Higher
MC
40</td><td>A</td><td>85</td><td>$^{211}_{83}Bi \rightarrow {}^{207}_{81}Th + {}^{4}_{2}He$
$^{207}_{81}Th \rightarrow {}^{207}_{82}Pb + {}^{0}_{-1}e$</td></tr>
<tr><td>2011
Higher
MC
40</td><td>A</td><td>65</td><td>☑A Alpha radiation stopped by smoke particles and long half-life for device long life
☒B Gamma radiation would not be stopped by smoke particles and cannot be used
☒C A short half-life would mean the smoke-detector would not work for long
☒D Gamma radiation would not be stopped by smoke particles and cannot be used</td></tr>
<tr><td>2013
Higher
MC
39</td><td>B</td><td>74</td><td>☒A This graphs shows the relationship between chemical reaction rate and temp
☑B Rate of radioactive decay does not change when temperature is varied
☒C This graph represents the activity of an enzyme against temperature
☒D This graph shows an increase in rate when temperature is increased</td></tr>
<tr><td>2014
Higher
MC
40</td><td>D</td><td>76</td><td>☒A beta radiation is negative and is attracted to the positive plate
☒B beta radiation is negative and is attracted to the positive plate
☒C beta radiation is negative and is attracted to the positive plate
☑D alpha bends to negative, beta bends to positive and gamma does not bend</td></tr>
<tr><td>2015
OLD
Higher
MC
40</td><td>A</td><td>61</td><td>☑A radioactive calcium will have a different mass number from non-radioactive calcium
☒B All calcium atoms have same chemical properties (as they have 2,8,8,2 arrangement)
☒C All calcium atoms have an atomic number if 20
☒D All Calcium atoms have 20 electrons and an arrangement of 2,8,8,2</td></tr>
</table>

<table>
<tr><th>H</th><th>Answer</th><th>Reasoning</th></tr>
<tr><td>2000
Higher
4a</td><td>Nuclear Equation with:</td><td>$${}^{252}_{98}Cf + {}^{11}_{5}B \rightarrow {}^{257}_{103}Lr + 6\,{}^{1}_{0}n$$</td></tr>
<tr><td>2001
Higher
1a</td><td>Neutron or ${}^{1}_{0}n$</td><td>The atomic and mass numbers must balance on both sides of the equation:
$${}^{99}_{43}Tc + {}^{1}_{0}n \rightarrow {}^{100}_{43}Tc$$</td></tr>
<tr><td>2001
Higher
1b</td><td>${}^{100}_{43}Tc \rightarrow {}^{101}_{44}Ru + {}^{0}_{-1}e$</td><td><table><tr><th>Radiation</th><th>Effect on Atomic Number</th><th>Effect on Mass Number</th></tr><tr><td>Alpha</td><td>Decrease by 2</td><td>Decrease by 4</td></tr><tr><td>Beta</td><td>Increase by 1</td><td>No change</td></tr><tr><td>Gamma</td><td>No change</td><td>No change</td></tr></table></td></tr>
<tr><td>2001
Higher
1c</td><td>$\frac{1}{8}$</td><td><table><tr><th>Time (s)</th><th>No of half-lives</th><th>Fraction Left</th></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>16</td><td>1</td><td>$\frac{1}{2}$</td></tr><tr><td>32</td><td>2</td><td>$\frac{1}{4}$</td></tr><tr><td>48</td><td>3</td><td>$\frac{1}{8}$</td></tr></table></td></tr>
<tr><td>2002
Higher
2a</td><td>5800 years</td><td>when Radioactive Count Rate = 72 → time = 0 years
when Radioactive Count Rate = 36 → time = 5800 years
Time for radioactive count to half (half-life) = 3800 - 0 years = 5800 years</td></tr>
<tr><td>2002
Higher
2b</td><td>${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$</td><td>β-emission: neutron splits into proton (stays in nucleus) and electron (emitted from nucleus)
β-emission: atomic increases by 1 and mass number is unchanged</td></tr>
<tr><td>2002
Higher
2c</td><td>Fossil fuels take millions of years to form not thousands</td><td>Too many half-lives of ${}^{14}C$ will have passed over the millions of years needed to form coal for accurate measurement of the radioactivity (not much ${}^{14}C$ is left!)</td></tr>
<tr><td>2003
Higher
3a</td><td>Graph showing points at:</td><td><table><tr><td>Time (days)</td><td>0</td><td>140</td><td>280</td><td>420</td><td>560</td></tr><tr><td>Mass of ${}^{210}Po$ (g)</td><td>200</td><td>100</td><td>50</td><td>25</td><td>12.5</td></tr></table></td></tr>
<tr><td>2003
Higher
3b</td><td>${}^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$</td><td>α-emission: atomic number decreases by 2 and mass number decreases by 4</td></tr>
<tr><td>2004
Higher
2a</td><td>${}^{32}_{15}P \rightarrow {}^{32}_{16}S + {}^{0}_{-1}e$</td><td>βeta emission involves the splitting of a neutron in the nucleus into a proton (stays in the nucleus) and an electron (emitted as a βeta particle)</td></tr>
<tr><td>2004
Higher
2b(ii)</td><td>42.9days</td><td><table><tr><th>Time (days)</th><th>Mass of ${}^{32}P$ remaining</th></tr><tr><td>0</td><td>8g</td></tr><tr><td>14.3</td><td>4g</td></tr><tr><td>28.6</td><td>2g</td></tr><tr><td>42.9</td><td>1g</td></tr></table></td></tr>
<tr><td>2005
Higher
6b(ii)</td><td>Same half-life</td><td>The half-life does not change regardless of the compound/state the isotope of U is in.</td></tr>
<tr><td>2006
Higher
14a(i)</td><td>${}^{241}_{95}Am \rightarrow {}^{237}_{93}Np + {}^{4}_{2}He$</td><td>α-emission: atomic number decreases by 2 and mass number decreases by 4</td></tr>
</table>

<table>
<tr><td>2006
Higher
14a(ii)</td><td>alpha particle not very penetrating</td><td>Alpha particles are stopped by paper and are not very penetrating.
Beta particles are stopped by aluminium and are more penetrating.
Gamma rays are (not completely) stopped by lead and are very penetrating.</td></tr>
<tr><td>2007
Higher
3a</td><td>$^{3}_{1}H \rightarrow {}^{3}_{2}He + {}^{0}_{-1}e$</td><td><table>
<tr><th>Radiation Type</th><th>Effect on Atomic Number</th><th>Effect on Mass Number</th></tr>
<tr><td>Alpha</td><td>decrease by 2</td><td>decrease by 4</td></tr>
<tr><td>Beta</td><td>increase by 1</td><td>no change</td></tr>
<tr><td>Gamma</td><td>no change</td><td>no change</td></tr>
</table></td></tr>
<tr><td>2007
Higher
3b(ii)</td><td>36.9 years</td><td><table>
<tr><th>Percentage Remaining</th><th>Fraction Remaining</th><th>Time Taken</th></tr>
<tr><td>100%</td><td>1</td><td>0 years</td></tr>
<tr><td>50%</td><td>$\frac{1}{2}$</td><td>12.3 years</td></tr>
<tr><td>25%</td><td>$\frac{1}{4}$</td><td>24.6 years</td></tr>
<tr><td>12.5%</td><td>$\frac{1}{8}$</td><td>36.9 years</td></tr>
</table></td></tr>
<tr><td>2008
Higher
5a</td><td>Beta β Particle</td><td>$^{99}_{42}Mo \rightarrow {}^{99}_{43}Tc + {}^{0}_{-1}e$</td></tr>
<tr><td>2008
Higher
5b(i)</td><td>Curve with points:</td><td><table>
<tr><td>Time (hours)</td><td>0</td><td>6</td><td>12</td><td>18</td><td>24</td></tr>
<tr><td>Mass (g)</td><td>0.5</td><td>0.25</td><td>0.125</td><td>0.06</td><td>0.003</td></tr>
</table></td></tr>
<tr><td>2008
Higher
5b(ii)</td><td>Short half-life</td><td>The half life of isotope is short enough that it does last in the body for very long.</td></tr>
<tr><td>2009
Higher
16a</td><td>Answer to include:</td><td>$^{227}_{90}Th \rightarrow {}^{223}_{88}Ra + {}^{4}_{2}He$</td></tr>
<tr><td>2009
Higher
16b</td><td>Alpha particles are not very penetrating</td><td>Alpha particles are stopped by a piece of paper and are not very penetrating. It is unlikely that a significant amount of alpha particles would leave the body and affect others.</td></tr>
<tr><td>2009
Higher
16c</td><td>0.48g</td><td><table>
<tr><th>Time (days)</th><th>% Remaining</th></tr>
<tr><td>0</td><td>100%</td></tr>
<tr><td>19</td><td>50%</td></tr>
<tr><td>38</td><td>25%</td></tr>
<tr><td>57</td><td>12.5%</td></tr>
</table>
12.5% remaining ∴ 87.5% has decayed

87.5% = 0.42g
100% = 0.42g x$^{100}/_{87.5}$
= 0.48g</td></tr>
<tr><td>2009
Higher
17a</td><td>neutron : proton
7 : 6
1.17 : 1</td><td>$^{13}_{6}C$
No of protons = atomic number = 6
No. of neutrons = mass number – atomic number = 13-6 = 7</td></tr>
<tr><td>2010
Higher
6a</td><td>Equation showing:</td><td>$^{11}_{6}C \rightarrow {}^{11}_{5}B + {}^{0}_{+1}e$</td></tr>
<tr><td>2010
Higher
6b</td><td>20</td><td><table>
<tr><td>Rate</td><td>640</td><td>320</td><td>160</td><td>80</td></tr>
<tr><td>No of $t_{\frac{1}{2}}$</td><td>0</td><td>1</td><td>2</td><td>3</td></tr>
</table>
$3x\ t_{\frac{1}{2}} = 60$ min ∴ $t_{\frac{1}{2}} = {}^{60}/_{3} = 20$min</td></tr>
</table>

<table>
<tr><td>2010
Higher
6c</td><td>Pure ^{11}C contains more ^{11}C nuclei than same mass of glucose containing ^{11}C atoms</td><td>The half-life of ^{11}C is the same regardless of temperature and chemical form (element, compound or ion). The half-life of the ^{11}C nucleus is constant. The intensity of the radiation depends on the number of ^{11}C nuclei present. Pure ^{11}C contains more nuclei than the same mass of a compound containing ^{11}C nuclei.</td></tr>
<tr><td>2011
Higher
12a</td><td>Proton:neutron ratio is too high/low</td><td>There is a zone of stability in the proton:neutron ratio. Atoms which are outwith this zone are unstable and can breakdown by radioactive decay.</td></tr>
<tr><td>2011
Higher
12b</td><td>Answer to include:</td><td>$^{131}_{53}I \rightarrow ^{131}_{54}Xe + ^{0}_{-1}e$</td></tr>
<tr><td>2011
Higher
12c(i)</td><td>8 days</td><td><table><tr><td>Mass of iodine = 100pg</td><td>time = 0 days</td></tr><tr><td>Mass of iodine = 50pg</td><td>Time = 8 days</td></tr></table></td></tr>
<tr><td>2012
Higher
4a</td><td>Equation showing:</td><td>$^{89}_{38}Sr \rightarrow ^{89}_{39}Y + ^{0}_{-1}e$</td></tr>
<tr><td>2012
Higher
4b(i)</td><td>no effect/no change</td><td>Half-life is not effected by physical state (solid/liquid/gas/solution), chemical state (atom/molecule/ion) or by changes of temperature</td></tr>
<tr><td>2012
Higher
4c</td><td>$\frac{1}{4}$</td><td><table><tr><th>Time (days)</th><th>Fraction remaining</th></tr><tr><td>0</td><td>1</td></tr><tr><td>14</td><td>$\frac{1}{2}$</td></tr><tr><td>28</td><td>$\frac{1}{4}$</td></tr></table></td></tr>
<tr><td>2013
Higher
12a</td><td><table><tr><td>0</td></tr><tr><td>+1</td></tr></table></td><td>$^{40}_{19}K \rightarrow ^{40}_{18}Ar + ^{0}_{+1}e$</td></tr>
<tr><td>2013
Higher
12b</td><td>2.52×10^{9}</td><td>If 75% of ^{40}K has decayed then 25% of ^{40}K must remain<table><tr><th>Percentage</th><th>Time</th></tr><tr><td>100%</td><td>0</td></tr><tr><td>50%</td><td>1.26×10^{9} years</td></tr><tr><td>25%</td><td>2.52×10^{9} years</td></tr></table></td></tr>
<tr><td>2014
Higher
7a</td><td>$^{1}_{1}p$</td><td><table><tr><th>Total mass number before and after the arrow must equal</th><th>Total atomic number before and after the arrow must equal</th></tr><tr><td>14 + 1 = 14 + X
∴ X = 14 + 1 - 14 = 1</td><td>7 + 0 = 6 + Y
∴ Y = 7 – 6 = 1</td></tr></table><table><tr><th>Particle</th><th>Atomic Number</th><th>Mass Number</th></tr><tr><td>Proton</td><td>1</td><td>1</td></tr><tr><td>Neutron</td><td>0</td><td>1</td></tr><tr><td>Electron</td><td>-1</td><td>0</td></tr></table></td></tr>
<tr><td>2014
Higher
7b</td><td>Neutron splits into proton and electron</td><td>During Beta-emission, a neutron splits into a proton and an electron. The electron is emitted as a beta particle and the proton remains in the nucleus.
$^{1}_{0}n \rightarrow ^{1}_{1}p + ^{0}_{-1}e$
Neutron in nucleus   Proton stays in nucleus   β particle ejected</td></tr>
<tr><td>2014
Higher
7c(i)</td><td>24225 years</td><td>From graph: 5% of carbon-14 content at 4.25 half lives
1 half-life = 5700 years
4.25 half-lives = 5700 years x $^{4.25}/_{1}$ = 24225 years</td></tr>
</table>

2014 Higher 7c(ii)	Too many half-lives have passes to measure	When too many half-lives have passed, it is not possible to measure half-life with any accuracy as there is too little ^{14}C left in the sample.
2015 Higher 8a	Equation showing:	$^{60}_{27}Co \rightarrow \, ^{60}_{28}Ni + \, ^{0}_{-1}e$
2015 Higher 8b	Gamma is high energy or very penetrating	Gamma radiation is high energy electromagnetic radiation. It needs a thick layer of lead metal to stop it and will penetrate the packaging and kill the bacteria inside to sterilise the insides of the package until it is opened.
2015 Higher 8c(i)	21.08	see table below
2015 Higher 8c(ii)	No change	The half-life of a radioisotope is determined by the ratio of protons to neutrons. Changes in temperature, concentration, physical state and chemical state do not alter the half-life of the radioisotope.

Radioactivity	Number of Half-lives	Time (years)
1	0	0
$^1/_2$	1	1x5.27 = 5.27
$^1/_4$	2	2x5.27 = 10.54
$^1/_8$	3	3x5.27 = 15.81
$^1/_{16}$	4	4x5.27 = 21.08