

**M1.(a)**  $(3.0 \times 10^{-10}/24) \times 6.02 \times 10^{23}$  seen ✓

$$(7.52 \times 10^{10})$$

1

(b) Decay constant =  $(0.69 / 14.8 \text{ h}^{-1})$  or  $1.3 \times 10^{-5} \text{ s}^{-1}$  ✓

$$A = 1.30 \times 10^{-5} \times 7.5 \times 10^{10} \quad \checkmark$$

$$9.75 \times 10^5 \text{ Bq} \quad \checkmark$$

Allow 2 or 3 sf

*Allow use of  $A = \lambda N$  with an incorrectly calculated decay constant*

3

(c) Activity 3.5 h later should be  $A = 9.8 \times 10^5 e^{-0.0466 \times 3.5}$  ✓

$$8.33 \times 10^5 \text{ Bq} \quad \checkmark$$

$$\text{Volume of liquid} = (8.33 \times 10^5 / 3600) \times 15 = 3470 \text{ cm}^3 \quad \checkmark$$

3

(d) Estimate gives 3700 compared with 3500 ✓

Flask has more mass than average / liquid is not water ✓

2

[9]

**M2.D**

[1]

**M3.D**

[1]

M4.(a) (i)  $\lambda (= \ln 2 / T_{1/2} = 0.693 / 5740) = 1.2 \times 10^{-4} \text{ (yr}^{-1}\text{)} \checkmark$   
 $(1.21 \times 10^{-4} \text{ yr}^{-1})$

*only allow  $3.83 \times 10^{-12} \text{ s}^{-1}$  if the unit has been changed  
 working is not necessary for mark*

1

(ii) (use of  $N_t = N_o e^{-\lambda t}$  and activity is proportional to  $N$   
 $A_t = A_o e^{-\lambda t}$ )

$0.375 = \exp - (1.21 \times 10^{-4} \times t) \checkmark$

$t = \frac{\ln(\frac{1}{0.375})}{1.21 \times 10^{-4}} \checkmark$

$t = 8100 \text{ or } 8200(\text{yr}) \checkmark$

*1<sup>st</sup> mark substitution, allow EC from (i)*

*2<sup>nd</sup> mark rearranging, allow EC from (i)*

*Allow  $t / T_{1/2} = 2^n$  approach*

*3<sup>rd</sup> mark no EC (so it is not necessary to evaluate a CE)*

*so max 2 for a CE*

*full marks can be given for final answer alone. A minus in the  
 final answer will lose the last mark*

3

- (b) (i) (it is difficult to measure accurately)  
 the small drop / change in activity / count-rate  
 the small change / drop in the ratio of C-14 to C-12  $\checkmark$

the activity would be very small / comparable to the background

or the ratio of C-14 to C-12 is too small

or there are too few C-14 atoms

or there is very little decay

or the level of C-14 (in the biosphere) is uncertain (this long ago)  $\checkmark$

*1<sup>st</sup> mark needs some reference to a change in count-rate or  
 activity for the mark*

*be lenient in 2<sup>nd</sup> mark*

*in reading a script assume C-14 is the subject. Eg 'there is*

*little activity to work with' scores mark. Also allow any*

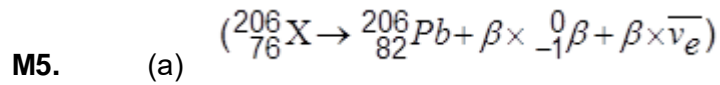
*reasonable suggestion. Eg carbon may have been removed*

*by bonding to surrounding material*

*Don't allow, 'All the carbon has decayed'*

2

[6]



$\beta = 6$  ✓

1

- (b) (i) the energy **required** to split up the nucleus ✓  
 into its individual neutrons and protons/nucleons ✓  
 (or the energy **released** to form/hold the nucleus ✓  
 from its individual neutrons and protons/nucleons ✓)

2

(ii)  $7.88 \times 206 = 1620 \text{ MeV}$  ✓ (allow 1600-1640 MeV)

1

- (c) (i) U, a graph starting at  $3 \times 10^{22}$  showing exponential fall passing through  $0.75 \times 10^{22}$  near  $9 \times 10^9$  years ✓  
 Pb, inverted graph of the above so that the graphs cross at  $1.5 \times 10^{22}$  near  $4.5 \times 10^9$  years ✓

2

- (ii) ( $u$  represents the number of uranium atoms then)

$$\frac{u}{3 \times 10^{22} - u} = 2$$

$$u = 6 \times 10^{22} - 2u$$
 ✓

$$u = 2 \times 10^{22} \text{ atoms}$$

1

- (iii) (use of  $N = N_0 e^{-\lambda t}$ )

$$2 \times 10^{22} = 3 \times 10^{22} \times e^{-\lambda t}$$
 ✓

$$t = \ln 1.5 / \lambda$$

$$\text{(use of } \lambda = \ln 2 / t_{1/2}\text{)}$$

$$\lambda = \ln 2 / 4.5 \times 10^9 = 1.54 \times 10^{-10} \checkmark$$

$$t = 2.6 \times 10^9 \text{ years } \checkmark \text{ (or } 2.7 \times 10^9 \text{ years)}$$

3

[10]

**M6.** boron numbers correct: A = 11; Z = 5

B1

$\beta^+$  correct: A = 0; Z = (+)1

B1

$\nu_e$  (not anti neutrino) with numbers correct: 0,0

B1

3

[3]

**M7.** (a) correct numbers for beta+ (0, (+)1) and chromium (52)

B1

(electron) neutrino with correct numbers (0,0)

B1

2

(b)  $W^+/W^-$  (intermediate vector) boson (not Z boson)

B1

1

[3]

<p><b>M8.</b> (a) plutonium is toxic/large mass of plutonium</p>	<p>B1</p>	
<p>harmful if released into atmosphere/explosion occurred</p>	<p>B1</p>	
<p>alphas dangerous when ingested/during launch etc</p>	<p>B1</p>	<p><b>max2</b></p>
<p>(b) unaffected</p>	<p>B1</p>	
<p>chemical bonding involves electrons (atomic) radioactivity is nuclear (owtte)/same number of nuclei present</p>	<p>B1</p>	<p>2</p>
<p>(c) (i) <math>T_{1/2} = \ln 2 / \lambda</math></p>	<p>C1</p>	
<p><math>2.51 \times 10^{-10}</math></p>	<p>A1</p>	<p>2</p>
<p>(ii) molar mass calculated (0.270 kg)</p>	<p>C1</p>	
<p>use of 33 kg</p>	<p>C1</p>	
<p>number of moles in sample (122.2)</p>	<p>C1</p>	
<p>multiplication of value by Avogadro's number</p>	<p>C1</p>	

		C1	
	$7.36 \times 10^{25}$		
		A1	5
(iii)	(c) (i) $\times$ (c) (ii)		
		C1	
	$1.83 \times 10^{16}$ cao		
		A1	
	Bq		
		B1	3
(d)	(i) uranium correct (234,92)		
		B1	
	alpha correct (4,2) – accept He or $\alpha$ symbol		
		B1	2
(ii)	use of 1 g generating 500 mW		
		C1	
	16500 W total		
		C1	
	recognition that activity $\times$ energy of one alpha = power		
		C1	
	$9.00 \times 10^{-13}$ (J)		
		A1	4

[20]

