Marking Scheme

#1

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)		LHS – RHS (3.0155 – 3.01493 – 0.00055 i.e. standard knowledge of conservation of mass-energy (1) ×931 or equivalent (× c^2) (1) 0.0186 [MeV] (2.98 × 10^{-15} [J]) (1)	1	1 1		3	2	
	(b)	(i)	Mass of p + 2n (3.0246u) - 3.0155 (1) Dividing by 3 **and** ×931 (or equivalent) (1) Answer = 2.82 [MeV / nucleon] (4.52 × 10^{-13} [J/nucleon]) (1)		3		3	2	
		(ii)	Tritium decays to helium-3 **or** helium has a better proton/neutron ratio **or** proton has a smaller mass than neutron (1) And emits energy **or** products have lower mass **or** helium more stable (1) You would expect the products to have a greater BE/N **or** contrary to what you would expect (1)			3	3		
			Question total	**1**	**5**	**3**	**9**	**4**	**0**

#2

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
4	(a)		Diagram of radiation in *B*-field or *E*-field (or description) [1] α, β deviate in opposite directions [1] α, β and γ radiation all go correct directions [1]	1	1 1		3		
	(b)	(i)	Decay constant obtained 1.51 × 10^{-7} [s^{-1}] or 0.013 [day^{-1}] or 1.58$T_{½}$ [1] $3.5e^{-0.013 \times 84}$ or equivalent e.g. $2^{1.58}$ [1] Answer = 1.169 [cps] (no more required) [1]		3		3	3	
		(ii)	Subtracting background radiation from initial (3 cps) [1] Calculating correct cps after 84 days (i.e. 1.002 cps) [1] Adding background radiation (i.e. 1.502) [1] Valid conclusion: close to expected or okay / due to randomness and low numbers ecf [1]			4	4	2	
			Question 4 total	**1**	**5**	**4**	**10**	**5**	**0**

#3

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)		Falling amplitude (1) [Air] resistance **or** dissipative forces **or** equivalent (1)	2			2		
	(b)		$T = 2\pi\sqrt{\frac{0.200}{22.0}}$ [s] (1) = 0.599 [s] (1) T read from graph = 0.60 [s] (1) Prediction convincing [no significant difference] (1)			4	4	2	
	(c)		Point at 0.15 s marked – no tolerance (first displacement zero) (1) $v_{max} = 0.020 \times \frac{2\pi}{0.60}$ [m s^{-1}] (1) = 0.21 m s^{-1} **UNIT** (1) Too large owing to energy dissipation in first quarter cycle (1) **Accept** less detailed reason, such as 'because of damping' **Alternative for last 3 marks:** $v_{max} = 0.018 \times \frac{2\pi}{0.60}$ [m s^{-1}] (1) = 0.19 m s^{-1} **UNIT** (1) Too small because amplitude has fallen or equivalent (1) **Alternative for last 3 marks (mean found):** $v_{max} = 0.019 \times \frac{2\pi}{0.60}$ [m s^{-1}] (2) = 0.20 m s^{-1} **UNIT** (1) no comment required	1	1 1 1		4	2	
	(d)		Data from one maximum or minimum on the graph (other than at t = 0) substituted into the given equation or equivalent accept slips (1) $\lambda = 0.35$ [s^{-1}] [±0.03 s^{-1}] (1)		2		2	1	
			Question total	**3**	**5**	**4**	**12**	**5**	**0**

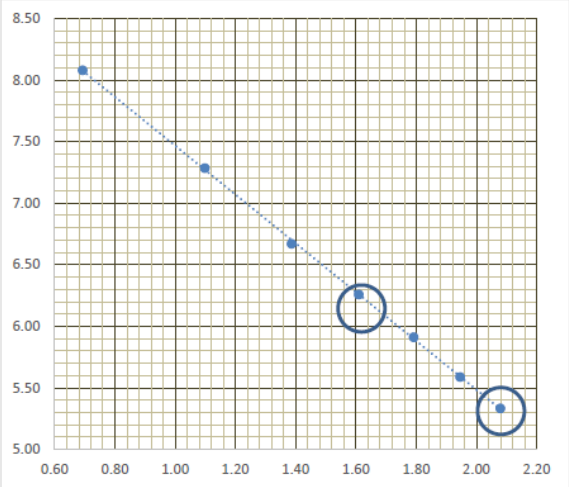
#4

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
6	(a)		N.B. no marks for beta and alpha Answer = 232 (1) Answer = 90 (1)		2		2		
	(b)		Conversion to second ($\times 10^9 \times 365 \times 24 \times 3600$) [$4.4\times10^{17}$] (1) Use of decay constant = $\frac{0.693}{\text{half-life}}$ [1.6×10^{-18} s^{-1}] (1) $N = \frac{5.0 \times 10^{-3}\ \text{kg}}{3.9 \times 10^{-25}\ \text{kg}}$ [allow $\frac{5\times10^{-3}}{232\times1.66\times10^{-27}}$] (1) Use of $A = \lambda \times N$ (1) Answer = 20 kBq ((unit)) (1) [accept s^{-1} for Bq] [Accept: correct answer in other units, e.g. 1.7×10^9 day^{-1} If not in Bq and no unit 3max]	1 1 1	1 1 1		5	4	
	(c)	(i)	**Either** Half-life around 3.8 throws (or get λ from equation or check that decreased by a sixth once) (1) 2× half-lives around 7.8 throws (or calculate another point using λ or check that decreased by a sixth again) (1) Expected activity as one sixth checked e.g. $\frac{6\,000}{6} \approx 1\,009$ (or check that reduced by a sixth for 3rd occasion) (1) Considered conclusion - all is about right (1) Or Exp decay if same interval → same fractional change (1) Calculation of fractional change for a given throw interval (1) Calculation of fractional change for two further same throw intervals (1) Conclusion: about right (1) Or Calculate λ 3 times using three different point → conclusion NB conclusion only after legitimate work			4	4	3	4
		(ii)	Smaller numbers involved (1) More [%] random error expected (1)			2	2		2
			Question 6 total	**2**	**5**	**6**	**13**	**7**	**6**

#5

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)		4,2 for helium (1) 205, 81 for thalium (1)	1	1		2		
	(b)		**Binding energy method:** BE of Bi = 7.87 × 209 (=1 644.83) (1) Correct method for working out mass defect of He or Tl (1) Conversion of mass defect to energy i.e. ×931 **or** $E = mc^2$ (1) Values correct for BE 28.40 and 1 620.03 (1) Final answer = 3.6 MeV (1) **Alternative:** Calculating mass of 83p and 126n (=210.7021 u) (1) BE of Bi = 7.87 × 209 (=1 644.83) (1) Subtracting mass defect for Bi mass (=208.9354 u) (1) LHS mass - RHS mass (=0.0039 u) (1) Final answer = 3.63 MeV (1)			5	5	4	
	(c)	(i)	Sub into half-life = $\frac{0.693}{\lambda}$ (gives 1.16×10^{-27}) (1) Number of mol = $\frac{1}{209}$ **OR** mass of 1 atom = $209 \times 1.66 \times 10^{-27}$ (1) Number of nuclei/atoms = 2.88×10^{21} (1) Answer = 3.3×10^{-8} Bq (1) **unit mark**	1	1 1 1		4	4	
		(ii)	3.3×10^{-8} **ecf** $\times 5 \times 365 \times 24 \times 3\,600$ OR $N = N_0 e^{-\lambda t}$ used (1) Answer = 525 (1)		2		2	2	
			Question total	**2**	**6**	**5**	**13**	**10**	**0**

#6

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		1.61 and 2.08 for ln distance (1) 600 × 0.4 seen (or 240 counts or implied) (1) ln(corrected) answers = 6.26 and 5.33 (implies previous) (1)		3		3	2	3
	(b)		 One mark each for the circled points plotted correctly		1		1	1	1
	(c)		Line of best fit as shown above (1) Correct method for gradient (1) Gradient = -1.98 (allow ± 0.05) (1)		3		3	3	3
	(d)		Taking logs correctly e.g. $\log C = \log k - 2 \times \log d$ (1) Comparison with $y = mx + c$ **OR** gradient clearly identified (1)		2		2	2	2
	(e)		Gradient agrees well with inverse square law (1) Points are close to line of best fit (1) Line of best fit is straight (1)			3	3		3
	(f)		Absorbs other radiation	1			1		1
	(g)		Ionising (1) Kills cells / causes cancer / DNA damage / causes cataracts etc. (1) Hence unethical & linked to risk (1)			3	3		
			Question total	**1**	**9**	**6**	**16**	**8**	**13**

#7

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	Charge: 6 = 7 -1 + 0 **or** 0 = 1 - 1 + 0 **or** $-\frac{1}{3} = \frac{2}{3} - 1 + 0$ (1) Baryon number: 14 = 14 + 0 + 0 **or** 1 = 1 + 0 + 0 **or** $\frac{1}{3} = \frac{1}{3} + 0 + 0$ **or** 42 = 42 + 0 + 0 (1) Lepton number: 0 = 0 + 1 – 1 **or** 6 = 6 + 1 – 1 (1)		3		3		
		(ii)	Change of quark flavour [from d to u] (1) Neutrino involved accept symbol (1) Accept long half-life		2		2		
	(b)	(i)	Use of the equation $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ (1) $T_{\frac{1}{2}} = 1.81 \times 10^{11}$ [s] (1) 5 730 [year] (1)	1	1 1		3	3	
		(ii)	Use of the equation $A = \lambda N$ (1) Method for obtaining N correct ($6.02 \times 10^{23} \times 1 \times 10^{-12}$) (1) Answer = 2.30 Bq **unit mark** (1)	1	1 1		3	3	
		(iii)	$0.34 \times 10^{-12} = 1 \times 10^{-12} e^{-\lambda t}$ i.e. substitution or into $\frac{1}{2^n}$ (1) Taking logs correctly e.g. $\log A = \log A_0 - \lambda t$ (1) 2.82×10^{11} [s] or 8 900 [year] (1)	1	1 1		3	3	
	(c)		11, 5 for boron (1) Positron symbol correct e.g. e+ or beta + (1) Neutrino symbol correct (ν_e) but accept ν (1) Any fourth particle added lose 1 mark		1	1 1	3		
	(d)		**Any 3 × (1) from:** • cannot tell who is correct or words to that effect • further experiments or research must be carried out • experiments at higher (collision) energies (to find other particles) / bigger or better colliders • time/history will (probably) show who was correct • further theory / theoretical research • reference to the Higgs behaving as expected or not as expected • those who claim not should suggest an alternative • Higgs thought to be detected with 5σ [confidence] **Don't accept** any reference to charge or baryon number or lepton number conservation			3	3		
			Question total	**3**	**12**	**5**	**20**	**9**	**0**