A-LEVEL
Physics
PHYA5-1 – Nuclear and Thermal Physics
Mark scheme

2450
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Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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<tr><th>Question</th><th>Answers</th><th>Additional Comments/Guidance</th><th>Mark</th><th>ID details</th></tr>
<tr><td>1 (a)</td><td><table><tr><th>equation showing the interaction that forms ${}^{32}_{15}\mathrm{P}$</th><th>tick all correct equations</th></tr><tr><td>${}^{31}_{15}\mathrm{P} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{32}_{15}\mathrm{P} + {}^{1}_{0}\mathrm{n}$</td><td></td></tr><tr><td>${}^{31}_{15}\mathrm{P} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{32}_{15}\mathrm{P} + {}^{1}_{1}\mathrm{H}$</td><td></td></tr><tr><td>${}^{31}_{15}\mathrm{P} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{32}_{15}\mathrm{P} + {}^{4}_{2}\alpha$</td><td></td></tr><tr><td>${}^{31}_{15}\mathrm{P} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{32}_{15}\mathrm{P} + {}^{1}_{1}\mathrm{p}$</td><td></td></tr></table>Tick the second and fourth line for a mark ✓</td><td></td><td>1</td><td></td></tr>
<tr><td>1 (b)</td><td>kinetic energy (lost) by the hydrogen isotope / deuterium approaching the nucleus / phosphorous nucleus is equal to the potential energy (gain) ✓
$6.5 \times 10^{-13} = \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{15 \times 1.6 \times 10^{-19} \times 1 \times 1.6 \times 10^{-19}}{r}$ ✓
$r = 5.3 \times 10^{-15}$ (m) ✓</td><td>First mark can come form a clear equation with symbols or substitution into the equation. (note kinetic energy may be implied by the language used continuing from the question)</td><td>3</td><td></td></tr>
<tr><td>Total</td><td></td><td></td><td>4</td><td></td></tr>
</table>

Question	Answers	Additional Comments/Guidance	Mark	ID details
2 (a)	probability of decay per unit time/given time period ***OR*** fraction of atoms decaying per second ***OR*** nuclear decay constant is the constant of proportionality in $\frac{dN}{dt} \propto N$ ✓ (the proportion may be given in words)		1	
2 (b)	use of $T_{\frac{1}{2}} = \frac{ln2}{\lambda}$ $T_{\frac{1}{2}}$ = ln2/3.84 × 10^{-12} s ✓ (1.805 × 10^{11} s) = (1.805 × 10^{11}/3.15 × 10^{7}) = 5730 year ✓ answer given to 3 sf ✓	If rounding occurs at the first calculation the final answer comes out as 5750 yr. 3 sf mark stands alone.	3	
2 (c)	number of nuclei = N = 3.50 × 10^{23} × 1/10^{12} ✓ (= 3.50 × 10^{11} nuclei) (using $\frac{\Delta N}{\Delta t} = -\lambda N$) rate of decay = 3.84 × 10^{-12} × 3.50 × 10^{11} = 1.34 Bq ✓	No AE for a power of 10 error. The final mark can come from substitution or a calculation to at least 3 sf.	2	

Question	Answers	Additional Comments/Guidance	Mark	ID details
2 (d)	($N = N_0e^{-\lambda t}$ and activity is proportional to the number of nuclei $A \propto N$ use of $A = A_0e^{-\lambda t}$) $0.85 = 1.34 \times e^{-3.84 \times 10^{-12} \times t}$ ✓ $t = \left(\frac{ln\left(\frac{1.34}{0.85}\right)}{3.84 \times 10^{-12}}\right) = 1.19 \times 10^{11}$ s ✓ (1.185×10^{11} s) t = 3760 year ✓	If 1.4 Bq is used answer become 1.30×10^{11} s and 4130 yr. If 1.3 Bq is used answer become 1.11×10^{11} s and 3510 yr. s to yr conversion is a stand alone mark.	3	
2 (e)	the axe handle may have been made with the wood some time after the tree was cut down the background activity is high compared to the observed count rates the count rates are <u>low</u> or sample size/mass is <u>small</u> or there is statistical variation in the recorded results possible contamination (not by radiation) uncertainty in the ratio of carbon-14 in carbon thousands of years ago any two ✓✓		2	
Total			**11**	

Question	Answers	Additional Comments/Guidance	Mark	ID details
3 (a)	the amount of energy required to separate a nucleus ✓ into its separate neutrons and protons OR nucleons ✓ (or energy released on formation of a nucleus ✓ from its separate neutrons and protons OR nucleons ✓)	1st mark is for correct energy flow direction 2nd mark is for binding or separating nucleons wording must not imply the removal of a single nucleon. (nucleus is in the question but a reference to an atom will lose the mark) ignore discussion of SNF etc both marks are independent	2	
3 (b) (i)	$4\,{}^{1}_{0}n$ or ${}^{1}_{0}n + {}^{1}_{0}n + {}^{1}_{0}n + {}^{1}_{0}n$ ✓	Must see subscript and superscripts	1	
3 (b) (ii)	binding energy of U = 233 × 7.60 ✓ (= 1771 MeV) binding energy of Kr and Ba = 91 × 8.55 + 139 × 8.37 ✓ (= 1941 MeV) energy released (=1941 – 1771) = 170 (MeV) ✓ ($170 \times 1.60 \times 10^{-13}$) = 2.72×10^{-11} (J)	1st mark is for 233 × 7.60 seen anywhere 2nd mark for 91 × 8.55 + 139 × 8.37 ***OR*** 1941 but this is only given if there are no extra terms or conversions present (ignore which way round the subtraction is made) A correct answer can score 3 marks	3	
3 (b)(iii)	loss of mass (= E / c^2) = $2.72 \times 10^{-11} / (3.00 \times 10^{8})^{2}$ ✓ = 3.02×10^{-28} (kg) ✓ ***OR*** = 170 / 931.5 (u) ✓ (= 0.183 u)	Both marks for correct answer only allow CE from (b)(ii)	2	

	$= 3.03 \times 10^{-28}$ (kg) ✓			

Question	Answers	Additional Comments/Guidance	Mark	ID details
3 (c)	Fission fragments are (likely) to be above/to the left of the line of stability ✓ fission fragments are (likely) to have a larger N/Z ratio than stable nuclei ***OR*** fission fragments are neutron rich owtte ✓ and become neutron or β- emitters ✓	Ignore any reference to α or γ emission. A candidate must make a choice for the first two marks. Stating that there are more neutrons than protons is not enough for a mark. (look at diagram) 1st mark reference to graph 2nd mark – high N/Z ratio or neutron rich 3rd mark beta minus Note not just beta.	3	
Total			**11**	

Question	Answers	Additional Comments/Guidance	Mark	ID details
4 (a) (i)	(use of mean kinetic energy = 3/2 k T) $= 3/2 \times 1.38 \times 10^{-23} \times (273 + 25.0)$ ✓ 6.17×10^{-21} (J) ✓		2	
4 (a) (ii)	total internal energy = $6.17 \times 10^{-21} \times 1.50 \times 6.02 \times 10^{23}$ = 5.57×10^{3} (J) ✓	Allow ecf from 4 (a)(ii)	1	
4 (b)			Max 6	

Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response.

Level 1 (1 – 2 marks) Low Level	Level 2 (3 – 4 marks) Intermediate Level	Level 3 (5 – 6 marks) High Level
The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. There will be a few of the guidance points mentioned, but there will be little cohesion in the writing. Before taking the above into consideration a candidate making two or less relevant statements from any of the three groups of marking points listed below is placed in this level. One point for one mark and two points for two marks	The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. Before taking the above into consideration a candidate making three or four relevant statements from any of the three groups of marking points listed below will be placed in this level. If all the statements come from only one group a score of 3 marks will be given. Four points from at least two groups will score 4 marks.	The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. Before taking the above into consideration a candidate making five or more relevant statements from two or three groups of marking points listed below will be placed in this level. Six statements covering all three groups scores 6 marks but if five or more only come from two groups a maximum score of 5 may be awarded. Significant errors in the physics will exclude a candidate from this top level.

Statements expected in a competent answer should include some of the following marking points.

Group A
molecules are in rapid random motion/many molecules are involved
molecules change their momentum or accelerate on collision with the walls

Group B
reference to Newton's 2nd law either $F = ma$ or F = rate of change of momentum

reference to Newton's 3rd law between molecule and wall
relate pressure to force $P = F/A$

Group C
mean square speed of molecules is proportional to temperature
as temperature increases so does change of momentum or change in velocity

there is a shorter time between collisions as the temperature increases

the pressure increases as the temperature increases.

Total			**9**

Question	Answers	Additional Comments/Guidance	Mark	ID details
5 (a)	(heat supplied by glass = heat gained by water) (use of $m_g\ c_g\ \Delta T_g = m_w\ c_w\ \Delta T_w$) $0.200 \times 840 \times (28.0 - T_f) = 0.250 \times 4190 \times (T_f - 2.0)$ ✓ $T_f = 5.6$ (°C) ✓	1st mark for RHS or LHS of substituted equation 2nd mark for 5.6 °C Alternatives: 6 °C is substituted into equation (on either side shown will get mark)✓ resulting in 3696 J~4190 J ✓ or 6 °C substituted into LHS ✓ (produces ΔT = 3.5 °C and hence) = 5.5 °C ~ 6 °C ✓ 6 °C substituted into RHS✓ (produces ΔT = 25 °C and hence) = 3 °C ~ 6 °C ✓ (large difference is a result of (T_f – 2.0) having a large relative error) or other alternatives using relative changes in temperature for example from 2 °C	2	

Question	Answers	Additional Comments/Guidance	Mark	ID details
5 (b)	(heat gained by ice = heat lost by glass + heat lost by water) (heat gained by ice = $mc\Delta T + ml$) heat gained by ice = $m \times 4190 \times 2.0 + m \times 3.34 \times 10^5$ ✓ (heat gained by ice = m × 342400) heat lost by glass + heat lost by water = 0.200 × 840 × (5.6 – 2.0) + 0.250 × 4190 × (5.6 – 2.0) ✓ (= 4376 J) *m* (=4376 / 342400) = 0.013 (kg) ✓ or (using water returning to its original temperature) (heat supplied by glass = heat gained by ice) (heat gained by glass = 0.200 × 840 × (28.0 – 2.0)) heat gained by glass = 4368 (J) ✓ (heat used by ice = $mc\Delta T + ml$) heat used by ice = $m(4190 \times 2.0 + 3.34 \times 10^5)$ ✓ (= *m*(342400)) *m* (=4368/342400) = 0.013 (kg) ✓	NB correct answer does not necessarily get full marks 3rd mark is only given if the first 2 marks are awarded the first two marks are given for the formation of the substituted equation not the calculated values if 6 °C is used the final answer is 0.014 kg or 0.015 kg.	3	
Total			**5**	