A-LEVEL
PHYSICS A
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.

Further copies of this Mark Scheme are available from aqa.org.uk

Question	Answers	Additional Comments/Guidance	Mark	ID details
1 (a)	the amount of energy required to separate a nucleus ✓ into its separate neutrons and protons/nucleons ✓ (or energy released on formation of a nucleus ✓ from its separate neutrons and protons/constituents ✓)	1st mark is for correct energy flow direction 2nd mark is for binding or separating nucleons (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	
1 (b)(i)	$2\,{}^{1}_{0}\mathrm{n}$ or ${}^{1}_{0}\mathrm{n} + {}^{1}_{0}\mathrm{n}$ ✓	must see subscript and superscripts	1	
1 (b)(ii)	binding energy of U = 235 × 7.59 ✓ (= 1784 (MeV)) binding energy of Tc and In = 112 × 8.36 + 122 × 8.51✓ (= 1975 (MeV)) energy released (=1975 – 1784) = 191 (MeV) ✓ (allow 190 MeV)	1st mark is for 235 × 7.59 seen anywhere 2nd mark for 112 × 8.36 + 122 × 8.51 or 1975 is only given if there are no other terms or conversions added to the equation (ignore which way round the subtraction is positioned) Correct final answer can score 3 marks	3	
1(b)(iii)	energy released = 191 × 1.60 × 10^{-13} ✓ (= 3.06 × 10^{-11} J)	Allow CE from (b)(ii) working must be shown for a CE otherwise full marks can be given	2	

	loss of mass (= E / c^2) = $2.91 \times 10^{-11} / (3.00 \times 10^8)^2$) = 3.4×10^{-28} (kg) ✓ or = 191/931.5 u ✓ (= 0.205 u) = $0.205 \times 1.66 \times 10^{-27}$ (kg) = 3.4×10^{-28} (kg) ✓	for correct answer only note for CE answer = (b)(ii) $\times 1.78 \times 10^{-30}$ (2.01×10^{-27} is a common answer)		
1 (c)(i)	line or band from origin, starting at 45° up to *Z* approximately = 20 reading *Z* =80, *N* = 110→130 ✓	Initial gradient should be about 1 (ie Z=20 ; N = 15 → 25) and overall must show some concave curvature. (ignore slight waviness in the line) If band is shown take middle as the line If line stops at N>70 extrapolate line to N = 80 for marking	1	
1 (c)(ii)	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 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. 1st mark reference to graph 2nd mark – high N/Z ratio or neutron rich 3rd mark beta <u>minus</u> Note not just beta.	3	
Total			**12**	

Question	Answers	Additional Comments/Guidance	Mark	ID details
2 (a)(i)	λ (= ln 2 / $T_{1/2}$ = 0.693 / 5740) = 1.2 × 10^{-4} (yr^{-1}) ✓ (1.21 × 10^{-4} yr^{-1})	only allow 3.83 × 10^{-12} s^{-1} if the unit has been changed working is not necessary for mark	1	
2 (a)(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 × 10^{-4} × t) ✓ $t = \frac{\ln\left(\frac{1}{0.375}\right)}{1.21\times10^{-4}}$ ✓ t = 8100 or 8200(yr) ✓	1st mark substitution, allow EC from (a)(i) 2nd mark rearranging, allow EC from (a)(i) Allow t / $T_{1/2}$ = 2^n approach 3rd 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	
2(b)(i) +2(b)(ii)	(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 ✓ 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 <u>C-14</u> atoms or there is very little decay	1st mark needs some reference to a change in count-rate or activity for the mark Be lenient in 2nd 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, '<u>All</u> the carbon has	2	

	or the level of C-14 (in the biosphere) is uncertain (this long ago)✓	decayed'.		
Total			**6**	

Question	Answers	Additional Comments/Guidance	Mark	ID details
3 (a)	the number of atoms in 12g of carbon-12 or the number of particles/atoms/molecules in one mole of substance ✓	Not – N_A quoted as a number	1	
3 (b)(i)	mean kinetic energy (= 3/2 kT) = $3/2 \times 1.38 \times 10^{-23} \times (273 + 22)$ $= 6.1 \times 10^{-21}$ (J) ✓	6×10^{-21} J is not given mark	1	
3 (b)(ii)	mass of krypton atom = $0.084 / 6.02 \times 10^{+23}$ ✓ (= 1.4×10^{-25} kg) $\overline{c^2}$ (= 2 × mean kinetic energy / mass = $2 \times 6.1 \times 10^{-21} / 1.4 \times 10^{-25}$) = $8.7 - 8.8 \times 10^{4}$ ✓ $m^2\ s^{-2}$ or $J\ kg^{-1}$ ✓	1st mark is for the substitution which will normally be seen within a larger calculation. Allow CE from (b)(i) Working must be shown for a CE otherwise full marks can be given for correct answer only. No calculation marks if mass has a physics error i.e. no division by N_A note for CE answer = (b)(i) × 1.43×10^{25}	3	
3 (c)	(at the same temperature) the	1st mark requires the word	2	

	mean kinetic energy is the same Or Gases have equal $\frac{1}{2}mc^2_{rms}$ Or mass is inversely proportional to mean square speed / m $\propto 1/\overline{c^2}$ ✓ $\overline{c^2}$ or mean square speed of krypton is less ✓	mean/average or equivalent in an algebraic term 2nd mark 'It' will be taken to mean krypton. So, 'It is less' can gain a mark Allow 'heavier' to mean more massive' Allow vague statements like speed is less for 2nd mark but not in the first mark		
Total			**7**	

Question	Answers	Additional Comments/Guidance	Mark	ID details
4 (a)	the energy required to change the state of a unit mass of water to steam/gas ✓ when at its boiling point temperature /100°C / without a change in temperature) ✓	Allow 1 kg in place of unit. Allow liquid to vapour/gas without reference to water. Don't allow 'evaporation' in first mark.	2	
4 (b)(i)	thermal energy given by copper block (= $mc\Delta T$) = 0.047 × 390 × (990 – 100) = 1.6 × 10^4 (J) ✓ 2 sig figs ✓	Can gain full marks without showing working A negative answer is not given credit. sig fig mark stands alone	2	
4(b)(ii)	thermal energy gained by water		2	

	and copper container ($=mc\Delta T_{\text{water}} + mc\Delta T_{\text{copper}}$) $= 0.050 \times 4200 \times (100 - 84) +$ $0.020 \times 390 \times (100 - 84)$ or = 3500 (J) ✓ (3485 J) available heat energy ($=1.6 \times 10^4$ $- 3500) = 1.3 \times 10^4$ (J) ✓ allow both 12000J and 13000 J	Allow CE from (b)(i) working must be shown for a CE Take care in awarding full marks for the final answer – missing out the copper container may result in the correct answer but not be worth any marks because of a physics error. (3485 is a mark in itself) ignore sign of final answer in CE (many CE's should result in a negative answer)		
4(b)(iii)	(using $Q = ml$) $m = 1.3 \times 10^4 / 2.3 \times 10^6$ = 0.0057 (kg) ✓ Allow 0.006 but not 0.0060 (kg)	Allow CE from (b)(ii) answers between 0.0052 → 0.0057 kg resulting from use of 12000 and 13000 J	1	
Total			**7**	

Question	Answers	Additional Comments/Guidance	Mark	ID details
5 (a)	It forms a (biological) shield to reduce the (intensity of) radiation from/ for protection from ✓ <u>neutron</u> (and gamma) radiation ✓	Be lenient in 1st mark. 'Absorbs radiation' is enough to score.	2	
5(b)	See below - QWC		6	
Total			**8**	

QWC Mark Scheme

question	answers	extra information	mark
5 (b)			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. Examiners should also refer to the information on page 4 and apply a 'best-fit' approach to the marking.

0 marks	Level 1 (1–2 marks)	Level 2 (3–4 marks)	Level 3 (5–6 marks)
	Low Level (Poor to limited): 1 or 2 marks 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	**Intermediate Level (Modest to adequate): 3 or 4 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	**High Level (Good to excellent): 5 or 6 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

	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	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.	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 or order of events will exclude a candidate from this top level.

examples of the points made in the response	**extra information**
Statements expected in a competent answer should include some of the following marking points. X group X ($\beta^- \gamma$) needs significant screening(allow lead here) is highly active therefore produces heat as activity $\propto$ 1/ half-life (only counted once regardless of which group it is in) so lasts for a short time quoted as 80 days or more Y group Y (α) is easy to screen with metal container (if metal is quoted it must be realistic ie not lead) as activity $\propto$ 1/ half-life (only counted once) is active for a very long time quoted as 80 years or more problems over container fatigue Treatment group By remote control remove waste <u>initially</u> place in a cooling pond/water tank the water acts as a shield water dissipates heat/lowers temperature <u>cooling pond</u> is on site/close to source as activity $\propto$ 1/ half-life(only counted once)	Marking strategy add up points made by candidates from the list to give an initial score. Low band If 2 points or less are given the number will be the lower band score. Middle Band If 3 points or 4 are given this is the score provided some points are given in two of the groups. Otherwise a score of 3 is given. Top band If 5 or 6 points are given this is the score but some must be made in each of the 3 groups. If from 2 groups score 5 if from 1 group score 3. If the script gives points but they are out of order, eg. put in steel barrels and then place in cooling ponds, Or if some true facts are mixed with some erroneous ones the candidate cannot be in the top band. Once the script has been read through the mark may be adjusted as a consequence of the organisation and style of the writing. facts must be related to the situation to be of value. So ‘Alpha radiation is highly ionising and

keep for 1 – 3 years – it will then be cooler highly active waste will be greatly reduced make suggestions for longer term storage – vitrify the active material (to prevent leaking) store underground storage/salt mines in barrels / steel containers geological considerations etc	dangerous to the body' is not a main fact as it is assumed all radiations are harmful. Also facts must be realistic to be considered. 'It is best to store the radioactive waste in lead boxes to screen workers from the radiation' may have some merit but it would not count as a fact.