

Name of the Student: \_\_\_\_\_

Max. Marks : 19 Marks

Time : 19 Minutes

Mark Schemes

### Q1.

(a)  $1\checkmark$  idea of **maximising distance**

use tongs / tweezers / handling tool (when handling source to keep as far away from source as possible)

OR keep at least 2 metres away (if observing)

*award 1 mark for each valid procedure (unless contradicted)*

*do not award more than 1 mark for safety procedure 1 and do not award more than 1 mark for safety procedure 2*

*do **not** credit the same marking point for **different** do not award more than 1 mark for safety procedure 1 procedures*

*for  $1\checkmark$  treat as neutral: 'keep source at arm's length / far away' / 'use pliers' / don't go close (to the source)*

$2\checkmark$  idea of **limiting exposure time during** experiment

remove source from lab / room when not in use / after experiment

OR idea of put / replace / keep source in a castle / container when not in use / in the open / after experiment or write

*for  $2\checkmark$  do not insist on 'lead'*

*treat as neutral: 'use a lead container'*

*treat as neutral: 'limit time of exposure' / 'work as quickly as possible' / 'don't keep source out of box for too long' / 'keep source sealed'*

$3\checkmark$  is about **shielding** using a named absorber

stand behind a lead absorber / screen (when source is in the open)

*for  $3\checkmark$  accept aluminium or steel for lead; use of lead apron*

$4\checkmark$  is safe use of source when removed from castle

never point (open end of) the source at anyone / at yourself

OR do not look directly at / look into the source

*for  $4\checkmark$  accept 'avoid eyes'*

*treat as neutral: 'avoid direct contact' / 'don't touch source' / 'always point source at ground'*

$5\checkmark$  is about **good practice**

read local rules (about the use of radioactive sources) /

OR read / post warning / notice on the door

for <sub>5</sub> ✓ accept 'report any damage to a source'

treat as neutral: 'use safety screen' / 'don't stand in front' / 'don't ingest / swallow' / 'wash hands after use' / 'wear safety glasses / goggles / gloves / lab coats' / 'use film badge'

no credit for procedures that are the responsibility of the teacher / radiation protection adviser, eg 'obtained signed consent form'

MAX 2

(b) 5 ✓

correct answer only

1

(c) A

OR  $^{222}_{86}\text{Rn}$  / radon 222 /  $\text{Rn}_{222}$  ✓

B

OR  $^{218}_{84}\text{Po}$  / polonium 218 /  $\text{Po}_{218}$  ✓

I

OR  $^{210}_{82}\text{Pb}$  / lead 210 /  $\text{Pb}_{210}$  ✓

if candidates have provided more than 3 responses, each extra error / contradiction negates one correct response; if there are 3 or more errors / contradictions, award no marks

answers may be given **in any order**

accept unnamed isotope with correct A, Z eg  $^{222}_{86}\text{X}$

eg while the suggestion that A, B and I are correct earns 3 the suggestion that A, B, I and J are correct earns 3 – 1 = 2

3

(d) suitable procedures to eliminate systematic error are:

remove (all radioactive) source(s) (from the room)

OR

measure  $A_b$  before the source is present / in another room

OR

put source in (lead) castle / (lead) container / behind a (lead) absorber <sub>1</sub> ✓

zero / reset the counter AND/OR stopwatch (before use)

do not insist on references to systematic or random error but give no credit for explicit talk-out eg 'use a long integration time to eliminate systematic error'

for <sub>1</sub> ✓ treat as neutral: 'measure  $A_b$  with no source near' / 'check source is shielded / far away / out of range / sealed' / 'in another area' / 'point detector away from the source (or vice-versa)' / 'don't point source at counter' / 'put detector behind source'

OR

check the counter AND/OR stopwatch has no zero error <sub>2</sub>✓

*for <sub>2</sub>✓ treat as neutral: 'zero / reset the equipment (before use)' / 'zero the detector'*

measure  $A_b$  on same day as experiment is carried out <sub>3</sub>✓

*for <sub>3</sub>✓ treat as neutral: 'measure  $A_b$  after experiment to double-check'*

measure  $A_b$  in same room / location / area as that where experiment is to be carried out <sub>4</sub>✓

*for <sub>4</sub>✓ treat as neutral: / 'keep detector in the same position' / 'measure  $A_b$  in different positions'*

suitable procedure to reduce percentage uncertainty in  $A_b$  is:

use long(er) (integration) time / prolonged time

OR

(total of) at least 100 s <sub>5</sub>✓

*for <sub>5</sub>✓ accept idea of a suggested total time, taking account of repeats, exceeding 100 s (eg 10 repeated 10 s counts and 1 single 100 s single count amount to the same thing) treat as neutral: 'repeat and average' ignore anomalous results' / 'use room with high background count / record large reading' / 'use more than one detector'*

MAX 3

(e) use of 5.5 MeV shown by **working** on **Figure 4** <sub>1</sub>✓

minimum thickness MAX 3sf that rounds to 12 mm <sub>2</sub>✓<sub>3</sub>✓

OR

minimum thickness MAX 3sf that rounds to 11 mm / MAX 3sf that rounds to 13 mm <sub>23</sub>✓

*for <sub>1</sub>✓ use of 5.5 MeV can be inferred from **Figure 4** as a (horizontal) **line, a mark** on the vertical axis or **a mark** on the curve / intersection between curve and a vertical line, **above 5 MeV and below 6 MeV**; a single line / mark between 5 and 6 MeV with no subsequent working can score <sub>1</sub>✓*

*any line does not have to be ruled or perfectly parallel to the grid line; allow a cross or a small blob as the mark on the curve;*

*do not insist on seeing a vertical line*

*if more than one line is drawn / mark is made then mark as per scheme if a clear decision has been made about which read-off has been used to provide the result for the **thickness**;*

*allow only one **thickness** given as final answer*

*<sub>2</sub>✓ <sub>3</sub>✓ OR <sub>23</sub>✓ can be earned without any working on the grid / other intermediate working*

OR

use of 7.8 MeV shown by working on **Figure 4** AND minimum thickness is 16, 17 or 18 mm <sub>123</sub>✓

*for <sub>123</sub>✓ use of 7.8 MeV can be inferred from **Figure 4** as a line,*

(f)  $d = \sqrt{k} \times \frac{1}{\sqrt{A}} - e$  OR  $d = \sqrt{k} \times \sqrt{\frac{1}{A}} - e$  OR  $d = \sqrt{\frac{k}{A}} - e$  seen 1✓

states  $\sqrt{k}$  = gradient OR  $k$  = gradient<sup>2</sup> 2✓

gradient from  $\Delta d$  divided by  $\frac{1}{\sqrt{A}}$  with  $\Delta \frac{1}{\sqrt{A}} \geq 0.5$  3✓

$k$  minimum 2 sf in range  $1.7(0) \times 10^5$  to  $1.9(5) \times 10^5$  4✓

unit for  $k$  = mm<sup>2</sup> Bq or mm<sup>2</sup> s<sup>-1</sup> 5✓

for **statement** that  $k$  = gradient mark as follows:

for  $d = k \times \frac{1}{\sqrt{A}} - e$  **AND**  $k$  = gradient 12✓ = 1 MAX;

award 3✓ as above

45✓ = 1MAX ecf for the following:

$k$  in range 410 to 450 or 2 sf  $4.1$  to  $4.5 \times 10^2$  mm Bq<sup>0.5</sup> or mm s<sup>-0.5</sup>

OR

$k$  in range 0.41(0) to 0.45(0) m Bq<sup>0.5</sup> or m s<sup>-0.5</sup>

OR

$k$  in range 41.(0) to 45.(0) cm Bq<sup>0.5</sup> or cm s<sup>-0.5</sup>

for 1✓  $d$  must be the subject;

allow obvious slips, eg  $D$  for  $d$

for 2✓ allow  $\sqrt{k} = m$  if  $y = mx + c$  is quoted so inference that  $\sqrt{k} =$  gradient is clear; this mark is for **explaining** the step and **not** for performing the calculation

for 3✓ the mark is for the process, not the result; evidence of acceptable steps on grid with plausible result are enough; no credit if false origin missed allow working subsumed into calculation of  $k$

for 4✓ gradient based on  $d$  in mm (expected = 433 mm Bq<sup>0.5</sup>) POT 10<sup>5</sup> required

for 5✓ the unit given for  $k$  must be consistent with the POT of the result for  $k$  / gradient<sup>2</sup>

order not important Bq mm<sup>2</sup> is acceptable; do not accept incorrect symbol, eg bq for Bq

otherwise:

if for 4✓ gradient based on  $d$  in m (expected  $\approx 0.43$  m Bq<sup>0.5</sup>)  $k$  in range 0.17(0) to 0.19(5)

then for 5✓ m<sup>2</sup> Bq or m<sup>2</sup> s<sup>-1</sup>

if for  $\checkmark_4$  gradient based on  $d$  in  $\text{cm}$  (expected  $\approx 43 \text{ cm Bq}^{0.5}$ )  $k$  in range  $1.7(0) \times 10^3$  to  $1.9(5) \times 10^3$   
 then for  $\checkmark_5$   $\text{cm}^2 \text{ Bq}$  or  $\text{cm}^2 \text{ s}^{-1}$

2  
1  
2

(g) second mark ( $\checkmark_2$ ) is contingent on award of first ( $\checkmark_1$ )

an unsupported answer or an answer obtained by scale drawing or by extrapolation off the grid score zero

attempts to find  $e$  by calculation by any valid method using gradient or  $k$  with all data **correctly** substituted in **their** expression;

allow use of  $y$  for  $d$ ,  $x$  for  $\frac{1}{\sqrt{A}}$ ,  $m$  for  $\sqrt{k}$  and  $c$  for  $e$ ;

attempts to solve for  $e$   $\checkmark_1$

for  $\checkmark_1$  use of  $y = mx + c$  with recognisable data **correctly** substituted, eg

$e = \text{their gradient} \times \frac{1}{\sqrt{A}} - d$  with substitution of their gradient and

values of values of  $d$  and  $\frac{1}{\sqrt{A}}$  from a point on the line from **Figure 6**  
 OR

$e = \sqrt{k} \times \frac{1}{\sqrt{A}} - d$  with substitution of their  $k$  etc  
 OR

(-)  $e = \text{gradient} \times \text{horizontal intercept}$ , with substitution of their gradient and horizontal intercept

ignore POT errors in their gradient / their  $k$ ;

allow mixed units and read-off errors of 1 small square

1

$\geq 2$  sf result in range  $\geq 28(.0)$  and  $\leq 32(.0)$  (mm)  $\checkmark_2$

for  $\checkmark_2$  answer in range only (no ecf from 01.6) allow negative answer

1

[19]