Name of the Student:_____
Max. Marks : 18 Marks **Time : 18 Minutes**

Mark Schemes

Q1.

(a) (i) momentum (= *E/c*)
= $5.94 \times 10^{-11} / 3.00 \times 10^{8} = 2.0 \times 10^{-19}$ (kg m s^{-1})
($= 1.98 \times 10^{-19}$ kg m s^{-1})
Or evidence of use of $E = hc / \lambda$ ✔
$\lambda = (h / mv = 6.63 \times 10^{-34} / 1.98 \times 10^{-19}) = 3.35 \times 10^{-15}$ (m) ✔
(allowable range 3.32×10^{-15} - 3.37×10^{-15} m)

3.348×10^{-15} m alone may score 1 mark

A completed calculation to at least 3 sf must be seen for 2nd mark

2

(ii) nuclear radius = 0.61λ / sin $\theta = 0.61 \times 3.35 \times 10^{-15}$ / sin 42°
$= 3.1 \times 10^{-15}$ (m) ✔ (allow $2.95 – 3.1 \times 10^{-15}$ m which is a range incorporating 3.32×10^{-15} - 3.37×10^{-15} m and 42° – 43°)

(The answer must be to 2 sf or better

note 3.3×10^{-15} , 42° gives 3.008×10^{-15} m i.e. 3.0×10^{-15})

1

(b) (i) diagram to show a labelled α source, foil target and detector (which is not simply a forward facing screen so there must be some indication it can move around the target e.g. a curved arrow / positioned at an angle / or screen curved round target or detectors shown in at least two positions) ✔

with evacuated vessel or an item to collimate the beam ✔ (the evacuated vessel does not have to be drawn so a simple label of 'in a vacuum' will gain the mark.) (A tube or a plate(s) must be drawn with a collimator label or a label on an emergent alpha beam from the drawn item (which is distinct from the source) will gain a mark)

'detector' has alternatives e.g. fluorescent screen / scintillator / zinc sulphide

2

(ii) The mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC).

Descriptor
High Level – Good to Excellent
Both observations should be given ie most α particles pass straight through the foil and that some α's are backscattered. Again both of these must be explained. Additionally one approach to finding the upper limit to the radius must be given and interpreted.
The information presented as a whole should be well organised using appropriate specialist vocabulary. There should only be one or two spelling or grammatical errors for this mark.

6 marks = all 3 bullet points covered in full.

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5 marks = Same as 6 marks but one explanation is omitted or poorly expressed

5 - 6

Intermediate Level – Modest to Adequate

Both observations should be given ie most α particles pass straight through the foil and that some α's are backscattered. Both of these observations can be explained or one of them explained along with the observation necessary to obtain the upper limit to the nuclear radius but without the explanation of how to use the data.

The grammar and spelling may have a few shortcomings but the ideas must be clear.

4 marks = for first two bullet points covered in full.

Alternatively both observations given but only one explained along with an observation necessary to find the upper limit to the nuclear radius.

3 marks = for both observations given but only one explained

3 - 4

Low Level – Poor to Limited

Any two observations or interpretations but an interpretation must come with the appropriate observation.

There may be many grammatical and spelling errors and the information may be poorly organised.

2 marks for two observations or one observation along with its interpretation.

1 mark = Any observation..

1 - 2

The description expected in a competent answer should include:

1. most α particles pass straight through
2. which suggests an atom is composed of mainly open space
3. α particles can be backscattered or scattered by more than 90°
4. which suggests

i. they have collided with something more massive than themselves (using momentum considerations)

ii. they have been repelled by a concentrated positive charge (using coulomb repulsion)

these together suggest a 'solar system' configuration for the atom.

5. Consider the proportion of α's passing straight through the foil, i.e. how much of the straight through beam is stopped by the foil.

Or

Appreciate that scattering of α's close to 180° takes place which means the α's have not touched the nuclear surface.

6. First alternative data can be related to how much of the beam is intercepted by nuclei. Using the number of atomic layers / thickness of foil and the nuclear cross-sectional area the upper limit to the radius may be found

Or If second alternative is used some detail is needed to gain this point.

Either a discussion of the loss KE = gain PE to find upper limit to the radius

Or the idea that backscattering is not observed / falls off if the alpha comes close to the nucleus because the strong nuclear force (SNF) takes over and so provides an upper limit to the radius.

(owtte)

Do not award 'large space between atoms'.

The question is a QWC and not all the points are expected to be given as detailed on the left. This check list gives a brief idea of the main parts expected.

(note the pairing of 1 and 2, 3 and 4, 5 and 6 where the second of each pair cannot be given in isolation but the first of each pair does not have to perfect)

If it is obvious the candidate is talking about an alpha particle but calls it

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something different do not over penalise. E.g. miss out a pairing of marks then mark as if alpha)

Quick check list.

1. Most alpha's go straight on

2. Because an atom has mainly empty space

3. A few alpha's are backscattered

4. Because of nuclear positive charge or large nuclear mass

5. Method suggested to find R (drop in straight on beam Or backscattering means α's have not touched nucleus)

6. Some detail such as ref. to (nuclear) area <u>and</u> (foil) thickness Or alpha KE to PE giving r Or if α's touch surface SNF stops scattering.

[11]

Q2.

(a) nuclear fallout / testing / weapons / nuclear accidents / Chernobyl / nuclear waste / nuclear medicine / X-rays / specific uses of radioactive sources eg medical tracers CT scan etc. / cosmic rays as a result of air travel ✔

(Any source of radiation that an individual may encounter which would not have existed 100 years ago)

No mark for general answers such as 'medical' or Nuclear Power / nuclear plant.

If a list is given all must be correct but ignore generalisations such as medical or nuclear power.

1

(b) (i) $I_{15CCR} = 2050 - 40 = 2010$ ✔

Use of inverse square law eg $I_{CCR90} = I_{CCR15} \left(\frac{d_{15}}{d_{90}}\right)^2$ = 2010 × (0.15 / 0.90)^2 = 55.8

$I_{90CR} = 55.8 + 40$

$I_{90CR} = 96$ counts min^{-1} ✔

regardless of order:

1st mark subtraction of background in original data

2nd mark is for using inverse square function

3rd mark is for the answer

3

(ii) (reduce impact of) random error / decrease the (percentage) uncertainty / improve the statistics (because the percentage error is proportional to the inverse square-root of the count) ✔ (owtte)

The answer must be an uncertainty related statement and not increases reliability / accuracy or increased chance of a reading (although these ideas can accompany a correct answer) Ignore comparisons with the background count.

1

(iii) use (sensible) absorber between source and detector ✔ (sensible absorber means it must have a noticeable effect e.g. 1mm of metal / aluminium sheet / 5mm perspex but do not allow metal foil / paper sheets. Also its effect must not be so great that it reduces the gamma rays noticeably)

(These two marks are independent)

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β shown by count rate falling when sheet of aluminium absorber is used ✔ Or (using the existing apparatus)
Compare the results (at various distances) in air with the expected inverse square law ✔
Below the range of beta law does not work but above range it does. ✔

2nd mark no mark given if count rate falls to zero as γ is still present

(magnetic deflection is not common but if seen.

Use of magnetic deflection ✔ correct deflection of beta from the beam ✔)

(If a cloud chamber is suggested. Observe the tracks in a cloud chamber ✔ beta tracks have varying lengths or they are curly / not straight ✔

(The value of the range of beta is not a marking point so accept 15 – 80 cm if a number is given)

2

[7]

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