M1.(a) A α particles ✓

[auto mark question]

1

(b) (i)

type of radiation	Typical range in air / m
α	0.04 ✓
β	0.40 ✓

Allow students to use their own distance units in the table
α allow 0.03 → 0.07 m
β allow 0.20 → 3.0 m.
If a range is given in the table use the larger value.
A specific number is required e.g. not just a few cm.

2

(ii) reference to the inverse square law of (γ radiation)
or
reference to lowering of the solid angle (subtended by the detector as it moves away)
or
radiation is spread out (over a larger surface area as the detector is moved away) ✓

(owtte)
Ignore any references to other types of radiation.
Any contradiction loses the mark. For example, follows inverse square law so intensity falls exponentially.

1

(c) dust may be ingested / taken into the body / breathed in ✓

First mark for ingestion not just on the body

causing (molecules in human tissue / cells) to be made cancerous / killed / damaged by ionisation ✓

Second mark for idea of damage from ionisation

2

[6]

M2. (a) any 2 from:

the sun, cosmic rays, radon (in atmosphere), nuclear fallout (from previous weapon testing), any radioactive leak (may be given by name of incident) nuclear waste, carbon-14 ✓

1

(b) (i) (ratio of area of detector to surface area of sphere)

ratio = $\frac{0.0015}{4\pi(0.18)^2}$ ✓

0.0037 ✓ (0.00368)

2

(ii) activity = 0.62/(0.00368 × 1/400) give first mark if either factor is used.

67000 ✓ Bq accept s^{-1} or decay/photons/disintegrations s^{-1} but not counts s^{-1} ✓ (67400 Bq)

3

(c) (use of the inverse square law)

$\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$ or calculating k = 0.020 from $I = k/x^2$ ✓

$I_2 = 0.62 \times \left(\frac{0.18}{0.28}\right)^2$ ✓ 0.26 counts s^{-1} ✓(allow 0.24-0.26)

3

[9]

M3. (a) number correct for alpha **(1)**

number correct for beta **(1)**

alpha decay first goes via Tl **(1)**

numbers correct for Tl (208, 81) **(1)** beta decay first goes via Po **(1)**

numbers correct for Po (212, 84) **(1)**

6

(b) (i) use of GM tube + counter/rate-meter **(1)**
measurement of count rate **(1)**
at range of distances + suitable ruler or tape measure **(1)**
specifies suitable range **(1)**
determines background & corrects **(1)**
safety precaution given **(1)**
graph of count rate or corrected count rate against $1/d^2$ **(1)**

max 6

(ii) gamma not absorbed **(1)**
spreads uniformly from a point source/spherically symmetrically **(1)**
area over which it spreads is proportional to radius squared **(1)**
alpha and beta are absorbed in addition to spreading out **(1)**

max 3

[15]

M4. (a) R (= $r_0A^{1/3}$) = 1.3 × 10^{-5} × $(238)^{1/3}$ **(1)**
= 8.0(6) × 10^{-15}m **(1)**

2

(b) (use of inverse square law e.g. $\frac{I_1}{I_2} = \left(\frac{x_1}{x_2}\right)^2$ gives)

$10 = \left(\frac{x_2}{0.03}\right)^2$ **(1)**

x = 0.095 m **(1)**
(0.0949 m)

2

(c) (use *of* $A = A_o exp(-\lambda t$ gives) 0.85 = 1.0 exp (–λ52) **(1)**

$$\lambda = \frac{\ln(100/0.85)}{52}$$ **(1)**

$= 3.1(3) \times 10^{-3} s^{-1}$ **(1)**

3

(d) it only emits γ rays **(1)**
relevant properties of γ radiation e.g. may be detected outside the body/weak ioniser and causes little damage **(1)**
it has a short enough half-life and will not remain active in the body after use **(1)**
it has a long enough half-life to remain active during diagnosis **(1)**
the substance has a toxicity that can be tolerated by the body **(1)**
it may be prepared on site **(1)**

any three **(1)(1)(1)**

3

[10]