M1.(a) (i) any **one** from:

- food / drink
- rocks / building materials
- cosmic rays / rays from space
  accept correctly named example

1

(ii) any **one** from:

- nuclear power / coal power (stations)
  accept nuclear waste
- nuclear accidents
  accept named accident eg Chernobyl
- nuclear weapons testing
  accept named medical procedure which involves a radioactive source
  accept radiotherapy
  nuclear activity / radiation is insufficient
  *do **not** accept CT scans*

1

(iii) different number of / fewer protons
accept does not have 86 protons
accept only has 84 protons
or different atomic number
*do **not** accept bottom number different*
reference to mass number negates this mark

1

(b) 168
accept 169 if clear, correct method is shown
*allow **1** mark for a correct dose ratio involving the spine*
eg 2:140 etc
***or** ratio of days to dose is 1.2*
***or** ratio of dose to days is 0.83*

2

(c) (i)

Group A	Group B
J M O	K L N

all correct
any order within each group

1

(ii) similar (number) / same (number) / large (number)
accept the same specific number in each group eg three
reference to other factors such as age is neutral

1

(iii) how many people in each group developed cancer
a clear comparison is required

1

(iv) *there are no marks for **Yes** or **No** the mark is for the reason*

Yes
the benefit of having the scan is greater than the risk **or** the risk is (very) small (compared to the chance from natural causes)
accept the risk is much greater from natural causes

No
no additional risk is acceptable

1

[9]

M2. (a) (average) time taken for the amount / number of nuclei / atoms (of the isotope in a sample) to halve
or
time taken for the count rate (from a sample containing the isotope) to fall to half
accept (radio)activity for count rate

1

(b) *60* ±*3* (days)

1

indication on graph how value was obtained

1

(c) (i) cobalt(-60)

1

gamma not deflected by a magnetic field
or
gamma have no charge
dependent on first marking point
accept (only) emits gamma
gamma has no mass is insufficient
*do **not** accept any reference to half-life*

1

(ii) strontium(-90)

1

any **two** from:

- *only* has beta
- alpha would be absorbed
- gamma unaffected
- *beta penetration / absorption depends on thickness of paper*

*if thorium(-232) or radium(-226) given, max **2** marks can be awarded*

2

(iii) cobalt(-60)

1

shortest half-life

accept half-life is 5 years

dependent on first marking point

1

so activity / count rate will decrease quickest

1

(iv) *americium(-241) / cobalt(-60) / radium(-226)*

1

gamma emitter

1

(only gamma) can penetrate lead *(of this box)*

do not allow lead fully absorbs gamma

1

[14]

M3 (a) (i) 1.25 (mSv)

1

(ii) any **two** from:

- (frequent) flying
  accept stated occupation that involves flying
- living at altitude
- living in areas with high radon concentrations
  accept a specific area, eg Cornwall
- living in a building made from granite (blocks)
- having more than the average number of X-rays
  or
  having a CT scan
  accept more medical treatments
- working in a nuclear power station
  accept any suggestion that could reasonably increase the level from a specific source

2

(b) (i) to be able to see the effect of exposure (to radon gas)
or
as a control
accept to compare (the effect of) exposure (with no exposure)

1

(ii) increased levels of exposure increases the risk (of developing cancer)
accept exposure (to radon gas) increases the risk

1

smoking increases the (harmful) effect of radon
answers that simply reproduce statistics are insufficient

1

(c) LNT model – risk increases with increasing radiation (dose) level

accept in (direct) proportion
accept low doses increase the risk

1

Radiation hormesis - low radiation (dose) levels reduce the risk

1

(d) two valid points made – examples:

- animals have no choice and so should not be used
- should not make animals suffer
- better to experiment on animals than humans
- experiments lead to a better understanding / new knowledge
- experiments may lead to health improvement / cures for humans

results for animals may not apply to humans is insufficient

2

[10]

M4. (a) (i) 2.5

1

(ii) The radiation dose from natural sources is much greater than from artificial sources

1

(b) (i) any **one** from:

- different concentrations in different rooms
- to average out daily fluctuations
  accept to find an average
  accept to make the result (more) reliable / valid
  *do **not** accept to make more accurate on its own*

1

(ii) average level (much) higher (in **C** and **D**)
accept converse

1

some homes have very high level (in **C** and **D**)
*accept maximum level in **A** and **B** is low*

1

or

maximum level in some homes (in **C** and **D**) is very high
*accept higher radiation levels (in **C** and **D**) for **1** mark*

[5]

M5. (a) (i) nuclear reactor

1

star

1

(ii) nuclei are joined (not split)

accept converse in reference to nuclear fission

*do **not** accept atoms are joined*

1

(b) (i) any **four** from:

- neutron
- (neutron) absorbed by U (nucleus)

  ignore atom
  *do **not** accept reacts*
  *do **not** accept added to*
- forms a larger nucleus
- (this larger nucleus is) unstable
- (larger nucleus) splits into two (smaller) nuclei / into Ba and Kr
- releasing three neutrons and energy

  accept fast-moving for energy

4

(ii) 56 (Ba)

1

57 (La)

*if proton number of Ba is incorrect allow **1** mark if that of La is 1 greater*

1

$^{0}_{-1}\beta$

accept e for β

$^{139}_{56}Ba \longrightarrow {}^{139}_{57}La + {}^{0}_{-1}\beta$

*scores **3** marks*

1

[10]

M6. (a) (both graphs show an initial) increase in count rate

accept both show an increase

1

(b) only the right kidney is working correctly

1

any **two** from:

*if incorrect box chosen maximum of **1** mark can be awarded*
reference to named kidney can be inferred from the tick box

- count-rate / level / line for <u>right</u> kidney decreases (rapidly)
  it decreases is insufficient
- count-rate / level / line for <u>left</u> kidney does not change
  it does not change is insufficient
- radiation is being passed out into urine – if referring to right kidney
- radiation is not being passed out – if referring to the left kidney
- <u>left</u> kidney does not initially absorb as much technetium-99

2

[4]