



## Hazards and Uses of Radiation

Name: \_\_\_\_\_

Class: \_\_\_\_\_

Date: \_\_\_\_\_

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Time: **364 minutes**

Marks: **364 marks**

Comments:

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## Mark schemes

1

- (a) Nucleus splitting into two fragments and releasing two or three neutrons

1

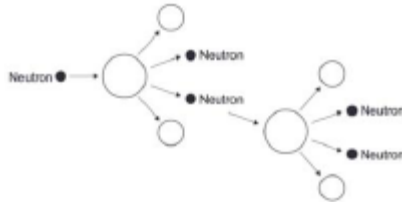
(at least one) fission neutron shown to be absorbed by additional large nucleus and causing fission

1

two or three additional neutrons released from fission reaction

1

*This diagram would gain all 3 marks:*



- (b) lowering the control rods increases the number of neutrons absorbed

*accept converse description*

1

(so) energy released decreases

1

*allow changing the position of the control rods affects the number of neutrons absorbed for 1 mark*

- (c) rate of increase between 240 and 276 (MW / min)

2

*allow 1 mark for attempt to calculate gradient of line at 10 minutes*

[7]

2

- (a) 2 protons and 2 neutrons

*accept 2p and 2n*

*accept (the same as a) helium nucleus*

*symbol is insufficient*

*do not accept 2 protons and neutrons*

1

- (b) (i) gamma rays

1

(ii) loses/gains (one or more) electron(s)

1

(c) any **one** from:

- wear protective clothing
- work behind lead/concrete/glass shielding
- limit time of exposure
- use remote handling

*accept wear mask/gloves*

*wear goggles is insufficient*

*wear protective equipment/gear is insufficient*

*accept wear a film badge*

*accept handle with (long) tongs*

*accept maintain a safe distance*

*accept avoid direct contact*

1

(d) 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 apply a 'best-fit' approach to the marking.

**Level 3 (5 – 6 marks):**

There is a description of all three types of radiation in terms of at least two of their properties

**or**

a full description of two types of radiation in terms of all three properties.

**Level 2 (3 – 4 marks):**

There is a description of at least two types of radiation in terms of some properties

**or**

a full description of one type of radiation in terms of all three properties

**or**

the same property is described for all three radiations

**Level 1 (1 – 2 marks):**

There is a description of at least one type of radiation in terms of one or more properties.

**Level 0 (0 marks):**

No relevant information

## examples of physics points made in the response

### alpha particles

- are least penetrating
- are stopped by paper / card
  
- have the shortest range
- can travel (about) 5cm in air
  
- are (slightly) deflected by a magnetic field
- alpha particles are deflected in the opposite direction to beta particles by a magnetic field

### beta particles

- (some are) stopped by (about) 2mm (or more) of aluminium/metal
- can travel (about) 1 metre in air
- are deflected by a magnetic field
- beta particles are deflected in the opposite direction to alpha particles by a magnetic field

*accept (some are) stopped by aluminium foil*

### gamma rays

- are the most penetrating
- are stopped by (about) 10cm of lead
- have the longest range
- can travel at least 1 km in air
- are not deflected by a magnetic field

6  
[10]

3

(a) cell damage or cancer

*accept kills / mutates cells*

*radiation poisoning is insufficient*

*ionising is insufficient*

1

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

- use tongs to pick up source
- wear gloves
- use (lead) shielding
- minimise time (of exposure)
- maximise distance (between source and teacher).

*accept any other sensible and practical suggestion*

*ignore reference to increasing / decreasing the number / thickness of lead sheets*

1

(ii) background

1

- (c) (i) curve drawn from point 2, 160  
do **not** accept straight lines drawn from dot to dot 1
- (ii) (also) increases  
less radiation passes through is insufficient 1
- (iii) 50  
accept any value from 40 to 56 inclusive 1
- (d) gamma 1
- only gamma (radiation) can pass through lead  
accept alpha **and** beta cannot pass through lead  
a general property of gamma radiation is insufficient 1

[8]

4

- (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)  $60 \pm 3$  (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]

5

(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

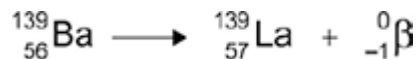
57 (La)

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

1



*accept e for  $\beta$*



*scores 3 marks*

1

[10]

6

(a) (i) 18

1

(ii) the count rate for the source

1

(iii) the alpha radiation would not cover such a distance

1

(iv) plots correct to within  $\frac{1}{2}$  small square

*allow 1 mark for 4 correct points plotted*

2

correct curve through points as judged by eye

1

(v) two attempts at finding 'half-distance' using the table

*20 to 10 cpm  $d = 0.4$  m*

*125 to 56 cpm  $d = 0.2$  m*

*31 to 14 cpm  $d = 0.4$  m*

*allow 1 mark for one attempted comparison*

2



obeyed or not obeyed

*dependent on previous two marks*

1

- (b) (i) there is no effect on the count rate in experiment 1 because the field is parallel  
**or** beta particles are not deflected **or** there is no force

1

count rate is reduced in experiment 2 because field is perpendicular **or** beta particles are deflected **or** there is a force

1

- (ii) only background radiation (as beta do not travel as far)

1

slightly different values show the random nature of radioactive decay

1

[13]

7

- (a) cosmic rays

1

radon gas

1

- (b) (i) Radioactive decay is a random process

1

- (ii) 19

1

- (iii) 140

*accept 159 – their (b)(i) correctly calculated*

1

- (iv) gamma

1

the count stayed the same

1

**or**

gamma does not have a charge

*accept gamma is an electromagnetic wave*

(so) gamma is not deflected / affected by the magnetic field

*accept magnet for magnetic field*

*do **not** accept is not attracted to the magnet*

*last two marks may be scored for an answer in terms of why it cannot be alpha or beta*

*only answer simply in terms of general properties of gamma are insufficient*

1

(c) lead absorbs (some of the) radiation  
*accept radiation cannot pass through (the lead)*

**or**

less radiation emitted into the (storage) room

1

(d) Should radioactive waste be dumped in the oceans

1

**[10]**

**8**

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

- nuclear power (stations)  
*accept nuclear waste*  
*accept coal power stations*
- nuclear weapons (testing)  
*accept nuclear bombs / fallout*
- nuclear accidents  
*accept named accident, eg Chernobyl or Fukushima*  
*accept named medical procedure which involves a radioactive source*  
*accept radiotherapy*  
*accept X-rays*  
*accept specific industrial examples that involve a radioactive source*  
*nuclear activity / radiation is insufficient*  
*smoke detectors is insufficient*

1

(ii) (radioactive decay) is a random process

*accept an answer in terms of background / radiation varies (from one point in time to another)*

1

(b) any **one** from:

- (maybe) other factors involved  
*accept a named 'sensible' factor, eg smoking*
- evidence may not be valid  
*accept not enough data*
- may not have (a complete) understanding of the process (involved)

1

(c) (i) 2

1

2

1

(ii) 218

*correct order only*

1

84

1

(d) 3.8 (days)

*allow 1 mark for showing correct method using the graph provided  
no subsequent steps*

*correct answers obtained using numbers other than 800 and 400  
gain 2 marks provided the method is shown*

2

[9]

9

(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*

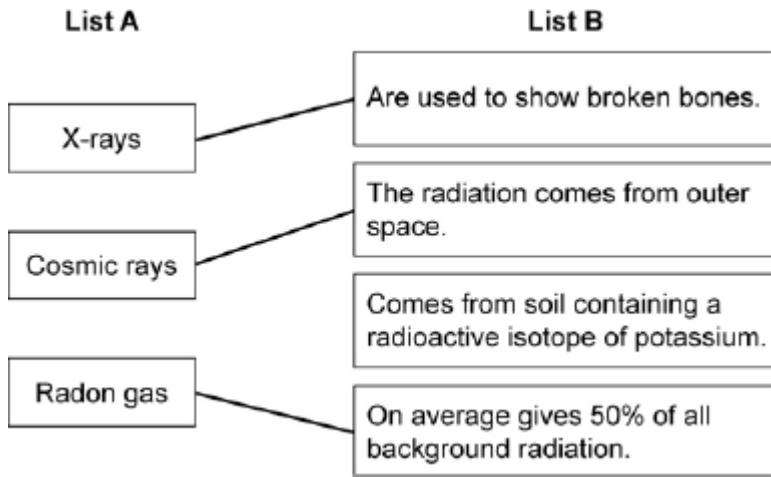
- count-rate / level / line for right kidney decreases (rapidly)  
*it decreases is insufficient*
- count-rate / level / line for left kidney does not change  
*it does not change is insufficient*
- radiation is being passed out into urine – if referring to right kidney
- radiation is not being passed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

2

[4]

10

(a) 1 mark for each correct line



*if more than 1 line has been drawn from a box in List A then all those lines are marked incorrect*

3

(b) higher in village B

1

by 6 units

*allow 1 mark for correctly obtaining a height difference of 180 (m) / 4 times higher – this refers to height not radiation levels*

*accept for 3 marks in village A it is 2 units (extra) and in village B it is 8 units (extra) allow 1 mark for a correct radiation calculation based on incorrect height readings*

2

[6]

11

(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]

12

(a) (i) on average, cosmic rays produce less background radiation than rocks.

1

having no X-rays reduces a person's radiation dose.

1

(ii) 4

*allow 1 mark for 350 / 4*

*allow 1 mark for an answer 3.5*

2

(b) (i) (risk) increases

1

(ii) C

*reason only scores if **C** chosen*

1

shows a lower risk for low doses (than for zero exposure)

*accept risk reduces when you go from low to moderate (doses)*

1

(c) (i) *no mark for YES or NO, marks are for the explanation*

YES

fewer mice exposed first to a low dose

1

get cancer (than those only exposed to a high dose)

*only scores if first marking point scores*

NO

the results are for mice (1)

and may not be applicable to people (1)

1

(ii) ethical

1

[10]

13

- (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]

14

(a) cobalt-(60)

1

gamma (radiation) will pass through food / packaging  
*this can score if technetium chosen*

1

long half-life so level of radiation (fairly) constant for (a number) of years  
*this can score if strontium / caesium is chosen*  
*accept long half-life so source does not need frequent replacement*  
*accept answers in terms of why alpha and beta cannot be used*  
*gamma kills bacteria is insufficient*

1

(b) (i) people may link the use of radiation with illness / cancer  
*accept (they think) food becomes radioactive*  
*accept (they think) it is harmful to them*  
*'it' refers to irradiated food*

1

(ii) not biased / influenced (by government views)

1

- (iii) any **two** from:
- data refers only to (cooked) chicken
  - data may not generalise to other foods
  - the content of some vitamins increases when food / chicken is irradiated
  - no vitamins are (completely) destroyed
  - (only) two vitamins decrease (but not significantly)  
*accept irradiated chicken / food contains a higher level of vitamins*  
*marks are for the explanation only*

2

- (iv) so can choose to eat / not eat that (particular) food  
*accept irradiated food may cause health problems*  
*(for some people)*  
*accept people may have ethical issues*  
*(over eating irradiated food)*

1

- (c) (i) electron  
from nucleus / neutron  
***both parts required***

1

- (ii) 90 years  
*allow 1 mark for showing 3 half-lives*

2

[11]

15

- (a) (i) half / 50 %
- (ii) Measure the radon gas level in more homes in this area
- (b) (i) 86
- (ii) 222

1

1

1

1

[4]



16

(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)

<b>Group A</b>	<b>Group B</b>
<b>J M O</b>	<b>K L N</b>

*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

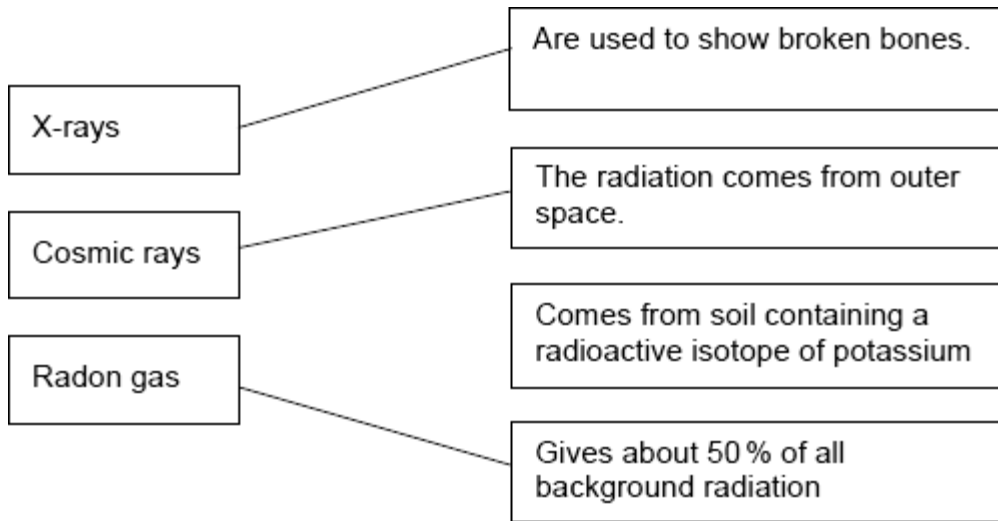
1

**[9]**

17

1 mark for each correct line

If more than 1 line has been drawn from a box in **List A** then all those lines are marked incorrect.



[3]

18

(a) gamma will pass through the body

*it refers to gamma*

**or**

alpha will not pass through the body

*answers must relate to the body*

*accept skin for body*

1

gamma is only slightly ionising

*accept gamma causes less damage to cells / tissue*

**or**

alpha is heavily ionising

*do **not** accept gamma causes no damage to cells*

*less harmful is insufficient*

1

(b) (i) (both graphs show an initial) increase in count-rate

*accept both show an increase*

1

(ii) 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 right kidney decreases (rapidly)  
*it decreases is insufficient*
- count-rate / level / line for left 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

2

- (c) (i) time taken for number of nuclei to halve  
**or**  
time taken for the count-rate to halve

1

- (ii) short half-life – the level of radiation (in the body) decreases rapidly  
*it refers to short life isotope*

1

to a safe / very small level

**or**

a long half-life – the radiation remains in the body / for a long time

level of radiation remains high

*answers in terms of damage eg cancer are insufficient*

1

[9]

19

- (a) (i) 2.5

1

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

1

- (b) (i) other factors may be involved

*accept a specific suggestion*

*eg they may be exposed to other types of radiation*

*accept cannot be sure (in many cases) that the cause of death is  
radon (poisoning)*

1

(ii) 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

(iii) 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*

**or**

maximum level in some homes (in **C** and **D**) is very high

*accept higher radiation levels (in **C** and **D**) for 1 mark*

1

**[6]**

**20**

(a) (i) half /  $\frac{1}{2}$  / 50%

*accept 1 (part) in 2 (parts) 1*

1

(ii) (the) food (we eat) is radioactive

*accept because of the food (we eat)*

*accept we breathe in radon*

*radon in the air is neutral*

1

(b) higher in village B

1

by 6 units

*allow 1 mark for correctly obtaining a height difference of 180(m)/ 4 times higher – this refers to height and not radiation levels*

*accept for 3 marks in village A it is 2 units (extra) and in village B it is 8 units (extra)*

*allow 1 mark for a correct radiation calculation based on incorrect height readings*

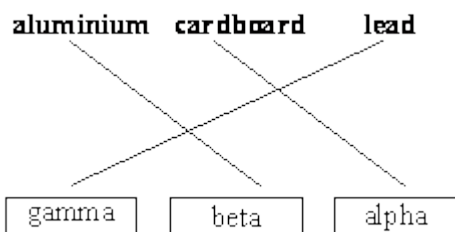
2

**[5]**

21

- (a) (i) **P** 1  
(ii) **Q** 1

(b) 3 lines correct



*allow 1 mark for 1 correct line*  
*two lines drawn from any source or box – both incorrect*

2

- (c) (i) **K** 1  
(ii) 56 1  
*accept 50 – 60 inclusive*  
(iii) **K** 1  
(iv) to inject... tracer 1

[8]

22

- (a) (i) beta and gamma 1  
*both answers required*  
*accept correct symbols*  
(ii) alpha and beta 1  
*both answers required*  
*accept correct symbols*  
(iii) gamma 1  
*accept correct symbol*

(b) nothing (you do to a radioactive substance / source) changes the count rate / activity / rate of decay / radiation (emitted)

*accept it = radiation emitted*

**or** (reducing) the temperature does not change the activity / count rate / rate of decay / radiation (emitted)

1

(c) (i) has one more neutron

*correct answer only*

1

(ii) 14 days

*no tolerance*

*allow 1 mark for showing a correct method on the graph*

2

(iii) any **two** from:

- beta particles / radiation can be detected externally
- beta particles / radiation can pass out of / through the plant
- long half-life gives time for phosphorus to move through the plant / be detected / get results
- phosphorus-32 is chemically identical to phosphorus-31
- phosphorus-32 is used in the same way by a plant as phosphorus-31

2

[9]

23

(a) top and bottom boxes identified

1

(b) Medical (treatment)

or X-rays

*answer must be in table  
accept treatment for medical treatment*

1

(c) 15

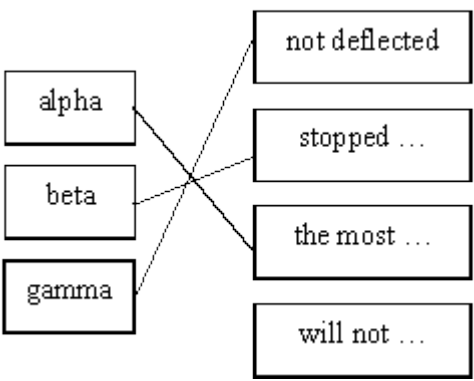
*allow 1 mark for correctly identifying 300 as the average dose*

2

[4]

24

(a) 3 lines correctly drawn



*1 mark for each correct line if more than one line is drawn from a box in List A all lines from that box are wrong*

3

(b) nucleus

*accept nuclei  
do **not** accept nuclear*

1



(c) Y

*do not accept gamma*

any **two** from:

*do not accept other properties of gamma*

- least dangerous (inside the body)  
*do not accept not dangerous*  
*accept not as harmful as alpha*  
*(inside the body)*
- least ionising
- penetrates through the body  
*do not accept can be detected externally*

1

- is a gas / can be breathed in  
*accept it is not a solid*  
*(cannot score if Z chosen)*  
*if X chosen can score this gas mark*  
*if Z chosen can score both gamma marks*

2

(d) any **one** from:

*do not accept kills bacteria*

- longer shelf life  
*accept stays fresh longer / stops it going bad / mouldy*
- food can be supplied from around the world
- wider market for farmers
- cost to consumers (may be) lower
- less likely to / will not get food poisoning  
*accept infection / disease / ill for food poisoning*

1

[8]

25

(a) (i) 3 fewer neutrons

*accept fewer neutrons*

*accept different number of neutrons*

*do not accept different number of electrons*

1

- (ii) electron from the nucleus  
*both points needed* 1
- (iii) 32 (days)  
*allow 1 mark for clearly obtaining 4 half-lives* 2
- (iv) has a **much** longer half-life  
*accept converse answers in terms of iodine-131*  
*accept it has not reached one half-life yet* 1
- little decay happened / still in the atmosphere  
*accept it is still decaying* 1
- (b) any **two** from:  
*marks are for reasons*
- some children developed TC before 1986
  - some children (after 1986) that developed TC did not live in highly contaminated areas
  - the (large) increase can (only) be explained by (a large increase in) radiation as caused by Chernobyl
  - all areas would be contaminated (and raise the risk of TC)
  - no evidence (of effect) of other variables 2
- (c) People not exposed (to the radiation but who were otherwise similar)  
*accept people not affected (by the radiation)* 1

(d) any **two** from:

*answers should be in terms of nuclear power and **not** why we should not use other fuels*

- produce no pollutant / harmful gases  
*accept named gas or greenhouse gases*  
*do **not** accept no pollution*
- produces a lot of energy for a small mass (of fuel) **or** is a concentrated energy source  
*accept amount for mass*  
*accept high energy density*
- it is reliable **or** it can generate all of the time
- produces only a small volume of (solid) waste  
*accept amount for volume*

2

[11]

26

(a) (i) protons

1

neutrons

*answers may be in either order*

1

(ii) 86

1

(iii) two fewer protons and two fewer neutrons

*do **not** accept two fewer protons and neutrons*

**or** 84 protons 134 neutrons

*do **not** accept 218 protons and neutrons*

1

(b) (i) 0.4

*accept  $\frac{2}{5}$  / accept 40 % for 2 marks*

*allow 1 mark for correct totalling = 1.8*

*allow 1 mark for a clearly correct method with a clearly incorrect total*

2

(ii) any **one** from:

- nuclear weapon testing  
*do **not** accept nuclear*
- nuclear power (stations)  
*accept nuclear/ radioactive waste*
- nuclear accidents
- medical  
*accept X-rays*

1

(c) (i) 2

*accept 2:1*  
*accept twice as big*  
*ignore units*

1

(ii) No with a reasonable reason explained

only going for two weeks so

**or** even staying for a year

total exposure well under lowest limit for causing cancer

*1 mark is for a time frame*

*1 mark is for correctly relating to a dose*

1

**or** Yes with a reasonable reason explained

all levels of radiation are (potentially) hazardous (1)

*accept low doses could still cause cancer*

*accept all levels affect you*

*do **not** accept radiation dose is high(er)*

*do **not** accept level of background radiation is higher in Germany*

harm caused by lower doses may not have been recorded (1)

**or** evidence may not be complete

**or** insufficient research into effect of small doses

1

[10]

28

- (a) (i) alpha 1
- (ii) damages them / changes DNA  
*accept kills them / destroys*  
*accept causes cancer*  
*accept causes cell mutations*  
*do **not** accept they ionise cells on its own* 1
- (b) count is (roughly) the same 1
- gamma is not affected by magnetic field  
*accept magnet for magnetic field* 1
- or**
- alpha and beta are deflected by a magnetic field (1)  
count would go down significantly (1)
- (c) time taken for number of nuclei to halve  
*do **not** accept time for radioactivity to halve*
- or**
- time taken for count rate to fall to half  
(its initial value)  
*do **not** accept time for nuclei to halve* 1
- (d) not enough time to take measurements / make observations 1
- before level of radiation became insignificant 1

[7]

29

- (a) (i) electromagnetic (wave / radiation)  
*accept em (wave / radiation)*  
*ignore reference to frequency* 1
- (ii) gamma can penetrate the crate / box / packaging  
*accept converse (but must relate to both alpha and beta)*  
*ignore just gamma radiation kills bacteria*  
*accept can get through to food* 1
- (iii) neutrons 1
- (b) (i) absorb gamma / radiation  
*accept it stops / reduces the radiation* 1
- (ii) any **one** from:
- slow down the conveyor belt
  - food does more than one circuit
  - stay on the conveyor belt longer
  - food closer to the source / radiation  
*ignore larger doses / use more of the source*  
*ignore thinner packaging* 1

(c) (i) idea of testing food on humans / animals

1

no (measured) ill effects **or** monitor their health

*accept monitor people that have eaten the food*

*accept a measurement / comparison for 1 mark*

*eg measure the amount of radiation in treated food*

*comparison plus a reason for the comparison would get 2 marks*

*eg idea of measuring level of radiation in treated food **with** no*

*measurable increase in level = 2 marks **or** comparing it to*

*untreated food = 2 marks*

1

(ii) so can make own decision about eating or not eating treated food

*accept may be against their religious / moral views*

*accept some people prefer food that hasn't been tampered with*

*ignore in case they don't like the idea of eating treated food*

*accept don't want to eat treated food*

*ignore might be allergic to the food*

*eg think it will give them cancer = 0 marks*

*think it will give you cancer so I need to know so that I can choose =*

*1 mark*

1

[8]

30

(i) any **one** from:

the ground

the air

radon (gas)

building materials

buildings

rocks / granite

food

cosmic rays or solar rays

*do **not** accept mobile phones*

X-rays

nuclear weapons testing

nuclear power stations / accidents

*accept from outer space*

*accept sun but **not** sunlight*

*accept medical uses*

1

(ii) 2

allow  $\frac{1200}{60 \times 10}$  **or**  $\frac{120}{600}$  **or** 120

2

[3]

31

(a) (i) two protons and two neutrons **or** the nucleus of a helium atom

1

(ii) different numbers of neutrons **or** one has (3) more or less neutrons than the other

*accept different mass (numbers)*

*if give a number as a difference it must be 3*

1

(iii)

*if polonium or hydrogen chosen gets 0 marks*

technetium (99) or none

1

any **two** from:

*do **not** accept gamma rays are less dangerous*

gamma rays less dangerous inside the body

gamma radiation less likely to be absorbed by cells **or** gamma rays do not ionise cells

gamma rays can penetrate the body (to be detected externally)

*first 3 points valid if either technetium or iridium or none is given*

2

short half-life so safe levels inside body soon reached

half-life long enough to obtain measurements

half-life short enough not to cause long term damage

*last 3 points valid if either technetium or uranium or none is given*

(b)  $2200 \pm 200$

*allow 1 mark for attempted use of 70% on the graph*

2

[7]



- 32** (i) photographic film / paper  
*accept X-ray film* 1
- (ii) (when developed) the film is darker  
*must have a comparison* 1
- (iii) to prevent them receiving / being exposed to too much radiation **or**  
so they know how much radiation they have been exposed to  
*accept if he gets too much radiation there may be something wrong with the plant*  
*any statement making reference to a need for preventive or corrective action gains 1 mark*  
*an isolated statement of fact of the effect of radiation gains 0 marks* 1
- [3]**

- 33** (i) radon (gas)  
*do **not** accept gas* 1
- (ii) background 1
- [2]**

- 34** (a) all points correctly plotted  
*tolerance  $\pm \frac{1}{2}$  square on y axis only*  
*allow 1 mark for 3 correctly plotted points* 2
- attempt made to draw a smooth curve  
*do **not** accept dot-to-dot line* 1
- (b) (i) 3 days  $\pm$  0.2  
**or** any value correctly obtained using their graph line  
*if no line drawn in (a), answer must be exactly 3* 1
- (ii) 3 days or their (b)(i) 1

(c) radon-222

*accept radon **or** 222*

*accept alpha or 3.8*

*correct isotope required for reason to score*

1

has the shortest half-life

*accept the others have longer half-lives*

1

[7]

35

(i) any **one** from

cosmic rays

rocks

food

air

1

(ii) any **one** from

medical

nuclear power stations

nuclear weapons testing

food

***but do not** accept food in both (1) and (ii)*

1

[2]

36

(a) X emits beta

*accept  $\beta$*

1

Y emits alpha, beta, gamma

*must have all three accept  $\alpha$ ,  $\beta$ ,  $\gamma$*

1

(b) gamma

*accept beta and gamma*  
*any mention of alpha loses first mark*

1

radiation can penetrate (the plastic)

1

kills bacteria **or** microbes **or** micro-organisms **or** viruses  
*not germs*

1

[5]

37

(i) radiation (received by the body) due to our environment

*not naturally occurring radiation*  
*accept radiation all around us*  
*accept radiation that is always there*

1

(ii) larger than average dose of cosmic rays

*must have idea of comparison*

1

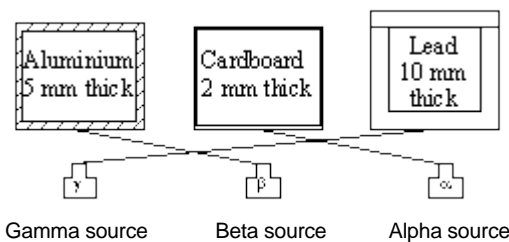
when flying less air to absorb **or** shield from radiation

1

[3]

38

(a) all 3 correct



*allow 1 mark for one or two possible links*  
*no marks for more than one line from a source or to a box*

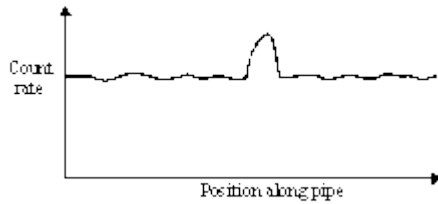
2

(b) (i) geiger-müller (tube)

*accept G-M (tube)*  
*accept geiger tube or geiger counter*

1

(ii) steady line rising then falling at leak



*must be one peak only*

1

(c) (i) can penetrate (skull **or** head)

*accept goes through body*

*accept most penetrating*

*do **not** accept strongest*

*do **not** accept can penetrate skin*

1

(ii) cancer cells receive full dose **or** more radiation

*accept healthy cells not damaged*

1

healthy **or** other cells receive low dose only

*do **not** accept it is safer*

1

(iii) any **two** properties from:

- travel through a vacuum  
*do **not** accept they are an energy form*
- travel at same speed in air **or** vacuum
- can be diffracted  
*treat as a list ignoring 1 and 2*
- can be reflected
- can be refracted
- travel in straight lines
- all transverse
- can be polarised
- transfer energy

2

[9]

39

- (a) (i) an unstable nucleus **or** atom **or** isotope  
*accept nucleus has too much energy*  
an atom **or** nucleus **or** isotope which decays 1
- (ii) sodium – 24  
*if Mg-27 chosen can get third mark if explained*  
sufficiently long to allow circulation and take readings  
short enough that levels of radiation in the body will become insignificant quickly 3
- (iii) each axis is given a linear scale 1  
curve concave to axes drawn 1  
(curve) shows correct half-life of five years  
*must show two half lives check first two plotted points correct to  $\pm$  half square* 1
- (b) any **three** points from the following:
- waste remains radioactive for a long time **or** waste has to be disposed of
  - waste may leak from its storage point
  - possibility of accident at power station **or** in transport of fuel
  - contamination of the local environment
  - people living close to a power station may have a greater risk of developing cancer **or** leukaemia  
*accept harmful to people*
  - high cost to decommission power station  
*do **not** accept expensive*
- 3

[10]

<b>40</b>	(a) (i)	cosmic rays	1	
	(ii)	any <b>two from:</b> rocks cosmic rays food radon	2	
	(b) (i)	15	1	
	(ii)	450 <i>e.c.f. 465 – (d)(i)</i> <i>do <b>not</b> accept negative number</i>	1	
	(iii)	beta <i>count (greatly) reduced by aluminium</i> <i><b>or</b> alpha not reach GM tube and gamma would pass (unaffected) through the aluminium</i> <i>accept aluminium stops beta</i>	2	
				<b>[7]</b>

<b>41</b>	(a) (i)	it is random <i>do <b>not</b> accept unpredictable</i> <i>do <b>not</b> accept irregular</i>	1	
	(ii)	source adds nothing <b>or</b> little to the count  continues to record background level <i>accept a clear explanation of background</i>	1	
	(b) (i)	an electron  <i>accept <math>\frac{0}{-1} e</math></i>	1	
	(ii)	<u>electromagnetic</u> wave with <b>high frequency</b> or short wavelength <i>must have high frequency <b>or</b> short wavelength</i>	1	

(iii) 15

*allow 1 mark for 3 iterative steps 584/2 292/2 146/2*

*allow 1 mark for 45/3*

3

(iv) [A] a safe level of radiation reached much quicker

*could answer in terms of isotope but answer must be clear whether it refers to isotope or sodium-24*

1

[B] long enough to obtain measurements

1

[10]

42

(a) (i) electron  
neutron  
proton  
nucleus

*1 mark for each correct label*

4

(ii) H-1 has no neutrons  
H-3 has 2 neutrons

*more neutrons gets 1 mark*

2

(iii) nucleus unstable

2

(b) lead/concrete  
lead/concrete needed to stop gamma rays

2

[10]

43

(a) two from:  
internal/bodies  
thoron  
building materials  
soil  
food  
rocks  
radon  
gamma rays  
cosmic rays/outer space

*any 2 for 1 mark each*

2

- (b) only a very small amount of the background radioactivity comes from nuclear power owtte.  
*accept any sensible response for 1 mark* 1
- (c) use G.M. tube/meter/counter or film  
'count' higher than or compare with background/normal/control or film is blacker  
*for 1 mark each* 2
- (d) more neutrons/different number  
*gains 1 mark*
- but** I-131 has 4 extra neutrons = 2  
**or** I-131 has 78 neutrons I-127 has 74 (2)  
*gains 2 marks* 2
- (e) (i) emits radiation  
ionises  
molecules  
in cells  
radiation damages cells/mutation/kills cells  
may cause cancer  
 $\beta$  /  $\gamma$  / radiation is penetrating  
half-life is long enough for damage to be caused  
*any 4 for 1 mark each (4 from above)* 4
- (ii) e.g. replace I-127 in body/body cannot tell the difference/causes thyroid cancer/causes cancer (but not if already given in (i))  
*for 1 mark* 1
- (iii) **Either** No  
half-life = 8 days many half lives have passed/attempts to calculate number of half-lives **or** explains meaning of half-life so very little left/become harmless  
*for 1 mark each*
- or** Yes half-life = 8 days such a large quantity was released although little left it is still harmful  
*for 1 mark each* 3

[15]

44

#### Quality of written communication

*The answer to this question requires ideas in good English in a sensible order with correct use of scientific terms. Quality of written communication should be considered in crediting points in the mark scheme*



Any **three** from

radon releases (alpha) radiation

*accept radon is radioactive*

1

(radon **or** radiation causes) harm **or** damage to body **or** cells

*accept cause cancer / mutations /*

*radiation sickness*

1

idea that living near radiation over long period will lead to large 'dose' of radiation

radon (is a gas) that can be breathed in

1

[3]

45

Quality of written communication

correct use of **three** scientific terms e.g. radiation /  $\alpha$  **or**  $\beta$  **or**  $\gamma$  / cells /  
ionisation / mutation (not cells or body) / chromosomes / DNA /  
genes / cancer

1

any **three** from:

(materials emit) radiation

named type of radiation ( $\alpha$  **or**  $\beta$  **or**  $\gamma$ )

damage / harm / kill

*dangerous is neutral*

cells / chromosomes / DNA / genes

cancer

mutations

ionisation

gloves or glass absorb radiation / prevent radiation reaching body or cells

3

[4]

46

- (i) (strontium-90)  
beta rays partly absorbed by aluminium  
*accept gamma rays not absorbed **and** alpha all absorbed  
if phosphorus -32 then one mark max for beta ray explanation*

1

long half life means it can be used for a long time

1

- (ii) (technetium-99)  
(gamma) rays will pass out of body / less likely to be absorbed  
*accept (gamma) less damaging or alpha / beta will damage cells if  
cobalt -60 then one mark max for gamma ray explanation*

1

short half life means it will not affect body over a long period

1

[4]

47

- (a) sensible scales  
*full use of y axis*

1

completely accurate plotting

1

a smooth curve going through all bar one of the points  
*do not accept a dot-to-dot graph if two parts shown for curves  
accept the more correct*

1

at least one line or a clear mark showing how to obtain the half life  
from the graph and obtaining between 13 and 15  
*at the bottom of the page cross or ticks in the order of the mark  
scheme*

1

- (b) (i) to let the beta particles get through  
*accept must be there to let the radiation through **or** if thick they may  
be stopped*

1

(ii) alpha particles would be stopped by the glass **or** cannot penetrate glass  
*do not accept alphas are weak*

1

- (c) (i) it will give more counts per minute for a small quantity **or** it does not last  
so long so may not be as dangerous  
*accept answers in terms of 5 years assume it refers appropriately*

1

- (ii) it will not be there long enough to act as a tracer **or** it could cause radiation damage as all its activity will be in the first place it enters the system  
*accept answer in terms of 5 seconds*  
*accept not there long enough to work assume it refers appropriately*

1

[8]

48

- (a) evidence of  $\frac{7350}{15}$   
*gains 1 mark*

**but**

490  
*gains 2 marks*

**but**

4900  
*gains 3 marks*

units  $\text{cm}^3$   
*for 1 further mark*

4

- (b) some of radioactive solution gets into cells/body organs  
some of radioactive solution gets into urine (in the kidney)  
the radioactive solution becomes less radioactive during the test  
variability in readings  
*in any order for 1 mark each*

3

- (c) *ideas that*

- won't lose (too) much radioactivity during the test
- won't stay radioactive/harm cells for too long after test is over  
*for 1 mark each*

2

[9]

49

(a)  $\gamma$ /gamma

- because more penetrating
- so can reach/damage cells from outside body/through skin

**but**

$\alpha$ /alpha

- does more damage/more likely to cause cancer
- can only do this if inside the body/cells  
*each • for 1 mark*  
*[credit same ideas expressed conversely]*

4

(b) • must emit alpha /  $\alpha$  radiation

- *idea that* half-life must be just long enough to kill cancer cells  
*each for 1 mark*  
*[do not credit simply short half-life]*  
*(allow 'must be liquid / in solution)*

2

(c) *evidence of repeated halving then*

$n$   $\approx$  3.6

*gains 1 mark*

**but**

answer in range

22 – 25.2 days

(ie  $>6$  and up to 7 half lives)

*gains 2 marks*

2

**[8]**