**M1.**(a)     (i)      neutron

**1**

(ii)     neutron  
proton

*both required, either order*

**1**

(iii)    2

**1**

number of protons

*do not accept number of electrons*

**1**

(b)     (i)      any **one** from:

•        beta

•        gamma

*accept correct symbols*

*accept positron / neutrino / neutron*

*cosmic rays is insufficient*

**1**

(ii)     electrons

**1**

(iii)    are highly ionising

**1**

(c)     (i)      mutate / destroy / kill / damage / change / ionise

*Harm is insufficient*

**1**

(ii)     much smaller than

**1**

**[9]**

**M2.**(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

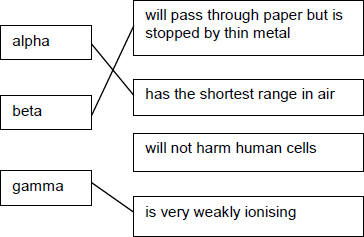
**1**

(d)     Should radioactive waste be dumped in the oceans

**1**

**[10]**

**M3.**(a)    3 lines correct



*allow* ***1*** *mark for each correct line*

*if more than one line is drawn from any type of radiation box then all of those lines are wrong*

**3**

(b)     Gamma radiation will pass through the body

**1**

(c)     half

**1**

(d)     protons

**1**

**[6]**

**M4.**(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]**

**M5.**         (a)      (i)     **L**

**1**

(ii)     **M**

**1**

(b)     To make a smoke detector work.

**1**

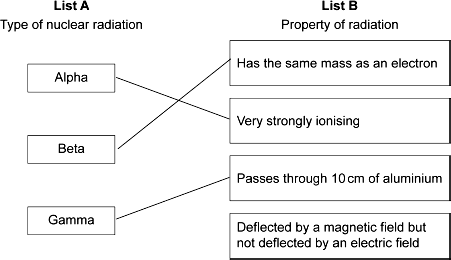
(c)     **40**

*no tolerance*

**1**

**[4]**

**M6.**          (a)     **1** mark for each correct line



*if more than 1 line is drawn from any box in List* ***A****, none of those lines gain any credit*

**3**

(b)     (i)      (the detector) reading had gone down

*‘it’ equals detector reading*

*accept the reading in the table is the smallest*

*accept 101 is (much) lower than other readings / a specific value eg 150*

*do* ***not*** *accept this answer if it indicates the readings are the thickness*

**1**

more beta (particles / radiation) is being absorbed / stopped

*accept radiation for beta particles / radiation*

*accept fewer particles being detected*

**1**

(ii)     six years

**1**

(iii)    alpha would not penetrate the cardboard

*accept the basic property – alpha (particles) cannot pass through paper / card*

*accept alpha (particles) are less penetrating (than beta)*

*range in air is neutral*

**1**

**[7]**

**M7.**(a)     inside the Sun

**1**

(b)     fusion

**1**

(c)     energy

**1**

**[3]**

**M8.**         (a)      (i)     **K** and **L**

*both answers required either order*

**1**

(ii)     (1) same number of protons

*accept same number of electrons*

*accept same atomic number*

**1**

(2) different numbers of neutrons

**1**

(b)     (i)     90

**1**

(ii)     140

**1**

(c)     alpha (particle)

*reason may score even if beta or gamma is chosen*

**1**

mass number goes down by 4**or**number of protons and neutrons goes down by 4  
**or**number of neutrons goes down by 2

*candidates that answer correctly in terms of why gamma* ***and*** *beta decay are not possible gain full credit*

**1**

atomic / proton number goes down by 2**or**number of protons goes down by 2

*accept an alpha particle consists of 2 neutrons and 2 protons for* ***1*** *mark*

*accept alpha equals 42He or 42α for* ***1*** *mark*

*an alpha particle is a helium nucleus is insufficient for this mark*

**1**

**[8]**

**M9.**(a)     (i)      splitting of a(n atomic) nucleus

*do not accept splitting an atom*

**1**

(ii)     Neutron

**1**

(b)     (i)      nuclei have the same charge  
**or**nuclei are positive

*accept protons have the same charge*

**1**

(ii)     (main sequence) star

*accept Sun or any correctly named star*

*accept red (super) giant*

**1**

(c)     (i)      any **two** from:

•        easy to obtain / extract

•        available in (very) large amounts

•        releases more energy (per kg)

*do* ***not*** *accept figures only*

•        produces little / no radioactive waste.

*naturally occurring is insufficient*

*seawater is renewable is insufficient*

*less cost is insufficient*

**2**

(ii)     any **one** from:

*accept any sensible suggestion*

•        makes another source of energy available

•        increases supply of electricity

•        able to meet global demand

•        less environmental damage

*accept a specific example*

•        reduces amount of other fuels used.

*accept a specific example*

**1**

(d)     12

*allow* ***1*** *mark for obtaining 3 half-lives*

**2**

**[9]**

**M10.**(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]**

**M11.**(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]**

**M12.**          (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]**

**M13.**(a)    78

**1**

(b)     atomic

**1**

(c)     (i)      131

*correct order only*

**1**

54

**1**

(ii)     32 (days)

*allow* ***1*** *mark for showing 4 half-lives provided no subsequent step*

**2**

(iii)    limits amount of iodine-131 / radioactive iodine that can be absorbed

*accept increases level of non-radioactive iodine in thyroid*

*do* ***not*** *accept cancels out iodine-131*

**1**

so reducing risk of cancer (of the thyroid)

*accept stops risk of cancer (of the thyroid)*

**1**

**[8]**

**M14.**          (a)     (i)      beta and gamma

*both answers required*

*accept correct symbols*

**1**

(ii)     alpha and beta

*both answers required*

*accept correct symbols*

**1**

(iii)     gamma

*accept correct symbol*

**1**

(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

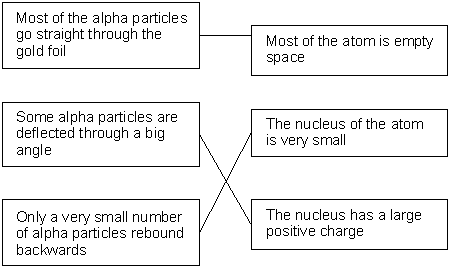
**2**

**[9]**

**M15.**          (a)     (mass of) positive charge

**1**

(b)     three lines correct



*allow* ***1*** *mark for 1 correct line*

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

**2**

(c)     new scientific evidence / data is obtained

**1**

which cannot be explained by the model

**1**

**[5]**

**M16.**(a)     neutrons and protons

**1**

(b)     0

**1**

(+)1

**1**

(c)     (i)      total positive charge = total negative charge

*accept protons and electrons have an equal opposite charge*

**1**

(because) no of protons = no of electrons

**1**

(ii)     ion

**1**

positive

**1**

(d)     Marks awarded for this answer will be determined by the quality of communication as well as the standard of the scientific response. Examiners should apply a best-fit approach to the marking.

**0 marks**No relevant content

**Level 1 (1 – 2 marks)**There is a basic description of at least **one** of the particles in terms of its characteristics.

**Level 2 (3 – 4 marks)**There is a clear description of the characteristics of **both** particles  
**or**a full description of either alpha **or** beta particles in terms of their characteristics.

**Level 3 (5 – 6 marks)**There is a clear and detailed description of **both** alpha and beta particles in terms of their characteristics.

**examples of the physics points made in the response:**

**structure**

•        alpha particle consists of a helium nucleus

•        alpha particle consists of 2 protons and 2 neutrons

•        a beta particle is an electron

•        a beta particle comes from the nucleus

**penetration**

•        alpha particles are very poorly penetrating

•        alpha particles can penetrate a few cm in air

•        alpha particles are absorbed by skin

•        alpha particles are absorbed by thin paper

•        beta particles can penetrate several metres of air

•        beta particles can pass through thin metal plate / foil

•        beta particles can travel further than alpha particles in air

•        beta particles can travel further than alpha particles in materials eg metals

**deflection**

•        alpha particles and beta particles are deflected in opposite directions in an electric field

•        beta particles are deflected more than alpha particles

•        alpha particles have a greater charge than beta particles but beta particles have much less mass  
**or**beta particles have a greater specific charge than alpha particles

**6**

**[13]**

**M17.**(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 β*

**

*scores* ***3*** *marks*

**1**

**[10]**

**M18.**(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]**

**M19.**(a)     protons, electrons

*both required, either order*

**1**

neutrons

**1**

electron, nucleus

*both required, this order*

**1**

(b)     2.7 (days)

*allow* ***1*** *mark for showing correct use of the graph*

**2**

(c)      put source into water at **one** point on bank

*accept the idea of testing different parts of the river bank at different times*

**1**

see if radiation is detected in polluted area

*accept idea of tracing*

**or**

put source into water at three points on bank (1)   
see if radiation is detected downstream of factory **or** farmland **or** sewage treatment works (1)

**1**

**[7]**