**M1.**          (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]**

**M2.**          (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  / 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]**

**M3.**          (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]**

**M4.**          (a)     (i)      centre

**1**

(ii)     protons and neutrons

**2**

(iii)     different number of neutrons

*gets 1 mark*

heavier

*gets 1 mark*

3 more neutrons or specified numbers

*gets 2 marks*

**2**

(b)     atom hit by neutron;  
splits into smaller nuclei;  
further neutrons released;  
neutrons released when one atom splits  
cause further fission;  
energy released.

*any 4 for 1 mark each*

**4**

**[9]**

**M5.**          (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  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]**

**M6.**          (a)     (i)      element with equal number of protons, different number neutrons  
**or**same atomic/proton number different mass/nuclear number

**1**

(ii)     time taken for activity **or** count rate **or** number of nuclei to decrease to half

*accept parents atoms* ***or*** *radioactive isotope*

*do not accept time taken for radioactivity/substance/ material to halve*

**1**

(iii)     12 (s)

**1**

          (b)     (i)      22800 (years)

*allow 1 mark for iterative steps 80-40-20-10-5* ***or*** *statement of 4 half-lives*

**2**

(ii)     decay (of carbon 14) over 150 years is insignificant

*accept very little decay*

*accept change is too small*

**1**

(c)     either argument gains full credit

*accept any 3 valid points from for and/or against arguments*

FOR

          – massive dilution of waste  
– reduces concentration (within a given volume) to insignificant levels  
– distant from habitation

AGAINST

          – pollution (of the sea/beach)  
– mutation **or** harm caused to living things (animals/plants)  
– effect on food chain  
– long period of time necessary

**3**

**[9]**

**M7.**          (a)     two half lives

*gains 1 mark*

**but**20 minutes

*gains 2 marks*

**2**

(b)     alphas will be stopped by skin / air **or** do not penetrate betas and gammas  
can reach / damage organs / cells

*for 1 mark each*

**2**

**[4]**

**M8.**          (a)     (i)      it is random

*do* ***not*** *accept unpredictable*

*do* ***not*** *accept irregular*

**1**

(ii)     source adds nothing **or** little to the count

**1**

continues to record background level

*accept a clear explanation of background*

**1**

          (b)     (i)      an electron

*accept e*



**1**

(ii)     electromagnetic wave with **high frequency** or short wavelength

*must have high frequency* ***or*** *short wavelength*

**1**

(iii)     15

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

*allow I 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]**

**M9.**          (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]**

**M10.**          (i)      7 **or** 8

**1**

          correct data extracted from graph e.g. takes 8 days to drop from 50 to 25

*allow appropriate annotation of graph*

**1**

(ii)      long enough to destroy cancer cells

*do not accept dangerous unqualified*

**1**

          but short enough to minimise damage to surrounding tissues

**1**

**[4]**

**M11.**          (a)     electron

*accept e*

**1**

(b)     5400 – 7000

          horizontal line drawn corresponding to their halving

**1**

**or**

          a cross in the correct position on the line

**1**

(c)     count rate converted to 14.5/min for 1g mass

*accept 14.5 clearly marked on graph*

**1**

decay time taken as 750 years ± 100 years

*accept 750 years clearly marked on graph*

**1**

refer their answer to 837 years (or approximately 800 **or** a value 837 - 937 years)

no the shirt was made after he died (if numbers justify)

**or**

yes it could have been his shirt (if numbers justify)

*allow an alternative answer working backwards from 837 years*

**1**

**[6]**