Mark schemes

(a) (i) splitting of a(n atomic) nucleus
do not accept splitting an atom

(ii) Neutron

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

(ii) (main sequence) star
accept Sun or any correctly named star
accept red (super) giant

(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

(ii) any one from:
- makes another source of energy available
- increases supply of electricity
- able to meet global demand
- less environmental damage
- reduces amount of other fuels used.
accept any sensible suggestion
accept a specific example
accept a specific example

(d) 12
allow 1 mark for obtaining 3 half-lives

2

(a) neutrons and protons

(b) 0
(c) (i) total positive charge = total negative charge
  
  \textit{accept protons and electrons have an equal opposite charge}

  (because) no of protons = no of electrons

(ii) ion

  positive
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
(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

(b) $60 \pm 3$ (days)

indication on graph how value was obtained

(c) (i) cobalt(-60)

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

(ii) strontium(-90)

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

(iii) cobalt(-60)

shortest half-life

accept half-life is 5 years

dependent on first marking point

so activity / count rate will decrease quickest

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

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

do not allow lead fully absorbs gamma

(a) (i) neutron

(ii) neutron proton

both required, either order

(iii) 2

number of protons
do not accept number of electrons

(b) (i) any one from:

• beta

• gamma

accept correct symbols
accept positron / neutrino / neutron

accept cosmic rays is insufficient

(ii) electrons

(iii) are highly ionising

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

Harm is insufficient

(ii) much smaller than

(a) J

reason only scores if J is chosen

(only) stars (about) the same / smaller size / mass as the Sun become black dwarfs

accept smaller than the Sun
accept it is the smallest

accept (only) small stars become black dwarfs
(b) (i) become a supernova
or
it will explode
    
    *ignore subsequent correct stages*

(ii) cannot take measurements needed
or
do not have the technology

    *do not accept cannot measure mass*

(iii) advances in (measuring) techniques / technology / knowledge

(c) any five from:

    *ignore any information up to the end of the main sequence*

    *Apply the list rule if more than 5 points are made*

    • star expands (to become)
    • a red giant

        *red supergiant is incorrect*

    • heavier elements are formed (by fusion)

        *elements heavier than iron are formed is incorrect*

    • star shrinks (to become)
    • a white dwarf

        *supernova, neutron star, black hole are incorrect*

    • star cools / fades
    • star stops emitting energy / radiation

        *star loses all energy is insufficient*
(a) (same) number of protons
   *same atomic number is insufficient*

(b) (i) nuclei split
   *do not accept atom for nuclei / nucleus*

(ii) (nuclear) reactor

(c) beta

any one from:
- atomic / proton number increases (by 1)
  *accept atomic / proton number changes by 1*
- number of neutrons decreases / changes by 1
- mass number does not change
  *(total) number of protons and neutrons does not change*
- a neutron becomes a proton

(d) (average) time taken for number of nuclei to halve
   or
   (average) time taken for count-rate / activity to halve

(e) (i) 6.2 (days)
   *Accept 6.2 to 6.3 inclusive*
   *allow 1 mark for correctly calculating number remaining as 20 000*
   *or*
   *allow 1 mark for number of*
   *80 000 plus correct use of the graph (gives an answer of 0.8 days)*

(ii) radiation causes ionisation
   *allow radiation can be ionising*

   that may then harm / kill healthy cells
   *accept specific examples of harm, eg alter DNA / cause cancer*

(iii) benefit (of diagnosis / treatment) greater than risk (of radiation)
   *accept may be the only procedure available*

(a) (i) nuclear reactor

star
(ii) nuclei are joined (not split)
   accept converse in reference to nuclear fission
do not accept atoms are joined

(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

(ii) 56 (Ba)

57 (La)
   if proton number of Ba is incorrect allow 1 mark if that of La is 1 greater

\[ _{0}^{1} \beta \]

accept e for \( \beta \)

\[ {}^{139}_{56}\text{Ba} \rightarrow {}^{139}_{57}\text{La} + {}_{-1}^{0}\beta \]

scores 3 marks

(a) (i) 18

(ii) the count rate for the source

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

(iv) plots correct to within \( \frac{1}{2} \) small square
   allow 1 mark for 4 correct points plotted

correct curve through points as judged by eye
(v) two attempts at finding ‘half-distance’ using the table

\[
\begin{align*}
20 \text{ to } 10 \text{ cpm } d &= 0.4 \text{ m} \\
125 \text{ to } 56 \text{ cpm } d &= 0.2 \text{ m} \\
31 \text{ to } 14 \text{ cpm } d &= 0.4 \text{ m}
\end{align*}
\]

allow 1 mark for one attempted comparison

obeyed or not obeyed

\textit{dependent on previous two marks}

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

count rate is reduced in experiment 2 because field is perpendicular \textbf{or} beta particles are deflected \textbf{or} there is a force

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

slightly different values show the random nature of radioactive decay

\[13\]

(a) 3 lines correct

\begin{itemize}
  \item \textbf{alpha} \hspace{2cm} \text{will pass through paper but is stopped by thin metal}
  \item \textbf{beta} \hspace{2cm} \text{has the shortest range in air}
  \item \textbf{gamma} \hspace{2cm} \text{will not harm human cells}
  \item \text{is very weakly ionising}
\end{itemize}

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

(b) Gamma radiation will pass through the body

(c) half
(d) protons

(a) uranium-235

accept any correct indication

(b) splits / breaks (into two smaller parts)

nucleus is separated is insufficient
do not accept atom splits – on its own

and (two / three) neutrons

(c) steam

correct order only

turbine

generator