Mark schemes

1 (a) J

reason only scores if J is chosen

1

(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

1

(b) (i) become a supernova

or

it will explode

ignore subsequent correct stages

1

(ii) cannot take measurements needed

or

do not have the technology

*do **not** accept cannot measure mass*

1

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

1

(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

5

[10]

2 (a) (same) number of protons

same atomic number is insufficient

1

(b) (i) nuclei split

*do **not** accept atom for nuclei / nucleus*

1

(ii) (nuclear) reactor

1

(c) beta

1

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

1

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

1

(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)

2

(ii) radiation causes ionisation

allow radiation can be ionising

1

that may then harm / kill healthy cells

accept specific examples of harm, eg alter DNA / cause cancer

1

(iii) benefit (of diagnosis / treatment) greater than risk (of radiation)

accept may be the only procedure available

1

[11]

3 (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]

4

(a) uranium-235

accept any correct indication

1

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

nucleus is separated is insufficient

*do **not** accept atom splits – on its own*

1

and (two / three) neutrons

1

(c) steam

correct order only

1

turbine

1

generator

1

[6]

5 (a) (i) plutonium (239)

accept Pu / Thorium / MOX (mixed oxide)

*do **not** accept uranium-238 **or** hydrogen*

1

(ii) (energy) used to heat water and

1

produce (high pressure) steam

1

the steam drives a turbine (which turns a generator)

1

(b) Neutron(s) shown 'hitting' other U-235 nuclei

one uranium nucleus is sufficient

1

U-235 nuclei (splitting) producing 2 or more neutrons

1

(c) any **two** from:

- neutrons are absorbed (by boron / control rods)
- there are fewer neutrons
- chain reaction slows down / stops

accept fewer reactions occur

2

[8]

6 (a) forces (within the star) are balanced

if specific forces are mentioned they must be appropriate

1

(b) (i) bigger the mass (of the star) the shorter the 'main sequence' period

accept bigger the star the shorter the time

1

(ii) any **one** from:

- insufficient evidence
- do not know (exact) amount of hydrogen in star
  accept do not know (exact) mass of star
- time too long (to measure directly)
- may be other factors (not yet known) that determine length of 'main sequence' period
- values are based on theory / calculation

1

(iii) faster than

1

larger stars have a shorter 'main sequence' period so they must have the faster (rate of) nuclear fusion

there must be a link between shorter 'main sequence' and nuclear fusion, this may be implied from the first marking point

1

the end of 'main sequence' happens as the hydrogen in (the core of) a star is used up

or

(since) they use up hydrogen at a faster (rate)

accept more massive stars (are brighter so) release energy faster

1

(c) 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 also refer to the information in the Marking guidance, and apply a 'best-fit' approach to the marking.

0 marks
No relevant content.

Level 1 (1-2 marks)
There is a basic description of what happens to a star much larger than the Sun after the 'main sequence' period.
OR
Two stages are correctly named and are in the correct sequence.

Level 2 (3-4 marks)
There is a clear description of what happens to a star much larger than the Sun after the 'main sequence' period.
AND
At least two stages are correctly named and are in the correct sequence.

Level 3 (5-6 marks)
There is a detailed description of what happens to a star much larger than the Sun after the 'main sequence' period.
AND
At least three stages are named, in the correct sequence. There are no additional incorrect stages given.

Examples of the points made in the response:

extra information

- (the core of the) star runs out of hydrogen
- (the star) expands (to form)
- (the star) cools (to form)
    - *the core shrinks*
    - *helium starts to fuse to form other elements*
- a red supergiant

  accept super red giant
  *do **not** accept red giant*

    - (outer layers) explode
        - *fusion of lighter elements to form heavier elements (up to iron)*
- as a supernova
    - elements heavier than iron are formed

      accept heaviest elements are formed
    - core shrinks
- becoming a neutron star

- if mass large enough (core collapses)

- (to form) a black hole

if a correct description and sequence for a star the same size as the Sun and much bigger than the Sun given without clearly indicating which is which is limited to Level 2

6

[12]

7 (a) fusion

*do **not** credit any response which looks like 'fission'*

1

of hydrogen / H (atoms)

credit only if 1st mark point scores

1

(b) fusion of other / lighter atoms / elements

reference to big bang nullifies both marks

1

during supernova / explosion of star(s)

1

(c) the (available) evidence: supports this idea
or
does not contradict this idea
or
can be extrapolated to this idea
or
(electromagnetic) spectrum from other stars is similar to sun

1

[5]

8 (a) *answers must be in terms of nuclear fuels*

concentrated source of energy

idea of a small mass of fuel able to generate a lot of electricity

1

that is able to generate continuously

accept it is reliable

***or** can control / increase / decrease electricity generation*

idea of available all of the time / not dependent on the weather

ignore reference to pollutant gases

1

the energy from (nuclear) <u>fission</u>

1

is used to heat water to steam to turn turbine linked to a generator

1

(b) carbon dioxide is not released (into the atmosphere)

1

but is (caught and) stored (in huge natural containers)

1

[6]

9

(a) (i) (nuclear) fission is the splitting of a (large atomic) nucleus

*do **not** accept particle/atom for nucleus*

1

(nuclear) fusion is the joining of (two atomic) nuclei (to form a larger one)

do not accept particles/atoms for nuclei

1

(ii) energy

accept heat/radiation/nuclear energy

accept gamma (radiation)

do not accept neutrons/neutrinos

1

(b) (i) uranium (–235)

accept U (–235)

ignore any numbers given with uranium

accept thorium

accept MOX (mixed oxide)

*do **not** accept hydrogen*

1

(ii) (same) number of protons

accept (same) atomic number

accept (same) positive charge

ignore reference to number of electrons

1

[5]

10

(a) (i) protostar

correct order only

1

red giant

1

black dwarf

1

(ii) Alpha Centauri A

accept any correct indication, eg alpha, centauri, A

reason only scores if Alpha Centauri A is chosen

1

stars (about) same size as Sun form white / black dwarfs
or
very large stars form red super giants / supernova/black hole

it is the same size as the Sun is insufficient

same life cycle as the Sun is insufficient

1

(b) Atomic nuclei inside the star join together

1

[6]

11 (a) a protostar is at a lower temperature
or
a protostar does not emit radiation /energy

1

as (nuclear) fusion reactions have not started

accept heat or light for energy

1

(b) by (nuclear) fusion

accept nuclei fuse (together)

nuclear fusion and fission negates this mark

1

of hydrogen to helium

1

elements heavier than <u>iron</u> are formed in a <u>supernova</u>

accept a specific example e.g. heavier elements such as gold are formed in a supernova

accept heavier elements (up to iron) formed in red giant/red super giant

reference to burning (hydrogen) negates the first 2 marks

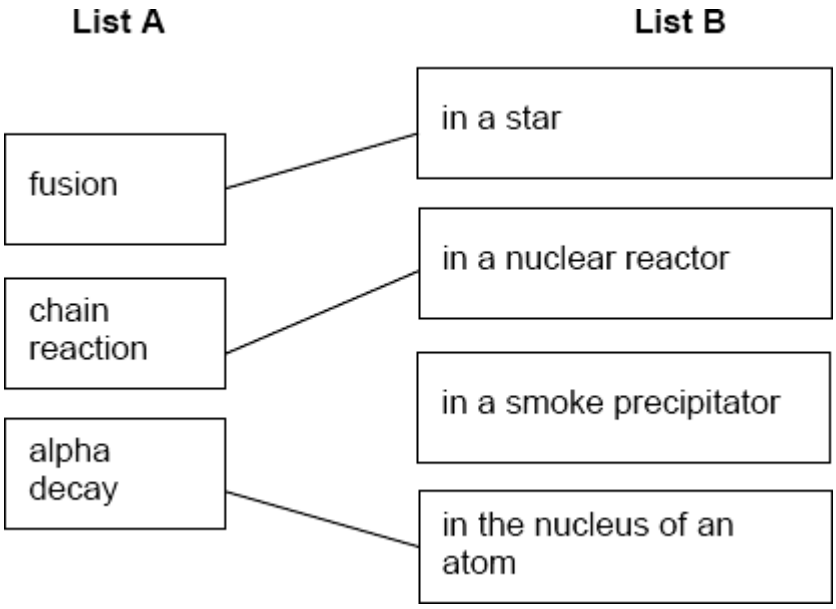
1

[5]

12 **three** lines correct

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

*if more than 1 line is drawn from a box in **List A**, mark each line incorrect*



[3]

13 (a) gravitational attraction

accept 'gravity'

accept (nuclear) fusion

1

(b) radiation 'pressure' and gravity / gravitational attraction

must be in correct context

1

are balanced / in equilibrium

accept are equal and opposite

*do **not** accept 'equal'*

or

there is sufficient / a lot of hydrogen / fuel

*do **not** accept constant supply of hydrogen*

to last a very long time / for (nuclear) fusion

this mark only scores if linked to the supply of hydrogen / fuel

reference to burning negates both marks

1

(c) (i) (conversion of) hydrogen to helium

accept (conversion of) lighter elements to heavier elements

1

by (nuclear) fusion

*note do **not** credit spelling of 'fusion' which could be 'fission'*

reference to burning negates both marks

1

(ii) massive supply / lots of hydrogen

1

(d) distributed throughout the Universe / space

*do **not** accept Solar System for Universe*

1

[7]

14 beta

reason may score even if alpha or gamma given

1

any **two** from:

- mass number does not change
  or
  total number of protons and neutrons does not change
- atomic / proton number increases by 1
  or
  number of protons increases by 1
- number of neutrons goes down by 1

*allow for **2** marks a neutron splits / changes into a proton and electron / beta*

*candidates that answer correctly in terms of why alpha **and** gamma are not possible, gain both marks*

2

[3]

15 (a) (forces due to) gravity and radiation pressure

1

correct direction of forces

1

(forces) are balanced / equilibrium / equal

*accept for **3** marks an answer in terms of*
sufficient hydrogen (1)
to keep fusion reaction (1)
reference to burn / burning negates this mark
going at a continuous /steady rate (1)
*if fuel is used instead of hydrogen maximum of **2** marks*

1

(b) the Sun will remain stable (for several billion years)

1

based on evidence

accept a specific example of evidence
eg that the Sun has remained stable during the life of our planet / for 4.5 billion years
or
still contains more than 50 % hydrogen
or
by comparison with the lifecycle of (similar) stars
allow a refutation
eg not based on prejudice / whim / hearsay / folk law / historical or religious authority

1

[5]

16 (a) (i) (two) nuclei (of light elements) join

accept hydrogen atoms for nuclei

1

forming a larger / heavier nucleus / one

accept comparative term equivalent to larger
accept forms a helium (nucleus / atom) this mark only scores if fusion is in terms of hydrogen atoms

1

(ii) stars

accept a named star
e.g. the Sun
accept nebula
mention of planets negates answer

1

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

- (currently) only experimental
- reaction does not last long enough
- use more energy than they produce
  allow difficult to control
  *do **not** allow inefficient on its own*

1

(ii) any **one** from:

- will give another source of energy
- unlimited fuel supplies / energy
  accept unlimited hydrogen
- would not produce any radioactive waste
  accept less radioactive waste
  accept nuclear for radioactive
  *do **not** accept toxic waste*
- want to show that it can be done
  accept any sensible suggestion
  *do **not** accept answers only in terms of fossil fuels or carbon dioxide*

1

[5]

17 (a) gravitational force(s) (1)
accept 'gravity'

balanced by (force(s) due to) radiation pressure (1)
accept equal

2

(b) by (nuclear) fusion (1)

of hydrogen to helium (other light elements) (1)

allow 'low density' for light

accept hydrogen nuclei / atoms form helium

response must clearly link one element(s) producing others

fusion to produce helium (2)

heavy element / elements heavier than iron are only produced (by fusion) in a supernova (1)

allow dense for heavy

ignore any reference to elements undergoing radioactive decay (to form other elements)

3

[5]

18

(a) isotopes

1

(b) $^{231}_{90}Th$

1

correct order only

1

(c) (i) (nuclear) fission

accept fision

*do **not** accept any spelling that may be confused with fusion*

1

(ii) neutron / neutrons

1

(d) plutonium (239)

accept MOX (mixed oxide)

accept Pu

*do **not** accept uranium 238 / hydrogen*

1

[6]

19

(a) (enough) dust and gas (from space)

accept nebula for dust and gas

accept hydrogen for gas

mention of air negates this mark

1

pulled together by:

- gravitational attraction
  or
- gravitational forces
  or
- gravity

1

(b) forces (in the star) are balanced

accept equal and opposite for balanced

accept in equilibrium for balanced

1

forces identified as gravity and radiation pressure

both forces are required

*gravitational forces inwards balance / equal radiation pressure outwards for **2** marks*

*accept for **2** marks an answer in terms of sufficient hydrogen to keep the fusion reactions going*

*accept for **1** mark an answer in terms of sufficient fuel to keep the fusion reactions going*

1

(c) (explodes as) a supernova

1

any **one** from:

- outer layer(s) thrown into space

  *do **not** accept just 'thrown into space'*

- scatters dust and gas into space (for the formation of new stars)

  *do **not** accept just 'dust and gas'*

- elements distributed throughout space

  *do **not** accept just 'distributed'*

- matter left behind / core may form a neutron star

  *do **not** accept just 'neutron star'*

- a black hole will form if the gravitational forces are enormous / sufficient mass is left behind

  *do **not** accept just 'black hole'*

  *do **not** accept any references to 'dark bodies' or 'black dwarfs'*

  black hole forms if star is large enough is insufficient

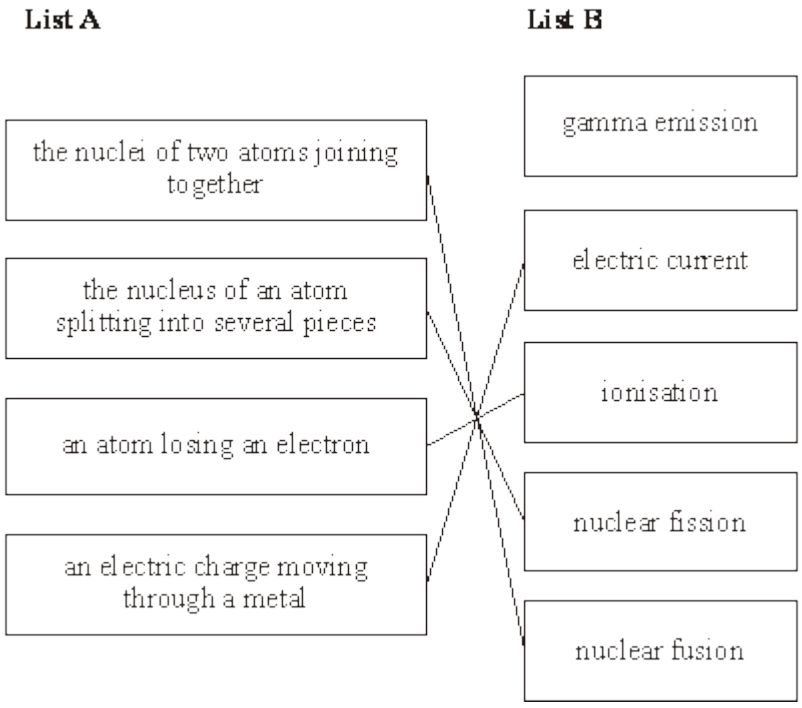
1

[6]

20 **four** lines correct

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

if more than 1 line is drawn from a box in List A, mark each line incorrect



[4]

21 (a) fusion (1)

of hydrogen/H (atoms)(1)

*do **not** credit any response which looks like 'fission' **or** the 'word' 'fussion'*

credit only if a nuclear reaction

2

(b) fusion of other/lighter atoms/elements (1)

reference to big bang nullifies both marks

during super nova/explosion of star(s) (1)

2

(c) explosion of star(s)/super nova (1)

reference to big bang nullifies both marks reference to the star running out of energy/material nullifies both marks

at the end of the 'life' of star(s) / when they 'die' (1)

2

[6]

22 (a)

Particle	Relative Mass	Relative charge
Proton	1	
Neutron		0

accept one, accept +1
*do **not** accept –1*

1

accept zero

*do **not** accept no charge/ nothing/neutral unless given with 0*

1

(b) equal numbers/amounts of protons and electrons

1

protons and electrons have equal but opposite charge

accept protons charge +1 and electron charge –1

accept (charge) on proton
cancels/balances (charge) on electron

accept positive (charges) cancel out the negative(charges)

neutrons have no charge is neutral

*do **not** accept total charge of protons, electrons (and neutrons) is 0 unless qualified*

1

(c) (i) (3) fewer neutrons

accept lower/ smaller mass number

*do **not** accept different numbers of neutrons*

any mention of fewer/more protons/electrons negates mark

accept answers in terms of U-238 providing U-238 is specifically stated i.e. U-238 has (3) more neutrons

1

(ii) neutron

1

(iii) (nuclear) fission

accept fision

*do **not** accept any spelling that may be taken as fusion*

1

[7]

23 (a) gravitational

accept gravity

*do **not** accept weight*

1

(b) (i) planet(s)

accept comet(s)

accept asteroid(s)

*do **not** accept moon(s)*

1

(ii) balanced

accept equal / the same / are in equilibrium

1

(iii) Milky Way

accept milky way

1

[4]

24 (a) (i) the bigger the masses (of the dust and gases then) the bigger the force / gravity (between them)

accept the converse

1

(ii) the greater the distance (between the dust and gases then) the smaller the force / gravity (between them)

accept the converse

1

(b) radiation 'pressure' and gravity / gravitational attraction
these are balanced / in equilibrium

1

must be in correct context
*do **not** accept are equal*

or there is sufficient / a lot of hydrogen / fuel to last a very long time

second mark consequent on first

1

(c) any **two** from:

- hydrogen runs out / is used up
- nuclei larger than helium nuclei formed

  *accept bigger atoms are formed however do **not** accept any specific mention of an atom with a mass greater than that of iron*
- (star expands to) / become(s) a red giant

2

[6]

25 (a) (i) (nuclear) fission

*accept fision providing clearly **not** fusion*

1

(ii) (released) neutrons are absorbed by further (uranium) nuclei

accept hit nuclei for absorbed / hit
*do **not** accept atom for nuclei*

1

more neutrons are released (when new nuclei split)

*accept for **both** marks a correctly drawn diagram*

1

(iii) increases by 1

or goes up to 236

1

(b) any **two** from:

- (more) neutrons are absorbed
  accept there are fewer neutrons
- (chain) reaction slows down / stops
  accept keeping the (chain) reaction controlled
- less energy released
  accept heat for energy
  accept gases (from reactor) are not as hot

2

[6]

26 (a) (a) supernova (explosion)

1

(b) solar system contains heavy elements / elements heavier than hydrogen and helium (1)

these (heavy) elements are / were formed by (nuclear) fusion (1)
accept minor misspellings for 'fusion'
*but **not** anything which could also be 'fission'*

(at the very high temperature(s)) in a super nova / when stars explode (1)

3

[4]

27 (a) dust
accept 'solid (s)'

1

space
accept 'from supernova / supernovum / supernovas'

1

(b) By atoms joining together
only one ticked or otherwise unambiguously identified

1

(c) Milky Way (galaxy)

1

(d) The answer depends on beliefs and opinions, not scientific evidence.

only one ticked or otherwise unambiguously identified

1

[5]

28

(a) (i) (nuclear) fusion

*allow minor misspellings but do **not** credit any response which could be fission*

1

(ii) (in) stars

accept supernova / red giants / white dwarves

*do **not** allow the Sun*

1

(iii) (by) supernova / explosion of star

*do **not** credit just 'explosion(s)'*

1

(b) the (available) evidence:
supports this idea
or does not contradict this idea
or can be extrapolated to this idea

1

[4]

29

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.

*Maximum of **1** mark if ideas not well expressed*

any **two** from:

dust <u>and</u> gas **or** remnants of a super nova

accept hydrogen for dust and gas
*do **not** accept hydrogen burns*

pulled together by (force of) gravity

nuclear fusion starts

although candidates may include more detail these points are essential to score the credit

[2]

30 (a) (i) (large) nucleus hit by a neutron

1

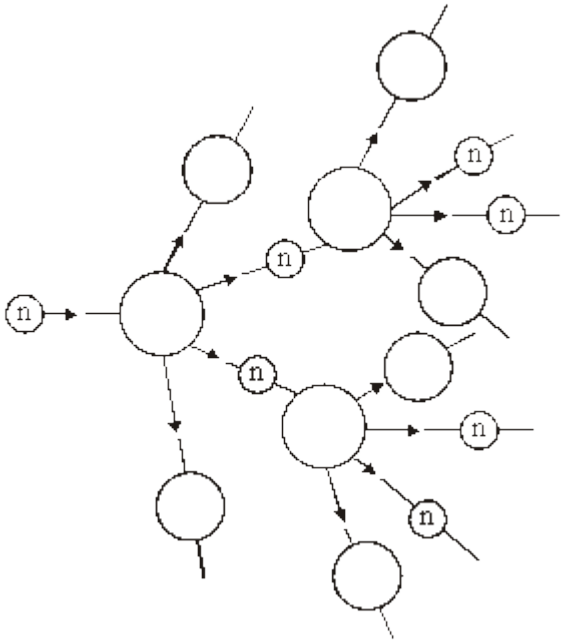
splits into (smaller) nuclei **and** neutron(s) (+ energy)

1

(ii) additional neutrons collide with nuclei causing further fission

allow full credit for a correct labelled diagram
accept 2 or more neutrons given out at each fission reaction

diagram shows 3 discernible sizes, with smaller nuclei and neutrons at same stage



1

(b) cost of (building and) de-commissioning is very high **or**
cost of building is higher

accept a correct description of de-commissioning

accept high cost to keep the power station safe / secure
accept high cost of reprocessing / storage of nuclear waste

1

(c) less pollution from transport carrying the fuel

accept coal produces more pollutant gases
accept correct named gases
accept more radiation pollution from coal than nuclear
accept more waste from coal than nuclear
*do **not** accept any reference to burning uranium*
*do **not** accept answers in terms of global warming **or** acid rain unless developed*

1

[5]

31 (a) any **two** from:

- nuclei / atoms of light elements fuse

accept hydrogen or helium for light elements
accept join for fuse
*accept for **1** mark, by nuclear fusion*
answers about fission negates a mark

- each (fusion) reaction releases energy / heat / light
- lots of reactions occur

2

(b) presence of nuclei of the heaviest / heavy / heavier elements

accept atom for nuclei

1

(c) (i) (matter / mass) with such a high density / strong gravitational (field)

1

electromagnetic radiation / light is pulled in

accept nothing can escape
*do **not** accept answers in terms of an empty void*

1

(ii) X-rays

accept e-m radiation / e-m waves

1

[6]

32 (a) (i) both lose 2 protons and (2) neutrons

accept changes by 2 protons and 2 neutrons

1

(ii) different number of protons (in the nucleus)

accept different atomic number
*do **not** accept different number of protons and neutrons or different mass number*
ignore electrons

1

(iii) gamma involves no change in the number of protons (in the nucleus)
or gamma is a wave (not a particle)

*do **not** accept number of neutrons and / or protons*
ignore electrons

1

(b) (i) water because

*both material **and** reason required*

for all energy values the thickness of water needed to absorb (90% of) the radiation is more than the other materials

accept thickness of water required is always more than the other materials

1

(ii) 6

*allow **1** mark for obtaining both correct values 72 **and** 12 from graph*
*allow **1** mark for incorrect values 71 and / or 11 from graph evaluated correctly*

2

(c) any **three** from:

may be scored on annotated diagram provided not negated elsewhere

- most (alpha) particles passed undeflected / straight through the gold
- suggesting most of the atom is empty (space)
- a few (alpha) particles scattered / deflected through (very) large angles

  accept repelled
  *do **not** accept reflected / rebound / bounce back*
- suggesting a concentrated / small nucleus
- nucleus is positive because it repels the positive (alpha) particles

  *no reference to experiment, maximum **1** mark*

3

[9]

33 (a) fusion

accept fussion

1

energy producing process

accept heat and/or light for energy
accept fussion

1

(b) up to **2** points from:

__3__ marks for 3 points in sequence with no contradiction

- expands

__2__ marks for 2 points in sequence with no contradiction

- cools
- forms a red giant

__1__ mark for a correct point which is not contradicted

up to **2** points from:

do __not__ accept 'it turns red'

- contracts
- increases in temperature
- forms a white dwarf

ignore further reference to black dwarfs, black holes, nebulae, supernovae

3

[5]

34 (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]

35 (i) sensible answers e.g. risk of radioactive leak during transport eliminated
cheaper transport

1

(ii) 4 half-lives 4 × 6 = 24 seconds

3

[4]

36 (i) the nuclei
of hydrogen/smaller atoms
join to make helium/larger atoms

for 1 mark each

3

(ii) the mass of the large nucleus (atom) is less than the mass of the smaller nuclei (atoms)

for 1 mark

mass loss converted into energy or small mass loss given a large amount of energy

for 1 mark

2

[5]

37 (a) the Sun is subject to two balancing forces / 2 forces in equilibrium
the forces are: gravity making it contract **or** inward force due to gravity
and a force due to temperature / heat / energy / radiation pressure making it expand **or** outward force due to temperature / heat / energy / radiation pressure

for 1 mark each

3

(b) Read all the answer first. Stop after 6 marks.

hydrogen / fuel used up owtte the star will expand and become a red giant
it will contract under gravity become a white dwarf
it may explode and become a supernova throwing dust and gas into space
leaving a dense neutron star / black hole

(no mark for contradiction)
any six for 1 mark each

6

[9]

38 any **three** from

max 2 if stages but no explanation

- the star (Sun) expands because
  (inward) gravitational forces no longer balance (outward) force

  accept the star collapses rapidly causing the core temperature to increase and the star to expand
  accept it expands because the forces are unbalanced

- to become a red giant

- when the fusion stops it contracts / cools

  accept (when hydrogen is used up) it collapses under gravity
  accept when fusion stops it contracts and explodes

- to become a white dwarf

  accept to become a supernova / pulsar / neutron star / black hole (only if red giant has exploded)

[3]

39 (a) (i) any **two** from

(matter from) exploded star / supernova

matter so dense / gravity so strong

that electromagnetic radiation / light cannot escape from it

2

(ii) X-rays emitted

1

when gases or matter released from nearby stars spiral into it

1

(b) fusion (of nuclei)

1

of lighter elements / hydrogen helium

1

[6]

40 Quality of written communication: One mark for using correct scientific sequence : gravity → fusion → balance

1

any **four** from

- (dust and gas) pulled together by gravity
- (star formed when) it is hot enough
  accept (as mass is pulled together) it gets very hot
- <u>hydrogen</u> (and helium) nuclei <u>fuse</u>
- (these nuclear fusion reactions) release the energy / heat / light (which is radiated by stars)
- energy causes expansion
- gravitational pull is balanced by the expansion (force)

4

[5]

41 (a) materials produced when earlier stars exploded

accept the Sun is a second generation star

accept formed from nebulae

1

(b) **Quality of written communication:**
1 mark for correct sequencing balanced forces → expansion → contraction / explosion

1

any **five** from

gravity pulling matter together

accept idea that a star is very massive so its force of gravity is very strong

high temperatures that create expansion forces

nuclear fusion releases energy that causes the very high temperatures

these forces balance

star expands greatly

since expansion is greater than gravity

accept fuel runs out

forms a red giant

give no further marks if red giant → white dwarf, red dwarf etc

collapses inwards and explodes outwards

called a supernova

neutron star may form

leaves a small, dense object (a black hole)

accept nothing can escape from it

5

[7]

42 any **one** of

* between (stage) 2 and (stage) 3
* (in) the main sequence
* (in) the main stable period
* (it is a) yellow dwarf

[1]

43 (a) *evidence of conclusion* 4 × 1.007825 **or** 4.0313

each gain 1 mark

based on use of data that there is a (very small) loss of mass
or 0.0276 **but** a loss of mass of 0.0276 **for every helium atom or** 0.69%/0.7%

gains 3 marks

3

(b) *idea that* loss of mass results in release of energy

gains 1 mark

but small loss of mass results in huge energy release

gains 2 marks

2

[5]

44 (a) it use $E = mc^2$

mass in kg i.e. $0.001 \times \frac{0.7}{100}$

each gains 1 mark

but 000007

gains 2 marks

2.1×10^3

gains 3 marks

evidence of 0.000007

mass in kg (i.e. 0.0007 **or** 0.7/100000)

each gains 1 mark

squaring the speed of light
but 6.3×10^{11} *(credit alternative ways of stating this)*

gains 3 marks

units J/joule

for 1 further mark

(N.B credit kJ, MJ, GJ but check power of 10 for full credit)

4

(b) (i) *idea that* the bigger the mass the shorter the life

gains 1 mark

but *idea that* decrease in life is much more than proportional to increase in mass

or more than proportional to mass^2

gains 2 marks

2

(ii) *ideas that*:
greater mass means greater **core** temperature/pressure
greater core temperature/pressure means greater rate of fusion
increase in mass produces a proportionally much greater increase in the rate of fusion

each for 1 mark

3

[9]

45 ideas that

- formed from dust/gases
- pulled together by gravity
- massive so very large gravitational forces (pulling inwards)
- hydrogen → helium / fusion releases energy [<u>not</u> fission or just 'nuclear']
- high temperature creates high pressure (pushing outwards)
- long period when forces balance
- then expands → red giant / red star
- then contracts to (dense) white dwarf / white star

[<u>credit</u> if massive enough / more massive than sun, red giant → supernova → (very dense) neutron star but do not accept w.r.t. Sun itself]

[The whole of the (non bracketed part of) each idea <u>must</u> be present in some appropriate for in of words for each mark to be credited. To gain more than a single mark ideas must also be in correct sequence and/or appropriately related.]

any six 1 mark each

[6]