

AQA GCSE PHYSICS (HIGHER) • 8463

PHYSICS



EXAM QUESTION PACK

4.4.4 NUCLEAR FISSION AND FUSION (PACK 2)

SCORE

/100

PERCENTAGE

%

STEMUP

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Q1.

The statement in the box is from an article in a science magazine.

Scientists think that all the elements on Earth are also present throughout the Universe.

- (a) (i) Name the process by which these elements were formed.

_____ (1)

- (ii) Where did the elements form?

_____ (1)

- (iii) What caused these elements to be distributed throughout the Universe?

_____ (1)

- (b) Scientists have only examined a tiny fraction of the Universe. What is the basis for the statement in the science magazine?

(1)
(Total 4 marks)

Q2.

To gain full marks in this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words.

Explain briefly how stars like the Sun are thought to have been formed.

(Total 2 marks)

Q3.

- (a) Nuclear power stations use the energy released by *nuclear fission* to generate electricity.

- (i) Explain what is meant by *nuclear fission*.

(2)

- (ii) How does nuclear fission lead to a chain reaction?

You may give your answer as a labelled diagram.

(1)

- (b) Although nuclear fuels are relatively cheap the total cost of generating electricity using nuclear fuels is expensive. Why?

(1)

- (c) The table compares the energy released from 1 kg of coal and 1 kg of uranium.

Coal	29 MJ
Uranium	580 000 MJ

1 MJ = 1 000 000 joules

State **one** benefit to the environment of using a concentrated fuel like uranium to generate electricity rather than using the energy from coal.

(1)

(Total 5 marks)

Q4.

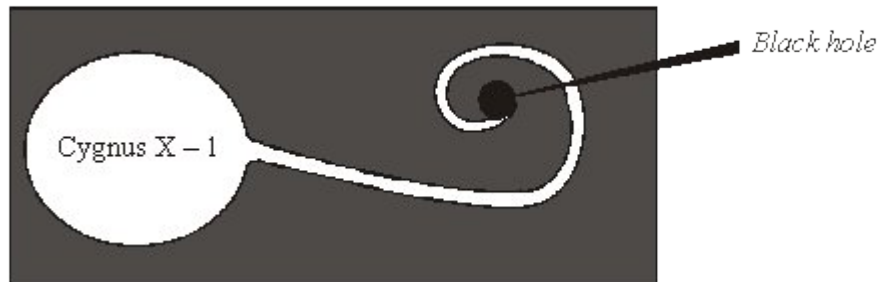
- (a) Explain how stars produce energy.

(2)

- (b) What evidence is there to suggest that the Sun was formed from the material produced when an earlier star exploded?

(1)

- (c) It is thought that gases from the massive star Cygnus X-1 are spiralling into a black hole.



- (i) Explain what is meant by the term *black hole*.

(2)

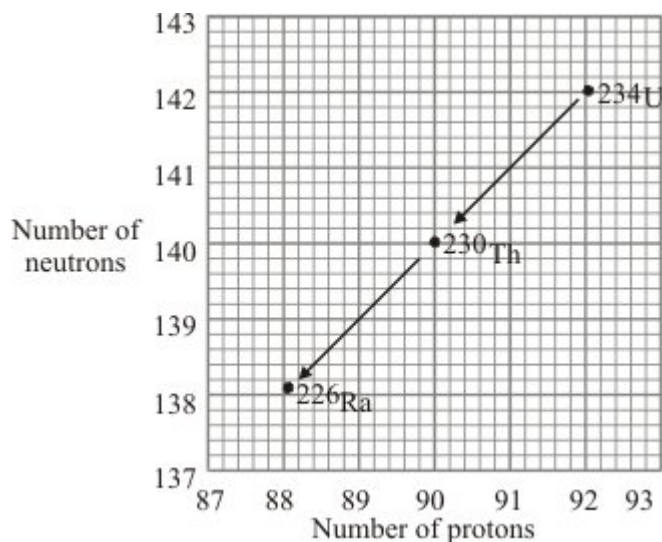
- (ii) What is produced as the gases from a star spiral into a black hole?

(1)

(Total 6 marks)

Q5.

- (a) Uranium-234 (^{234}U) is a radioactive element. The graph shows the number of protons and neutrons in the nuclei of the elements formed when uranium-234 decays.



- (i) How does the graph show that uranium-234 (^{234}U) and thorium-230 (^{230}Th) emit alpha particles?

(1)

- (ii) What makes uranium and thorium different elements?

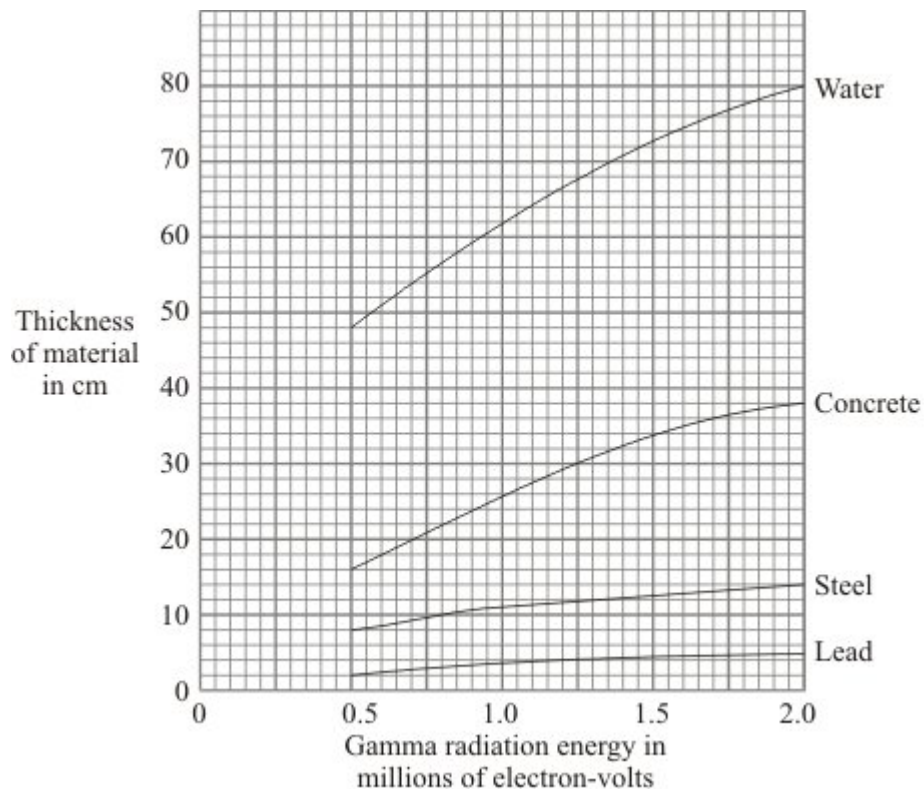
(1)

- (iii) Radioactive decay may also produce gamma radiation.

Why does the emission of gamma radiation **not** cause a new element to be formed?

(1)

- (b) The graph shows how the thickness of different materials needed to absorb 90% of the gamma radiation emitted by a source depends on the energy of the radiation. The energy of the gamma radiation is given in units called electron-volts.



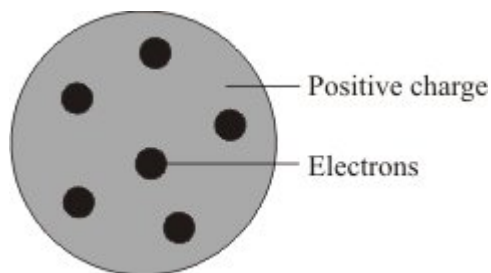
- (i) Which of the materials shown is least effective at absorbing gamma radiation? Use the information in the graph to give a reason for your answer.

(1)

- (ii) For gamma radiation of energy 1.5 million electron-volts, how many times more effective is steel than water at absorbing the radiation? Show clearly how you obtain your answer.

(2)

- (c) Scientists in the early twentieth century thought that atoms were made up of electrons scattered inside a ball of positive charge. This was called the 'plum-pudding' model of the atom.



Plum pudding model

Rutherford and Marsden did an experiment, in which a beam of alpha particles was aimed at a thin sheet of gold.
Explain how the results of this experiment led to a new model of the atom.
You may include one or more diagrams in your answer.

(3)

(Total 9 marks)

Q6.

- (a) Most of the Sun is hydrogen. Inside the core of the sun, hydrogen is being converted to helium. What name is given to this process and why is the process so important?

(2)

- (b) Describe what will happen to the Sun as the core runs out of hydrogen.

Q7.

The first commercial nuclear power station in the world was built at Calder Hall in Cumbria.

- (a) The fuel used at the Calder Hall power station is uranium. Natural uranium consists mainly of two isotopes: uranium-235 (${}_{92}^{235}\text{U}$) and uranium-238 (${}_{92}^{238}\text{U}$). The nucleus of a uranium-235 atom is different to that of a uranium-238 atom.

- (i) Where is the nucleus in an atom?

_____ (1)

- (ii) Name the **two** types of particle found in the nucleus.

_____ and _____ (2)

- (iii) How is the nucleus of a uranium-238 atom different to the nucleus of a uranium-235 atom?

_____ (2)

- (b) In the nuclear reactor fission of uranium atoms takes place in reactions such as the one shown below.



The nuclear reactions are carefully controlled in the power station so that a chain reaction takes place.

Explain, as fully as you can:

- (i) how fission of uranium atoms takes place in a nuclear reactor;

- (ii) how this leads to a chain reaction;

- (iii) why it can be used to generate electricity.

(4)

(Total 9 marks)

Q8.

The first commercial nuclear power station in the world was built at Calder Hall in Cumbria.

The atoms produced by the fission of uranium are also radioactive. The used fuel is sent to a reprocessing plant where it can be safely treated.

- (i) Calder Hall power station is next to the Sellafield reprocessing plant. Suggest an advantage of having the two plants close together.

(1)

- (ii) One of the radioactive products is iodine-138. This has a half-life of 6 seconds. A sample of radioactive material contains 2000 atoms of iodine-138. How long will it take for the number of iodine-131 atoms to decrease to 125?

Answer = _____ seconds

(3)

(Total 4 marks)

Q9.

Nuclear fusion in the Sun releases large amounts of energy.

- (i) Explain what is meant by nuclear fusion.

(3)

- (ii) Why is energy released by such nuclear fusion reactions?

(2)

(Total 5 marks)

Q10.

- (a) The Sun is at the stable stage of its life.

Explain, in terms of the forces acting on the Sun, what this means.

(3)

- (b) At the end of the stable stage of its life a star will change.

Describe and explain the changes that could take place.

(6)

(Total 9 marks)

Q11.

Our Sun is just one of many millions of stars in a galaxy called the Milky Way.

Our Sun is in the main stable period of a star's lifetime. The massive force of gravity draws its matter together. This force is balanced by the very high temperatures, from the fusion of hydrogen atoms, which tend to make the Sun expand. Describe and explain what will happen to the Sun as the hydrogen is eventually used up.

(Total 3 marks)

Q12.

Studying stars gives scientists evidence about the evolution of the Universe.

- (a) (i) In astronomy, what is meant by a black hole?

(2)

- (ii) How is it possible to detect a black hole?

(2)

- (b) The changes which happen in stars result in new elements being formed.

Nuclei of the heaviest elements are found in the Sun.

Describe how these nuclei are formed.

Q13.

One theory of the origin of the Universe was that billions of years ago all matter was in one place, then it exploded ('big bang').

Describe, in as much detail as you can, how our star (the Sun) formed from the time when there was just dust and gas (mostly hydrogen) up to now when it is in its main stable period.

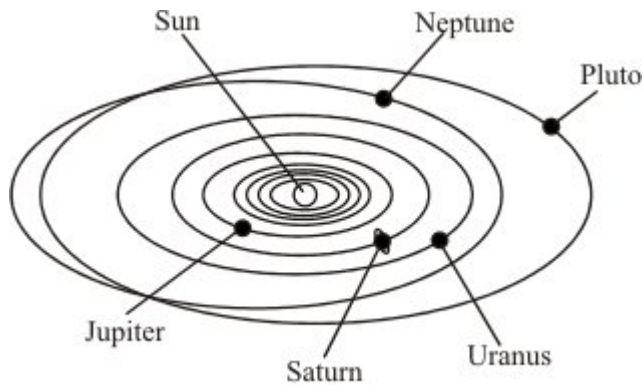
To gain full marks in this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words.

[illegible]

(Total 5 marks)

Q14.

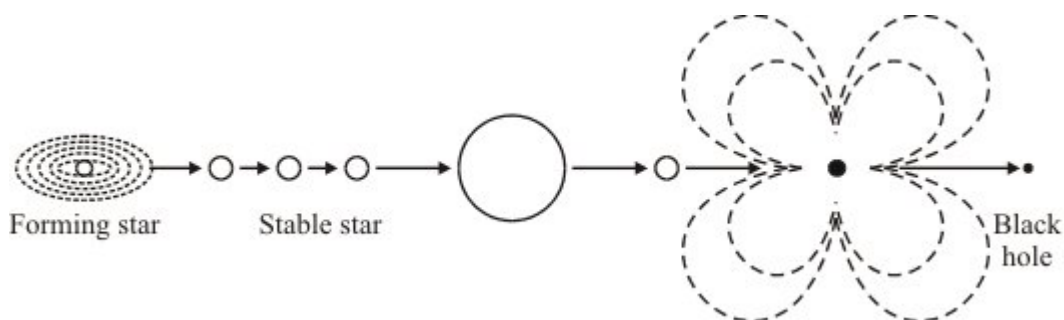
The Sun at the centre of our solar system is a star.



- (a) The Sun contains nuclei of the heaviest elements. Atoms of these heaviest elements are also present in the planets of the solar system. What does this suggest about the material from which the solar system is formed?

(1)

- (b) Stars form from gas (mostly hydrogen) and dust.



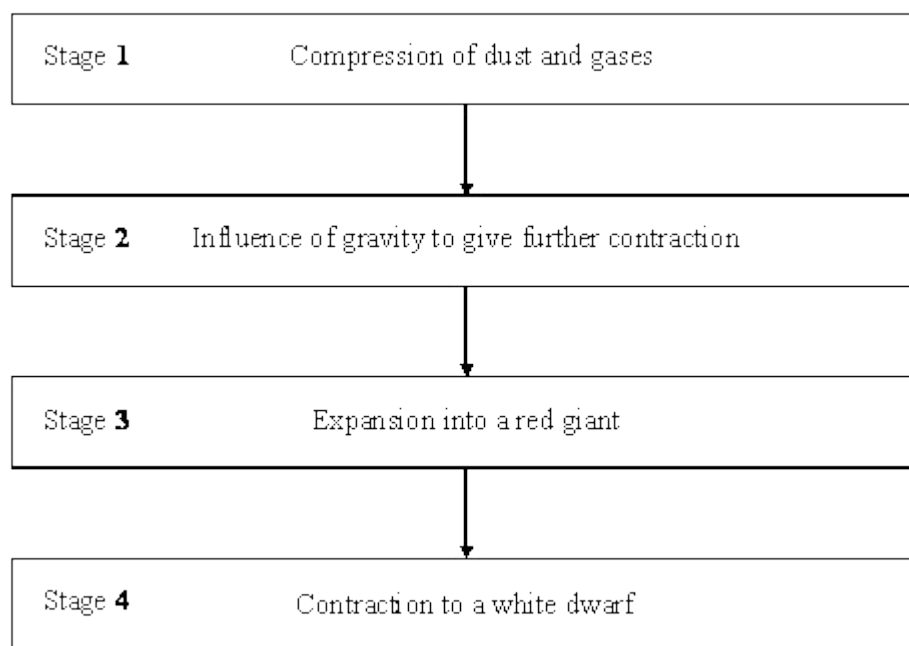
Describe, in as much detail as you can, what forces allow a stable star to exist and how the star may eventually form a black hole.

To gain full marks in this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words.

(6)
(Total 7 marks)

Q15.

The flowchart shows four stages thought to occur in the evolution of a star such as our Sun.



At a particular time a star might have reached one of these stages or be between stages or be at a further stage. What period in its evolution has our star, the Sun, reached?

(Total 1 mark)

Q16.

At the very high temperatures in the sun, hydrogen is converted into helium. It takes four hydrogen nuclei to produce one helium nucleus.

The table shows the relative masses of hydrogen and helium nuclei.

		Nucleus	Relative Mass
Hydrogen nucleus	Helium nucleus	hydrogen	1.007825
		helium	4.0037

- (a) Use these figures to calculate what happens to the mass of the sun as hydrogen is converted to helium.

(3)

- (b) Use your answer to part (a) to explain how the sun has been able to radiate huge amounts of energy for billions of years.

(2)

(Total 5 marks)

Q17.

The energy radiated by a **main sequence** star like the Sun is released by a nuclear fusion reaction in its core.

Read the following information about this reaction then use it to answer the questions below.

- The net result of the nuclear fusion reaction is that four hydrogen nuclei produce one helium nucleus. There is a loss of mass of 0.7%.
- For nuclear fusion to occur nuclei must collide at very high speeds.
- The energy released during the reaction can be calculated as shown:

$$\text{energy released [J]} = \text{loss of mass [kg]} \times (\text{speed of light [m/s}^2\text{)})$$

(The speed of light is 3×10^8 m/s)

- (a) Calculate the energy released when 1g of hydrogen fuses to form helium.

(Show your working.)

(4)

- (b) The table shows the lifetimes and surface temperatures of main sequence stars with different masses.

MASS OF STAR [SUN = 1]	LIFETIME ON MAIN SEQUENCE [MILLION OF YEARS]	SURFACE TEMPERATURE * [KELVIN]
0.5	200 000	4000
1	10 000	6000
3	500	11 000
15	15	30 000

[* The higher the surface temperature of a star, the higher the temperature and pressure in its core.]

- (i) Describe the relationship between the lifetime of a main sequence star and its mass.

(2)

- (ii) Suggest an explanation for this relationship.

(3)

(Total 9 marks)

Q18.

Describe, in as much detail as you can, the life history of a star like our Sun.

(Total 6 marks)

Mark schemes

Q1.

- (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]

Q2.

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 and 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]

Q3.

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

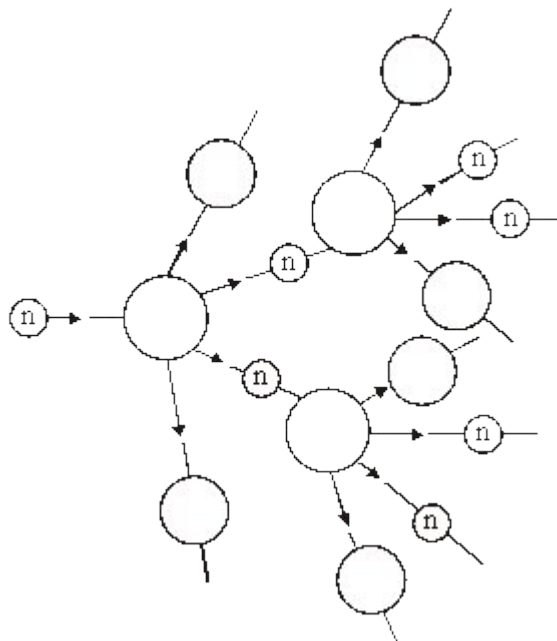
1

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]

Q4.

- (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)
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]

Q5.

- (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]

Q6.

(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]

Q7.

- (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]**Q8.**

- (i) sensible answers e.g. risk of radioactive leak during transport eliminated
 cheaper transport 1
- (ii) 4 half-lives $4 \times 6 = 24$ seconds 3

[4]**Q9.**

- (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]**Q10.**

- (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]

Q11.

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]

Q12.

- (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]

Q13.

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
- hydrogen (and helium) nuclei fuse
- (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]

Q14.

- (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]

Q15.

any **one** of

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

[1]

Q16.

- (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]

Q17.

- (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 mass²

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]

Q18.

ideas that

- formed from dust/gases
- pulled together by gravity
- massive so very large gravitational forces (pulling inwards)
- hydrogen → helium / fusion releases energy [not 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
[credit 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 must be present in some appropriate form 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]