**1** Stars go through a life cycle.

Some stars will finish their life cycle as a black dwarf and other stars as a black hole.

(a) The table below gives the mass, relative to the Sun, of three stars, **J**, **K** and **L**.

| **Star** | **Mass of the star relative to the Sun** |
|---|---|
| **J** | 0.5 |
| **K** | 14.5 |
| **L** | 20.0 |

Which **one** of the stars, **J**, **K** or **L**, will become a black dwarf? .....

Give a reason for your answer.

.....

.....

**(2)**

(b) Scientists can take the measurements needed to calculate the mass of many stars.

Scientists cannot calculate the mass of the star Betelgeuse.

They estimate that the star has a mass between 8 and 20 times the mass of the Sun.

(i) Betelgeuse is in the red super giant stage of its life cycle.

What will happen to Betelgeuse at the end of the red super giant stage?

.....

.....

**(1)**

(ii) Suggest **one** reason why scientists can only estimate and **not** calculate the mass of Betelgeuse.

.....

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**(1)**

(iii) In the future, it may become possible for scientists to calculate the mass of Betelgeuse.

Suggest **one** reason why.

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**(1)**

(c) Describe what happens to a star, after the main sequence period, for the star to eventually become a **black dwarf**.

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**(5)**
**(Total 10 marks)**

**2** (a) There are many isotopes of the element molybdenum (Mo).

What do the nuclei of different molybdenum isotopes have in common?

.....

**(1)**

(b) The isotope molybdenum-99 is produced inside some nuclear power stations from the nuclear fission of uranium-235.

(i) What happens during the process of nuclear fission?

.....

.....

**(1)**

(ii) Inside which part of a nuclear power station would molybdenum be produced?

.....

**(1)**

(c) When the nucleus of a molybdenum-99 atom decays, it emits radiation and changes into a nucleus of technetium-99.

$$^{99}_{42}\text{Mo} \longrightarrow {}^{99}_{43}\text{Tc} + \text{Radiation}$$

What type of radiation is emitted by molybdenum-99?

.....

Give a reason for your answer.

.....

.....

**(2)**

(d) Technetium-99 has a short half-life and emits gamma radiation.

What is meant by the term ‘half-life’?

.....

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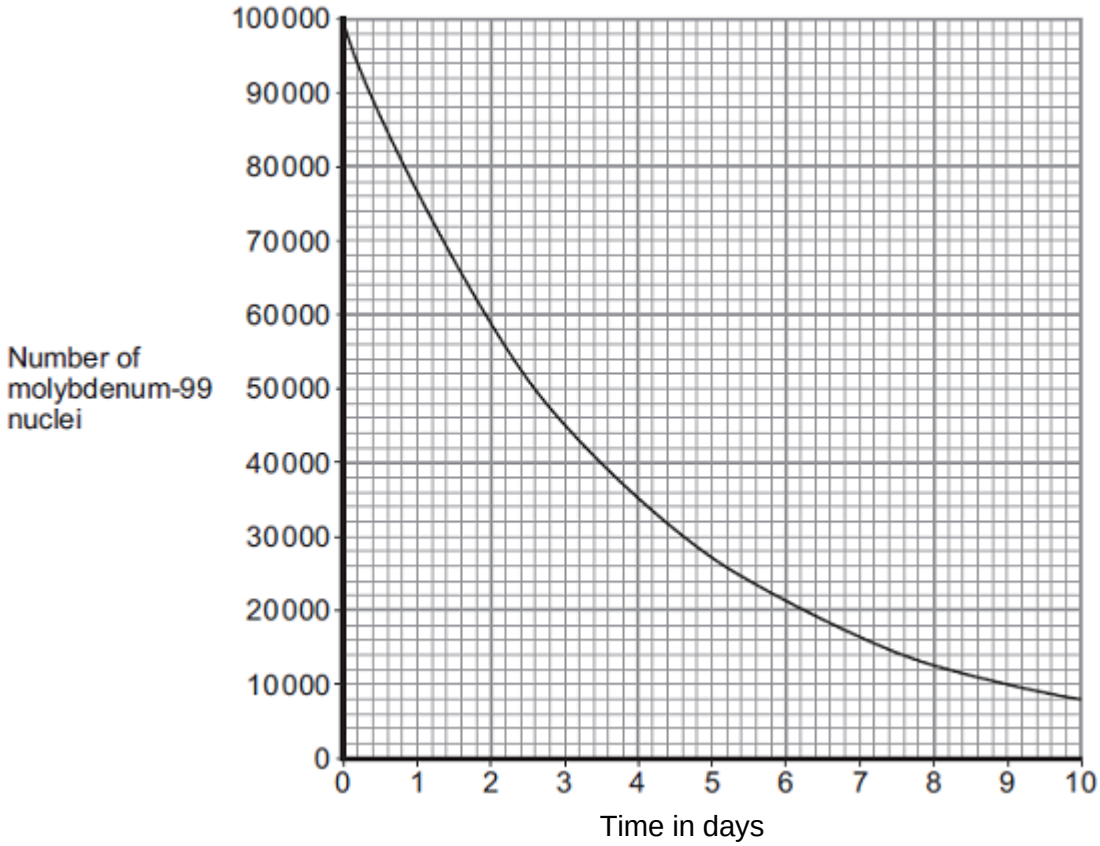
**(1)**

(e) Technetium-99 is used by doctors as a medical tracer. In hospitals it is produced inside a technetium generator by the decay of molybdenum-99 nuclei.

(i) The figure below shows how the number of nuclei in a sample of molybdenum-99 changes with time as the nuclei decay.




A technetium generator will continue to produce sufficient technetium-99 until 80% of the original molybdenum nuclei have decayed.

After how many days will a source of molybdenum-99 inside a technetium-99 generator need replacing?

Show clearly your calculation and how you use the graph to obtain your answer.

.....

.....

.....

Number of days = .....

**(2)**

(ii) Medical tracers are injected into a patient's body; this involves some risk to the patient's health.

Explain the risk to the patient of using a radioactive substance as a medical tracer.

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**(2)**

(iii) Even though there may be a risk, doctors frequently use radioactive substances for medical diagnosis and treatments.

Suggest why.

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**(1)**
**(Total 11 marks)**

**3** Nuclear fission and nuclear fusion are two processes that release energy.

(a) (i) Use the correct answer from the box to complete each sentence.

| | | |
|---|---|---|
| **Geiger counter** | **nuclear reactor** | **star** |

Nuclear fission takes place within a ..... .

Nuclear fusion takes place within a ..... .

**(2)**

(ii) State **one** way in which the process of nuclear fusion differs from the process of nuclear fission.

.....

.....

**(1)**

(b) The following nuclear equation represents the fission of uranium-235 (U-235).

$$^{1}_{0}n + ^{235}_{92}U \longrightarrow ^{236}_{92}U \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n + \text{energy}$$

Chemical symbols:

Ba - barium

Kr - krypton

(i) Use the information in the equation to describe the process of nuclear fission.

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**(4)**

(ii) An isotope of barium is Ba-139.
Ba-139 decays by beta decay to lanthanum-139 (La-139).

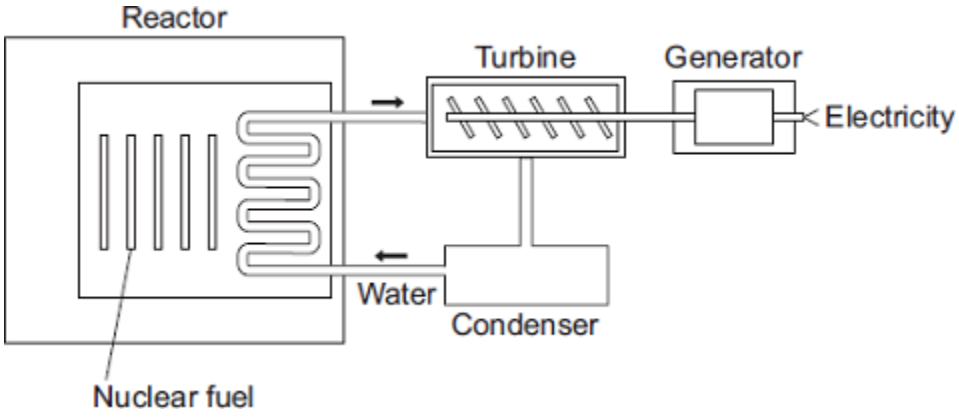
Complete the nuclear equation that represents the decay of Ba-139 to La-139.

$$^{139}Ba \longrightarrow \; ^{139}La \; + \; \ldots\ldots$$

..... ..... .....

**(3)**
**(Total 10 marks)**

**4** Nuclear power stations use the energy released from nuclear fuels to generate electricity.




(a) Which substance do the majority of nuclear reactors use as fuel?

Draw a ring around your answer.

**plutonium-239** **thorium-232** **uranium-235**

**(1)**

(b) Energy is released from nuclear fuels by the process of nuclear fission.

Describe what happens to the nucleus of an atom during nuclear fission.

.....

.....

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**(2)**

(c) Use words from the box to complete each sentence.

| | | | | | |
|---|---|---|---|---|---|
| **condenser** | **gas** | **generator** | **reactor** | **steam** | **turbine** |

The energy released from the nuclear fuel is used to heat water. The water turns into

..... and this is used to drive a ..... .

This turns a ..... to produce electricity.

**(3)**
**(Total 6 marks)**

**5** (a) Nuclear power stations generate about 14% of the world's electricity.

(i) Uranium-235 is used as a fuel in some nuclear reactors.

Name **one** other substance used as a fuel in some nuclear reactors.

.....

**(1)**

(ii) Energy is released from nuclear fuels by the process of nuclear fission.

This energy is used to generate electricity.

Describe how this energy is used to generate electricity.

Do **not** explain the nuclear fission process.

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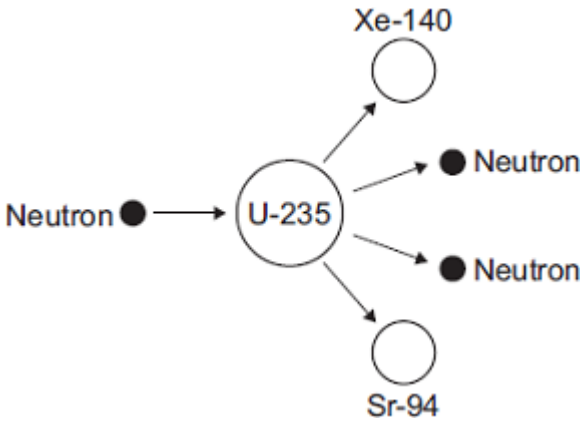
**(3)**

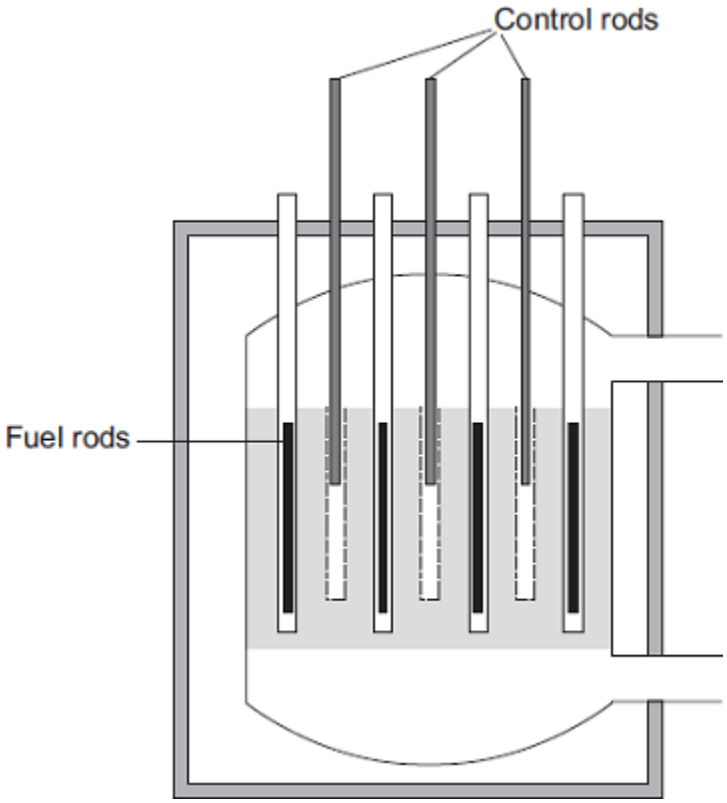
(b) The diagram shows the nuclear fission process for an atom of uranium-235.

Complete the diagram to show how the fission process starts a chain reaction.




**(2)**

(c) The diagram shows the cross-section through a nuclear reactor.




The control rods, made from boron, are used to control the chain reaction. Boron atoms absorb neutrons without undergoing nuclear fission.

Why does lowering the control rods reduce the amount of energy released each second from the nuclear fuel?

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**(2)**
**(Total 8 marks)**

**6** Stars go through a life cycle. About 90 % of all stars are in the 'main sequence' period of the life cycle.

(a) Stars are stable during the 'main sequence' period of the life cycle.

Why?

.....

.....

**(1)**

(b) The table gives an estimated time for the number of years that three stars, **X**, **Y** and **Z**, will be in the 'main sequence' period of their life cycle.

| **Star** | **Relative mass of the star compared to the Sun** | **Estimated 'main sequence' period in millions of years** |
|---|---|---|
| **X** | 0.1 | 4 000 000 |
| **Y** | 1.0 | 9 000 |
| **Z** | 40.0 | 200 |

(i) This data suggests that there is a pattern linking the mass of a star and the number of years the star is in the 'main sequence' period of its life cycle.

What is the pattern suggested by the data?

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.....

**(1)**

(ii) Scientists cannot give the exact number of years a star will be in the 'main sequence' period.

Suggest why.

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.....

**(1)**

(iii) Nuclear fusion is the process by which energy is released in stars.

Which **one** of the following can be concluded from the data in the table?

Draw a ring around the correct answer in the box to complete the sentence.

| | | |
|---|---|---|
| The rate of nuclear fusion in a large star is | faster than<br>the same as<br>slower than | in a small star. |

Explain the reason for your answer.

.....

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**(3)**

(c) *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate*.

Describe what happens to a star **much bigger** than the Sun, once the star reaches the end of the 'main sequence' period of its life cycle.

Your answer should include the names of the stages the star passes through.

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**(6)**
**(Total 12 marks)**

**7** Read this statement from a website.

> Immediately after the ‘big bang’, at the start of the Universe, there were only atoms of the element hydrogen (H).
>
> Now there are over one hundred elements.
> Scientists think that all the elements on Earth are also present throughout the Universe.

(a) Explain how atoms of the element (He) are formed in a star.

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**(2)**

(b) Explain how atoms of very heavy elements, such as gold (Au), were formed.

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**(2)**

(c) Scientists have only examined a tiny fraction of the Universe.

What is the basis for scientists thinking that the elements found on Earth are present throughout the Universe?

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**(1)**
**(Total 5 marks)**

**8** (a) Nuclear fuels and the wind are two of the energy sources used to generate electricity in the UK.

Explain the advantages of using energy from nuclear fuels to generate electricity rather than using energy from the wind.

Include in your answer a brief description of the process used to generate electricity from nuclear fuels.

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**(4)**

(b) In the UK, most electricity is generated in power stations that emit carbon dioxide into the atmosphere. The impact of these power stations on the environment could be reduced by the increased use of 'carbon capture' technology.

Describe how 'carbon capture' would prevent the build-up of carbon dioxide in the atmosphere.

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**(2)**
**(Total 6 marks)**

**9** (a) Nuclear fission is used in nuclear power stations to generate electricity. Nuclear fusion happens naturally in stars.

(i) Explain briefly the difference between *nuclear fission* and *nuclear fusion*.

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**(2)**

(ii) What is released during both nuclear fission and nuclear fusion?

.....

**(1)**

(b) Plutonium-239 is used as a fuel in some nuclear reactors.

(i) Name another substance used as a fuel in some nuclear reactors.

.....

**(1)**

(ii) There are many isotopes of plutonium.

What do the nuclei of different plutonium isotopes have in common?

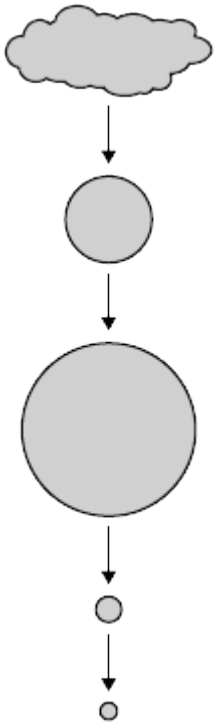
.....

**(1)**
**(Total 5 marks)**

**10** (a) The diagram shows the lifecycle of a star.

(i) Use words or phrases from the box to complete the sentences contained in the diagram.

| | | | |
|---|---|---|---|
| **black dwarf** | **black hole** | **protostar** | **red giant** |



Gas and dust are pulled together to form a

.....

The star gives out energy as a main sequence star.

The star expands forming a .....

The star shrinks to form a white dwarf.

The star fades away as a .....

**(3)**

(ii) The table compares the approximate size of three stars with the size of the Sun.

| Star | Size |
|---|---|
| Alpha Centauri A | the same as the Sun |
| Betelgeuse | 1120 times bigger than the Sun |
| Cephei | 1520 times bigger than the Sun |

Which **one** of these three stars has the lifecycle shown in part (a)(i)?

.....

Give a reason for your answer.

.....

.....

**(2)**

(b) Which one of the following describes the process by which energy is given out in stars?

Tick (✓) **one** box.

Atomic nuclei inside the star join together. ☐

Atomic nuclei inside the star split apart. ☐

Gases inside the star burn. ☐

**(1)**
**(Total 6 marks)**

**11** (a) As part of its life cycle, a star changes from being a protostar to a main sequence star.

Explain the difference between a protostar and a main sequence star.

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**(2)**

(b) The early Universe contained only atoms of hydrogen. The Universe now contains atoms of over one hundred different elements.

Explain how the different elements now contained in the Universe were formed.

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**(3)**
**(Total 5 marks)**

**12** The names of three different processes are given in **List A**.
Where these processes happen is given in **List B**.

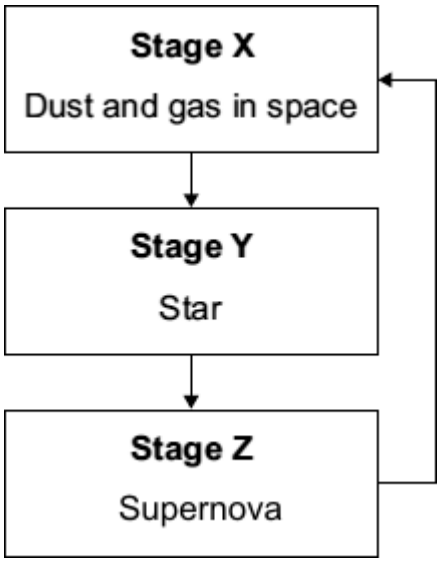
Draw a line to link each process in **List A** to where the process happens in **List B**.

Draw only **three** lines.

| **List A**<br>**Process** | **List B**<br>**Where it happens** |
|---|---|
| | in a star |
| fusion | |
| | in a nuclear reactor |
| chain reaction | |
| | in a smoke precipitator |
| alpha decay | |
| | in the nucleus of an atom |

**(Total 3 marks)**

**13** The flowchart shows a simple version of the life cycle of a star that is much more massive than the Sun.




(a) What causes the change from **Stage X** to **Stage Y**?

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**(1)**

(b) For most of its time in **Stage Y**, the star is stable.

Explain why the star remains stable.

.....

.....

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.....

**(2)**

(c) (i) Explain how a star is able to produce energy in **Stage Y**.

.....

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.....

**(2)**

(ii) Why is a star in **Stage Y** able to give out energy for millions of years?

.....

.....

**(1)**

(d) What happens to the elements produced in a supernova?

.....

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**(1)**
**(Total 7 marks)**

**14** When the nucleus of a radium-225 atom decays, it changes into a nucleus of actinium-225.

$$^{225}_{88}\text{Ra} \longrightarrow {}^{225}_{89}\text{Ac} + \boxed{\text{Radiation}}$$

What type of radiation is emitted by radium-225?

Draw a ring around your answer.

**alpha** **beta** **gamma**

Explain the reason for your answer.

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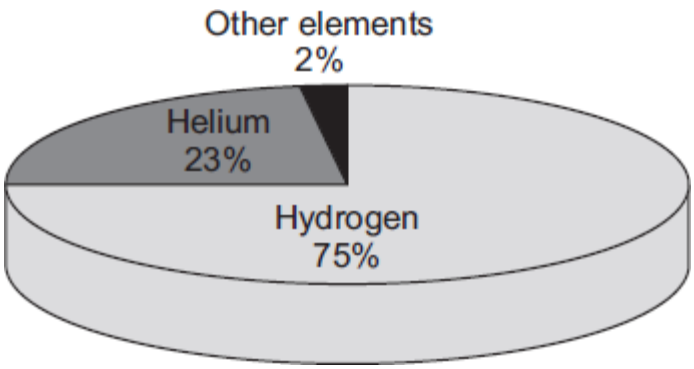
**(Total 3 marks)**

**15** This passage is from a web page.

## Our nearest star, the Sun

The pie chart shows the proportions of chemical elements in the Sun.




Most of the Sun's helium has been produced from the Sun's hydrogen by the process of nuclear fusion. This process also produces vast quantities of energy. The process takes place in the core of the Sun at a temperature of about 15 million °C and has been going on for about 4.5 billion years. During this period of time, the Sun has remained stable and scientists think that it will remain stable for several billion years into the future.

(a) Explain why the Sun remains stable.

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**(3)**

(b) A scientific opinion is expressed on this web page.

Identify this opinion and suggest how scientists could justify it.

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**(2)**
**(Total 5 marks)**

**16** The process of nuclear fusion results in the release of energy.

(a) (i) Describe the process of nuclear fusion.

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**(2)**

(ii) Where does nuclear fusion happen naturally?

.....

**(1)**

(b) For many years, scientists have tried to produce a controlled nuclear fusion reaction that lasts long enough to be useful. However, the experimental fusion reactors use more energy than they produce.

(i) From the information given, suggest **one** reason why nuclear fusion reactors are not used to produce energy in a nuclear power station.

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**(1)**

(ii) Suggest **one** reason why scientists continue to try to develop a practical nuclear fusion reactor.

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**(1)**
**(Total 5 marks)**

**17** (a) Our star, the Sun, is stable.

Explain what the conditions need to be for a star to remain stable.

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**(2)**

(b) Shortly after the 'big bang', hydrogen was the only element in the Universe.

Explain how the other elements came to be formed.

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**(3)**
**(Total 5 marks)**

**18** (a) Uranium atoms do not always have the same number of neutrons.
What are atoms of the same element that have different numbers of neutrons called?

.....

**(1)**

(b) By emitting an alpha particle, an atom of uranium-235 decays into an atom of thorium.

An alpha particle, which is the same as a helium nucleus, is represented by the symbol $^{4}_{2}He$ .

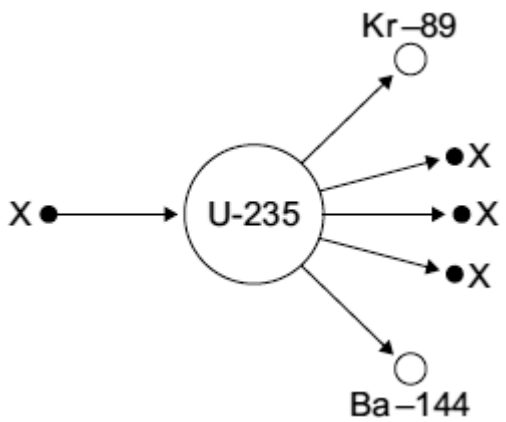
The decay can be represented by the equation below.

Complete the equation by writing the correct number in each of the two boxes.

$$^{235}_{92}U \longrightarrow \boxed{\phantom{00}} \; Th + \boxed{\phantom{00}} \; ^{4}_{2}He$$

**(2)**

(c) The diagram shows an atom of uranium-235 being split into several pieces.




(i) Name the process shown in the diagram.

.....

**(1)**

(ii) Name the particles labelled **X**.

.....

**(1)**

(d) Uranium-235 is used as a fuel in some nuclear reactors.
Name another substance used as a fuel in some nuclear reactors.

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**(1)**
**(Total 6 marks)**

**19** Every star goes through a ‘life cycle’.

(a) Describe how a star forms.

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**(2)**

(b) During a long period of its life, a star remains in a stable state.

Explain why a star remains stable.

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**(2)**

(c) Some stars are much more massive than the Sun.

Describe what will happen to a star, originally much more massive than the Sun, after it reaches its red giant stage.

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**(2)**
**(Total 6 marks)**

**20** Four different processes are described in **List A**. The names of these processes are given in **List B**.

Draw a line to link each description in **List A** to its correct name in **List B**.
Draw only **four** lines.

| List A | List B |
|---|---|
| the nuclei of two atoms joining together | gamma emission |
| the nucleus of an atom splitting into several pieces | electric current |
| an atom losing an electron | ionisation |
| an electric charge moving through a metal | nuclear fission |
| | nuclear fusion |

**(Total 4 marks)**

**21** Read this statement from a website.

> Immediately after the 'big bang', at the start of the Universe, there were only atoms of the element hydrogen (H).
>
> Now the Universe contains atoms of over one hundred elements.

(a) Explain how atoms of the element helium (He) are formed in a star.

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**(2)**

(b) Explain how atoms of very heavy elements, such as gold (Au), were formed.

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**(2)**

(c) Explain how, and when, atoms of different elements may be distributed throughout the Universe.

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**(2)**
**(Total 6 marks)**

**22** The table gives information about the three types of particle that make up an atom.

| **Particle** | **Relative mass** | **Relative charge** |
|---|---|---|
| Proton | | +1 |
| Neutron | 1 | |
| Electron | very small | –1 |

(a) Complete the table by adding the **two** missing values.

**(2)**

(b) Use the information in the table to explain why an atom has no overall electrical charge.

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**(2)**

(c) Uranium has two natural isotopes, uranium-235 and uranium-238.
Uranium-235 is used as a fuel inside a nuclear reactor.
Inside the reactor, atoms of uranium-235 are split and energy is released.

(i) How is the structure of an atom of uranium-235 different from the structure of an atom of uranium-238?

.....

.....

**(1)**

(ii) The nucleus of a uranium-235 atom must absorb a particle before the atom is able to split.

What type of particle is absorbed?

.....

**(1)**

(iii) The nucleus of an atom splits into smaller parts in a reactor.

What name is given to this process?

.....

**(1)**
**(Total 7 marks)**

**23** This passage is from a science magazine.

> *A star forms when enough dust and gas are pulled together. Masses smaller than a star may also be formed when dust and gas are pulled together.*

(a) What is the force which pulls the dust and gas together?

.....

**(1)**

(b) Complete the sentences.

(i) The smaller masses may be attracted by the star and become

..... .

**(1)**

(ii) Our nearest star, the Sun, is stable because the gravitational forces

and the radiation pressure are ..... .

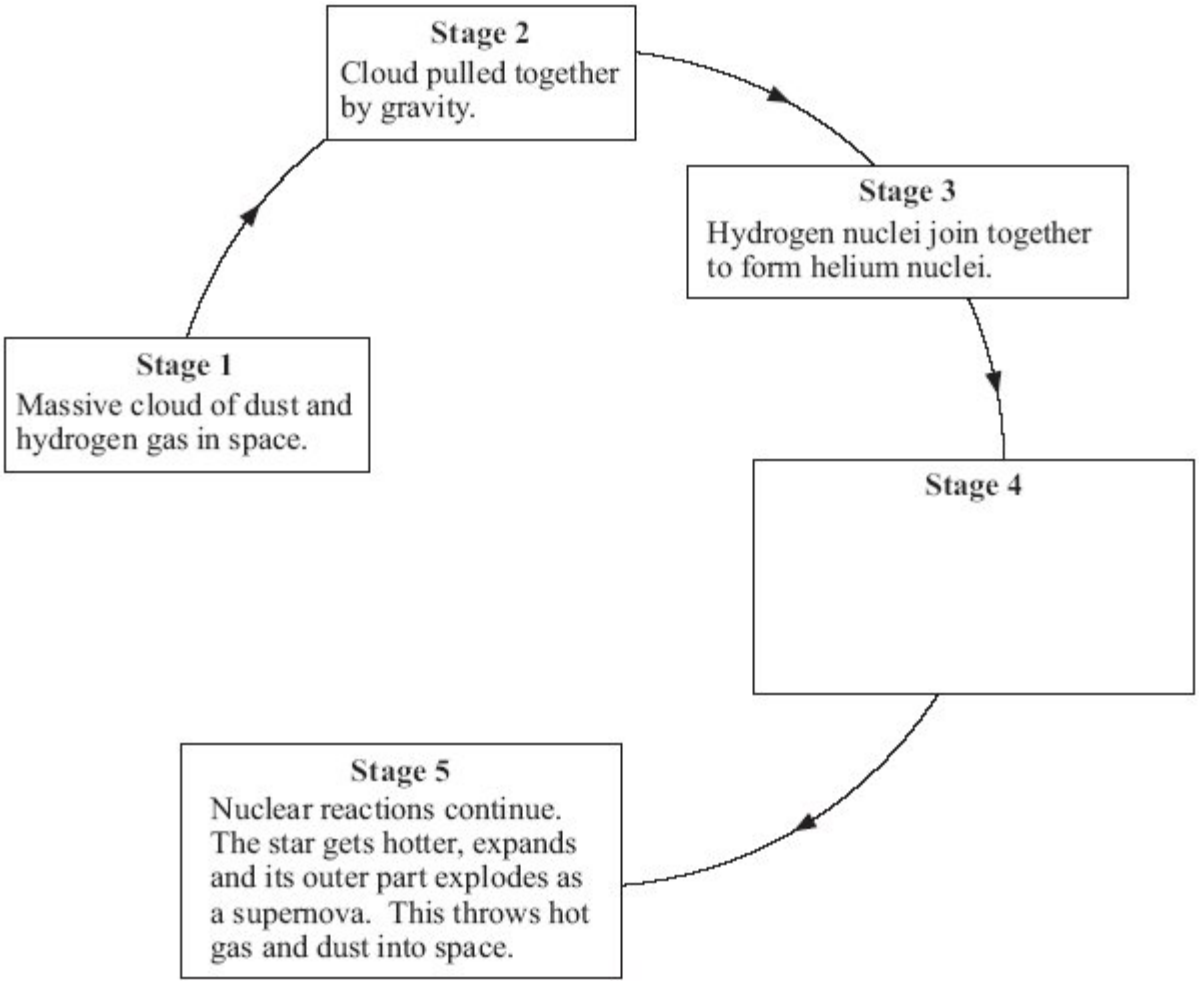
**(1)**

(iii) The Sun is one of billions of stars in the galaxy called the

..... .

**(1)**
**(Total 4 marks)**

**24** The diagram shows part of the life cycle of a star which is much bigger than the Sun.




(a) (i) What is the relationship between the masses of the dust and gas in the cloud in **Stage 2** and the force of gravity between them?

.....

.....

**(1)**

(ii) What is the relationship between the distance apart of the dust and gas in the cloud in **Stage 2** and the force of gravity between them?

.....

.....

**(1)**

(b) In **Stage 3** the star remains stable for millions of years.

Explain why.

.....

.....

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.....

**(2)**

(c) What happens in **Stage 4**?

.....

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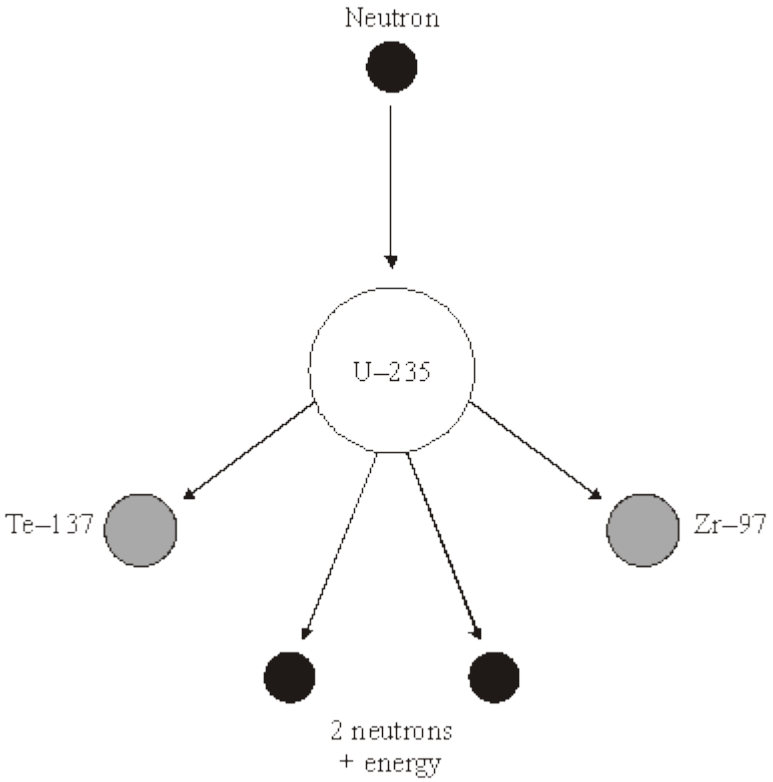
**(2)**
**(Total 6 marks)**

**25** (a) The diagram shows what can happen when the nucleus of a uranium atom absorbs a neutron.




(i) What name is given to the process shown in the diagram?

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**(1)**

(ii) Explain how this process could lead to a chain reaction.

You may wish to add further detail to the diagram to help your answer.

.....

.....

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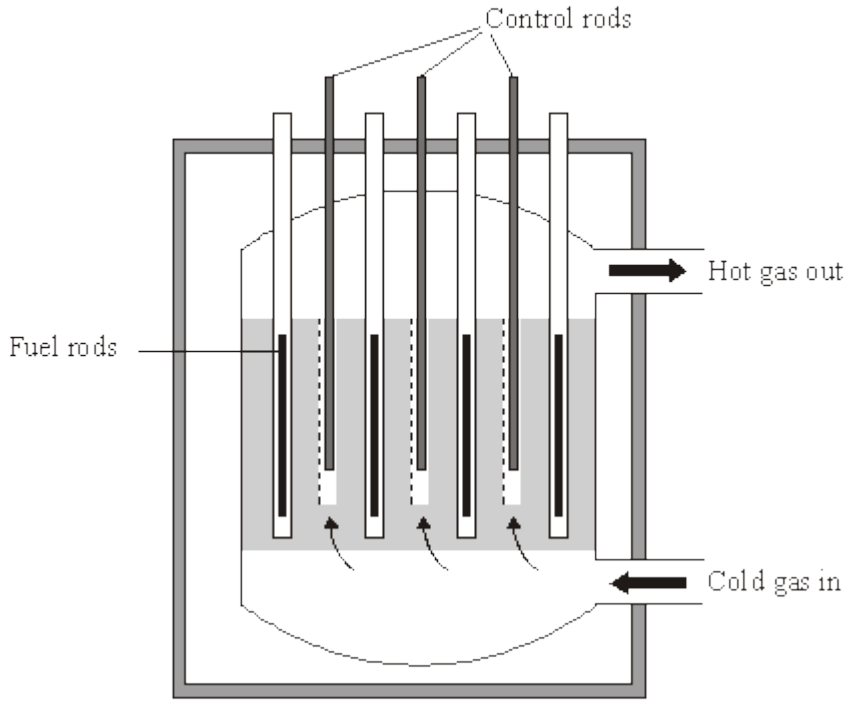
**(2)**

(iii) How does the mass number of an atom change when its nucleus absorbs a neutron?

.....

**(1)**

(b) Uranium-235 is used as a fuel in some nuclear reactors.




*Source: adapted from 'Physics Matters', by Nick England. Published by Hodder and Stoughton, 1989. Reproduced by permission of Hodder and Stoughton Ltd.*

The reactor contains control rods used to absorb neutrons.

Suggest what happens when the control rods are lowered into the reactor.

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**(2)**
**(Total 6 marks)**

**26** Read the passage.

> In the SolarSystem, the inner planets, such as the Earth, contain elements which are eavierthan the elements hydrogen and helium.
>
> Our star,the Sun, is a medium sized star. If a star is much more massive than the Sunit will eventually swell into a red giant, start to contract, continue tocontract and finally explode.

(a) What is the explosion called?

.....

**(1)**

(b) Explain why scientists believe that the Solar System was formed from the material produced when earlier stars exploded.

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**(3)**
**(Total 4 marks)**

**27** (a) Complete the **two** spaces in the sentence.

Stars form when enough ..... and gas from ..... are pulled together by gravitational attraction.

**(2)**

(b) How are stars able to give out energy for millions of years?

Put a tick (✓) next to the answer.

By atoms joining together ☐

By atoms splitting apart ☐

By burning gases ☐

**(1)**

(c) There are many billions of stars in our galaxy. Our Sun is one of these stars. What is the name of our galaxy?

.....

**(1)**

(d)

**Why was the Universe created?**

We cannot expect scientists to answer this question. What is the reason for this?

Put a tick (✓) next to the reason.

It will take too long to collect the scientific evidence. ☐

The answer depends on beliefs and opinions, not scientific evidence. ☐

There is not enough scientific evidence. ☐

**(1)**
**(Total 5 marks)**

**28** 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)**

**29** *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)**

**30** (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)**

**31** (a) Explain how stars produce energy.

.....

.....

.....

.....

**(2)**

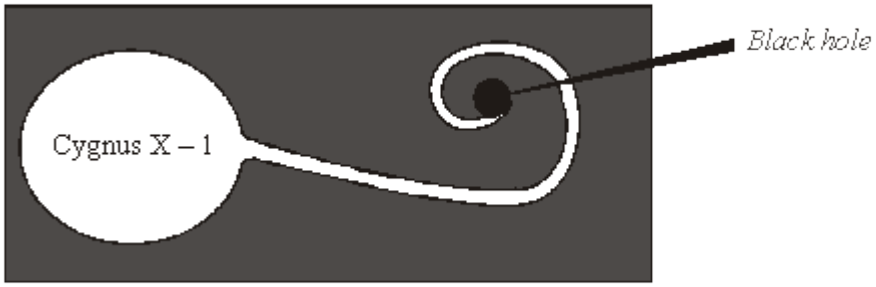
(b) What evidence is there to suggest that the Sun was formed from the material produced when an earlier star exploded?

.....

.....

**(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*.

.....

.....

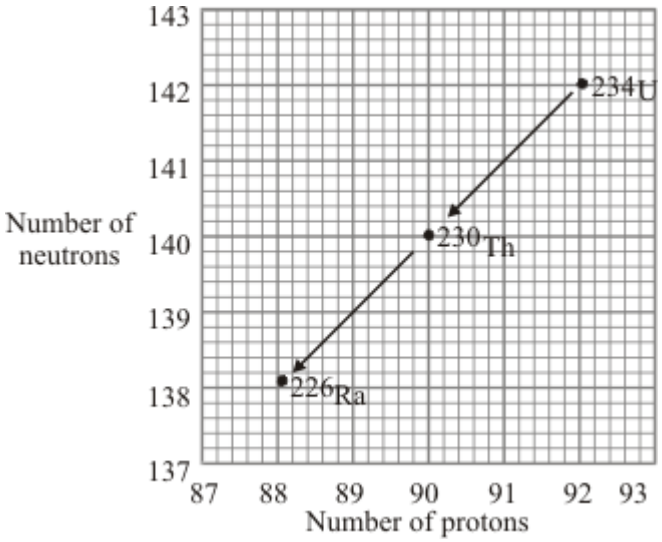
**(2)**

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

.....

**(1)**
**(Total 6 marks)**

**32** (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.

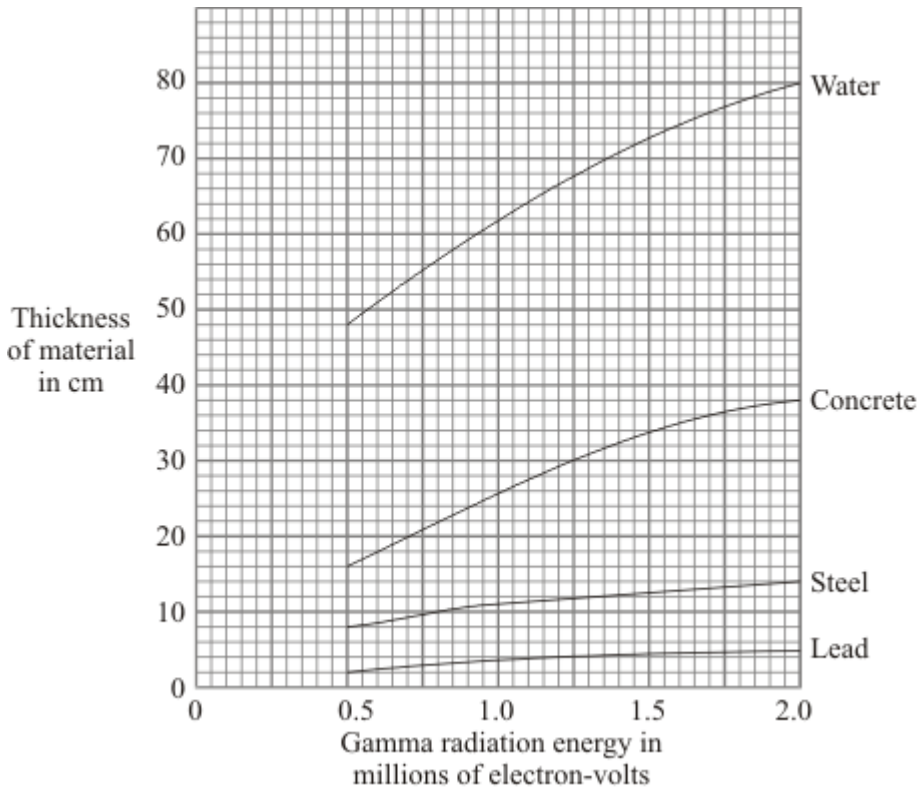
Why does the emission of gamma radiation **not** cause a new element to be formed?

.....

.....

**(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.

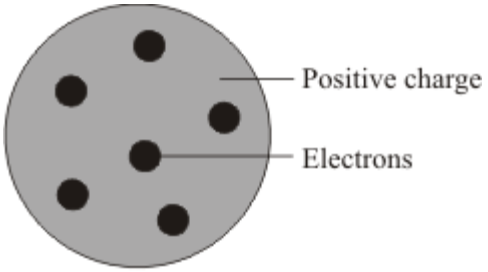
.....

.....

.....

**(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.

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.....

.....

**(3)**
**(Total 9 marks)**

**33** (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)**

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

.....

.....

.....

.....

.....

**(3)**
**(Total 5 marks)**

**34** 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 $\left({}^{235}_{92}U\right)$ and uranium-238 $\left({}^{238}_{92}U\right)$. 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.

$${}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{138}_{53}I + {}^{95}_{39}Y + 3({}^{1}_{0}n)$$

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)**

**35** 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)**

**36** Nuclear fusion in the Sun releases large amounts of energy.

(i) Explain what is meant by nuclear fusion.

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.....

.....

**(3)**

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

.....

.....

.....

.....

**(2)**
**(Total 5 marks)**

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

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

.....

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.....

.....

**(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.

.....

.....

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.....

.....

**(6)**
**(Total 9 marks)**

**38** 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.

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.....

**(Total 3 marks)**

**39** 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?

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**(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.

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.....

**(2)**
**(Total 6 marks)**

**40** 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.*

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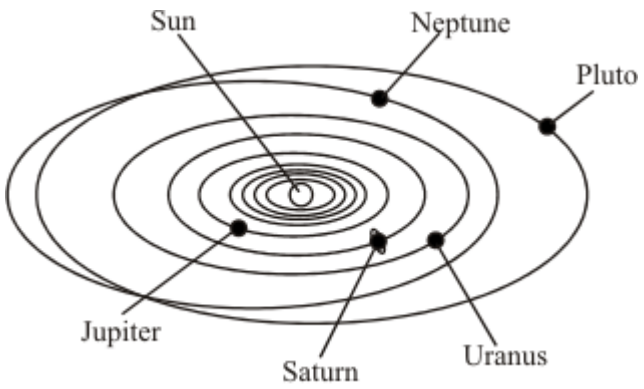
**(Total 5 marks)**

**41** 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?

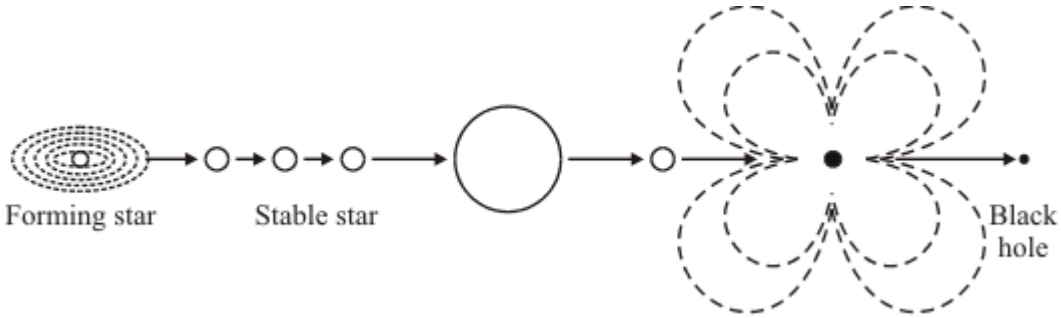
.....

.....

.....

**(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.*

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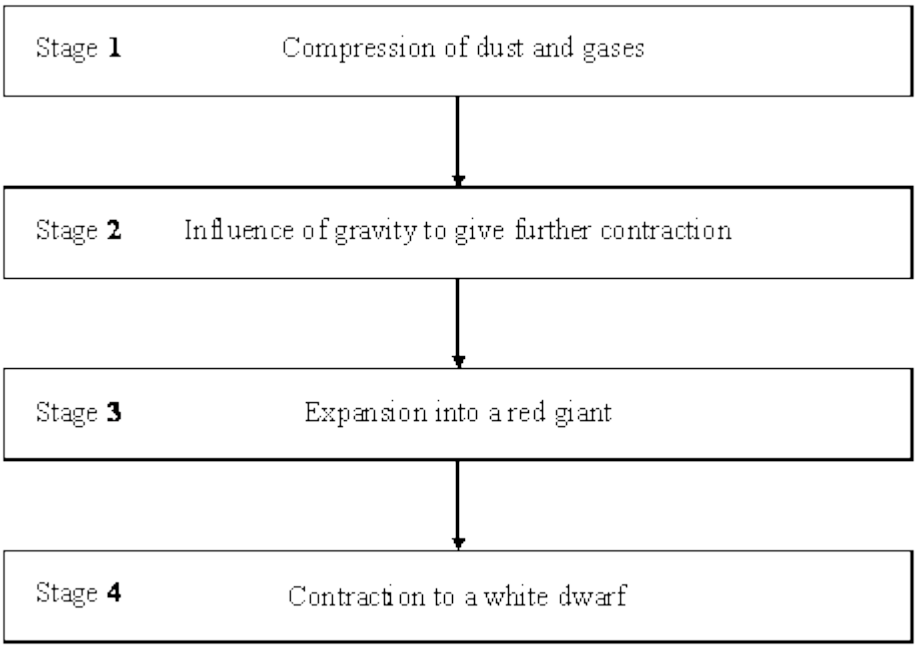
**(6)**
**(Total 7 marks)**

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



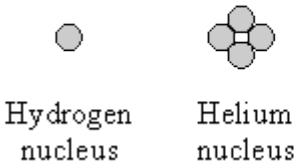

At a particular time a star might have reached one of these stages or be between stages or be at a further stage. What period in its evolution has our star, the Sun, reached?

.....

**(Total 1 mark)**

**43** 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 | 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)**

**44** 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:

energy released [J] = loss of mass [kg] × (speed of light [m/s²])

(The speed of light is $3 \times 10^8$ m/s)

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

(*Show your working*.)

.....

.....

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.....

.....

.....

**(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)**

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

.....

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.....

**(Total 6 marks)**

**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*

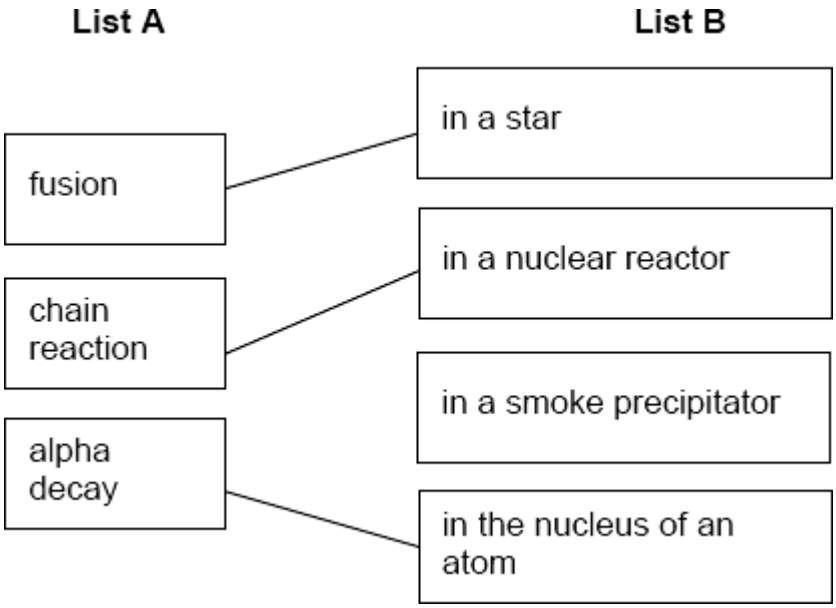
1

**[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*

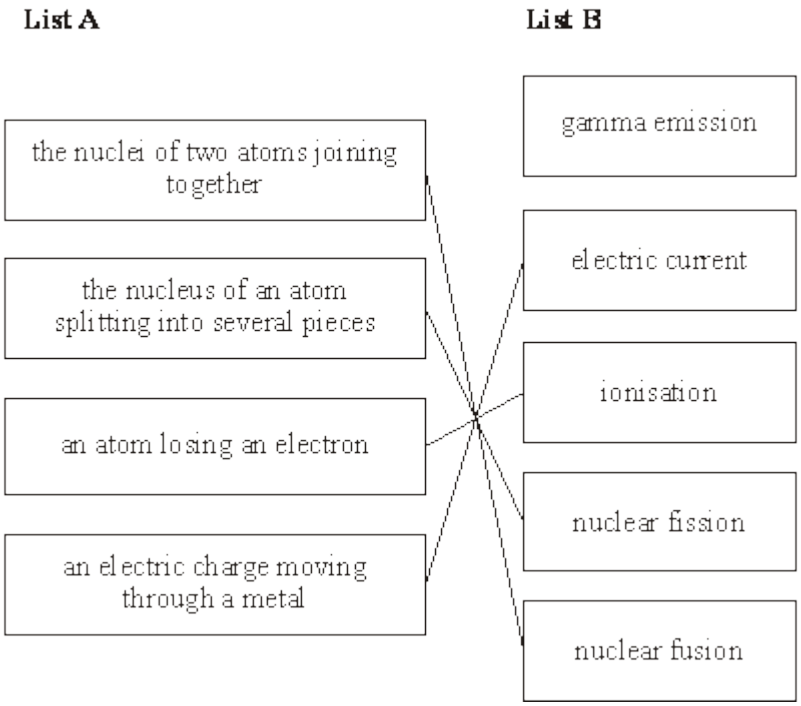
**1**

**[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 <u>masses</u> (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 <u>and</u> helium (1)

these (heavy) elements are / were formed by (nuclear) <u>fusion</u> (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

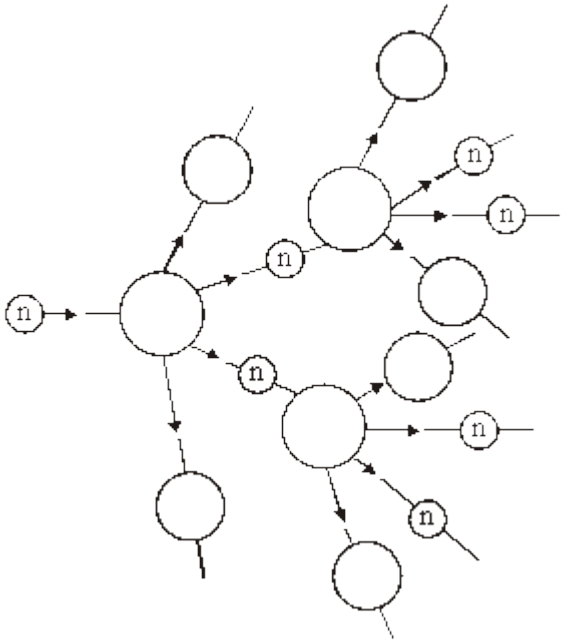
splits into (smaller) nuclei **and** neutron(s) (+ energy)

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*
- 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]**

**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*

$2.1 \times 10^3$

*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** $6.3 \times 10^{11}$ *(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]**