Nuclear Fission and Nuclear Fusion

Question Paper

Level	GCSE
Subject	Physics
Exam Board	AQA
Unit	P2
Topic	Nuclear Fission and Nuclear Fusion
Difficulty Level	Gold Level
Booklet	Question Paper

Time Allowed: **220 minutes**

Score: **/220**

Percentage: **/100**

Q1.(a) There are many isotopes of the element molybdenum (Mo).

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

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(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?

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(1)

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

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(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?

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Give a reason for your answer.

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(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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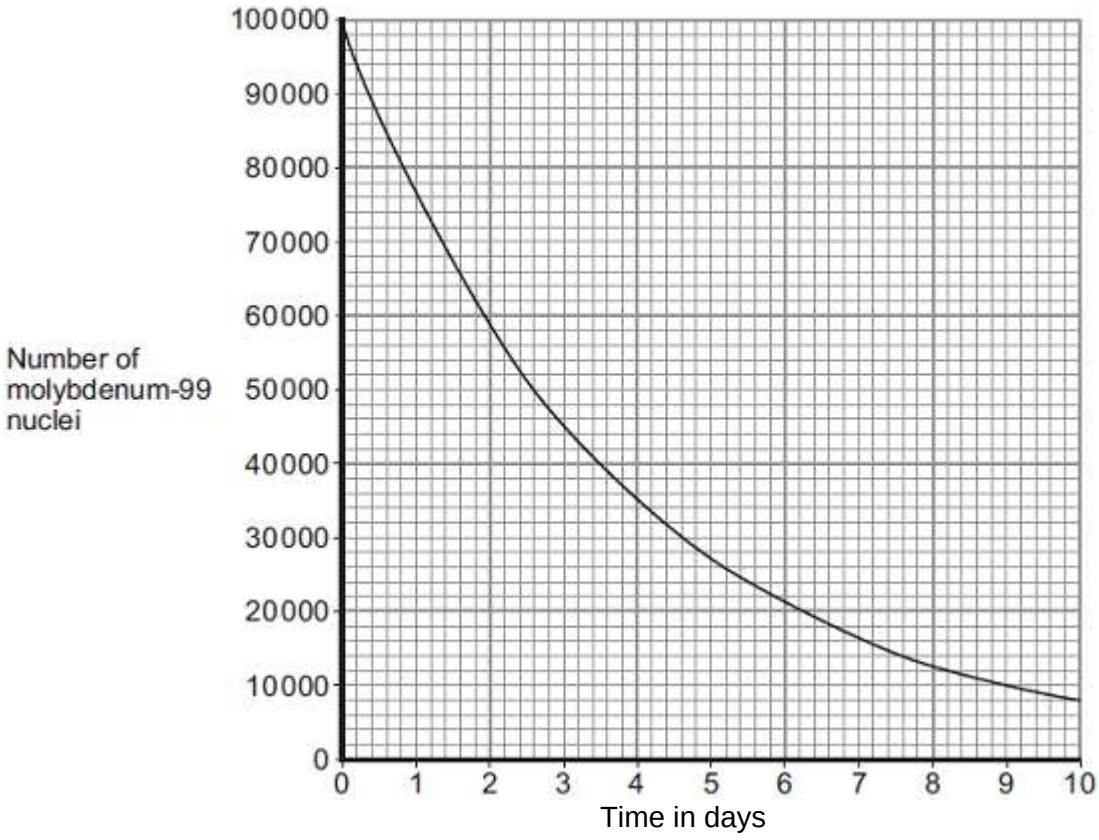
(1)

(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.

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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)

Q2.(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.

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(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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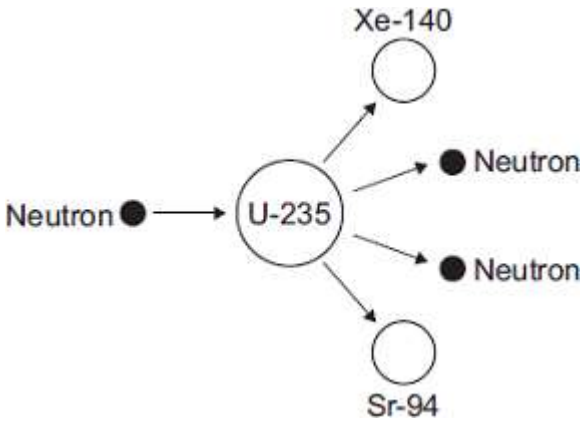
(3)

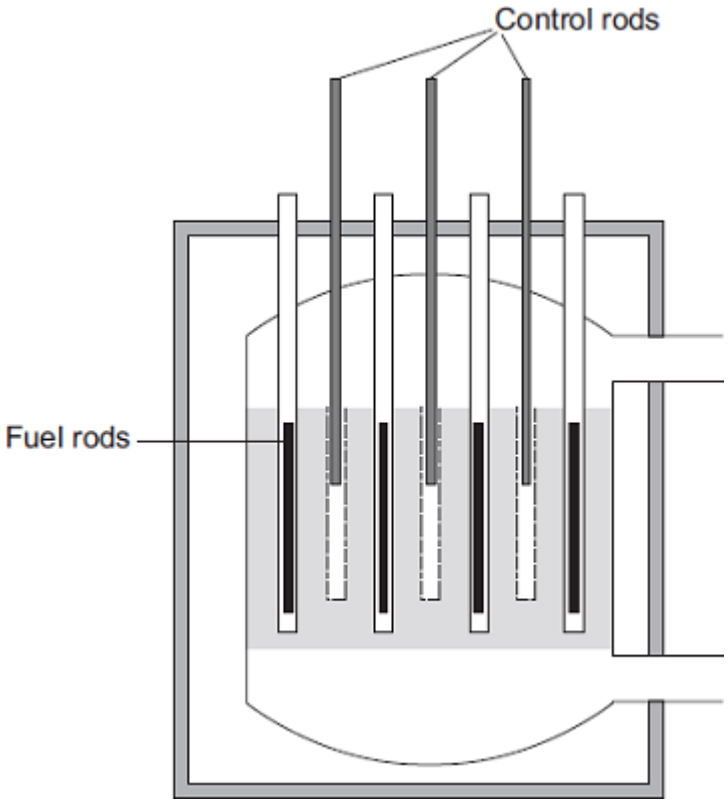
(b) The diagram shows the nuclear fission process for an atom of uranium-235.

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)

Q3. 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)

Q4. (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)

Q5.(a) Atoms of the isotope bismuth-212 decay by emitting either an alpha particle or a beta particle.
The equation represents what happens when an atom of bismuth-212 decays by beta emission into an atom of polonium-212.

$$^{212}_{83}\text{Bi} \longrightarrow {}^{212}_{84}\text{Po} + \text{beta particle}$$

(i) The bismuth atom and the polonium atom have the same mass number (212).

What is the *mass number* of an atom?

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(1)

(ii) Beta decay does **not** cause the mass number of an atom to change.

Explain why not.

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(2)

(b) When an atom of bismuth-212 emits an alpha particle, the atom decays into an atom of thallium.

An alpha particle is the same as a helium nucleus.
The symbol below represents an alpha particle.

$$^{4}_{2}He$$

(i) The equation below represents the alpha decay of bismuth-212.

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

$$^{212}_{83}Bi \longrightarrow \square \quad Tl \quad + \quad ^{4}_{2}He \qquad \square$$

(2)

(ii) It is impossible for the alpha decay of bismuth-212 to produce the same element as the beta decay of bismuth-212.

Explain why.

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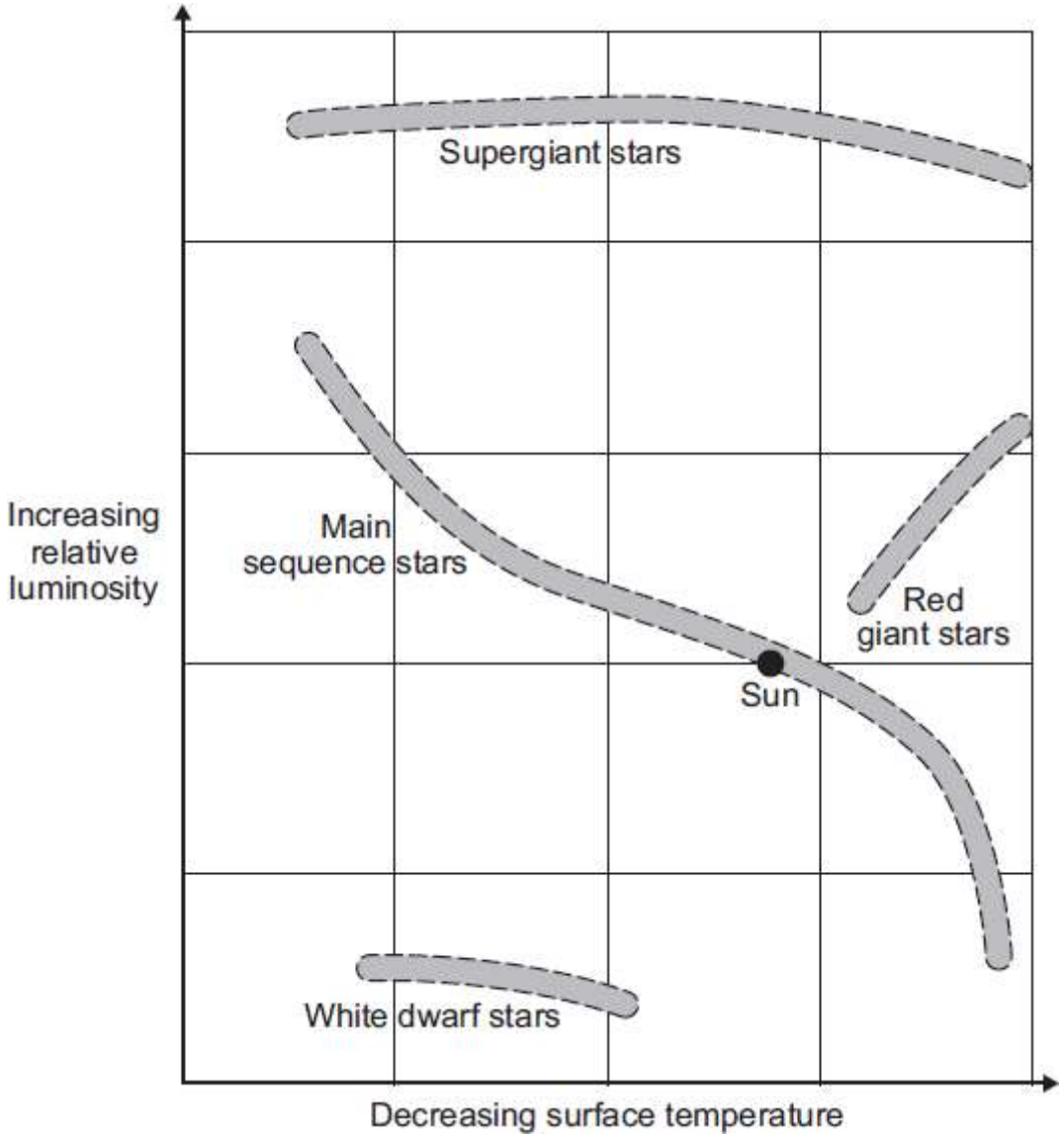
(2)
(Total 7 marks)

Q6. The diagram, drawn below, places stars in one of four groups.
Where a star is placed on the diagram is determined by the surface temperature and relative luminosity of the star.
A star with a relative luminosity of 1, emits the same amount of energy every second as the Sun.



(a) The Sun will spend most of its life cycle as a main sequence star. This is the stable period of the Sun's life cycle.

What happens to cause the stable period in the life cycle of a star to end?

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(1)

(b) Use the information in the diagram to describe what will happen to the Sun after the stable period ends.

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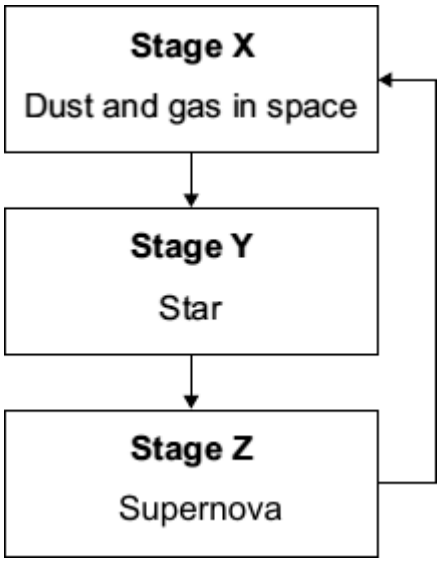
(3)
(Total 4 marks)

Q7. 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?

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(1)

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

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(1)
(Total 7 marks)

Q8. 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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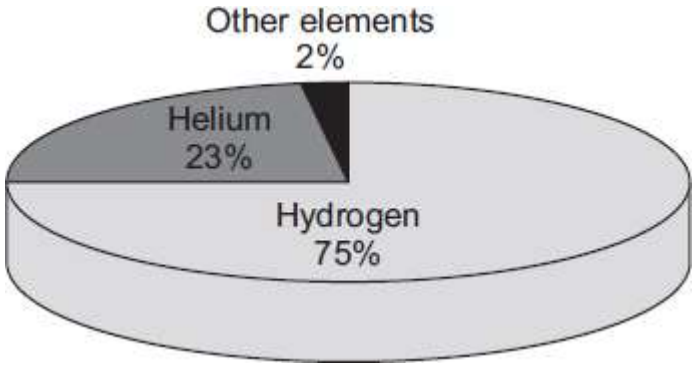
(Total 3 marks)

Q9. 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)

Q10. (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)

Q11. (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?

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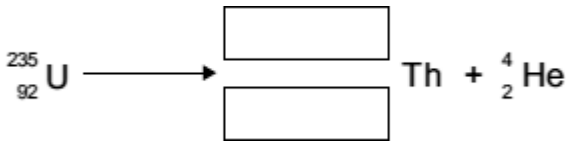
(1)

(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 $^{4}_{2}He$.

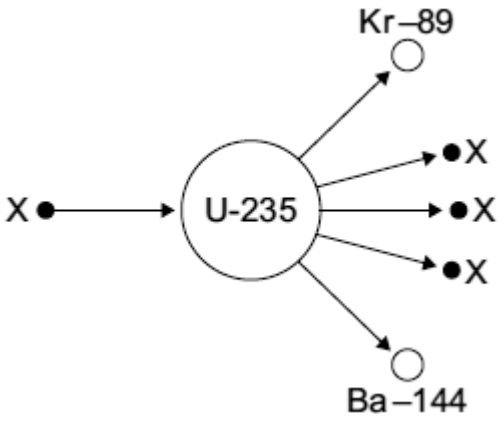
The decay can be represented by the equation below.

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



(2)

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



(i) Name the process shown in the diagram.

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(1)

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

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(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)

Q12. 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)

Q13. 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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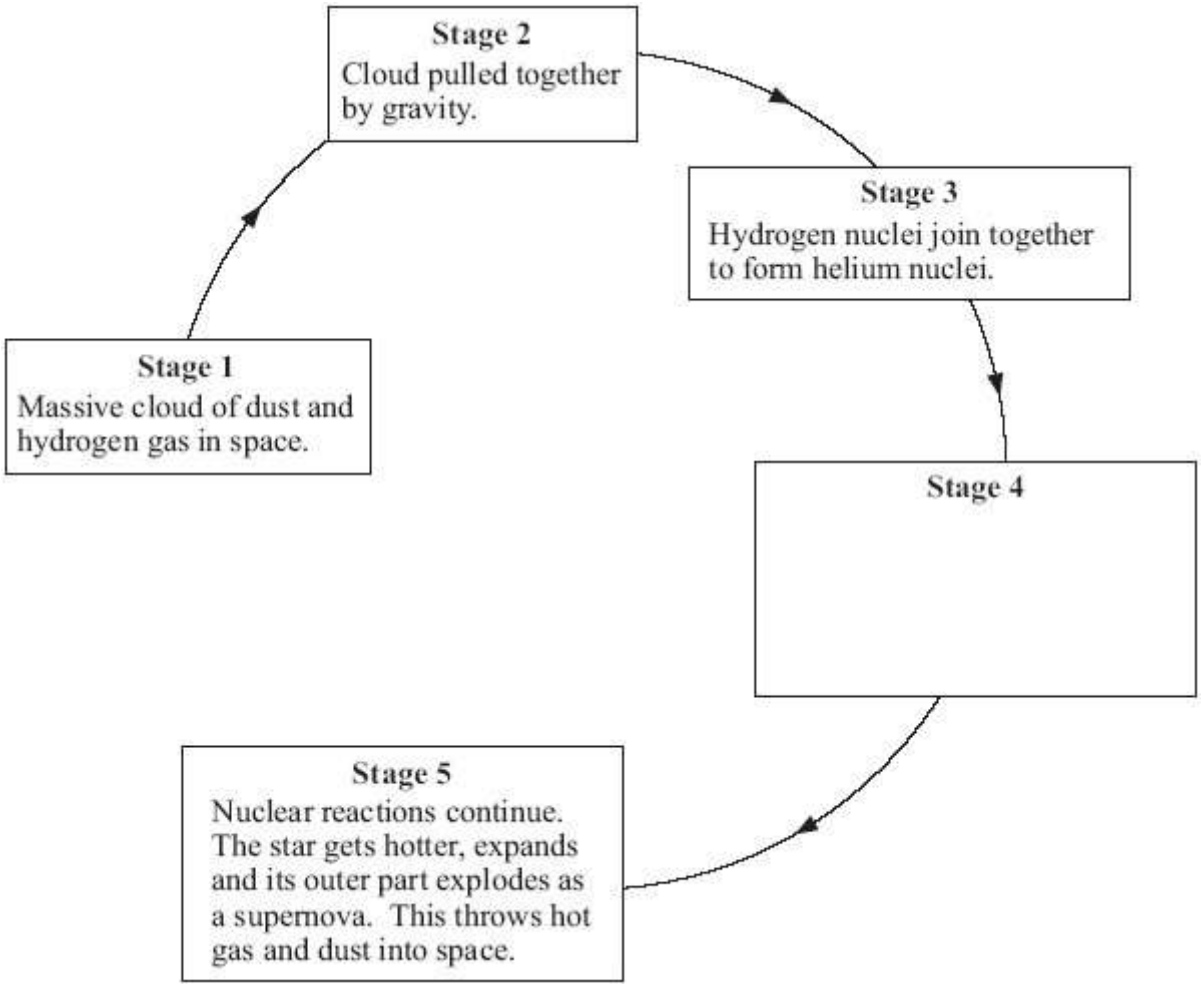
(2)
(Total 6 marks)

Q14. 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?

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(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?

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(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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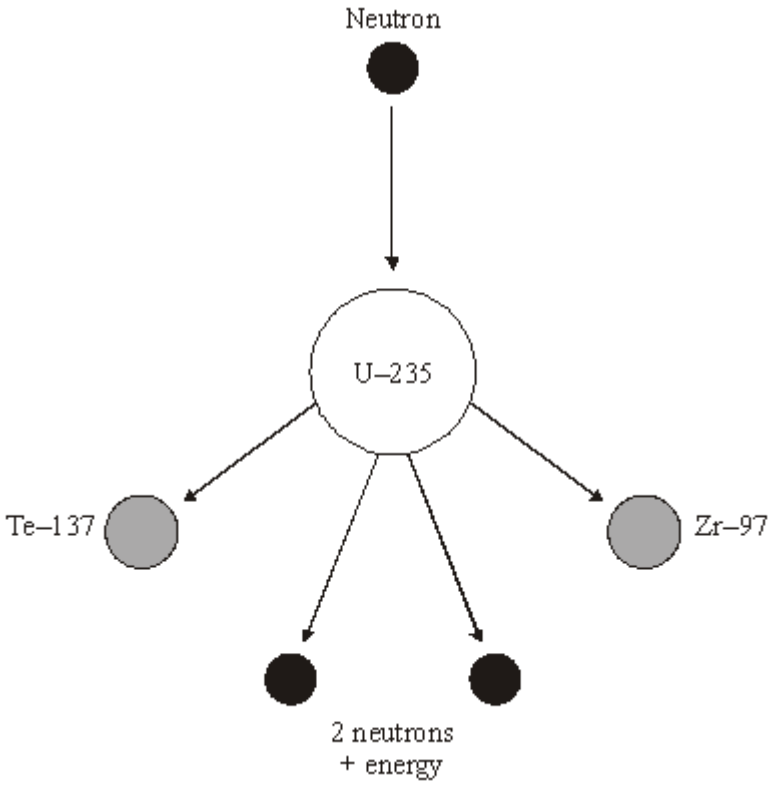
(2)
(Total 6 marks)

Q15. (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?

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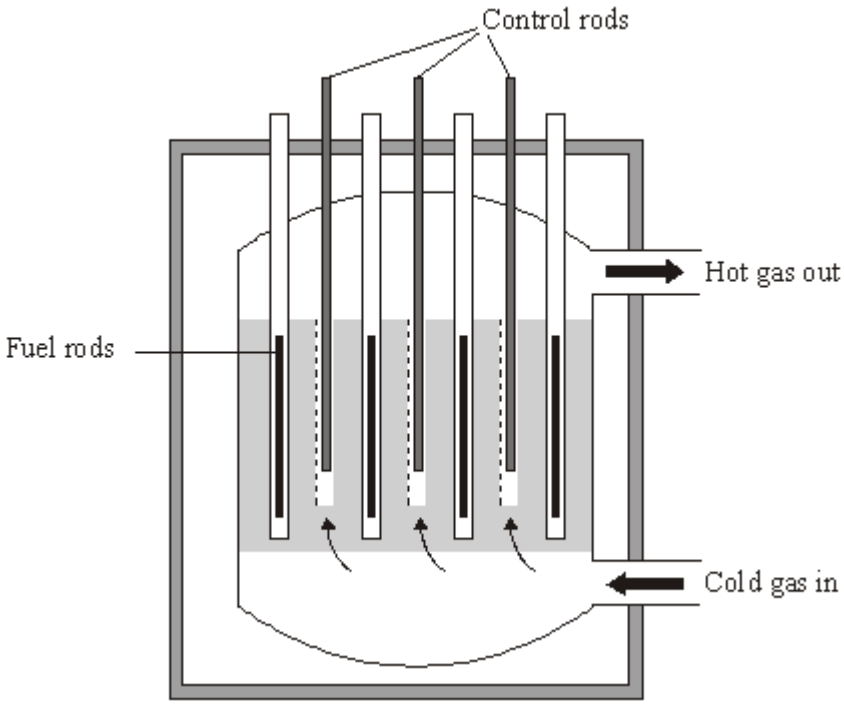
(1)

(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)

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Read the passage.

In the Solar System, the inner planets, such as the Earth, contain elements which are eavier than the elements hydrogen and helium.

Our star, the Sun, is a medium sized star. If a star is much more massive than the Sun it will eventually swell into a red giant, start to contract, continue to contract and finally explode.

(a) What is the explosion called?

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(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)

Q17. 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.

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(1)

(ii) Where did the elements form?

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(1)

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

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(1)

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

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(1)

(Total 4 marks)

Q18. (a) Nuclear power stations use the energy released by *nuclear fission* to generate electricity.

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

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(2)

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

You may give your answer as a labelled diagram.

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(1)

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

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(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.

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(1)
(Total 5 marks)

Q19. (a) Explain how stars produce energy.

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(2)

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

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(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*.

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(2)

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

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(1)

(Total 6 marks)

Q20. Stars do not stay the same forever.

(a) Over billions of years the amount of hydrogen in a star decreases. Why?

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(1)

(b) Describe how a massive star (at least five times bigger than the Sun) will change at the end of the 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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(4)

(c) The inner planets of the solar system contain atoms of the heaviest elements.

(i) Where did these atoms come from?

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(1)

(ii) What does this tell us about the age of the solar system compared with many of the stars in the Universe?

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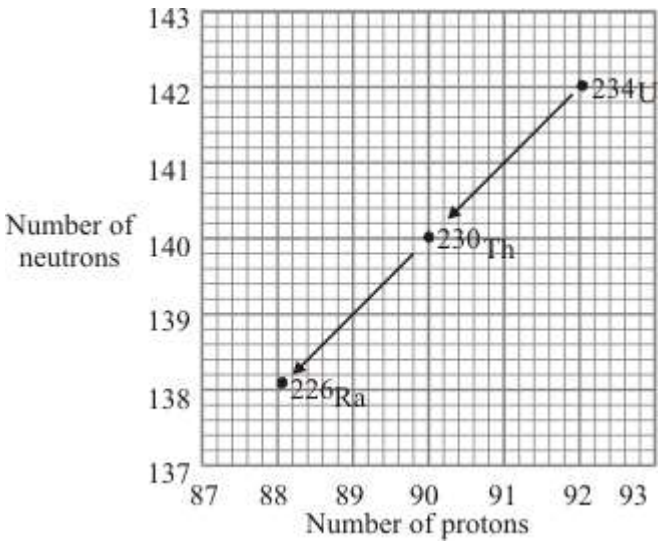
(1)

(Total 7 marks)

Q21. (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?

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(1)

(ii) What makes uranium and thorium different elements?

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(1)

(iii) Radioactive decay may also produce gamma radiation.

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

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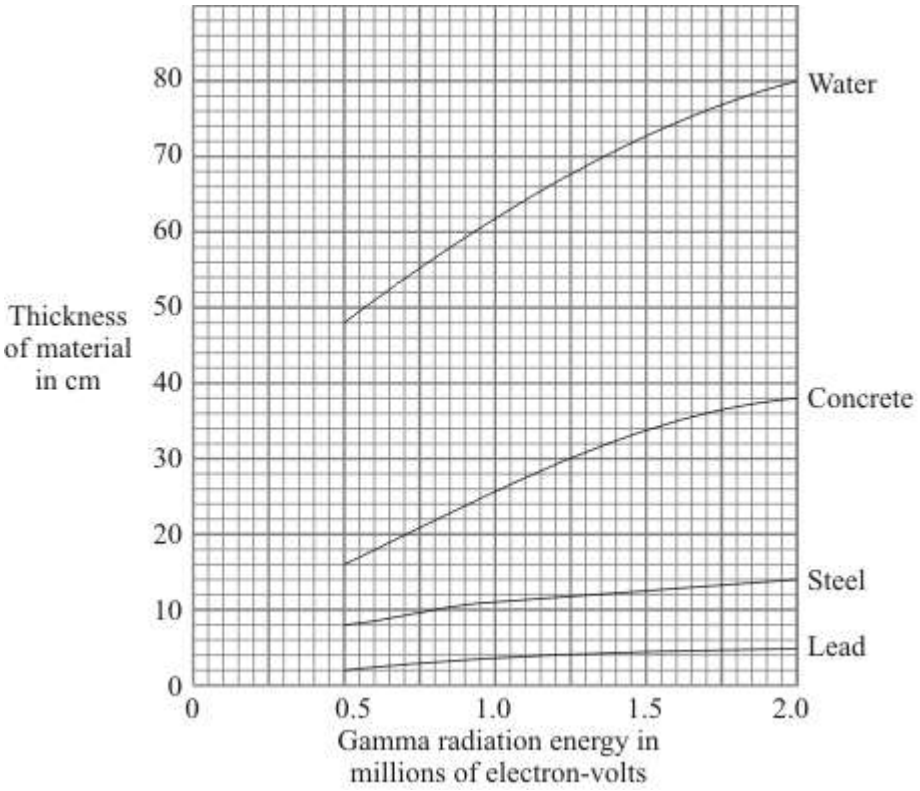
(1)

(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.

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(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.

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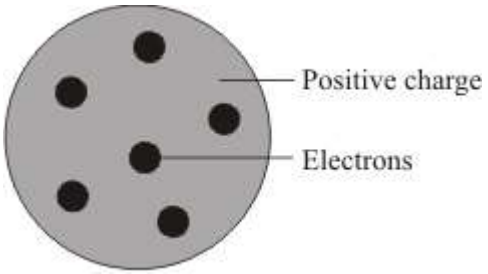
(2)

(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)

Q22. (i) Explain how stars like the Sun were formed.

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(2)

(ii) The Sun is made mostly of hydrogen. Eventually the hydrogen will be used up and the Sun will "die".

Describe what will happen to the Sun from the time the hydrogen is used up until the Sun "dies".

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(3)
(Total 5 marks)

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(a) The table shows the half-life of some *radioactive* isotopes.

Radioactive isotope	Half-life
magnesium-27	10 minutes
sodium-24	15 hours
sulphur-35	87 days
cobalt-60	5 years

(i) What is meant by the term *radioactive?*

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(1)

(ii) Which **one** of the isotopes in the table could form part of a compound to be used as a tracer in medicine? Explain the reason for your choice.

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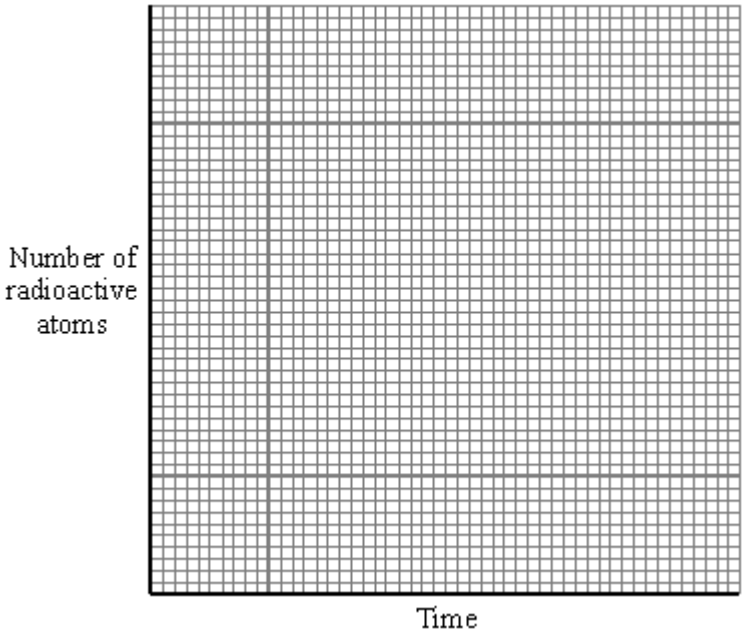
(3)

(iii) Draw a graph to show how the number of radioactive atoms present in the isotope cobalt-60 will change with time.



(3)

(b) Nuclear power stations provide about 17% of the world's electricity. They add less than 1% to the total background levels of radiation. Some people are opposed to the use of nuclear fuels for the generation of electricity. Explain why.

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(3)
(Total 10 marks)

Q24. (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?

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(2)

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

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(3)
(Total 5 marks)

Q25. Stars are formed from massive clouds of dust and gases in space.

(a) What force pulls the clouds of dust and gas together to form stars?

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(1)

(b) Once formed a star can have a stable life for billions of years. Describe the **two** main forces at work in the star during this period of stability.

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(2)

(c) What happens to this star once this stable period is over?

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(4)

(d) Suggest what might then happen to a planet close to this star.

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(1)

(Total 8 marks)

Q26. 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 $\left({}^{235}_{92}\mathrm{U}\right)$ and uranium-238 $\left({}^{238}_{92}\mathrm{U}\right)$. The nucleus of a uranium-235 atom is different to that of a uranium-238 atom.

(i) Where is the nucleus in an atom?

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(1)

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

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(2)

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

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(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;

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(ii) how this leads to a chain reaction;

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

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(4)
(Total 9 marks)

Q27. Describe briefly how stars such as the Sun are formed.

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(Total 2 marks)

Q28. 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?

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(2)
(Total 5 marks)

Q29. (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)

Q30. 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)

Q31. Studying stars gives scientists evidence about the evolution of the Universe.

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

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(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)

Q32. 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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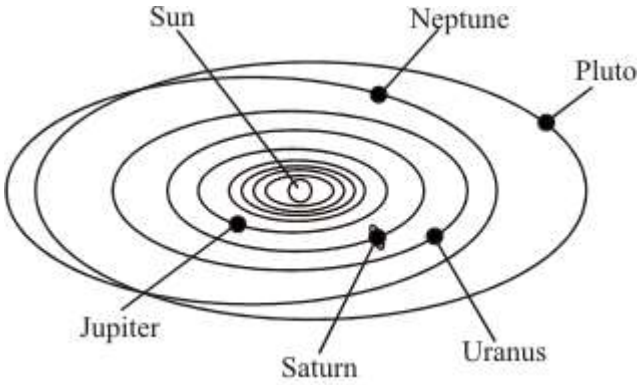
(Total 5 marks)

Q33. 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?

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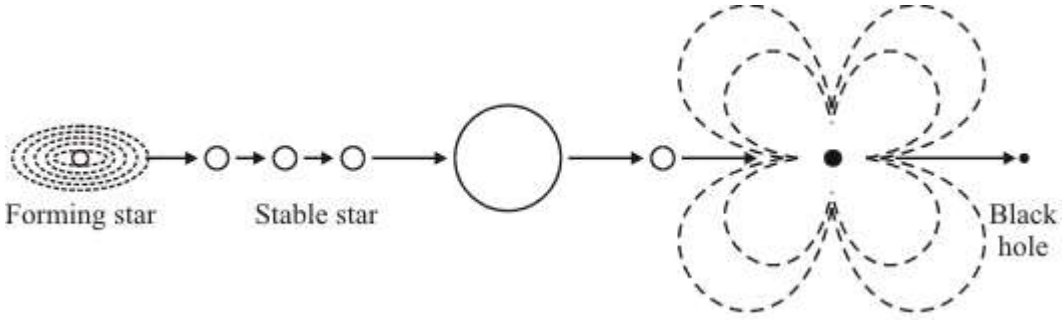
(1)

(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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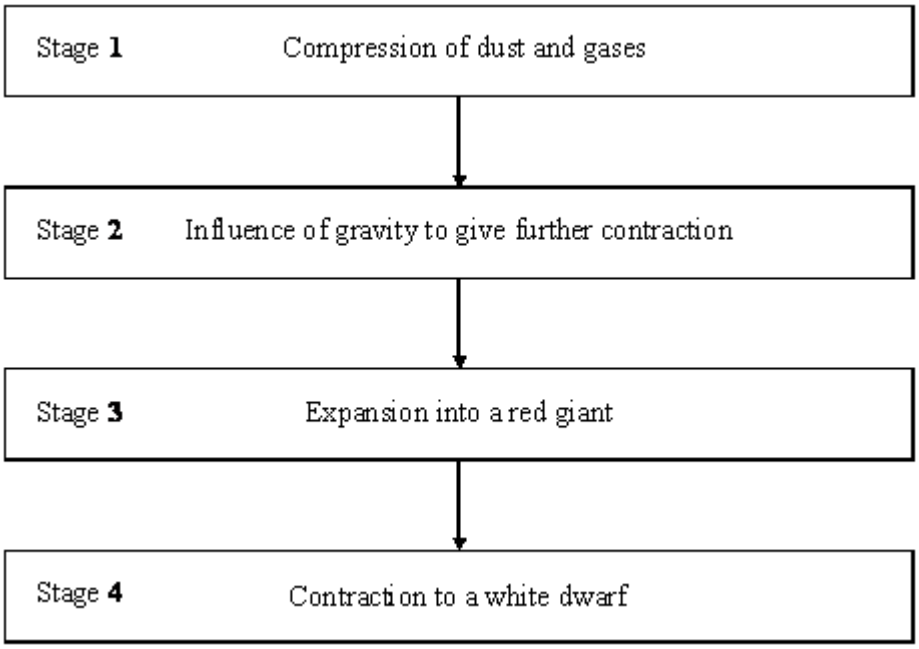
(6)
(Total 7 marks)

Q34. 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?

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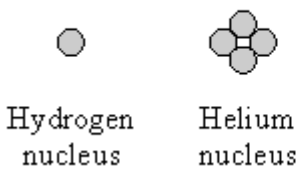
(Total 1 mark)

Q35. 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.

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(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.

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(2)
(Total 5 marks)

Q36. 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/s^2])

(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*.)

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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.

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(2)

(ii) Suggest an explanation for this relationship.

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(Total 9 marks)

Q37. Describe, in as much detail as you can, the life history of a star like our Sun.

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(Total 6 marks)