NUCLEAR FISSION AND FUSION

Q1.

(a) Uranium has two natural isotopes, uranium-235 and uranium-238.

Use the correct answer from the box to complete the sentence.

electrons	neutrons	protons

The nucleus of a uranium-238 atom has three more _____ than the nucleus of a uranium-235 atom.

(1)

(b) Uranium-235 is used as a fuel inside a nuclear reactor.
Energy is released from nuclear fuels by the process of nuclear fission.

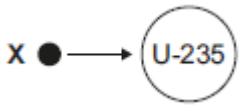
What is the energy released from nuclear fuels inside a nuclear reactor used for?

_____

(1)

(c) **Figure 1** shows the nucleus of an atom of uranium-235 (U-235) about to undergo nuclear fission.

Figure 1



(i) Before nuclear fission can happen the nucleus of a uranium atom has to absorb the particle labelled **X**.

What is particle **X**?

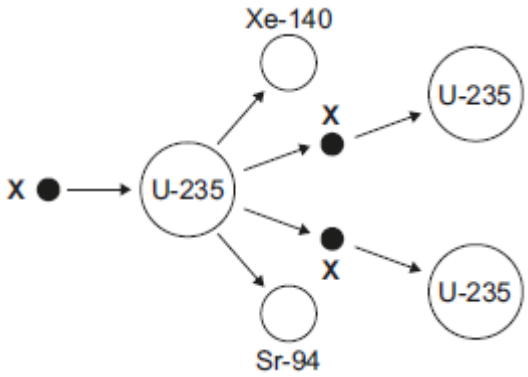
Tick (✔) **one** box.

an electron ☐ a neutron ☐ a proton ☐

(1)

(ii) The process of nuclear fission, shown in **Figure 2**, causes the nucleus of the uranium-235 (U-235) atom to split apart and release two of the particles X.

Figure 2



Complete **Figure 2** to show how the particles **X start** a chain reaction.

(2)

(Total 5 marks)

Q2.

(a) Brown dwarf stars are thought to have been formed in the same way as other stars. They are too small for nuclear fusion reactions to take place in them.
Brown dwarf stars emit infrared radiation but are not hot enough to emit visible light.

(i) Describe how a star is formed.

_____

_____

_____

_____

(2)

(ii) Describe the process of nuclear fusion.

_____

_____

_____

(1)

(iii) Scientists predicted that brown dwarf stars existed before the first one was discovered in 1995.

Suggest **one** reason why scientists are now able to observe and identify brown dwarf stars.

_____

_____

_____

(1)

(b) In the 18th century some scientists suggested a theory about how the planets formed in the Solar System. The theory was that after the Sun formed, there were cool discs of matter rotating around the Sun. These cool discs of matter formed the planets. The scientists thought this must have happened around other stars too.

(i) Thinking about this theory, what would the scientists have predicted to have been formed in other parts of the Universe?

_____

_____

(1)

(ii) Since the 1980s scientists studying young stars have shown the stars to be surrounded by cool discs of rotating matter.

What was the importance of these observations to the theory the scientists suggested in the 18th century?

_____

_____

(1)

(c) The Earth contains elements heavier than iron.

Why is the presence of elements heavier than iron in the Earth evidence that the Solar System was formed from material produced after a massive star exploded?

_____

_____

(1)

(Total 7 marks)

Q3.

Atoms are different sizes.

One of the heaviest naturally occurring stable elements is lead.

Two of its isotopes are lead-206 ($^{206}_{82}Pb$) and lead-208 ($^{208}_{82}Pb$).

(a) (i) What is meant by 'isotopes'?

_____

_____

_____

_____

(2)

(ii) How many protons are in the nucleus of a $^{206}_{82}Pb$ atom?

_____

(1)

(iii) How many neutrons are in the nucleus of a $^{206}_{82}Pb$ atom?

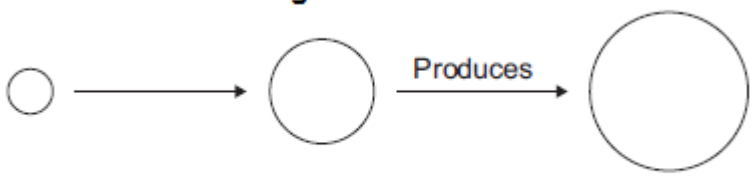
_____

(1)

(b) A nucleus can be accelerated in a particle accelerator and directed at a large nucleus. This produces a heavy nucleus that will decay after a short time.

This is shown in **Figure 1**.

Figure 1



Nucleus Large nucleus Heavy nucleus

(i) In 1984, nuclei of iron (Fe) were directed at nuclei of lead (Pb). This produced nuclei of hassium (Hs).

Complete the equation for this reaction by writing numbers in the empty boxes.

$$\square^{58}Fe + \begin{matrix}\square\\ \square\end{matrix}Pb = {}^{265}_{108}Hs + {}^{1}_{0}X$$

(3)

(ii) Use the correct answer from the box to complete the sentence.

an electron	**a proton**	**a neutron**

The particle **X** in part (b)(i) is _____ .

(1)

(iii) After acceleration the iron nuclei travel at a steady speed of one-tenth of the speed of light.

The speed of light is 3.00×10^8 m / s.

Calculate the time taken for the iron nuclei to travel a distance of 12 000 m.

_____

_____

Time taken = _____ s

(2)

(iv) Linear accelerators, in which particles are accelerated in a straight line, are **not** used for these experiments. Circular particle accelerators are used.

Suggest why.

_____

_____

_____

_____

_____

_____

(3)

(c) Hassium-265 ($^{265}_{108}Hs$) decays by alpha emission with a half-life of 0.002 seconds.

(i) What is meant by 'half-life'?

Tick (✓) **two** boxes.

	Tick (✓)
The average time for the number of nuclei to halve	
The time for count rate to be equal to background count	
The time for background count to halve	
The time for count rate to halve	

(2)

(ii) Complete the equation for the decay of Hs-265 by writing numbers in the empty boxes.

$$^{265}_{108}Hs = \frac{\square}{\square}Sg + \frac{\square}{\square}\alpha$$

(2)

(d) The table below shows how the atomic radius of some atoms varies with atomic number.

Atomic number	**Atomic radius in picometres (pm)**
15	100
35	115
50	130
70	150

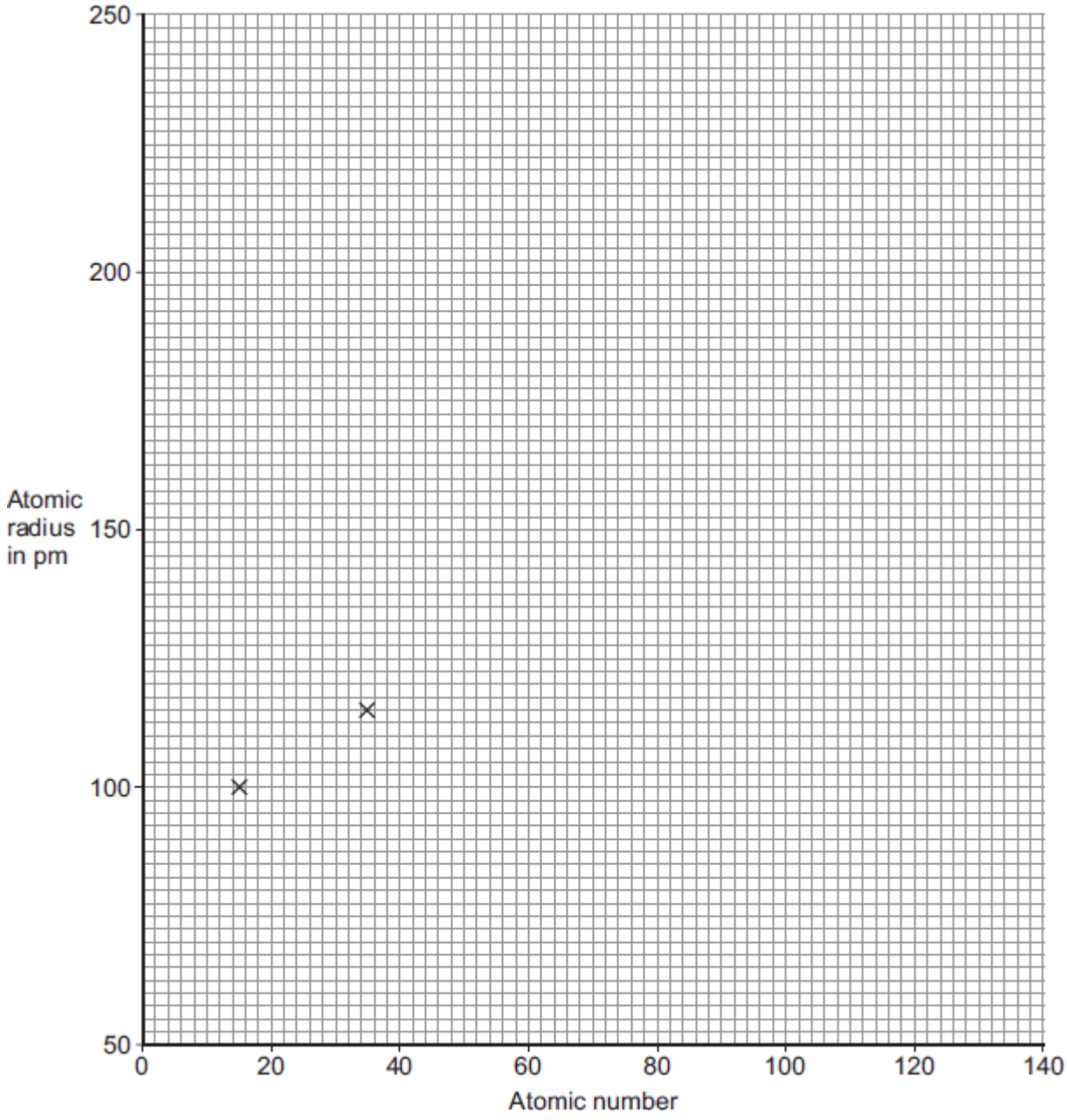
95	170

1 pm = 10^{-12} m

(i) On **Figure 2**, use the data from the table above to plot a graph of atomic radius against atomic number and draw a line of best fit.

Two points have been plotted for you.

Figure 2



(2)

(ii) Scientists believe that the element with atomic number 126 can be produced and that it will be stable.

Use your graph in **Figure 2** to predict the atomic radius of an atom with atomic number 126.

Atomic radius = _____ pm

(1)

(Total 20 marks)

Q4.

The equation below shows the process by which two atomic nuclei join to form a different nucleus.

$$ {}^{1}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} $$

(a) Where does the process shown by the equation above happen naturally?

Tick (✓) **one** box.

Inside the Earth ☐

Inside a nuclear power station ☐

Inside the Sun ☐

(1)

(b) Use the correct answer from the box to complete the sentence.

fission	**force**	**fusion**

The process of joining two atomic nuclei to form a different nucleus is called

nuclear _____ .

(1)

(c) What is released during this process?

Draw a ring around the correct answer.

charge **energy** **force**

(1)

(Total 3 marks)

Q5.

Many countries use nuclear power stations to generate electricity.
Nuclear power stations use the process of nuclear fission to release energy.

(a) (i) What is nuclear fission?

_____

_____

(1)

(ii) Plutonium-239 is one substance used as a fuel in a nuclear reactor. For nuclear fission to happen, the nucleus must absorb a particle.

What type of particle must be absorbed?

_____

(1)

(b) Nuclear **fusion** also releases energy.
Nuclear fusion happens at very high temperatures. A high temperature is needed to overcome the repulsion force between the nuclei.

(i) Why is there a repulsion force between the nuclei of atoms?

_____

_____

(1)

(ii) Where does nuclear fusion happen naturally?

_____

(1)

(c) In 1991, scientists produced the first controlled release of energy from an experimental nuclear **fusion** reactor. This was achieved by fusing the hydrogen isotopes, deuterium and tritium.

Deuterium is naturally occurring and can easily be extracted from seawater. Tritium can be produced from lithium. Lithium is also found in seawater.

The table gives the energy released from 1 kg of fusion fuel and from 1 kg of fission fuel.

Type of fuel	**Energy released from 1 kg of fuel in joules**
Fusion fuel	3.4×10^{14}
Fission fuel	8.8×10^{13}

(i) Suggest **two** advantages of the fuel used in a fusion reactor compared with plutonium and the other substances used as fuel in a fission reactor.

1. _____

_____

_____

2. _____

_____

_____

(2)

(ii) Some scientists think that by the year 2050 a nuclear fusion power station capable of generating electricity on a large scale will have been developed.

Suggest **one** important consequence of developing nuclear fusion power stations to generate electricity.

_____

_____

_____

(1)

(d) Tritium is radioactive.

After 36 years, only 10 g of tritium remains from an original sample of 80 g.

Calculate the half-life of tritium.

Show clearly how you work out your answer.

_____

_____

Half-life = _____ years

(2)

(Total 9 marks)

Q6.

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.

_____

_____

_____

(1)

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

Suggest **one** reason why.

_____

_____

_____

(1)

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

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(Total 10 marks)

Q7.

(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’?

_____

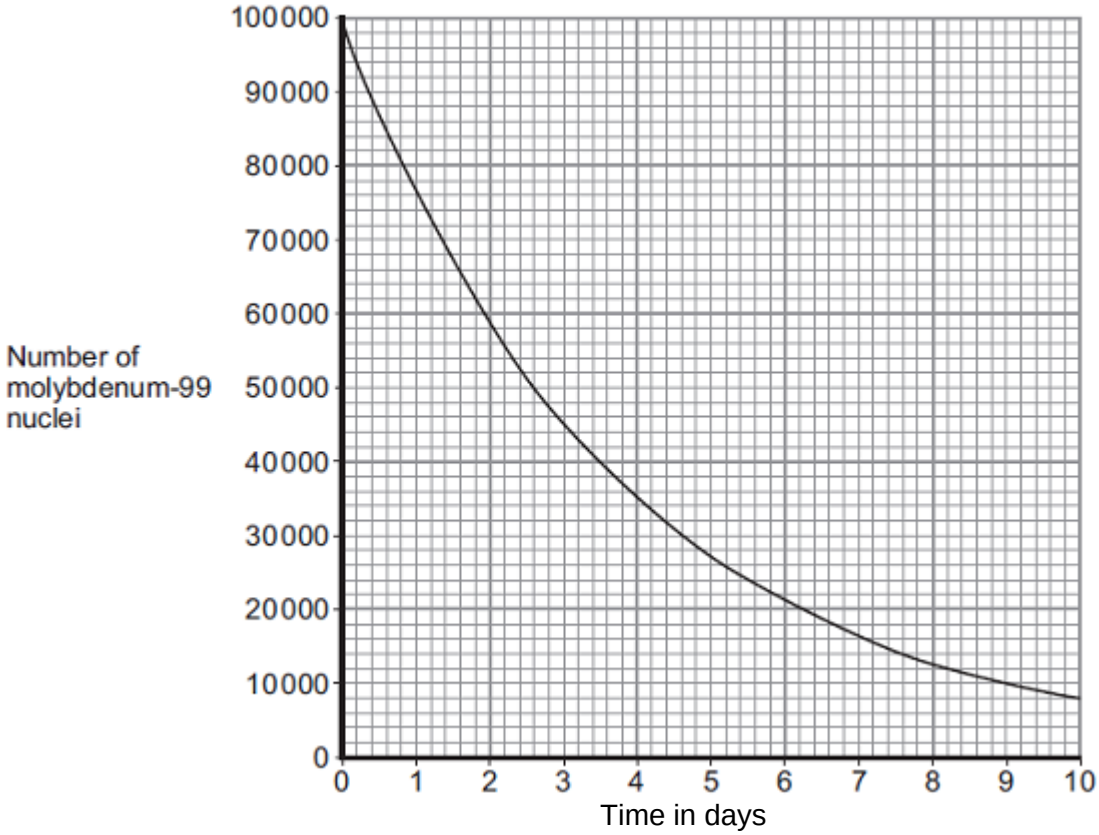
_____

_____

(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.

_____

_____

_____

_____

(2)

(iii) Even though there may be a risk, doctors frequently use radioactive

substances for medical diagnosis and treatments.

Suggest why.

_____

_____

(1)

(Total 11 marks)

Q8.

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.

_____

_____

_____

_____

_____

_____

_____

_____

(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.

$$^{139}\text{Ba} \longrightarrow {}^{139}\text{La} + \text{.....}$$

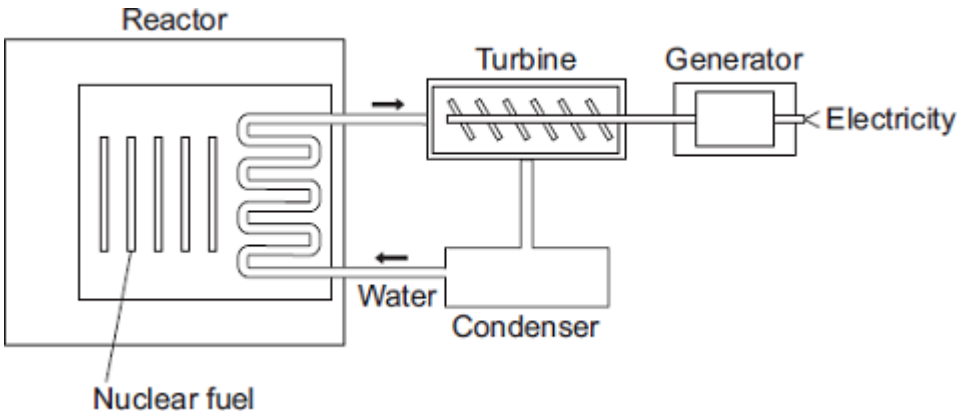
....

(3)

(Total 10 marks)

Q9.

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.

_____

_____

_____

_____

(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)

Q10.

(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.

_____

_____

_____

_____

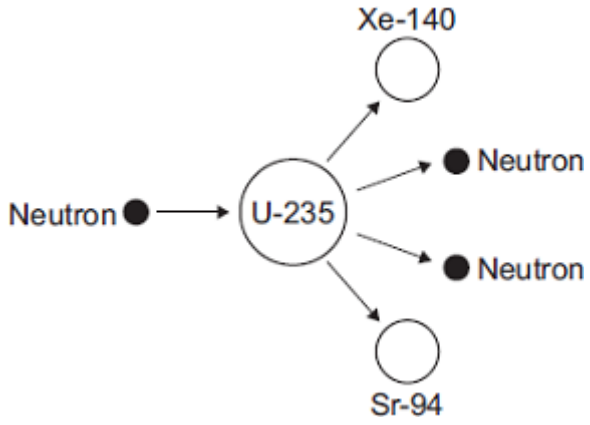
_____

_____

(3)

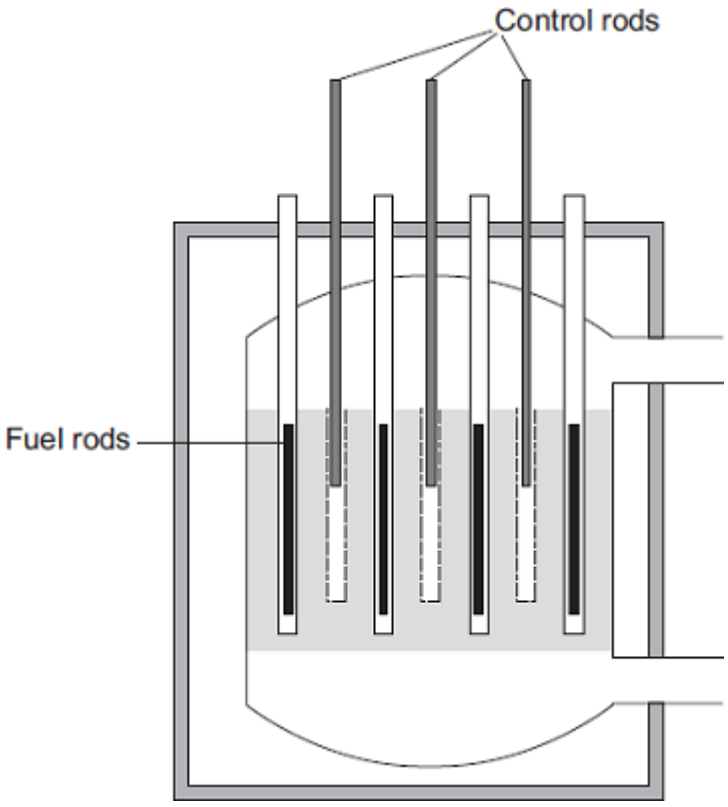
(b) The diagram shows the nuclear fission process for an atom of uranium-235.

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?

_____

_____

_____

_____

(2)

(Total 8 marks)

Q11.

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	Estimated 'main

	compared to the Sun	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?

_____

_____

(1)

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

Suggest why.

_____

_____

(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 / the same as / slower than] in a small star.

Explain the reason for your answer.

_____

_____

_____

_____

(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.

(6)
(Total 12 marks)

Q12.

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.

(2)

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

(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?

_____

(1)

(Total 5 marks)

Q13.

(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.

_____

_____

_____

_____

_____

_____

_____

_____

(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.

_____

_____

_____

_____

_____

(2)

(Total 6 marks)

Q14.

(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*.

_____

_____

_____

_____

_____

(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)

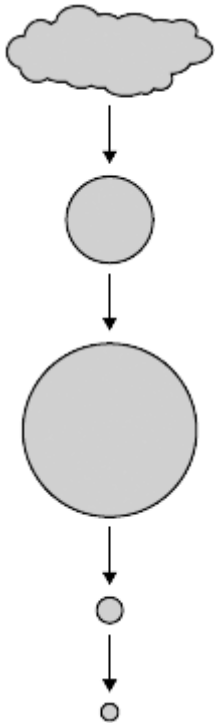
(Total 5 marks)

Q15.

(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)

Q16.

(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.

_____

_____

_____

_____

(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.

_____

_____

_____

_____

_____

_____

(3)

(Total 5 marks)

Q17.

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.

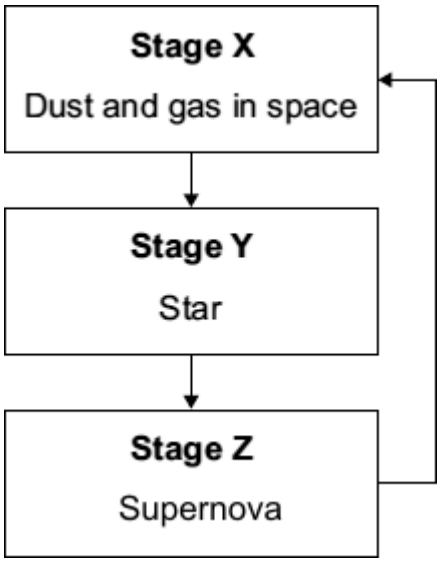
List A	**List B**
Process	**Where it happens**

fusion	in a star
chain reaction	in a nuclear reactor
alpha decay	in a smoke precipitator
	in the nucleus of an atom

(Total 3 marks)

Q18.

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**?

_____

(1)

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

Explain why the star remains stable.

_____

_____

_____

_____

(2)

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

_____

_____

_____

_____

(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?

_____

_____

(1)

(Total 7 marks)

Q19.

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.

_____

_____

_____

_____

_____

_____

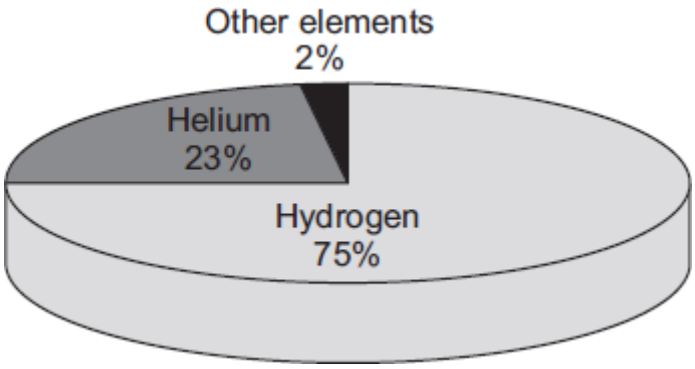
(Total 3 marks)

Q20.

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.

_____

_____

_____

_____

(3)

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

Identify this opinion and suggest how scientists could justify it.

_____

_____

_____

_____

(2)

(Total 5 marks)

Q21.

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

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

_____

_____

_____

_____

(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.

_____

_____

(1)

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

_____

_____

(1)

(Total 5 marks)

Q22.

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

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

_____

_____

_____

_____

_____

_____

(2)

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

Explain how the other elements came to be formed.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 5 marks)

Q23.

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

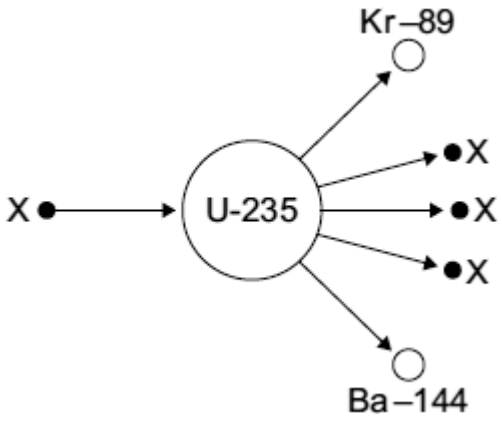
The decay can be represented by the equation below.

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

$$^{235}_{92}U \longrightarrow \square \quad Th + {}^{4}_{2}He$$

(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.

_____

(1)

(Total 6 marks)

Q24.

Every star goes through a 'life cycle'.

(a) Describe how a star forms.

_____

_____

_____

_____

_____

(2)

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

Explain why a star remains stable.

_____

_____

_____

_____

_____

(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.

_____

_____

_____

_____

_____

(2)

(Total 6 marks)

Q25.

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)

Q26.

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.

_____

_____

_____

_____

(2)

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

_____

_____

_____

_____

(2)

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

_____

_____

_____

_____

(2)

(Total 6 marks)

Q27.

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.

_____

_____

_____

_____

(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)

Q28.

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

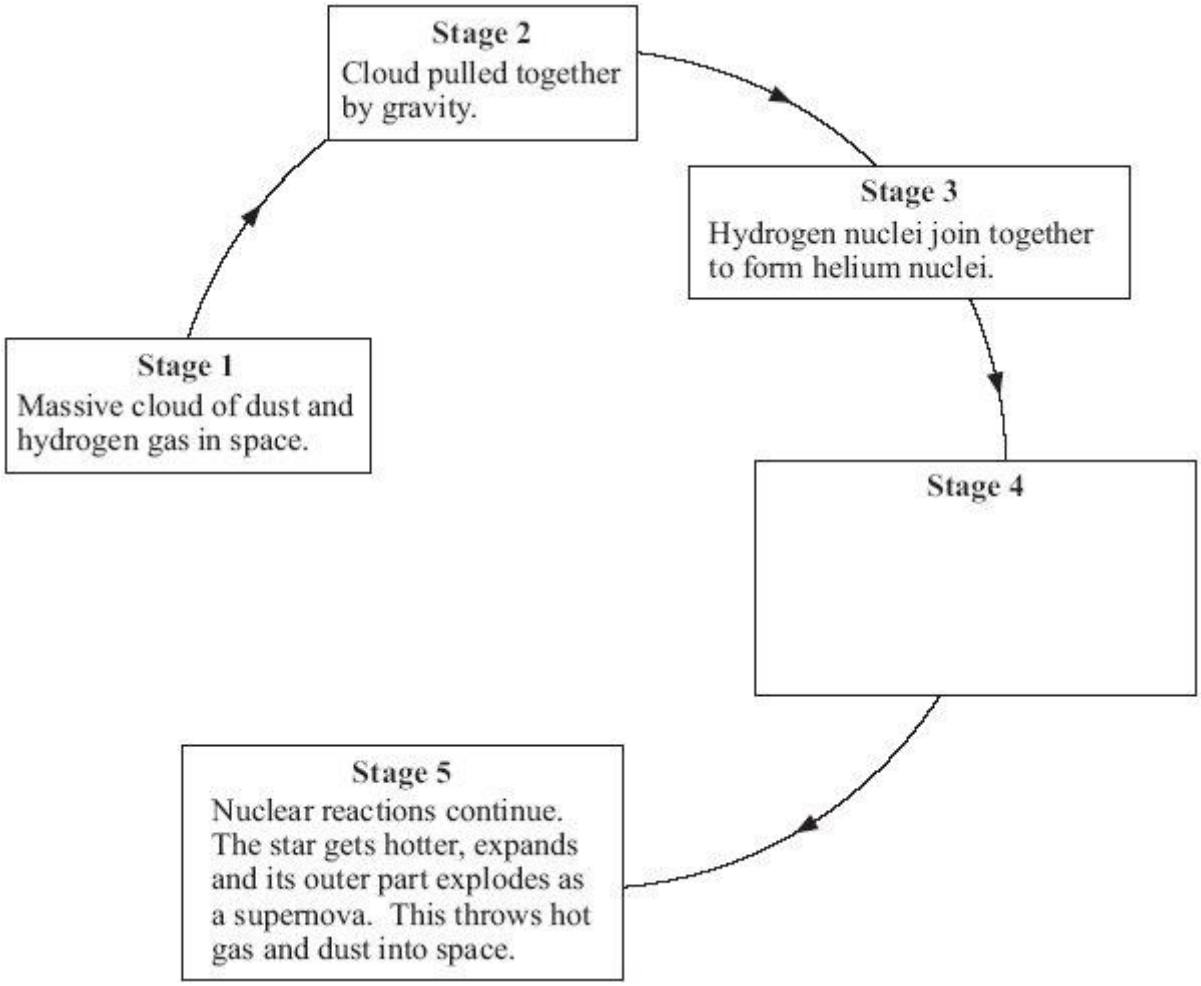
_____ .

(1)

(Total 4 marks)

Q29.

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.

_____

_____

_____

_____

_____

(2)

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

_____

_____

_____

_____

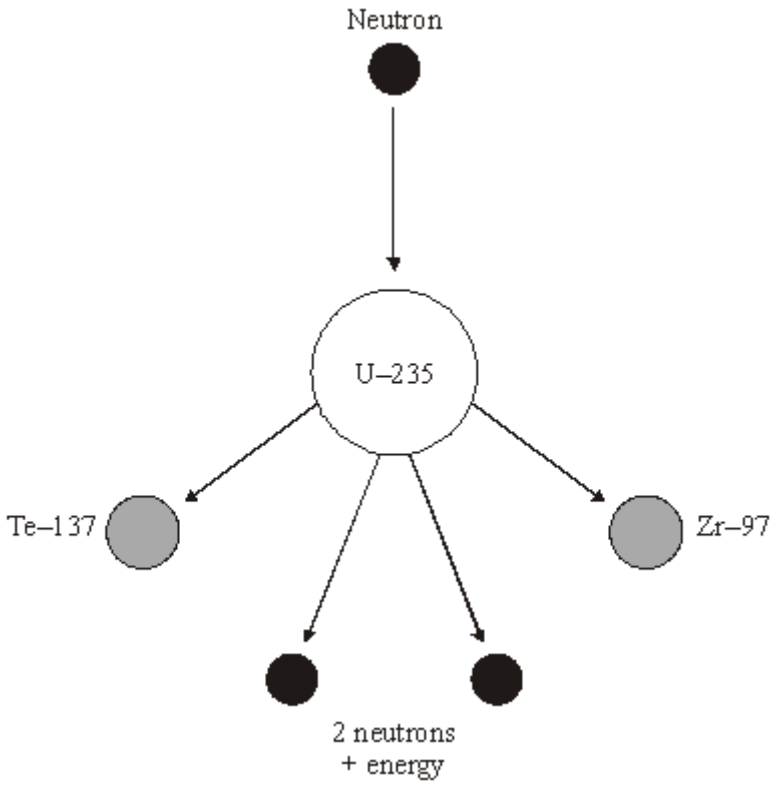
_____

(2)

(Total 6 marks)

Q30.

(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?

_____

(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.

_____

_____

_____

_____

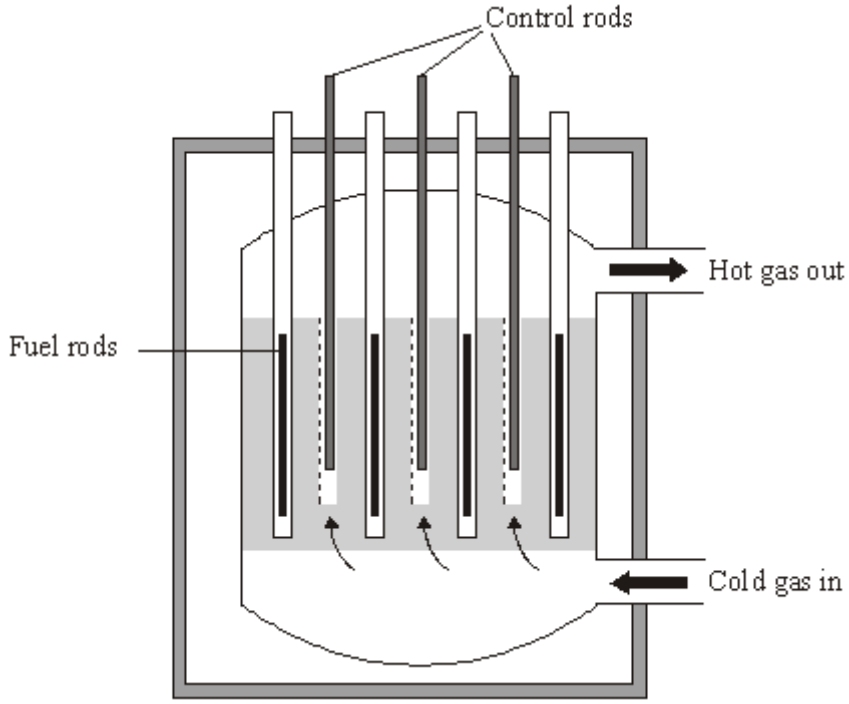
(2)

(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.

_____

_____

_____

_____

(2)

(Total 6 marks)

Q31.

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.

_____

_____

_____

_____

_____

_____

(3)

(Total 4 marks)

Q32.

(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)

Q33.

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)

Q34.

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)

Q35.

(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)

Q36.

(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?

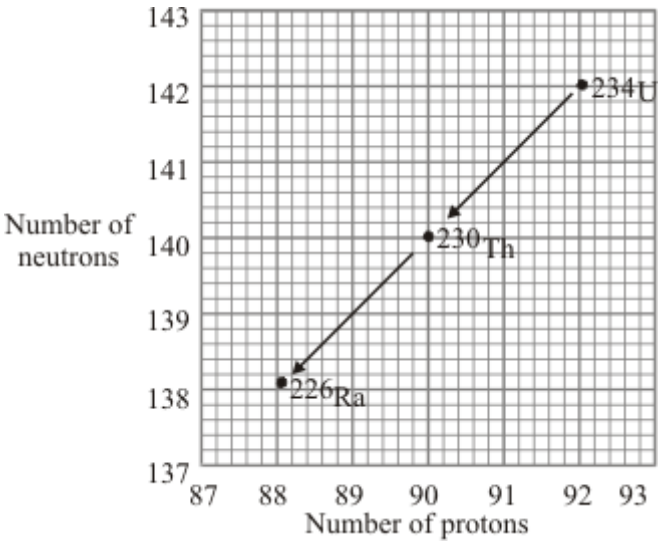
_____

(1)

(Total 6 marks)

Q37.

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



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

_____

(1)

(ii) What makes uranium and thorium different elements?

_____

(1)

(iii) Radioactive decay may also produce gamma radiation.

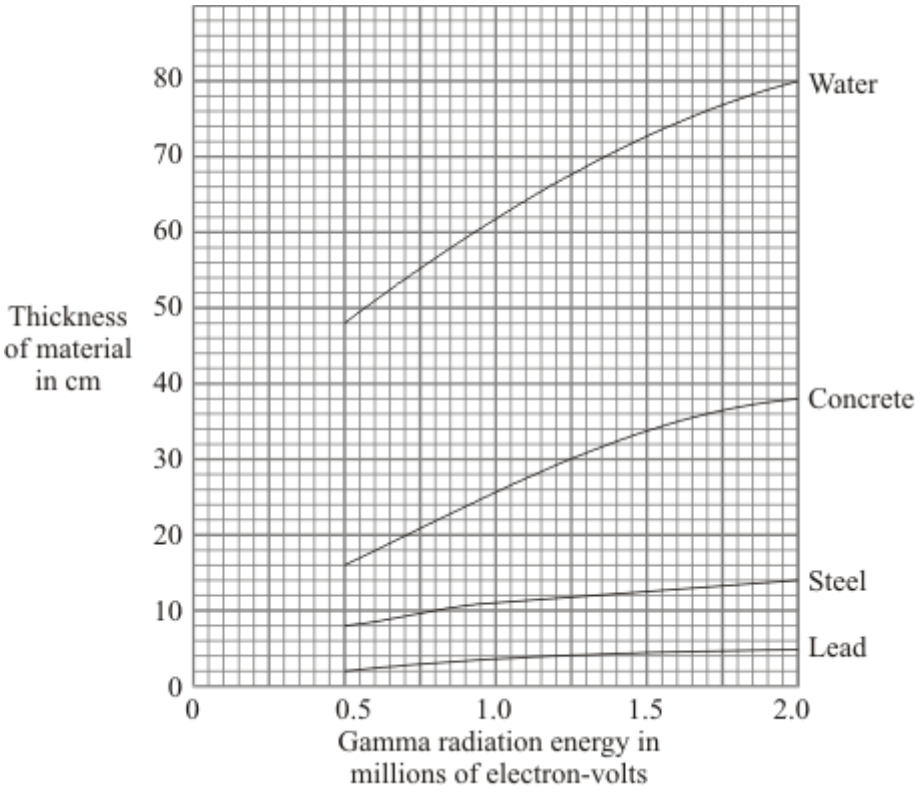
Why does the emission of gamma radiation **not** cause a new element to be formed?

_____

_____

(1)

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



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

_____

_____

(1)

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

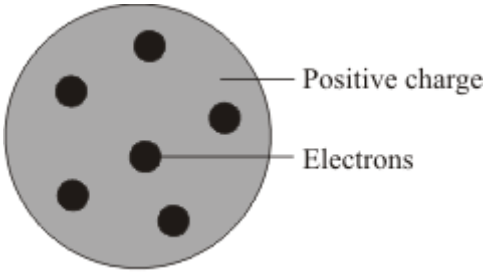
_____

_____

_____

(2)

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



Plum pudding model

Rutherford and Marsden did an experiment, in which a beam of alpha particles was

aimed at a thin sheet of gold.
Explain how the results of this experiment led to a new model of the atom.
You may include one or more diagrams in your answer.

(3)
(Total 9 marks)

Q38.

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

(2)

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

(3)
(Total 5 marks)

Q39.

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)

Q40.

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)

Q41.

Nuclear fusion in the Sun releases large amounts of energy.

(i) Explain what is meant by nuclear fusion.

_____

_____

_____

_____

_____

(3)

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

_____

_____

_____

_____

(2)

(Total 5 marks)

Q42.

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

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

_____

_____

_____

_____

_____

_____

(3)

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

Describe and explain the changes that could take place.

_____

_____

_____

_____

_____

_____

(6)

(Total 9 marks)

Q43.

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

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

_____

_____

_____

_____

_____

_____

(Total 3 marks)

Q44.

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

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

_____

_____

_____

_____

(2)

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

_____

_____

_____

_____

(2)

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

Nuclei of the heaviest elements are found in the Sun.

Describe how these nuclei are formed.

_____

_____

_____

_____

(2)

(Total 6 marks)

Q45.

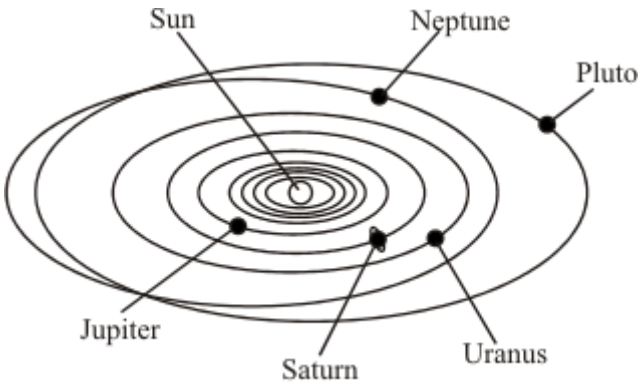
One theory of the origin of the Universe was that billions of years ago all matter was in one place, then it exploded (‘big bang’).
Describe, in as much detail as you can, how our star (the Sun) formed from the time when there was just dust and gas (mostly hydrogen) up to now when it is in its main stable 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.

(Total 5 marks)

Q46.

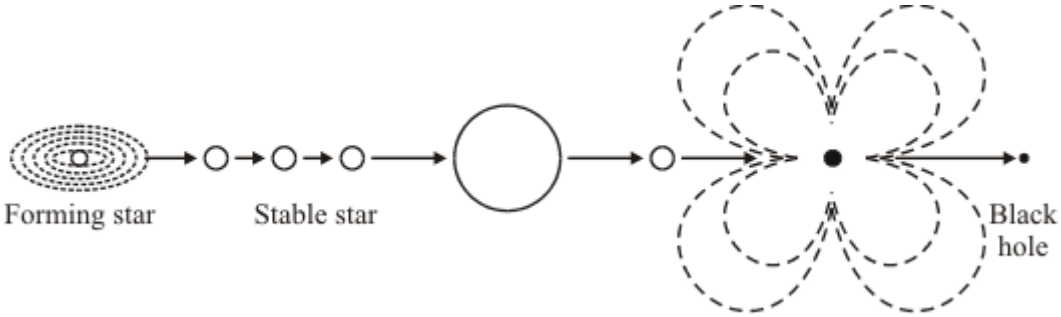
The Sun at the centre of our solar system is a star.



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

(1)

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



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

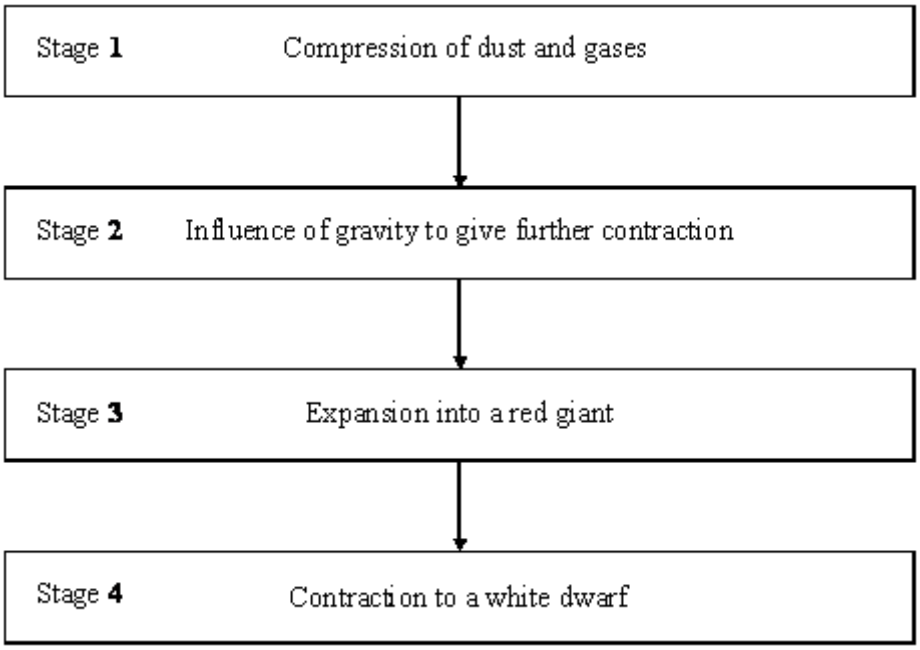
To gain full marks in this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words.

(6)

(Total 7 marks)

Q47.

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?

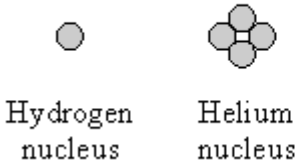
_____

(Total 1 mark)

Q48.

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)

Q49.

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*.)

_____

_____

_____

_____

_____

_____

(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)

Q50.

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

(Total 6 marks)