Nuclear Power (Fission and Fusion)

Questions

Q1.

Both U-235 and oil can be used as energy sources for generating electricity.

1 kg of natural uranium can result in the generation of 45 000 units of electricity.

1 kg of oil can result in the generation of 5.0 units of electricity.

Calculate the mass of oil needed to generate the same amount of electricity as 1kg of natural uranium.

(2)

mass of oil = ... kg

(Total for question = 2 marks)

Q2.

* Nuclear fission and nuclear fusion are two non-renewable sources of energy.

Compare nuclear fission and nuclear fusion as possible sources of energy for generating electricity using a nuclear reactor.

Your comparison should refer to

- the differences between nuclear fission and nuclear fusion
- the relative advantages and difficulties involved in using these sources.

(6)

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(Total for question = 6 marks)

Q3.

Use words from the box to complete the sentences about nuclear fission of uranium-235 (U-235).

chain	chemical	fuse
neutrons	protons	split

(3)

A neutron hits a nucleus of U-235 and causes the nucleus to ..... .

Each fission releases energy, two daughter nuclei and some ..... .

In a nuclear reactor, one fission can set off a controlled ..... reaction.

(Total for question = 3 marks)

Q4.

Stars may originate as a nebula.

(i) Describe the process that then occurs to produce the conditions necessary for nuclear fusion in a new star.

(3)

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(ii) The energy, E, released in nuclear fusion is equivalent to loss in mass, m, according to the equation.

$$E = mc^2$$

where c is the velocity of light.
$c = 3.00 \times 10^8$ m/s
In 1 second, the energy radiated by the Sun is 3.86×10^{26} J.
Calculate the loss in mass of the Sun in 1 second.

(2)

loss in mass = ... kg

(Total for question = 5 marks)

Q5.

Nuclear fusion provides the energy source for stars including the Sun.

Describe what happens during nuclear fusion.

(3)

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(Total for question = 3 marks)

Q6.

Figure 8 shows a helium nucleus.

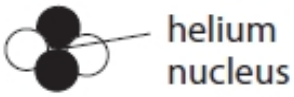

Figure 8

(i) Describe the difference between a fusion reaction and a fission reaction.

(2)

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(ii) Nuclear fusion does not happen at low temperatures because of electrostatic repulsion between

(1)

- ☒ **A** beta particles
- ☒ **B** electrons
- ☒ **C** neutrons
- ☒ **D** protons

(Total for question = 3 marks)

Q7.

Figure 8 shows a helium nucleus.

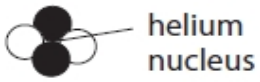

Figure 8

The energy released per kilogram of fuel in a fusion reaction is 845 000 GJ.

The energy released per kilogram of fuel in burning oil is 0.0394 GJ.

(i) Calculate the ratio of the energy released in fusion compared with the energy released in burning oil.

Use the equation

$$\text{ratio} = \frac{\text{energy released from fusion}}{\text{energy released by burning oil}}$$

(2)

ratio = ...

(ii) State **two** advantages of using a fusion reactor rather than burning oil in a power station.

(2)

1 .....

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2 .....

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(iii) State **two** of the difficulties that need to be overcome to produce a fusion reactor.

(2)

1 .....

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2 .....

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(Total for question = 6 marks)

Q8.

Fusion and fission are nuclear reactions in which large amounts of energy are released.

(i) In a fusion reaction, two hydrogen nuclei are forced together to form a helium nucleus.

Explain why a very high temperature is needed for this reaction to happen.

(3)

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(ii) In a fusion reaction, the combined mass of the two small nuclei is greater than the mass of the resulting nucleus.

This decrease in mass, m, appears as energy, E, according to the equation.

$$E = mc^2$$

c is the speed of light = 3.0×10^8 m/s.
The energy released in one fusion reaction is 4.5×10^{-12} J.
Calculate the decrease in mass.

(3)

decrease in mass = ... kg

(Total for question = 6 marks)

Q9.

Fusion and fission are nuclear reactions in which large amounts of energy are released.

* Nuclear fission is used in nuclear reactors in some power stations.

In the reactor, a fission chain reaction is maintained and controlled to produce a supply of energy to generate electricity. Figure 14 is a diagram of a nuclear reactor.

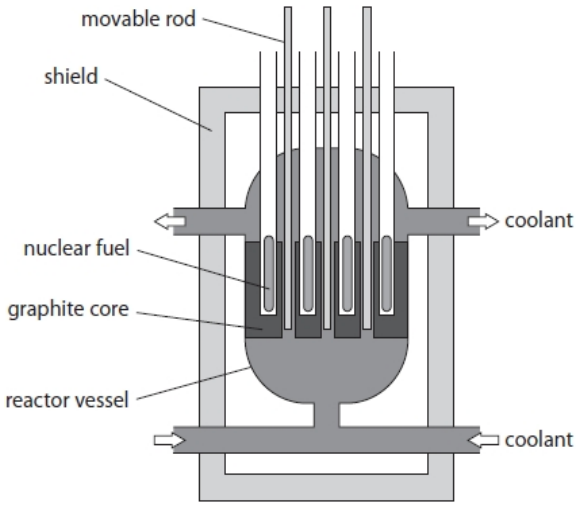

Figure 14

Explain how the graphite core and the movable rods are used to maintain and control the chain reaction.

(6)

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(Total for question = 6 marks)

Q10.

This question is about nuclear reactions.

When a uranium-235 (U-235) nucleus absorbs a neutron, the nucleus splits into smaller parts.

This reaction is called nuclear fission.

How many daughter nuclei are produced from the fission of one nucleus of uranium-235 (U-235)?

(1)

☒ **A** two

☒ **B** three

☒ **C** four

☒ **D** six

(Total for question = 1 mark)

Q11.

Both using nuclear fuel and burning oil produce harmful waste products.

State **one** harmful waste product from each process.

(2)

using nuclear fuel .....

.....

burning oil .....

.....

(Total for question = 2 marks)

Q12.

Nuclear power is used for generating electricity.

(i) State **two** advantages of generating electricity using nuclear power compared with generating electricity from gas-fired power stations.

(2)

1 .....

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2 .....

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(ii) Using nuclear power stations to generate electricity is unpopular with many people.

State **two** reasons why nuclear power stations are unpopular.

(2)

1 .....

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2 .....

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(Total for question = 4 marks)

Q13.

Figure 1 is a diagram of a nuclear reactor, used in the generation of electricity.

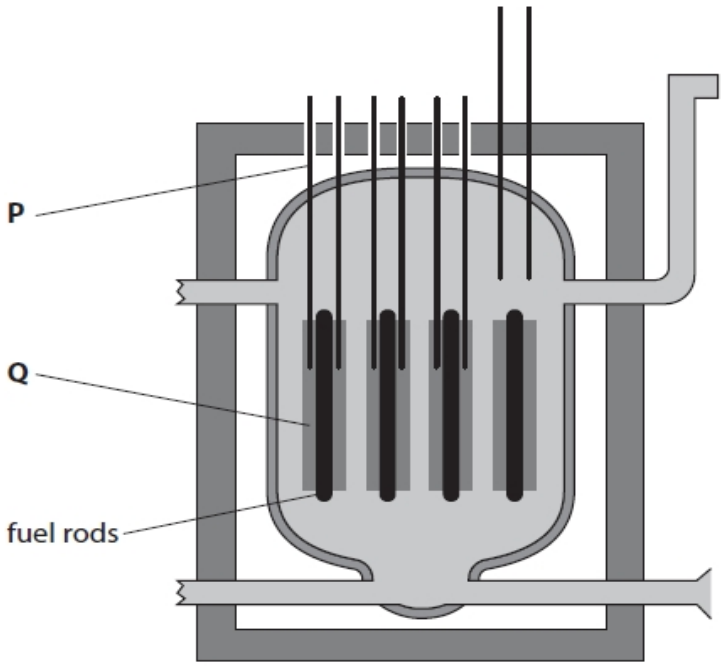

Figure 1

P may be used to shut down the reactor when necessary.
Q slows down neutrons to enable a chain reaction to take place.

State the name of the two parts labelled **P** and **Q**.

(2)

P .....

Q .....

(Total for question = 2 marks)

Q14.

This question is about nuclear reactions.

(i) When a uranium-235 (U-235) nucleus splits, neutrons are also emitted.

The neutrons may start a chain reaction.
Describe what is meant by a chain reaction.
You may draw a diagram to help with your answer.

(2)

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(ii) In the nuclear reactor of a power station, the chain reaction has to be controlled.

Explain the action of a moderator in a nuclear reactor.

(2)

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(iii) In a nuclear reactor there are 2.0×10^{17} fission reactions each second.

Each fission reaction releases 4.0×10^{-11} J of energy.
Calculate the energy released in 1 second.

(2)

energy released in 1 second = ... J

(Total for question = 6 marks)

Mark Scheme – Nuclear Power (Fission and Fusion)

Q1.

Question number	Answer	Additional guidance	Mark
	45 000 (1) 5 9000 (kg) (1)	 award full marks for the correct answer without working	(2)

Q2.

Question number	Indicative content	Mark
*	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive, and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. AO1 1 **(6 marks)** **fission** • (heavy) nucleus split • by a neutron • releases 2 daughter nuclei + more neutrons + energy • starts chain reaction **advantages** • already in use **disadvantages** • waste is radioactive • hard to dispose of • risk of accident	(6) AO1

	fusion • (light) nuclei joined • at high energy/temperature/pressure/particle density • releases (eg) helium + energy **advantages** • no harmful waste products **disadvantages** • not achieved yet (on a practicable scale) • difficulty in achieving high energy/temperature/pressure/particle density	

Level	Mark	Descriptor
	0	• No rewardable material.
Level 1	1-2	• Demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) • Presents an explanation with some structure and coherence. (AO1)
Level 2	3-4	• Demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) • Presents an explanation that has a structure which is mostly clear, coherent and logical. (AO1)
Level 3	5-6	• Demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) • Presents an explanation that has a well-developed structure which is clear, coherent and logical. (AO1)

Level	Mark	Additional Guidance	General additional guidance – the decision within levels e.g. - At each level, as well as content, the scientific coherency of what is stated will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	Additional guidance isolated facts	Possible candidate responses fission involves a nucleus being split by a neutron
Level 2	3–4	Additional guidance simple comparison of fission and fusion	Possible candidate responses fission involves a nucleus being split by a neutron whereas fusion requires combining two light nuclei.
Level 3	5–6	Additional guidance detailed comparison of fission and fusion and one advantage or one difficulty compared to the other	Possible candidate responses Fission involves nuclei split by a neutron. Fusion involves combining two light nuclei. The waste from fission is radioactive. Practicable fusion has not been achieved.

Q3.

Question number	Answer	Additional guidance	Mark
	split (1) neutrons (1) chain (1)	in this order	**(3)**

Q4.

Question Number	Answer	Additional guidance	Mark
(i)	a description to include: nebula collapses (1) under **gravity** (1) plus any one from: GPE converted into KE (1) OR (very) **high** temperatures/pressures reached (1)	 allow gas/dust for nebula allow condensing/coming together for collapses allow gravitational force producing (large) increase in **KE** of particles / more (frequent) collisions Ignore references to hot / heat	**(3)**

Question Number	Answer	Additional guidance	Mark
(ii)	rearrangement **and** substitution (1) (m =) $\frac{3.86 \times 10^{26}}{(3.00 \times 10^{8})^{2}}$ evaluation (1) (m =) 4.29×10^{9} (kg)	 ignore Power Of Ten (POT) error until evaluation allow numbers that round to 4.3×10^{9} (kg) award full marks for the correct answer without working 4.3 to any other power of ten scores 1 mark	**(2)**

Q5.

Question number	Answer	Additional guidance
	A description to include any three of the following	
	(smaller) nuclei / atoms / particles (1)	two named eg hydrogen (nuclei)
	come together / join (1)	allow fuse not 'bond'
	to produce a larger nucleus / atom / particle (1)	helium for nucleus
	needing high temperature / pressure (1)	accept fast (moving) nuclei
	overcoming repulsion (between nuclei) (1)	
	energy released (1)	ignore energy created

Q6.

Question Number	Answer	Additional guidance	Mark
(i)	a description referring to: fusion involves coming together / joining of particles / nuclei / atoms (1) fission involves (larger) particle(s) / nuclei /atoms breaking up (1)	 not just 'fuse together' that's just restating – more explanation needed particles etc. coming apart / separating no marks if just objects / things joining / coming apart	**(2)** AO 1 1

Question Number	Answer	Mark
(ii)	**D** protons **The only correct answer is D** *A 'beta particles' is incorrect, they are not found in nuclei to facilitate that repulsion* *B 'electrons' is incorrect, for the same reason as A* *C 'neutrons' is incorrect as they don't repel each other*	**(1)** AO 1 1

Q7.

Question Number	Answer	Additional guidance	Mark
(i)	substitution (1) $\frac{845\,000}{0.0394}$ evaluation (1) 21 000 000	answers that round to 21 000 000 $2.1(45) \times 10^7$ etc. award full marks for the correct answer without working	**(2)** AO 2 1

Question Number	Answer	Additional guidance	Mark
(ii)	any two from: • fusion power gives (many) more times the energy output (for the same mass used) • no greenhouse gases / CO_2 emissions (produced with the fusion alternative) • does not lead to global warming • no (radioactive) waste • does not deplete / use up a finite resource (e.g. oil)	may quote numbers here accept no or less pollution / no or less harmful gases etc. sustainable reference oil is running out ignore references to costs	**(2)** AO 1 1

Question Number	Answer	Additional guidance	Mark
(iii)	any two from: • problem of containment (the fusion gases / isotopes at high temperatures) • (maintaining) high temperature • (maintaining) high pressure		**(2)** AO 2 1

Q8.

Question Number	Answer	Additional guidance	Mark
(i)	an explanation linking: (high temperature means) high energy (1) (needed) to overcome (force of) repulsion (1) between nuclei / because they both have the same charge (1)	 accept "them" / hydrogen for nuclei	**(3)** AO 2 1

Question Number	Answer	Additional guidance	Mark
(ii)	substitution (1) $4.5 \times 10^{-12} = m\ (3.0 \times 10^{8})^{2}$ rearrangement (1) $(m =) \frac{4.5 \times (10^{-12})}{9.0 \times (10^{16})}$ evaluation (1) 5.0×10^{-29} (kg)	 accept substitution and rearrangement in either order ignore POT errors until evaluation award full marks for the correct answer with no working	**(3)** AO 2 1

Q9.

Question Number	Answer	Mark
*	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **AO1** • neutrons released in a chain reaction • slow(er) neutrons needed for fission • (some) neutrons are too fast • control rods can be moved in and out • control rods control speed of the reaction **AO2** • graphite core is the moderator • graphite core slows down the neutrons • moveable rods absorb neutrons • moveable rods make more or fewer neutrons available for fission	**(6)** AO 1 1 AO 2 1

Level	Mark	Descriptor
	0	No awardable content
Level 1	1-2	• An explanation that demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) • The explanation attempts to link and apply knowledge and understanding of scientific ideas, flawed or simplistic connections made between elements in the context of the question. (AO2)
Level 2	3-4	• An explanation that demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) • The explanation is mostly supported through linkage and application of knowledge and understanding of scientific ideas, some logical connections made between elements in the context of the question. (AO2)
Level 3	5-6	• An explanation that demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) • The explanation is supported throughout by linkage and application of knowledge and understanding of scientific ideas, logical connections made between elements in the context of the question. (AO2)

Q10.

Question number	Answer	Additional guidance	Mark
	A two B is not correct as a uranium nucleus does not split to give 3 daughter nuclei C is not correct as a uranium nucleus does not split to give 4 daughter nuclei D is not correct as a uranium nucleus does not split to give 5 daughter nuclei		**(1)** **AO1**

Q11.

Question number	Answer	Additional guidance	Mark
	using nuclear fuel: radioactive substances (1) burning oil: carbon dioxide (1)	 named radioactive substance / nuclear waste greenhouse gases named pollutant toxic/poisonous gases atmospheric pollutant / acid rain	**(2)**

Q12.

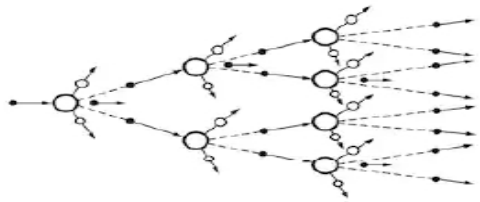
Question Number	Answer	Additional guidance	Mark
(i)	Any two advantages from: no CO_2 produced / reduces global warming more energy (per kg) no cross-country pipelines no cross-country pipelines	 no harmful waste gases to atmosphere high energy density fuel IGNORE reference to unqualified non-pollution cost renewable efficiency sped of production	**(2)**

Question Number	Answer	Additional guidance	Mark
(ii)	Any **two** reasons for unpopularity from **mp1** public perception that radioactivity is dangerous **mp2** radiation leaks from plant **mp3** nuclear accidents **mp4** risks of terrorist attacks **mp5** production/storage of nuclear waste **mp6** (nuclear) waste radioactive for a long time		(2)

Q13.

Question number	Answer	Additional guidance	Mark
	P - control rods (1) Q - graphite/moderator (1)	boron steel rods heavy water	(2)

Q14.

Question number	Answer	Additional guidance	Mark
i	A description including: EITHER neutrons are absorbed by uranium nuclei/atoms (1) more neutrons are produced/emitted (which are absorbed by uranium nuclei) (1) OR diagram (no labels needed) two nuclei/atoms splitting (1) four or more nuclei/atoms splitting (1)  	ignore any reference to bonds accept hit /collide with accept a controlled chain reaction diagram for 2 marks	(2) AO1

Question number	Answer	Additional guidance	Mark
ii	An explanation linking: (because the moderator/it) slows down/increases the chance of absorption of(1) neutrons (1)		(2) AO1

Question number	Answer	Additional guidance	Mark
iii	substitution(1) $2(.0 \times 10^{(17)}) \times 4(.0 \times 10^{(-11)})$ evaluation (1) $8(.0) \times 10^{6}$ (J)	accept 8000000(J) accept 8MJ 8 to any other power of ten scores 1 mark award full marks for correct answer without working.	(2) AO2