Leaving Cert Physics Long Questions 2018 - 2002

14. Nuclear Physics

Please remember to photocopy 4 pages onto one sheet by going A3→A4 and using back to back on the photocopier

Contents

The atom

2008 Question 10 [Ordinary Level]

Give two properties of an electron.

The diagram shows the arrangement used by Rutherford to investigate the structure of the atom. During the investigation he fired alpha-particles at a thin sheet of gold foil in a vacuum.

(i) What are alpha-particles?

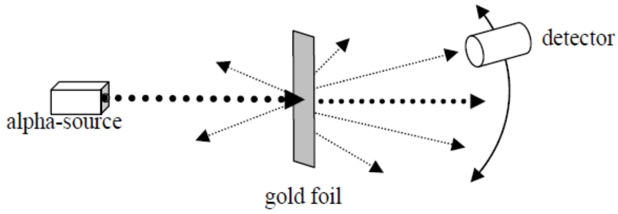
(ii) Describe what happened to the alpha-particles during the experiment.

(iii) What conclusion did Rutherford make about the structure of the atom?

(iv) How are the electrons arranged in the atom?

(v) Name a device used to detect alpha-particles.

(vi) Why was it necessary to carry out this experiment in a vacuum?



2011 Question 12 (d) [Ordinary Level]

The diagram shows the arrangement used to investigate the structure of the atom. During the investigation, alpha-particles were fired at a thin sheet of gold foil in a vacuum.

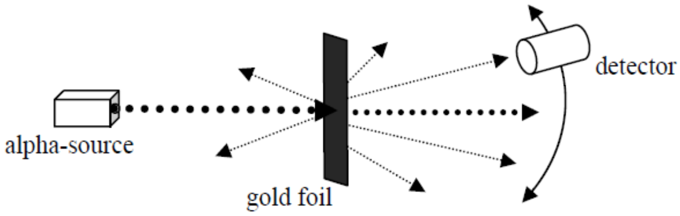
(i) What are alpha-particles?

(ii) What happened to the alpha-particles in the experiment?

(iii) What did the experiment reveal about the structure of the atom?

(iv) Name the scientist who designed the experiment.

(v) Name a suitable detector of alpha-particles.



2015 Question 11 [Ordinary Level]

Read the following passage and answer the accompanying questions.

Ernest Rutherford (1871–1937, Nobel Prize 1908) was a brilliant student from New Zealand who, thanks to a grant, moved to the glorious Cavendish Laboratory in Cambridge, full of hopes and ambitions. Later in his life he became a physics professor at the University of Manchester.

One day in 1909, in Manchester, he suggested to his collaborator Hans Geiger and to his student Ernest Marsden that they study the deflection of the so-called alpha-particles. These are positively charged helium ions produced by a radioactive source of radium bromide. This deflection occurs when the alpha-particles pass through a thin film of gold. Experiments of this kind had already been performed, and it had been observed that the alpha-particles are only slightly deflected when they cross the film.

The novelty of Rutherford's suggestion was that he asked his collaborators to check if any alpha-particle bounced back instead of going through the film. Why should a thin metal film reflect heavy high-speed bullets, like the alpha-particles produced by a radioactive source? Geiger and Marsden made their measurement and ran back breathlessly to Rutherford. They had observed that some alpha-particles were indeed bouncing back.

In Rutherford's words: "It was quite the most incredible event that has ever happened to me in my life". He had looked inside the atom and the image he saw was very different from what physicists had expected. A central nucleus, much smaller than the actual size of the atom, holds the entire positive charge and practically all the atomic mass. The rest is just a cloud of light electrons, carrying all the negative charge.

(Adapted from *A Zeptospace Odyssey*, Gian Francesco Giudice, Oxford University Press, 2010)

(*a*) What are alpha-particles?

(*b*) Name a source of alpha-particles.

(*c*) What material was used as the target in the experiment?

(*d*) How did Geiger and Marsden detect the alpha-particles?

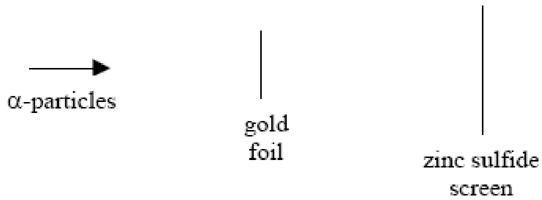
(*e*) What was the surprising result they observed?

(*f*) What force caused the deflection of the alpha-particles?

(*g*) Outline what the Geiger-Marsden experiment revealed about the structure of the atom.

(*h*) For what invention is Hans Geiger most famous?

2002 Question 12 (d) [Higher Level]



(i) The diagram shows a simplified arrangement of an experiment carried out early in the 20th century to investigate the structure of the atom.
Name the scientist who carried out this experiment.

(ii) Describe what was observed in this experiment.

(iii) Why was it necessary to carry out this experiment in a vacuum?

(iv) What conclusion did the scientist form about the structure of the atom?

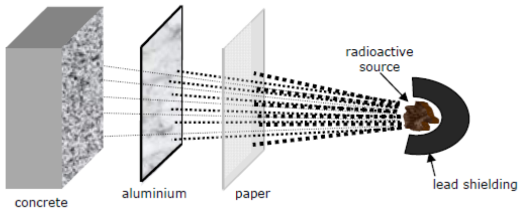
2017 Question 9 {first 2 parts only}

(i) Describe Rutherford's experiment to investigate the structure of the atom.

(ii) What conclusions about the nature of the atom did Rutherford make?

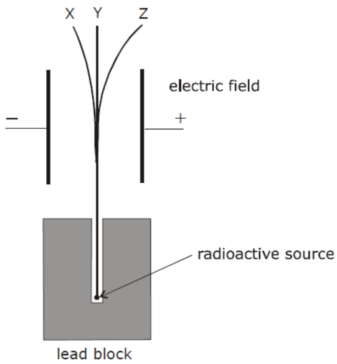
Radioactivity

2010 Question 12 (d) [Ordinary Level]



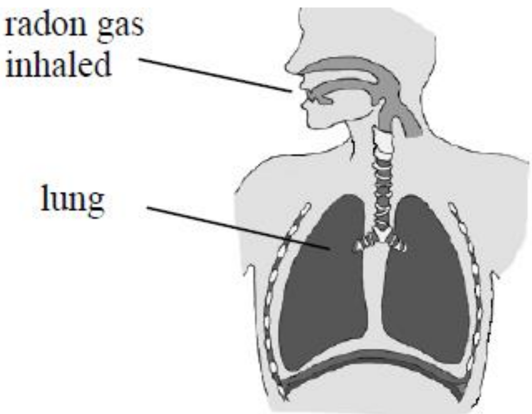
(i) What is radioactivity?
(ii) The diagram shows a shielded radioactive source emitting nuclear radiation.
How do you know that the source is emitting three types of radiation?
(iii) Name the radiation blocked by each material.
(iv) Give one danger associated with nuclear radiation.
(v) State two precautions that should be taken when handling radioactive substances.
(vi) Give two uses for radioactive substances

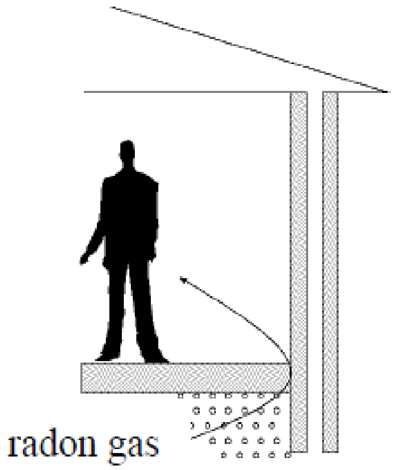
2004 Question 10 [Ordinary Level]



(i) What is radioactivity?
(ii) Name the French physicist who discovered radioactivity in 1896.
(iii) The diagram illustrates that three types of radiation are emitted from a radioactive source.
Name the radiations labelled (i) X, (ii) Y, (iii) Z, in the diagram.
(iv) Which one is the most ionising?
(v) Name a detector of ionising radiation.
(vi) Outline the principle on which the detector works.
(vii) Great care has to be taken when dealing with radioactive sources.
Give two precautions that should be taken when dealing with radioactive sources.
(viii) Give one use of a radioactive source.
(ix) Give one harmful effect of radiation.

2011 Question 10 [Ordinary Level]





Radon is a radioactive gas which emits alpha particles. Radon gas comes into houses through gaps in the floors. Exposure to radon gas can cause lung cancer

(i) What is radioactivity?
(ii) Name the other two types of radiation emitted by radioactive sources.
(iii) Describe an experiment to distinguish between the three types of radiation.
(iv) List three properties of one of these radiations.
(v) The most stable isotope of radon has a half-life of 4 days.
What are isotopes?
(vi) Why is it important to prevent radon gas entering your home?
(vii) If no more radon gas entered your home, how long would it be until one eight of the radon gas was left?
(viii) Give two uses of radioisotopes.

2007 Question 11 [Ordinary Level]

Read this passage and answer the questions below. Radon is a naturally occurring radioactive gas. It originates from the decay of uranium, which is present in small quantities in rocks and soils. Radon is colourless, odourless and tasteless and can only be detected using special equipment, like a Geiger-Müller tube, that can measure the radiation it releases. Because it is a gas, radon can move freely through the soil and enter the atmosphere. When radon reaches the open air, it is quickly diluted to harmless concentrations, but when it enters an enclosed space, such as a house, it can sometimes accumulate to unacceptably high concentrations. Radon can enter a building from the ground through small cracks in floors and through gaps around pipes and cables. Radon is drawn from the ground into a building because the indoor air pressure is usually lower than outdoors. Being radioactive, radon decays releasing radiation.

When radon is inhaled into the lungs the radiation released can cause damage to the lung tissue.

(a) What is radioactivity?
(b) What is the source of radon?
(c) Name a detector of radiation.
(d) How does radon enter a building?
(e) How can the build-up of radon in the home be prevented?
(f) Why is radon dangerous?
(g) Why is radon harmless in the open air?
(h) Name a radioactive element other than radon.

2002 Question 11 [Ordinary Level]

The world's most devastating nuclear accident happened at Chernobyl in the Ukraine in 1986. In the early hours of the morning of 26 April of that year, there were two loud explosions that blew the roof off and completely destroyed the No. 4 reactor, releasing during the course of the following days, 6 to 7 tonnes of radioactive material, with a total activity of about 10^{18} becquerels, into the atmosphere.

The discharge included over a hundred radioisotopes, but iodine and caesium isotopes were of main relevance from a human health and environmental point of view. Contamination in the surrounding areas was widespread, with the half-life of some of the materials measured in thousands of years.

Large numbers of people involved in the initial clean up of the plant received average total body radiation doses of about 100 mSv - about five times the maximum dose permitted for workers in nuclear facilities. Average worldwide total body radiation dose from natural 'background' radiation is about 2.4 mSv annually.

During, and soon after the accident and the initial clean-up, at least 30 plant personnel and firefighters died from burns and radiation. In the eight years following the accident, a further 300 suffered radiation sickness, and there are possible links between the accident and increased numbers of thyroid cancers in neighbouring regions.

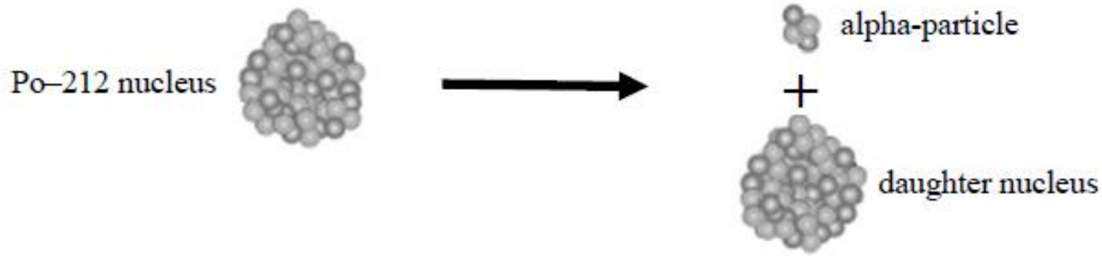
(Adapted from "Physics – a teacher's handbook", Dept. of Education and Science.)

(i) What is meant by a nuclear accident?
(ii) The No. 4 reactor was a fission reactor. What is nuclear fission?
(iii) Name two parts of a nuclear fission reactor.
(iv) What is measured in becquerels?
(v) Give two examples of radioisotopes.
(vi) What is meant by the half-life of a substance?
(vii) What is meant by background radiation?
(viii) Give two effects of radiation on the human body.

2016 Question 12 (a) [Higher Level]

(i) State the principle of conservation of momentum.

(ii) A polonium–212 nucleus decays spontaneously while at rest, with the emission of an alpha-particle. What daughter nucleus is produced during this alpha-decay?



(iii) The kinetic energy of the emitted alpha-particle is 8.9 MeV. Calculate its velocity.

(iv) Calculate the velocity of the daughter nucleus after the decay.

Half-life

2005 Question 12 (d) [Ordinary Level]

Na−25 is a radioactive isotope of sodium. It has a half life of 1 minute.

(i) What is meant by radioactivity?
(ii) Name a detector of radioactivity.
(iii) Explain the term half life.
(iv) What fraction of a sample of Na−25 remains after 3 minutes?
(v) Give one use of a radioactive isotope.

2007 Question 12 (d) [Higher Level]

(i) Explain the term half-life.
(ii) A sample of carbon is mainly carbon-12 which is not radioactive, and a small proportion of carbon-14 which is radioactive. When a tree is cut down the carbon-14 present in the wood at that time decays by beta emission.
Write a nuclear equation to represent the decay of carbon-14.
(iii) An ancient wooden cup from an archaeological site has an activity of 2.1 Bq.
The corresponding activity for newly cut wood is 8.4 Bq.
If the half-life of carbon-14 is 5730 years, estimate the age of the cup.
(iv) Name an instrument used to measure the activity of a sample.
(v) What is the principle of operation of this instrument?

2003 Question 11 [Higher Level]

Read the following passage and answer the accompanying questions.

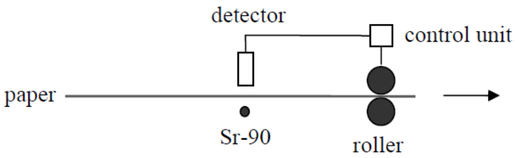
Irish Times: Monday, January 11,1999

Radioactive decay helps to determine exact dates.
Radioactive decay occurs with such precision that it is often used as a clock.
Carbon dating has been invaluable to archaeologists, historians and anthropologists.
The method is based on the measurement of ^{14}C, a radioactive isotope of carbon with a half-life of 5730 years. ^{14}C occurs to a small extent in the atmosphere together with the much more common ^{12}C.
Living organisms constantly exchange carbon with the atmosphere and the ratio of ^{14}C to ^{12}C in living tissue is the same as it is in the atmosphere.
This ratio is assumed to have remained the same since prehistoric times.
When an organism dies, it stops exchanging carbon with the atmosphere, and its ^{14}C nuclei keep disintegrating while the ^{12}C in the dead tissue remains undisturbed.

(i) What is radioactive decay?
(ii) What is an isotope?
(iii) Apart from “carbon dating”, give two other uses of radioactive isotopes.
(iv) How many neutrons are in a ^{14}C nucleus?
(v) ^{14}C decays to ^{14}N. Write an equation to represent this nuclear reaction.
(vi) How much of a ^{14}C sample remains after 11460 years?
(vii) Calculate the decay constant of ^{14}C.
(viii) Why does the ^{12}C in dead tissue remain “undisturbed”?

(Refer to the Periodic Table of the Elements in the Mathematics Tables, p.44.)

2011 Question 12 (d) [Higher Level]
In the manufacture of newsprint paper, heavy rollers are used to adjust the thickness of the moving paper. The paper passes between a radioisotope and a detector, and a pair of rollers, as shown.



The radioisotope used is Sr-90 and it emits beta-particles, which are recorded by the detector. The output from the detector adjusts the gap between the rollers, so that the paper is of uniform thickness.
(i) Name a suitable detector.
(ii) Describe how the reading on the detector may vary as the paper passes by.
(iii)Why would the radioisotope Am-241, which emits alpha-particles, **not** be suitable for this process?
(iv)Calculate the number of atoms present in a sample of Sr-90 when its activity is 4250 Bq.
The half-life of Sr-90 is 28.78 years.

2009 Question 12 (d) [Higher Level]
Smoke detectors use a very small quantity of the element americium-241. This element does not exist in nature and was discovered during the Manhattan Project in 1944.
Alpha particles are produced by the americium-241 in a smoke detector.
(i) Give the structure of an alpha particle.
(ii) How are the alpha particles produced?
(iii)Why do these alpha particles not pose a health risk?
(iv)Americium-241 has a decay constant of 5.1×10^{-11} s^{-1}.
Calculate its half life in years.
(v) Explain why americium-241 does not exist naturally.

2005 Question 8 [Higher Level]
Nuclear disintegrations occur in radioactivity and in fission.
(i) Distinguish between radioactivity and fission.
(ii) Give an application of radioactivity.
(iii)Give an application of fission.
(iv)Radioactivity causes ionisation in materials. What is ionisation?
(v) Describe an experiment to demonstrate the ionising effect of radioactivity.
(vi)Cobalt−60 is a radioactive isotope with a half-life of 5.26 years and emits beta particles.
Write an equation to represent the decay of cobalt−60.
(vii) Calculate the decay constant of cobalt−60.
(viii) Calculate the rate of decay of a sample of cobalt−60 when it has 2.5×10^{21} atoms.

2015 Question 12 (d) [Higher Level]
(i) Radon is a radioactive gas which is present in some rocks.
It can sometimes build up in houses and cause health concerns.
What is meant by the term *radioactive*?
(ii) Name a detector of radiation and describe, with the aid of a labelled diagram, its principle of operation.
(iii)Radon–210 decays by alpha-emission with a half-life of 144 minutes.
A sample of the gas contains 4.5×10^{15} atoms of this isotope.
How many radon–210 atoms will remain after one day?

2013 Question 9 [Higher Level]

(i) Define the becquerel.

(ii) Name one device used to detect ionising radiations.

(iii) Compare alpha, beta, and gamma emissions using the following headings: *(a)* penetrating ability, (*b*) deflection in a magnetic field.

The photograph shows one of the nuclear reactors at Chernobyl, where there was a fire in April 1986 that released large quantities of radioactive contaminants.
Among the contaminants were iodine–131 and caesium–137, which are two of the unstable isotopes formed by the fission of uranium–235.

(iv) Explain what happens during nuclear fission.

(v) Iodine–131 decays with the emission of a beta-particle and has a half-life of 8 days.
Write an equation for the beta-decay of iodine–131.

(vi) Estimate the fraction of the iodine–131 that remained after 40 days.

Caesium–137 has a half-life of 30 years and it remains a significant contaminant in the region around Chernobyl. It is easily absorbed into the tissues of plants as they grow.
Scientists collected a sample of berries growing near the abandoned power station.
The activity of the sample was measured at 5000 Bq.

(vii) Calculate the decay constant of caesium–137.

(viii) Hence calculate the number of caesium–137 atoms present in the sample.
(You may assume that all of the activity was caused by caesium–137.)

2017 Question 12 (b) [Higher Level]

Potassium–40 is a significant source of radioactivity in the human body.
Bananas are a principle source of potassium in our diet.
Potassium–40 has a half-life of 1.25×10^9 years and it is a beta-emitter.

(i) What is meant by radioactivity?

(ii) Name a device used to detect beta-radiation and explain its principle of operation.

The activity of a human body due to potassium–40 is 5400 Bq.

(iii) Write the nuclear equation for this decay.

(iv) Calculate the number of potassium–40 nuclei in this person.

2018 Question 12 (b) [Higher Level]

The radioactivity of an isotope of radon was measured each day for a week and the following data were recorded.

Time (days)	0	1	2	3	4	5	6	7
Activity (MBq)	600	490	400	330	270	220	180	150

(i) What is meant by radioactivity?

(ii) On graph paper, draw a decay curve (a graph of activity against time).

(iii) Use the decay curve to determine the half-life of the isotope.

(iv) Calculate the number of nuclei in the sample at the beginning of the investigation.

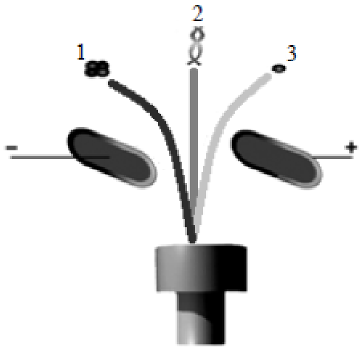
Fission and fusion: ordinary level questions

2014 Question 10 [Ordinary Level]

(i) What is meant by radioactivity?

(ii) In an experiment, the radiation from a radioactive source is passed through an electric field, as shown in the diagram.

What does this experiment indicate about radiation?



(iii) Which type of radiation is unaffected by electric fields?

(iv) Which type of radiation is positively charged?

(v) Which type of radiation is negatively charged?

(vi) Give the name of radiation types 1, 2 and 3, in that order.

(vii) Nuclear fission occurs in a nuclear power station. Name a suitable fuel for nuclear fission.

(viii) Explain the role of neutrons in nuclear fission.

(ix) Explain how the control rods can control the rate of fission, or stop the reaction completely.

(x) Iodine–131 is a product of nuclear fission. The half-life of iodine–131 is 8 days. What fraction of iodine–131 remains after 24 days?

2013 Question 12 (d) [Ordinary Level]

(i) Nuclear fission occurs in the reactor of a nuclear power station like the one shown in the photograph. What is nuclear fission?

(ii) Name a fuel used in a nuclear reactor.

(iii) How can the reaction in a nuclear reactor be controlled?

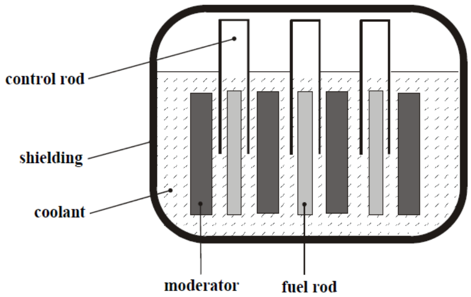
(iv) How is the energy produced in a reactor used to generate electricity?

(v) State a hazard of nuclear reactors.

2006 Question 9 [Ordinary Level]

The diagram shows a simple nuclear fission reactor.

Energy is released in a fission reactor when a chain reaction occurs in the fuel rods.



(i) What is meant by fission? Name a material in which fission occurs.

(ii) Describe how a chain reaction occurs in the fuel rods.

(iii) Explain how the chain reaction is controlled.

(iv) What is the purpose of the shielding?

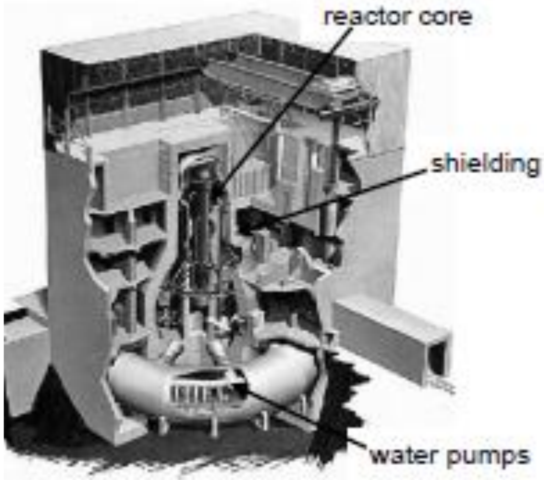
(v) Name a material that is used as shielding.

(vi) Describe what happens to the coolant when the reactor is working.

(vii) Give one effect of a nuclear fission reactor on the environment.

(viii) Give one precaution that should be taken when storing radioactive materials.

2012 Question 11 [Ordinary Level]
Read this passage and answer the questions below.
The Fukushima nuclear disaster



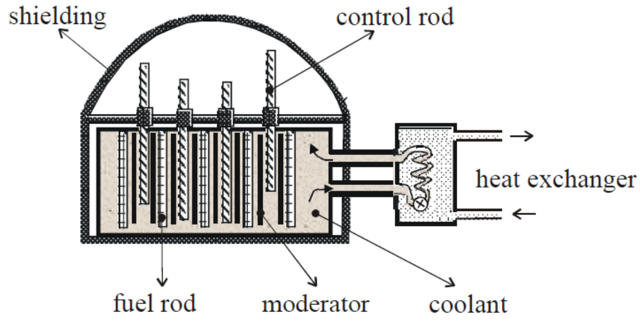
In March 2011, following a powerful earthquake, the Fukushima nuclear reactor in Japan was shut down automatically.
A nuclear reactor generates heat by splitting atoms of uranium in a process known as nuclear fission.
The uranium is contained in the reactor's fuel rods. A chain reaction is set up by the neutrons released during fission and these go on to split more atoms of uranium.
The power output of the reactor is adjusted by controlling the number of neutrons that are present. Control rods made of a neutron absorber capture neutrons.

Absorbing more neutrons in a control rod means that there are fewer neutrons available to cause fission. Therefore, pushing the control rods deeper into the reactor will reduce its power output, and extracting the control rods will increase it.

The Fukushima nuclear reactor continued to generate heat even after the chain reaction was stopped because of the radioactive decay of the isotopes created during nuclear fission. This decay cannot be stopped and the resulting heat must be removed by circulating cooling water through the reactor core.

When the reactor was shut down due to the earthquake, the pumps to keep the cooling water circulating should have been powered by electricity from the national grid or diesel generators. However, connections to the grid were damaged by the earthquake and the diesel generators were destroyed by the tsunami wave that followed the earthquake. As a result, no cooling was available for the reactor core and this resulted in the explosions and subsequent release of radiation, consisting of radioactive isotopes such as caesium and iodine, into the environment.
(Adapted from 'Wikipedia', June 2011)
(a) What is meant by nuclear fission?
(b) What is radioactivity?
(c) What is a nuclear chain reaction?
(d) What is the function of the control rods?
(e) What type of material are control rods made of?
(f) Why did the reactor still generate heat even though the chain reaction had stopped?
(g) Why is it important to remove the heat generated?
(h) Give one advantage of nuclear energy.

2003 Question 10 [Ordinary Level]



(i) What is radioactivity?
(ii) The diagram shows the basic structure of a nuclear reactor.
(iii) A nuclear reactor contains (i) fuel rods, (ii) control rods, (iii) moderator, (iv) heat exchanger.
(iv) Give the function of any two of these.
(v) In a nuclear reactor, energy is released by nuclear fission when a chain reaction occurs.
(vi) What is nuclear fission?
(vii) What is a chain reaction?
(viii) Thick shielding is placed around a nuclear reactor because of the penetrating power of the radiation emitted.
Name three types of radiation that are present in a nuclear reactor.
(ix) Name an instrument used to detect radiation.
(x) Plutonium is produced in a nuclear reactor. It is a highly radioactive substance with a very long half-life. When the fuel in a nuclear reactor is used up, the fuel rods are reprocessed to remove the plutonium.
(xi) Give two precautions that are taken when storing the plutonium.

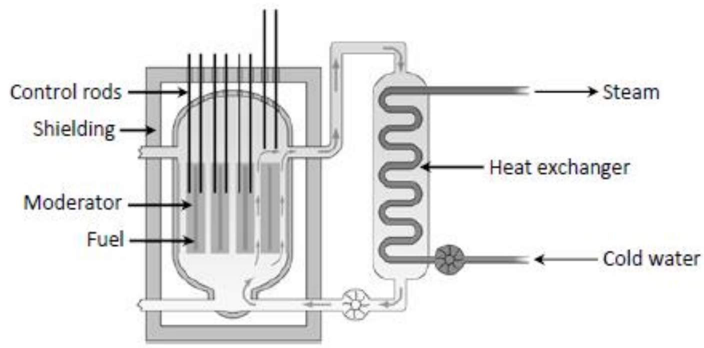
2009 Question 10 [Ordinary Level]

Radioactive elements are unstable and decay with the release of radiation.
(i) How would you detect radiation?
(ii) Name the three types of radiation.
(iii) Which radiation is negatively charged?
(iv) Which radiation has the shortest range?
(v) Which radiation is not affected by electric fields?
(vi) Nuclear fission occurs in a nuclear reactor.
(vii) What is nuclear fission?
(viii) What is the role of neutrons in nuclear fission?
(ix) Name a fuel used in a nuclear reactor.
(x) In a nuclear reactor, how can the fission be controlled or stopped?
(xi) How is the energy produced in a nuclear reactor used to generate electricity?
(xii) Give one advantage and one disadvantage of a nuclear reactor as a source of energy.

2017 Question 10 [Ordinary Level]

Radiation is released when radioactive elements decay.
(i) Name three types of radiation.
(ii) Which type of radiation has no charge?
(iii) Which type of radiation is the least penetrating?
(iv) Which type of radiation is not deflected by magnetic fields?
(v) State one danger associated with nuclear radiation.
(vi) State one precaution that should be taken when handling radioactive substances.

Radioactive fuels are used to generate power in a nuclear fission reactor like the one shown in the diagram.



(vii) What is nuclear fission?
(viii) Name a fuel used in nuclear reactors.
(ix) State the function of (*a*) the control rods and (*b*) the shielding in a reactor.
(x) What is the purpose of the heat exchanger?

Nuclear fission

2014 Question 8 [Higher Level]

A nuclear reactor is a device in which a sustained <u>chain reaction</u> takes place.
From each <u>nuclear fission</u>, only one (on average) of the emitted neutrons hits another nucleus to cause another fission. The power output from a sustained nuclear reaction doesn't grow, but is constant.

(i) Explain the underlined terms.

(ii) A substance called a moderator is mixed with the fuel in a nuclear reactor.
Control rods are used to control the rate of the reaction.
Give an example of a moderator.

(iii) Explain why a moderator is needed in a nuclear reactor

(iv) Explain how the control rods affect the rate of the reaction.

(v) A heat exchanger is used in a nuclear reactor.
Explain how the heat exchanger operates.

(vi) Why is it necessary to use a heat exchanger?

(vii) Plutonium is produced in a fission reactor when one of the neutrons released in the fission reaction converts uranium–238 into plutonium–239 with the emission of two beta-particles.
Write an equation for this nuclear reaction.

(viii) Each fission of a uranium–235 nucleus produces 202 MeV of energy.
Only 35% of this energy is used to generate electricity.
How many uranium–235 nuclei are required to undergo fission to generate a constant electric power of 1 GW for a day?

2016 Question 9 [Higher Level]

(i) Lise Meitner and Marie Curie are the only women scientists to have elements named after them.
In the case of Meitner this was for her work on <u>fission</u> and in the case of Curie it was for her discovery of radium and her work on <u>radioactivity</u>.
Explain the underlined terms.

(ii) The following is the nuclear equation of a fission reaction explained by Meitner.

$$^{238}_{92}\mathrm{U} + {}^{1}_{0}\boldsymbol{n} \rightarrow {}^{139}_{56}\boldsymbol{Ba} + {}^{97}_{36}\boldsymbol{Kr} + 3\,{}^{1}_{0}\boldsymbol{n}$$

Calculate the energy released during this reaction.

(iii) How many of the neutrons emitted in a fission reaction must, on average, cause a further fission so that the reaction is self-sustaining and safe?
Explain your answer.

(iv) The neutrons emitted are sometimes passed through a moderator.
Explain the function of the moderator.

(v) Radium–225 is a radioactive isotope that decays into an isotope of actinium.
Write a nuclear equation for the decay of radium–225.

(vi) Radium–225 has a half-life of 14.9 days.
Calculate the number of radium–225 nuclei in a sample that has an activity of 5600 Bq.

(Nuclear masses: U–238 = 3.9529 $\times 10^{-25}$ kg; Ba–139 = 2.3066 $\times 10^{-25}$ kg; Kr–97 = 1.6099 $\times 10^{-25}$ kg)

2008 Question 12 (c) [Higher Level]

(i) In 1939 Lise Meitner discovered that the uranium isotope U–238 undergoes fission when struck by a slow neutron. Barium–139 and krypton–97 nuclei are emitted along with three neutrons.
Write a nuclear reaction to represent the reaction.

(ii) In a nuclear fission reactor, neutrons are slowed down after being emitted.
Why are the neutrons slowed down?

(iii) How are they slowed down?

(iv) Fission reactors are being suggested as a partial solution to Ireland's energy needs.
Give one positive and one negative environmental impact of fission reactors.

2010 Question 12 (b) [Higher Level]

The following reaction occurs in a nuclear reactor:

$$^{235}\mathbf{U} + {}^{1}_{0}\boldsymbol{n} \rightarrow {}^{141}\boldsymbol{Ba} + \boldsymbol{X} + 3{}^{1}_{0}\boldsymbol{n} + \mathbf{202.5}\ \boldsymbol{MeV}$$

(i) Identify the element X.

(ii) Calculate the mass difference between the reactants and the products in the reaction

(iii) What is a chain reaction?

(iv) Give one condition necessary for a chain reaction to occur.

(v) Give one environmental impact associated with a nuclear reactor.

2018 Question 8 [Higher Level]

(i) Explain the terms nuclear fission and specific heat capacity.

(ii) Water can act as both a moderator and a coolant in a nuclear fission reactor.
What effect does a moderator have on the rate of fission?

(iii) How does a moderator have this effect?

(iv) In a nuclear reactor core, 5000 kg of water is heated so that its temperature increases by 70 K and it is converted into steam.
Calculate the energy absorbed by the water.

(v) In a fission reaction a neutron is absorbed by a uranium–235 nucleus. Barium–139 and krypton–94 nuclei are released as well as some neutrons.
Write a nuclear equation for this reaction.

(vi) Calculate the energy released, in MeV, in this reaction.

Nuclear fusion reactors could supply more energy than fission reactors.

(vii) Explain why fusion reactors are not yet a practical source of energy on Earth.

(viii) Give one other advantage that a fusion reactor would have over a fission reactor.

(specific heat capacity of water = 4180 J kg–1 K^{-1})
(specific latent heat of vaporisation of water = 2.23 × 106 J kg^{-1})
(mass of barium–139 nucleus = 138.90884 u,
mass of krypton–94 nucleus = 93.93436 u,
mass of uranium–235 nucleus = 235.04393 u)

Nuclear fusion

2016 Question 12 (d) [Ordinary Level]

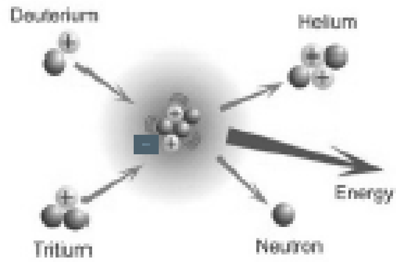
(i) Nuclear fusion is the source of the Sun's energy.
What is meant by nuclear fusion?
(ii) Name the other type of nuclear reaction used in nuclear power stations.
(iii) State one advantage and one disadvantage of each of these sources of nuclear energy.
(iv) Name the scientist whose equation $E = mc^2$ explained why a large amount of energy is available from a small mass of fuel in nuclear reactions.

2012 Question 8 [Higher Level]

Energy can be produced in a fusion reaction by combining a deuterium and a tritium nucleus as follows:

$$\mathbf{{}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + n + energy}$$

(i) Distinguish between nuclear fission and nuclear fusion.
(ii) What are the advantages of fusion over fission in terms of fuel sources and reaction products?
(iii) How much energy is produced when a deuterium nucleus combines with a tritium nucleus?
(iv) Calculate the force of repulsion between a deuterium and a tritium nucleus when they are 2 nm apart in free space.
(v) Fusion can only take place at very high temperatures. Explain why.



2006 Question 8 [Higher Level]

(i) Distinguish between fission and fusion.
(ii) The core of our sun is extremely hot and acts as a fusion reactor.
Why are large temperatures required for fusion to occur?
(iii) In the sun a series of different fusion reactions take place. In one of the reactions, 2 isotopes of helium, each with a mass number of 3, combine to form another isotope of helium with the release of 2 protons.
Write an equation for this nuclear reaction.
(iv) Controlled nuclear fusion has been achieved on earth using the following reaction:

$$\mathbf{{}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n}$$

What condition is necessary for this reaction to take place on earth?

(v) Calculate the energy released during this reaction.
(vi) Give one benefit of a terrestrial fusion reactor under each of the following headings:
(a) fuel; (b) energy; (c) pollution.

speed of light = 2.998×10^{-8} m s^{-1}; mass of hydrogen-2 nucleus = 3.342×10^{-27} kg ;
mass of hydrogen-3 nucleus = 5.004×10^{-27} kg; mass of helium nucleus = 6.644×10^{-27} kg;
mass of neutron = 1.674×10^{-27} kg

2018 Question 12 (b)

(i) **What is meant by radioactivity?**
Radioactivity is the (spontaneous) disintegration of a nucleus with the emission of one or more types of radiation.

(ii) ***On graph paper, draw a decay curve (a graph of activity against time).***
8 points plotted correctly (activity on the *y* axis)
Curve with good fit

(iii) **Use the decay curve to determine the half-life of the isotope.**
Pick a point on the activity axis and note the corresponding time.
Pick a second point where the activity is half the previous activity and note the corresponding time.
Note the time it takes to go from one time to the other.
It should correspond to 3.3 days = 285120 seconds

(iv) **Calculate the number of nuclei in the sample at the beginning of the investigation.**
First we need to calculate the decay constant λ:

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} \qquad \lambda = \frac{\ln 2}{285120} = 2.4 \times 10^{-6}\ \text{s}^{-1}$$

Now we can use A = λN to calculate the number of nuclei

$$N = \frac{A}{\lambda} = \frac{600 \times 10^{6}}{2.4 \times 10^{-6}}$$

$N = 2.5 \times 10^{14}$ nuclei

2018 Question 8

(i) **Explain the term *nuclear fission*.**
Nuclear fission is the splitting of a large nucleus into two similarly sized smaller nuclei with the emission of energy/neutrons.
Note that you will lose marks if you use the term *atom* instead of *nucleus*.
Explain the term *specific heat capacity*.
Specific heat capacity is the energy required to change the temperature of 1 kg of a substance by 1 K.

(ii) **What effect does a moderator have on the rate of fission?**
It increases the rate of fission

(iii) **How does a moderator have this effect?**
The moderator slows down the neutrons which increases the rate of capture by neighbouring nuclei.

(iv) **Calculate the energy absorbed by the water.**
Energy absorbed $= (mc\Delta\theta) + (ml)_{steam}$
$= (5000)(4180)(70) + (5000)(2.23\times10^{6})$
Energy $= 1.26 \times10^{10}$ J

(v) **Write a nuclear equation for this reaction.**

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n + kinetic\ energy$$

(vi) **Calculate the energy released, in MeV, in this reaction.**

mass of barium–139 nucleus = 138.90884 u
mass of krypton–94 nucleus = 93.93436 u
mass of uranium–235 nucleus = 235.04393 u
mass of neutron = ?? u

Loss in mass $= 3.0 \times 10^{-28}$ kg
$E = mc^2$
$E = 2.74 \times 10^{-11}$ J

To convert from J to eV we need to divide 2.74×10^{-11} J by the charge on an electron (1.6×10^{-19})

$E = 1.71 \times10^{8}$ eV = 171 MeV

(vii) **Explain why fusion reactors are not yet a practical source of energy on Earth.**
Too much energy is required (to overcome force of repulsion between nuclei).

(viii) **Give one other advantage that a fusion reactor would have over a fission reactor.**
Raw material readily available / less radioactive waste

2017 Question 12 (b)

(i) **What is meant by radioactivity?**
Radioactivity is the (spontaneous) disintegration of unstable *nuclei* with the emission of one or more types of radiation.

(ii) **Name a device used to detect beta-radiation and explain its principle of operation.**
Geiger-Muller tube
ionisation

(iii) **Write the nuclear equation for this decay.**

$$^{40}_{19}K \rightarrow {}^{0}_{-1}e + {}^{40}_{20}Ca$$

(iv) **Calculate the number of potassium–40 nuclei in this person.**
The symbol for the number of nuclei is *N* and the formula that relates *N* to the activity is: $A = \lambda N$
So first we need to find λ - the decay constant.

$$T_{1/2} = \frac{0.693}{\lambda} \qquad \lambda = \frac{\mathbf{0.693}}{\boldsymbol{T_{1/2}}}$$

Remember that we were told that potassium–40 has a half-life of 1.25×10^{9} years.
We will need to convert this into seconds.

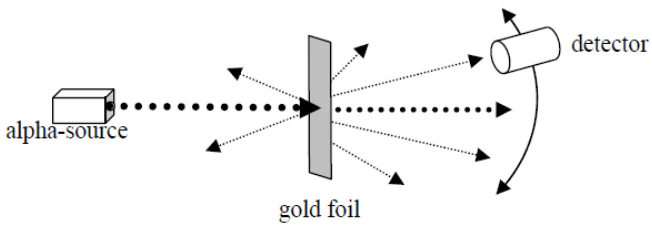
$$\lambda = \frac{\mathbf{0.693}}{(1.25 \times 10^{9})(365)(24)(60)(60)}$$

$$A = \lambda N \qquad N = \frac{A}{\lambda} \qquad N = \frac{5400}{\lambda}$$

$N = 2.07 \times 10^{20}$ nuclei

2017 Question 9 {first 2 parts}

(i) **Describe Rutherford's experiment to investigate the structure of the atom.**
He fired alpha particles at a very thin sheet of gold foil.
The alpha particles could be detected by small flashes of light that they produced on a fluorescent screen (see diagram).



He found that:

- Most alpha particles were undeflected and passed straight through the gold foil.
- Some were deflected through small angles.
- A very small number were turned back through angles greater than 90^{0}.

(ii) **What conclusions about the nature of the atom did Rutherford make?**
That it's mostly empty space with a small/dense/positive core

2016 Question 9

(i) **Explain the underlined terms.**
Fission: the breaking up of a large nucleus into smaller nuclei with the release of energy and neutrons
(–1 for "atom" instead of "nucleus")(–1 for omission of nuclear size) (–1 for omission of neutrons)
Radioactivity: the disintegration of a nucleus with the emission of one or more types of radiation.
(–1 for "atom" instead of "nucleus")

(ii) **Calculate the energy released during this reaction.**
Mass before = mass of uranium nucleus + mass of neutron
$= 3.9529 \times 10^{-25} + 1.674\,927\,28 \times 10^{-27}$
Mass before = 3.9696×10^{-25} kg

Mass after = mass of barium nucleus + mass of krypton nucleus + mass of 3 neutrons
$= 2.3066 \times 10^{-25}$ kg + 1.6099×10^{-25} kg + $3(1.674\,927\,28 \times 10^{-27})$

Mass after = 3.9667×10^{-25} kg

Loss in mass = total mass beforehand – total mass afterwards
$= (3.9696 \times 10^{-25}) - (3.9667 \times 10^{-25})$
$= 2.9 \times 10^{-28}$ kg

$E = mc^2$
Energy released = $(2.9 \times 10^{-28})(2.998 \times 10^{8})^2$

$E = 2.6 \times 10^{-11}$ J

(iii) **How many of the neutrons emitted in a fission reaction must, on average, cause a further fission so that the reaction is self-sustaining and safe?**
Explain your answer.
1
More than one would result in an uncontrolled reaction while less than one would result in the chain-reaction ending too quickly.

(iv) **Explain the function of the moderator.**
Slows down neutrons

(v) **Write a nuclear equation for the decay of radium–225.**

$$^{225}_{88}Ra \rightarrow {}^{225}_{89}\text{Ac} + {}^{0}_{-1}\text{e}$$

(vi) **Calculate the number of radium–225 nuclei in a sample that has an activity of 5600 Bq.**
$T_{1/2} = \frac{\ln 2}{\lambda}$
$\lambda = \frac{\ln 2}{T_{1/2}} = \frac{0.693}{14.9 \times 25 \times 60 \times 60}$ $\lambda = 5.38 \times 10^{-7}\ \text{s}^{-1}$

Activity = λN $N = \frac{A}{\lambda} = \frac{5600}{5.38 \times 10^{-7}}$ $N = 1.04 \times 10^{10}$ nuclei

2016 Question 12 (a)

(i) **State the principle of conservation of momentum.**

The principle of conservation of momentum states that in any collision between two objects, the total momentum before impact equals total momentum after impact, provided no external forces act on the system.

(ii) **What daughter nucleus is produced during this alpha-decay?**

$${}^{212}_{84}Po \rightarrow {}^{4}_{2}He + {}^{?}_{?}X$$

{The total number on top on the left must equal the total number on top on the right.
The same applies for the bottom.
Once you realise that the atomic number of the daughter product is 82 you then go to the periodic table of elements to identify this atom – it this case the element 'lead' has an atomic number of 82}

$${}^{212}_{84}Po \rightarrow {}^{4}_{2}He + {}^{208}_{82}Pb$$

Daughter nucleus is therefore lead–208

(iii)**The kinetic energy of the emitted alpha-particle is 8.9 MeV. Calculate its velocity.**

1eV =1.6 x 10^{-19} Joules
8.9 MeV = (8.9 x 10^{6})(1.6 x 10^{-19}) Joules
E = 1.426 × 10^{-12} J

$E_{kinetic} = ½mv^2$
1.426 × 10^{-12} = ½ mv^2

$$v^2 = (2)(\frac{1.426 \times 10^{-12}}{m})$$

Mass of alpha particle = 6.644 6565 ×10^{-27} kg {page 46 of log tables}

$$v^2 = (2)(\frac{1.426 \times 10^{-12}}{6.644\ 6565 \times 10^{-27}})$$

$v = 2.07 \times 10^7$ m s^{-1}

(iv)**Calculate the velocity of the daughter nucleus after the decay.**

{It's not obvious that we need to use conservation of momentum, but the clue was that the question asked us about it at the beginning. The context here is similar to firing a bullet out of rifle; initially the momentum of the rifle is 0, therefore the net momentum afterwards must be 0, therefore the momentum of the bullet going forward must be equal to the momentum of the rifle going backwards.
*Similarly we were told in this question that the "polonium–212 nucleus decays spontaneously **while at rest**", so total momentum before is zero, therefore the momentum after must be zero, so momentum of alpha particle must be equal and opposite to momentum of the lead nucleus.}*

Z	siombail symbol	mais adaimh mass of atom (u)
81	^{203}Tl	202.972 344
	^{205}Tl	204.974 428
82	^{204}Pb	203.973 044
	^{206}Pb	205.974 465
	^{207}Pb	206.975 897
	^{208}Pb	207.976 652

$(m_{alpha}v_{alpha}) = (m_{lead})(v_{lead})$

Mass of alpha particle = 6.644 6565 ×10^{-27} kg
Velocity of alpha particle = 2.07 × 10^{7} m s^{-1}
Mass of ${}^{208}_{82}Pb$ = 207.976652 atomic mass units *{see image on right from page 90 of the log tables}*.

1 u = 1.660 5402 × 10^{-27} kg (atomic) mass unit

One atomic mass unit = 1.6605402 ×10^{-27} kg *{page 64}*
Mass of ${}^{208}_{82}Pb$= (207.976652)(1.6605402 ×10^{-27}) = 3.453535913 ×10^{-25} kg

$(m_{alpha}v_{alpha}) = (m_{lead})(v_{lead})$
(6.644 6565 ×10^{-27})(2.07 × 10^{7}) = (3.453535913 ×10^{-25})(v_{lead})

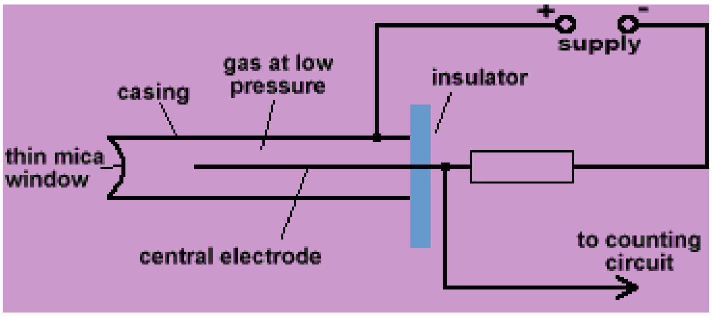
$v_{lead} = 4.0 \times 10^5$ m s^{-1}

2015 Question 12 (*d*)

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

An atom is *radioactive* if its nucleus undergoes spontaneous disintegration with the emission of one or more types of radiation

(ii) **Name a detector of radiation and describe, with the aid of a labelled diagram, its principle of operation.**



1. Radiation enters through the thin window on the left.
2. It causes ionisation of some of the rare-earth gas molecules inside.
3. The negative ions (electrons) accelerate towards the anode, colliding off (and ionising) other gas molecules along the way, giving rise to an avalanche effect.
4. These ions all reach the anode more or less together and are detected as a pulse.

(iii) **How many radon–210 atoms will remain after one day?**

The sample of the gas contains 4.5×10^{15} atoms and this number halves after each half life.

The number of minutes in a day = $24 \times 60 = 1440$ minutes

The half-life of radon-210 is 144 mins, so there are 10 half-lives in one day.

$(4.5 \times 10^{15}) \times ½ \times ½ \times ½ \times ½ \times ½ \times ½ \times ½ \times ½ \times ½ \times ½ = 4.4 \times 10^{12}$ atoms

2014 Question 8

(i) **Explain the underlined terms.**
A chain reaction is a self-sustaining reaction where fission neutrons go on to produce further fission (giving more neutrons) etc.
Fission is the splitting of a large nucleus into two (smaller) nuclei with the release of energy and neutrons.

(ii) **Give an example of a moderator.**
graphite / heavy water

(iii) **Explain why a moderator is needed in a nuclear reactor**
To slow down neutrons so as to increase the probability of fission.

(iv) **Explain how the control rods affect the rate of the reaction.**
By absorbing neutrons

(v) **Explain how the heat exchanger operates.**
Heat/energy from reactor transfers to a coolant which has a very high boiling point. Heat from the hot radioactive coolant passes to another series of pipes containing water without having to mix together. This turns the water into steam which then goes on to power a turbine.

(vi) **Why is it necessary to use a heat exchanger?**
So that the radioactive coolant can be contained, and it also allows very high temperatures to be obtained.

(vii) Write an equation for this nuclear reaction.

$$U_{92}^{238} + n_0^1 \rightarrow Pu_{94}^{239} + 2\beta_{-1}^0$$

(viii) **How many uranium–235 nuclei are required to undergo fission to generate a constant electric power of 1 GW for a day?**
Each nucleus that underdoes fission produces (202×10^6) *eV* of energy, or
$(202 \times 10^6)(1.6 \times 10^{-19}) = 3.23 \times 10^{-11}$ *Joules* of energy. $\{1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}\}$

Efficiency is 35%, so 35% of 3.23×10^{-11} J $= 1.13 \times 10^{-11}$ J

1GW $= 1 \times 10^9$ W $= 1\times 10^9$ Joules per second {1 Watt = 1 Joule per second}
1 GW for a day $= (1\times 10^9)(60)(60)(24)$ Joules
$= 8.64 \times 10^{13}$ J

So we need 8.64×10^{13}J, and each nucleus produces 1.13×10^{-11} J of useable energy.
So total number of nuclei required $= \frac{8.64 \times 10^{13}}{1.13 \times 10^{-11}} = 7.65 \times 10^{24}$ nuclei

2013 Question 9

(i) **Define the becquerel.**
One Bq = one disintegration per second.

(ii) **Name one device used to detect ionising radiations.**
GM tube / solid state detector *etc*.

(iii) **Compare alpha, beta, and gamma emissions using the following headings: *(a)* penetrating ability, (*b*) deflection in a magnetic field.**
Penetrating ability:
Gamma (most penetrating) > beta > alpha (least penetrating)
Deflection in a magnetic field:
Alpha, beta deflected, gamma not deflected. Alpha and beta deflected in opposite directions

(iv) **Explain what happens during nuclear fission.**
A large nucleus splits into two smaller nuclei with the emission of energy and neutrons

(v) **Write an equation for the beta-decay of iodine–131.**

$$^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\mathrm{e}$$

(vi) **Estimate the fraction of the iodine–131 that remained after 40 days.**
40 days = 5 half lives.
Fraction remaining = ½ × ½ × ½ × ½ × ½

$$= \frac{1}{32}$$

(vii) **Calculate the decay constant of caesium–137.**

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \qquad \lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$$

$T_{1/2}$ = (30)(365)(24)(60)(60) = 9.46×10^{8} seconds

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} \qquad \lambda = \frac{\ln 2}{9.46 \times 10^{8}} = 7.32 \times 10^{-10}\ \mathrm{s}^{-1}$$

(viii) **Hence calculate the number of caesium–137 atoms present in the sample.**
A = λN

$$N = \frac{A}{\lambda} = \frac{5000}{7.32 \times 10^{-10}}$$

N = 6.83×10^{12} atoms

2012 Question 8

(i) **Distinguish between nuclear fission and nuclear fusion.**
Fission: large nucleus splits into two smaller nuclei (of similar size)
Fusion: two small nuclei join to form a larger nucleus

(ii) **What are the advantages of fusion over fission in terms of fuel sources and reaction products?**
(hydrogen) fuel (from the sea) is plentiful – (uranium for fission is scarce)
no radioactive waste with fusion – (fission results in radioactive waste)

(iii) **How much energy is produced when a deuterium nucleus combines with a tritium nucleus?**
See page 83 of log tables to get masses of the nuclei in terms of atomic mass units (u).
Then jump to page 47 to convert from atomic mass units to kg: 1 *u* = 1.660 5402 × 10^{-27}kg
Pick your own adjective to describe this logic.

$${}_{1}^{2}H \quad + \quad {}_{1}^{3}H \quad \rightarrow \quad {}_{2}^{4}He \quad + \quad {}_{1}^{1}n \quad + \quad \text{energy}$$

2.014102 + 3.016049 → 4.002603 + 1.008672 + energy

5.030151 → 5.011275 + energy

Change in mass = 0.018875 u

1 *u* = 1.660 5402 × 10^{-27}kg
0.018875 *u* = 3.1344 × 10^{-29} kg

$E = mc^2 = (3.1344 \times 10^{-29})(3 \times 10^8)^2 = 2.82096 \times 10^{-12}$ J

(iv) **Calculate the force of repulsion between a deuterium and a tritium nucleus when they are 2 nm apart in free space.**
Note that the nuclei of deuterium and tritium both have just one proton (although deuterium has 1 neutron and tritium and 2 neutrons this doesn't affect the charge).
The charge on a proton is the same as the charge on an electron: 1.602 ×10^{-19} C

$$F = \frac{q_1 q_2}{4\pi\varepsilon d^2}$$

$$F = \frac{(1.602 \times 10^{-19})^2}{4\pi(8.854 \times 10^{-12})(2 \times 10^{-9})^2}$$

$F = 5.77 \times 10^{-11}$ N

(v) **Fusion can only take place at very high temperatures. Explain why.**
Nuclei must have very high speeds / energy to overcome force of repulsion between the nuclei if they are to combine

2011 Question 12 (d)

(i) **Name a suitable detector.**
GM tube (linked with a ratemeter/scaler)/ Solid state detector

(ii) **Describe how the reading on the detector may vary as the paper passes by.**
The count rate would decrease with increasing paper thickness.

(iii) **Why would the radioisotope Am-241, which emits alpha-particles, not be suitable for this process?**
The alpha-particles have poor penetrating power so would be easily blocked by the paper.

(iv) **Calculate the number of atoms present in a sample of Sr-90 when its activity is 4250 Bq.**
The half-life of Sr-90 is 28.78 years.

$T_{1/2}$ = (28)(365)(24)(60)(60) = 907606080 seconds

$T_{½} = \frac{\ln 2}{\lambda} = \frac{\ln 0.693}{\lambda}$ $\lambda = \frac{0.693}{T_{1/2}}$ $\lambda = \frac{0.693}{907606080}$ $\lambda = 7.637 \times 10^{-10}\ s^{-1}$

Activity = λN $4250 = (7.637 \times 10^{-10})(N)$ $N = 5.565 \times 10^{12}$ atoms

2010 Question 12 (b)

(i) **Identify the element X.**

We use log tables (page 79) to identify the number at the bottom for barium (Ba): 56
We use log tables (page 82) to identify the number at the bottom for uranium (U): 92

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + X + 3^{1}_{0}n + 202.5\ MeV$$

The total number on the bottom of the left (92) must equal the total number on the bottom of the right.
92 – 56 = 36
We then go back to the log tables (page 79) to ding out what element has an atomic number of 36.
Answer: Krypton (Kr)

(ii) **Calculate the mass difference between the reactants and the products in the reaction**

The kinetic energy of 202.5 MeV came from the mass that 'disappeared'. So we can use $E = mc^2$ to work backwords and find out the missing mass.
First we need to convert 202.5 MeV to Joules by using the fact that 1 eV = 1.6×10^{-19}Joules

202.5 MeV = $(202.5 \times 10^{6})(1.6 \times 10^{-19})$ = 3.24×10^{-11} Joules

$m = \frac{E}{c^2} = \frac{3.24 \times 10^{-11}}{(3 \times 10^{8})^2}$ m = 3.6×10^{-28} kg

(iii) **What is a chain reaction?**

It is a self-sustaining reaction where fission neutrons go on to produce further fission (giving more neutrons) etc.

(iv) **Give one condition necessary for a chain reaction to occur.**

The mass of fuel present must exceed the critical mass / at least one of the neutrons released must cause fission of another nucleus.

(v) **Give one environmental impact associated with a nuclear reactor.**

Toxic /radioactive waste, exposure to radiation, etc.

2009 Question 12 (d)

(i) **Give the structure of an alpha particle.**

It is composed of 2 protons and 2 neutrons

(ii) **How are the alpha particles produced?**

α-decay is produced when the americium (which is radioactive) undergoes radioactive decay.

(iii) **Why do these alpha particles not pose a health risk?**

They have a very short range so are either contained within the smoke detector itself or just travel a cm or two through the air.

(iv) **Americium-241 has a decay constant of 5.1×10^{-11} s^{-1}.**
Calculate its half life in years.

$T_{½} = \frac{\ln 2}{\lambda}$ $T_{1/2} = \frac{\ln 2}{5.1 \times 1010^{-11}}$ = 1.36×10^{10} seconds = 430.6 years

(v) **Explain why americium-241 does not exist naturally.**

{I don't think this was a fair question and shouldn't have appeared on the paper}
Its half life is very short (with respect to age of the universe) and because it is not a member of a decay series it is not produced 'in nature' (it is created artificially).

2008 Question 12 (c)

(i) Write a nuclear reaction to represent the reaction.

$$^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{139}_{56}Ba + {}^{97}_{36}Kr + 3\ {}^{1}_{0}n$$

(ii) Why are the neutrons slowed down?

Only relatively slow-moving neutrons cause fission.

(iii) How are they slowed down?

They collide with the molecules in the moderator.

(iv) Give one positive and one negative environmental impact of fission reactors.

Positive: no CO_2 emissions / no greenhouse gases / no gases to result in acid rain / less dependence on fossil fuels.

Negative: radioactive waste / potential for major accidents etc.

2007 Question 12 (d)

(i) Explain the term half-life.

Time for half the radioactive nuclei in a sample to decay

(ii) Write a nuclear equation to represent the decay of carbon-14.

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta$$

(iii) If the half-life of carbon-14 is 5730 years, estimate the age of the cup.

It takes one half-life for the activity to decrease from 8.4 Bq to 4.2 Bq.
It takes another half-life for the activity to decrease from 4.2 Bq to 2.1 Bq.
It therefore requires two half-lives to go from 8.4 Bq to 2.1 Bq
Each half-life is 5730 years. Therefore the total time that has passed is 11,460 years.
The cup is 11,460 years old.

(iv) Name an instrument used to measure the activity of a sample.

Geiger Muller tube.

(v) What is the principle of operation of this instrument?

The gas in the tube is ionised by radioactive particles and a pulse of charge/current flows.

2006 Question 8

(i) Distinguish between fission and fusion.

Nuclear fission is the break-up of a large nucleus into two smaller nuclei with the release of energy and neutrons.

Nuclear fusion is the combining of two small nuclei to form one large nucleus with the release of energy.

(ii) Why are large temperatures required for fusion to occur?

Nuclei are positively charged so enormous energy is required to overcome the very large repulsion.

(iii) Write an equation for this nuclear reaction.

$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2^{1}_{1}H$

(iv) What condition is necessary for this reaction to take place on earth?

Very large energy/temperature is necessary.

(v) Calculate the energy released during this reaction.

Mass beforehand = mass of hydrogen-2 nucleus + mass of hydrogen-3 nucleus

= 3.342×10^{-27} kg + 5.004×10^{-27} kg

= 8.346×10^{-27} kg

Mass after = mass of helium nucleus + mass of neutron

= 6.644×10^{-27} kg + 1.674×10^{-27} kg

= 8.318×10^{-27} kg

Loss in mass /defect mass = $(8.346 \times 10^{-27}) - (8.318 \times 10^{-27})$ = 2.8×10^{-29} kg

$E = mc^2$ E = $(2.8 \times 10^{-29})(2.998 \times 10^{8})^2$ E = 2.52×10^{-12} J

(vi) Give one benefit of a terrestrial fusion reactor under each of the following headings:

(a) fuel; (b) energy; (c) pollution.

Fuel: plentiful / cheap

Energy: vast energy released

Pollution: little (radioactive) waste / few greenhouse gases

2005 Question 8

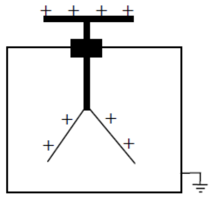
(i) Distinguish between radioactivity and fission.
Nuclear fission is the break-up of a large nucleus into two smaller nuclei with the release of energy and neutrons.
Nuclear fusion is the combining of two small nuclei to form one large nucleus with the release of energy.

(ii) Give an application of radioactivity.
Smoke detectors, carbon dating, tracing leaks, cancer treatment, sterilising, etc.

(iii) Give an application of fission.
Generating electrical energy, bombs

(iv) Radioactivity causes ionisation in materials. What is ionisation?
Ionisation occurs when a neutral atom loses or gains an electron.

(v) Describe an experiment to demonstrate the ionising effect of radioactivity.
Procedure: Bring a radioactive source close to the cap of a charged Gold Leaf Electroscope
Observation: Leaves collapse
Conclusion: The charge on the G.L.E. became neutralised by the ionised air.



(vi) Write an equation to represent the decay of cobalt−60.
$^{60}_{27}Co \rightarrow {}^{0}_{-1}e + {}^{60}_{28}Ni$

(vii) Calculate the decay constant of cobalt−60.
$T_{1/2} = \frac{ln2}{\lambda}$ $\lambda = \frac{ln2}{T_{1/2}}$ $\lambda = \frac{0.693}{1.66 \times 10^8}$ $\Rightarrow$ $\lambda = 4.18 \times 10^{-9}\ s^{-1}$

(viii) Calculate the rate of decay of a sample of cobalt−60 when it has 2.5×10^{21} atoms.
Rate of decay = Activity = λN
Rate of decay = $(4.18 \times 10^{-9})(2.5 \times 10^{21})$ = 1.04×10^{13} Bq

2003 Question 11

(i) **What is radioactive decay?**
Radioactivity is the breakup of unstable nuclei with the emission of one or more types of radiation.

(ii) **What is an isotope?**
Isotopes are atoms which have the same *atomic number* but different *mass numbers*.

(iii) **Apart from "carbon dating", give two other uses of radioactive isotopes.**
Medical imaging, (battery of) heart pacemakers, sterilization, tracers, irradiation of food, killing cancer cells, measuring thickness, smoke detectors, nuclear fuel

(iv) **How many neutrons are in a ^{14}C nucleus?**
Eight

(v) **^{14}C decays to ^{14}N. Write an equation to represent this nuclear reaction.**

$$^{14}_{6}C \rightarrow {}^{14}_{7}N \rightarrow {}^{0}_{-1}e$$

(vi) **How much of a ^{14}C sample remains after 11 460 years?**
11,460 years corresponds to two half-lives. After one half-life ½ remains; after two half-lives ¼ remains.

(vii) **Calculate the decay constant of ^{14}C.**

$T_{1/2} = \frac{ln2}{\lambda}$ $\lambda = \frac{ln2}{T_{1/2}}$ $\lambda = \frac{0.693}{(5730)(365)(24)(60)(60)}$ $T_{1/2} = 3.8\times10^{-12}\ s^{-1}$

(viii) **Why does the ^{12}C in dead tissue remain "undisturbed"?**
Carbon 12 is not radioactive so it doesn't change in anything else.

2002 Question 12 (d)

(i) Name the scientist who carried out this experiment.
Ernest Rutherford.

(ii) Describe what was observed in this experiment.
Most alpha particles passed straight through, some were deflected slightly and a small percentage bounced back.

(iii) Why was it necessary to carry out this experiment in a vacuum?
To prevent the alpha particles colliding with other particles.

(iv) What conclusion did the scientist form about the structure of the atom?
It consists of a small, dense, positively charged core with negatively charged electrons in orbit around it.