Physics
Leaving Certificate
Higher Level

Past Exam Questions on
The Atom, Nucleus and Radioactivity

Q9 Section B 2013

9. Define the becquerel. (6)

Name one device used to detect ionising radiations. (3)

Compare alpha, beta, and gamma emissions using the following headings: (*a*) penetrating ability, (*b*) deflection in a magnetic field. (9)

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.

Explain what happens during nuclear fission. (8)

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.
Estimate the fraction of the iodine–131 that remained after 40 days. (15)

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.

Calculate the decay constant of caesium–137. 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.) (15)

Q10 Part (a) Section B 2011

(*a*) List three quantities that are conserved in nuclear reactions. (6)

Write an equation for a nucleus undergoing beta-decay.

In initial observations of beta-decay, not all three quantities appear to be conserved. What was the solution to this contradiction? (12)

List the fundamental forces of nature in increasing order of their strength.

Which fundamental force of nature is involved in beta-decay? (12)

In the Large Hadron Collider, two protons with the same energy and travelling in opposite directions collide. Two protons and two charged pi mesons are produced in the collision.

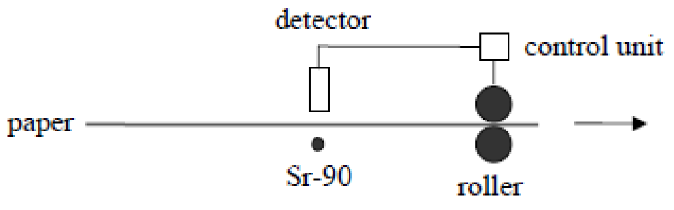
Why are new particles produced in the collision?

Write an equation to represent the collision. (12)

Show that the kinetic energy of each incident proton must be at least 140 MeV for the collision to occur. (14)

Q12 Part (d) Section B 2011

(*d*) 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. (6)

(ii) Describe how the reading on the detector may vary as the paper passes by. (9)

(iii) Why would the radioisotope Am-241, which emits alpha-particles, **not** be suitable for this process? (4)

(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. (9)

Q9 Section B 2010

9. What is thermionic emission? (6)

X-rays are produced when high-energy electrons collide with a target.

Draw a labelled diagram of an X-ray tube. (12)

What are X-rays and how do they differ from light rays?

Give two uses of X-rays. (18)

When electrons hit the target in an X-ray tube, only a small percentage of their energy is converted into X-rays. What happens to the rest of their energy and how does this influence the type of target used? (9)

A potential difference (voltage) of 40 kV is applied across an X-ray tube.

Calculate:

(i) the maximum energy of an electron as it hits the target

(ii) the frequency of the most energetic X-ray produced. (11)

(Plank constant = 6.6×10^{-34} J s ; charge on electron = 1.6×10^{-19} C)

Q12 Part (d) Section B 2009

(*d*) 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? (13)

Americium-241 has a decay constant of 5.1×10^{-11} s^{-1}.
Calculate its half life in years. (9)

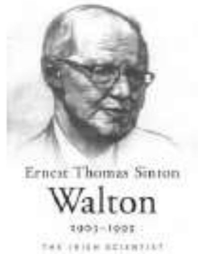
Explain why americium-241 does not exist naturally. (6)

Q5 Part (i) Section B 2008

(*i*) Name an instrument used to detect radioactivity.
What is the principle of operation of this instrument? (7)

Q10 Part (a) Section B 2007

(*a*) Read the following passage and answer the accompanying questions.



Ernest Walton was one of the legendary pioneers who made 1932 the *annus mirabilis* of experimental nuclear physics. In that year James Chadwick discovered the neutron; Carl Anderson discovered the positron; Fermi articulated his theory of radioactive decay; and Ernest Walton and John Cockcroft split the nucleus by artificial means. In their pioneering experiment Cockcroft and Walton bombarded lithium nuclei with high-energy protons linearly accelerated across a high potential difference (*c.* 700 kV). The subsequent disintegration of each lithium nucleus yielded two helium nuclei and energy. Their work gained them the Nobel Prize in 1951.

(Adapted from "Ernest Thomas Sinton Walton 1903 –1995 The Irish Scientist" McBrierty; 2003)

(i) Draw a labelled diagram to show how Cockcroft and Walton accelerated the protons. (6)
What is the velocity of a proton when it is accelerated from rest through a potential difference of 700 kV? (12)
Write a nuclear equation to represent the disintegration of a lithium nucleus when bombarded with a proton. (9)
Calculate the energy released in this disintegration. (12)

(ii) Compare the properties of an electron with that of a positron. (5)
What happens when an electron meets a positron? (3)

(iii) In beta decay it appeared that momentum was not conserved.
How did Fermi's theory of radioactive decay resolve this? (9)

(charge on electron = 1.6022×10^{-19} C; mass of proton = 1.6726×10^{-27} kg;
mass of lithium nucleus = 1.1646×10^{-26} kg; mass of helium nucleus = 6.6443×10^{-27} kg;
speed of light = 2.9979×10^{8} m s^{-1})

Q12 Part (d) Section B 2007

(*d*) Explain the term half-life. (6)

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. (9)

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. (6)

Name an instrument used to measure the activity of a sample.
What is the principle of operation of this instrument? (7)

Q5 Part (i) Section B 2006

(*i*) Describe the Bohr model of the atom. (7)

Q5 Part (j) Section B 2005

(*j*) Name the fundamental force of nature that holds the nucleus together.

or

Draw the truth table for an AND gate. (7)

Q8 Section B 2005

8. Nuclear disintegrations occur in radioactivity and in fission.

Distinguish between radioactivity and fission. (12)

Give an application of (i) radioactivity, (ii) fission. (6)

Radioactivity causes ionisation in materials. What is ionisation?

Describe an experiment to demonstrate the ionising effect of radioactivity. (15)

Cobalt–60 is a radioactive isotope with a half-life of 5.26 years and emits beta particles.

(i) Write an equation to represent the decay of cobalt–60.

(ii) Calculate the decay constant of cobalt–60.

(iii) Calculate the rate of decay of a sample of cobalt–60 when it has 2.5×10^{21} atoms. (23)

(Refer to Mathematics Tables, p. 44.)

Q11 Section B 2005

(a) Read the following passage and answer the accompanying questions.

Ernest Rutherford made the following point:

If the particles that come out naturally from radium are no longer adequate for my purposes in the laboratory, then maybe the time had come to look at ways of producing streams of fast particles artificially. High voltages should be employed for the task. A machine producing millions of alpha particles or protons would be required. These projectiles would be released close to a high voltage and would reel away at high speed. It would be an artificial particle accelerator. Potentially such apparatus might allow physicists to break up all atomic nuclei at will.

(Adapted from "The Fly in the Cathedral" Brian Cathcart; 2004)

(i) What is the structure of an alpha particle? (7)

(ii) Rutherford had bombarded gold foil with alpha particles. What conclusion did he form about the structure of the atom? (7)

(iii) High voltages can be used to accelerate alpha particles and protons but not neutrons. Explain why. (7)

(iv) Cockcroft and Walton, under the guidance of Rutherford, used a linear particle accelerator to artificially split a lithium nucleus by bombarding it with high-speed protons. Copy and complete the following nuclear equation for this reaction. (7)

$${}^{7}_{3}\text{Li} + {}^{1}_{1}\text{H} \longrightarrow$$

(v) Circular particle accelerators were later developed. Give an advantage of circular accelerators over linear accelerators. (7)

(vi) In an accelerator, two high-speed protons collide and a series of new particles are produced, in addition to the two original protons. Explain why new particles are produced. (7)

(vii) A huge collection of new particles was produced using circular accelerators. The quark model was proposed to put order on the new particles. List the six flavours of quark. (7)

(viii) Give the quark composition of the proton. (7)

(Refer to Mathematics Tables, p. 44.)