

State Examination Commission – Physics Higher Level, 2007

Question 10

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)

- (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)

Work done on charge (proton) = gain in kinetic energy of proton

$$\begin{aligned}
 W &= qV = E_k \\
 \Rightarrow qV &= \frac{1}{2}mv^2 \\
 v^2 &= \frac{2qV}{m} = \frac{2(1.6022 \times 10^{-19})(7 \times 10^5)}{(1.6726 \times 10^{-27})} \\
 v &= 1.16 \times 10^7 \text{ ms}^{-1}
 \end{aligned}$$

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)

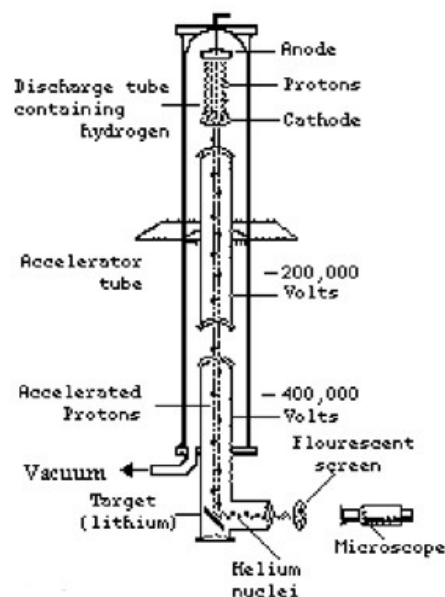
mass of reactants	=	1.1646×10^{-26}	+	1.6726×10^{-27}	=	1.33186×10^{-26} kg
mass of products	=	$2(6.6443 \times 10^{-27})$	=	1.32886×10^{-26} kg	=	1.32886×10^{-26} kg
				mass defect	=	3.00×10^{-29} kg
E	=	mc^2				
	=	$(3.00 \times 10^{-29})(2.9979 \times 10^8)^2$	=	2.7×10^{-12} J		

- (ii) Compare the properties of an electron with that of a positron. (5)

They are equal in mass but opposite in charge

What happens when an electron meets a positron? (3)

They annihilate each other with the release of energy



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

He resolved it by allowing the neutrino to carry away the missing momentum.