State Examination Commission – Physics Higher Level, 2009

Question 10 a

In 1932 Cockcroft and Walton succeeded in splitting lithium nuclei by bombarding them with artificially accelerated protons using a linear accelerator.
Each time a lithium nucleus was split a pair of alpha particles was produced.
How were the protons accelerated? How were the alpha particles detected? (8)
Write a nuclear equation to represent the splitting of a lithium nucleus by a proton.
Calculate the energy released in this reaction. (21)
Most of the accelerated protons did not split a lithium nucleus. Explain why. (6)
Cockcroft and Walton's apparatus is now displayed at CERN in Switzerland, where very high energy protons are used in the Large Hadron Collider.
In the Large Hadron Collider, two beams of protons are accelerated to high energies in a circular accelerator. The two beams of protons then collide producing new particles.
Each proton in the beams has a kinetic energy of 2.0 GeV.
Explain why new particles are formed.
What is the maximum net mass of the new particles created per collision? (15)
What is the advantage of using circular particle accelerators in particle physics? (6)

(mass of alpha particle = 6.6447×10^{-27} kg; mass of proton = 1.6726×10^{-27} kg; mass of lithium nucleus = 1.1646×10^{-26} kg; speed of light = 2.9979×10^{8} m s^{-1}; charge on electron = 1.6022×10^{-19} C)

In 1932 Cockcroft and Walton succeeded in splitting lithium nuclei by bombarding them with artificially accelerated protons using a linear accelerator. Each time a lithium nucleus was split a pair of alpha particles was produced.
How were the protons accelerated? How were the alpha particles detected? (8)

They were accelerated by applying a large p.d. across the accelerator tube, and the alpha particles were detected by the scintillations they caused on a zinc sulfide screen

Write a nuclear equation to represent the splitting of a lithium nucleus by a proton.

$$^{7}_{3}Li + ^{1}_{1}H \rightarrow 2\,^{4}_{2}He$$

Calculate the energy released in this reaction. (21)

mass defect $= 1.1646 \times 10^{-26} + 1.6726 \times 10^{-27} - 2(6.6447 \times 10^{-27}) = 2.92 \text{ x } 10^{-29}$ kg

energy released $E = mc^2 = 2.92 \text{ x } 10^{-29} \text{ x } (2.9979 \times 10^{8})^2 = 2.624 \text{ x } 10^{-12}$ J $=$ 16.38 MeV

Most of the accelerated protons did not split a lithium nucleus. Explain why. (6)

They passed straight through the mostly empty atom or were repelled/deflected by the very strong repulsive force between themselves and the positively charged nuclei

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In the Large Hadron Collider, two beams of protons are accelerated to high energies in a circular accelerator. The two beams of protons then collide producing new particles. Each proton in the beams has a kinetic energy of 2.0 GeV.
Explain why new particles are formed.

The kinetic energy of the protons is converted to mass in the form of these new particles.

What is the maximum net mass of the new particles created per collision? (15)

Mass created, $m = E/c^2 = (4 \text{ x} 10^{9} \text{ x } 1.6 \text{ x } 10^{-19})/(2.9979 \times 10^{8})^2 = 7.123 \text{ x } 10^{-27}$ kg

What is the advantage of using circular particle accelerators in particle physics? (6)

They are more compact and can accelerate particles to higher energies.