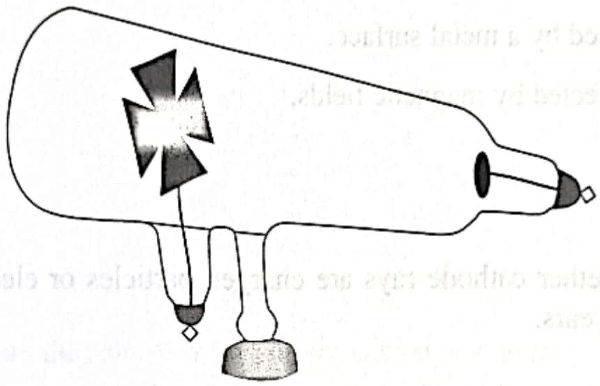
Questions

Module 8: From the Universe to the Atom

8.2 Structure of the Atom

Multiple-choice questions: 1 mark each

1. The diagram shows a type of cathode ray tube.



Which of the following statements CANNOT be inferred from observations made when using the apparatus shown?

(A) Cathode rays possess energy.

(B) Cathode rays possess momentum.

(C) Cathode rays travel in straight lines.

(D) Cathode rays cannot pass through metals.

2015 HSC Q3

2. What did the Geiger and Marsden experiment determine about the atom?

(A) Most alpha particles were deflected by the gold foil suggesting it was mainly empty space, while a small number passed through the gold foil suggesting a nucleus.

(B) Most alpha particles were deflected by a large angle back from the thin gold foil suggesting the atom was mainly empty space with a central nucleus.

(C) Most alpha particles went through the gold foil undeflected suggesting it was mainly empty space, while a small number rebounded from the gold foil suggesting a nucleus.

(D) Most alpha particles went through the gold foil with no deflection or only a slight deflection, suggesting the atom had a central nucleus.

3. JJ Thomson demonstrated that cathode rays are fundamental components of an atom. Eventually, cathode rays were renamed as:

(A) nucleus

(B) protons

(C) neutrons

(D) electrons

4. What does the Maltese cross apparatus demonstrate about cathode rays?

A. They travel in straight lines.

B. They consist of a beam of electrons.

C. They are absorbed by a metal surface.

D. They are not affected by magnetic fields.

2017 HSC Q9

5. The debate as to whether cathode rays are charged particles or electromagnetic waves continued for many years.

Which observation of cathode rays resolved this debate?

(A) Cathode rays can turn a paddle wheel.

(B) An electric field can deflect cathode rays.

(C) Cathode rays can penetrate thin metal foil.

(D) Fluorescent screens glow when struck by cathode rays.

2008 HSC Q12

6. JJ Thomson determined the charge/mass ratio of the electron by constructing a device which contained

(A) perpendicular magnetic fields.

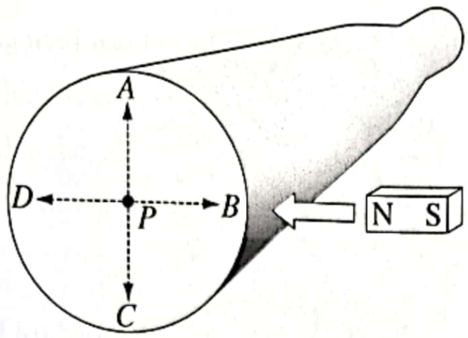
(B) perpendicular electric fields.

(C) parallel electric and magnetic fields.

(D) perpendicular electric and magnetic fields.

2010 HSC Q17

7. A cathode ray beam strikes the screen at point *P*, producing a bright spot. The north end of a magnet is brought towards the beam as shown.



Towards which point does the bright spot move?

(A) *A*

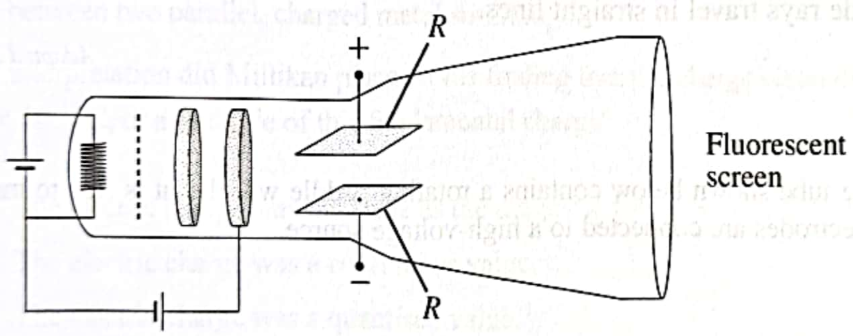
(B) *B*

(C) *C*

(D) *D*

2010 HSC Q16

8. The diagram shows the side view of a simple cathode ray tube.



What is the function of the components labelled *R*?

(A) To produce cathode rays

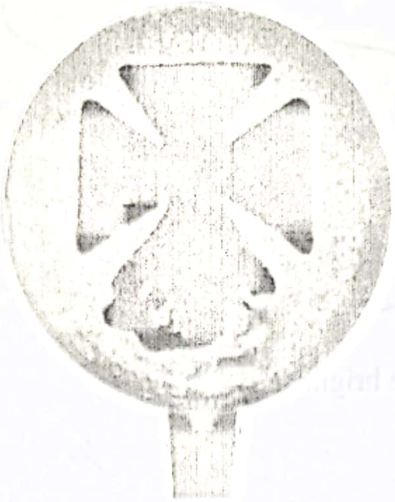
(B) To stop cathode rays striking the screen

(C) To deflect the cathode rays vertically

(D) To deflect the cathode rays horizontally

2002 HSC Q13

9. When using a discharge tube containing a Maltese cross, you will observe an image similar to the one shown below.



Which of the following statements is a valid conclusion from the observations made in this Maltese Cross investigation?

(A) Cathode rays pass through glass.

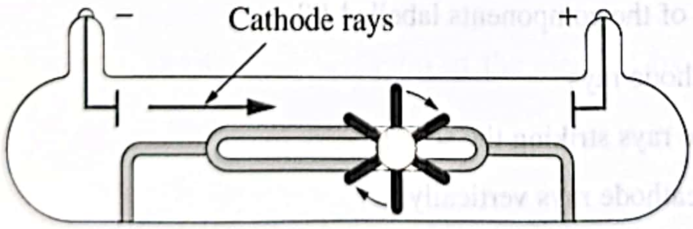
(B) Cathode rays pass through metals.

(C) Cathode rays are charged particles.

(D) Cathode rays travel in straight lines.

Adapted 2003 HSC Q12

10. The discharge tube shown below contains a rotating paddle wheel that is free to move. The tube's electrodes are connected to a high-voltage source.



Which of the following statements about cathode rays does this apparatus provide evidence for?

(A) Cathode rays travel in straight lines.

(B) Cathode rays are particles that have momentum.

(C) Cathode rays can only be produced in vacuum tubes.

(D) Cathode rays are waves of high frequency and short wavelength.

2005 HSC Q11

11. It was not until 1897 that JJ Thomson discovered the true nature of cathode rays.

What delayed the discovery of the true nature of cathode rays?

(A) The voltage being used was too high.

(B) The pressure within the earlier discharge tubes was too high.

(C) The pressure within the earlier discharge tubes was too low.

(D) Scientists did not know how to produce a uniform electric field.

12. What interpretation did Rutherford propose from the results of the Geiger-Marsden experiment?

(A) That the mass of an atom is not distributed throughout the space, but rather it is in a nucleus.

(B) That the mass of an atom is distributed throughout the space, rather than being located centrally in a nucleus.

(C) That negatively charged electrons are arranged around a positive nucleus.

(D) It showed that neutral particles were present in the nucleus.

13. Millikan's oil drop experiment entailed observing the motion of electrically charged droplets of oil between two parallel, charged metal surfaces.

What interpretation did Millikan place on his finding that the charge on an oil drop was always -1.6×10^{-19} C, or a multiple of this fundamental charge?

(A) The electric charge was the same as the magnetic forces between the plates.

(B) The electric charge was a continuous value.

(C) The electric charge was a quantised value.

(D) The electric charge was the same as the electric field strength.

14. Since Millikan's oil drop experiment found that the charge on an oil drop was always a simple multiple of -1.6×10^{-19} C, this showed that the smallest unit of charge must be equal to the charge on a single electron.

What did this result then enable physicists to determine?

(A) The mass of an electron.

(B) The mass of an oil drop.

(C) The mass of an atom.

(D) The mass of a proton.

Short-answer questions

15. How could a student test the hypothesis that cathode rays are streams of particles? In your answer refer to the results that would be observed.

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2011 HSC Q28(a) ... 3 marks

16. (a) What experimental evidence is there to suggest that cathode rays are particles?

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(b) What experimental evidence is there to suggest that cathode rays are found in all atoms?

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(c) What did Millikan's oil drop experiment measure?

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Adapted 1990 HSC Q Elective 1A (c), (d), new Q for (c) ... 2 + 1 + 1 = 4 marks

17. Thomson's experiment measures the charge/mass ratio of an electron.

Use an annotated diagram to show how Thomson's experiment can be performed.

2014 HSC Q28(a) ... 3 marks

18. The discovery of the neutron resulted from experiments in which a beryllium disc was bombarded with α-particles. This resulted in an unknown radiation being produced. This new radiation was at first thought to be γ-rays.

(a) Why was it difficult for the physicists of the time to distinguish between γ-rays and neutrons?

(b) What evidence subsequently led physicists to conclude that the radiation from the beryllium consisted of neutral particles, not γ-rays.

1992 HSC Q Elective 7 (c) ... 2+ 2 = 4 marks

19. An experiment was conducted to model Millikan's oil-drop experiment. In the experiment, different numbers of dominoes were placed inside seven identical boxes. The boxes were then sealed and weighed. The table below shows the mass of each sealed box and some preliminary analysis.

Box number	*Mass of box (including dominoes)* (g)	*Difference in mass between this box and the next box* (g)
1	15.45	17.2
2	32.65	25.8
3	58.45	4.3
4	62.75	8.6
5	71.35	12.9
6	84.25	43
7	127.25	

Analyse this experiment to assess its effectiveness in modelling Millikan's oil-drop experiment.

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Question Q19 continues

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End of Question 19

2018 NESA Sample HSC Physics Q25 ... 6 marks

20. In 1920, Rutherford suggested the existence of an undiscovered nuclear particle.

Explain how Chadwick confirmed Rutherford's prediction using conservation laws.

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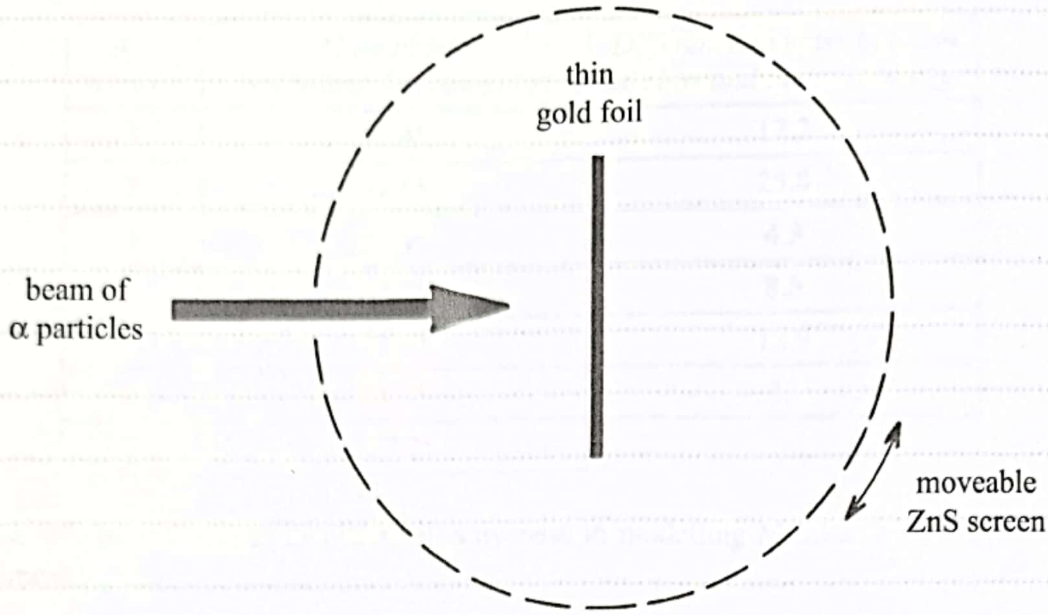
2009 HSC Q31(d) ... 3 marks

21. In an experiment by Rutherford, a narrow beam of α-particles was incident on a thin gold foil, as shown below. The scattered particles were detected by a moveable zinc sulfide (ZnS) screen.



(a) On the diagram above, illustrate the effect of the gold foil on the paths of the α-particles.

(b) How did these results support the nuclear model of the atom?

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Adapted 1986 HSC Q Elective 7 (b)(i)
– plus new Q for part (b) ... 2 + 2 = 4 marks

22. What results of Rutherford's experiment to investigate the structure of the atom indicated that the atom consisted of mainly empty space?

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1987 HSC Q Elective 7 (b) ... 1 mark

23. Thomson's 'plum pudding' model of the atom led to the prediction that α-particles would be deflected only slightly when passing through thin metal foil.

However, Rutherford's scattering experiment produced two unexpected results concerning the path if the α-particles. These results led him to propose a different model of the atom.

(a) Outline these two unexpected results.

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(b) How did Rutherford's model of the atom help him to explain each of these unexpected results?

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Adapted 1993 HSC Q Elective 7 (b) ... 2+ 3 = 5 marks

24. Chadwick's use of protons in his experiment overcame the problem scientists had when trying to detect neutrons.

(a) Outline why neutrons are hard to detect.

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(b) Explain why protons could be used instead of neutrons in Chadwick's experiment.

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... 1 + 2 = 3 marks

25. **Discuss the importance of Chadwick's discovery of the neutron in changing the model of the atom.**

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26. **Marsden and Geiger conducted an experiment in which they fired alpha particles at a thin gold foil. Most of the particles passed straight through.**

(a) **Describe how Rutherford's model of the atom explained these results.**

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(b) **Describe TWO problems associated with Rutherford's model and how these were explained by Bohr's model of the hydrogen atom.**

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2009 HSC Q31(a) ... 3 + 4 = 7 marks

27. When Chadwick discovered the neutron, he estimated its mass as 1.15 times the mass of the proton, quite close to its true value.

State the TWO laws of physics he used to make this estimate.

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2004 HSC Q31(a)(ii) ... 2 marks

28. James Chadwick discovered the neutron in 1932.

How did Chadwick apply conservation laws to make this discovery?

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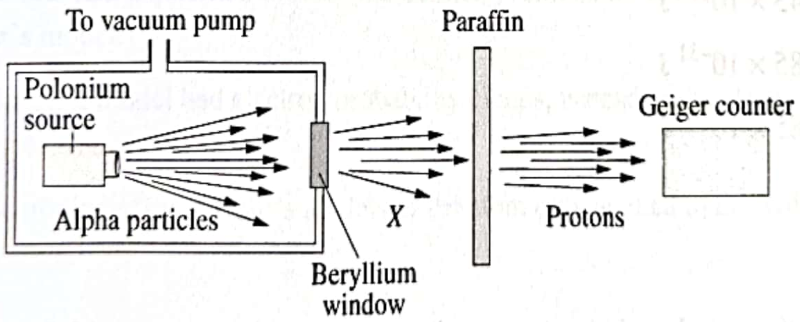
Adapted 2010 HSC Q36(e)(i) ... 3 marks

29. The diagram shows apparatus used to investigate subatomic particles.



How did Chadwick use a law of physics to identify a property of **X**?

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2018 HSC Q34(b)(i) ... 2 marks

8.2 Structure of the Atom

Multiple choice: 1 mark each

1. B	**2.** C	**3.** D	**4.** A	**5.** B	**6.** D	**7.** A	**8.** C
9. D	**10.** B	**11.** B	**12.** A	**13.** C	**14.** A		

Explanations:

1. B The shadow zone within the glow that occurs at the end of a cathode ray tube (CRT) shows (A), (C) and (D), but does NOT show (B). So (B) is the answer. A small paddle wheel that is made to rotate by cathode rays is usually used in a CRT to show that cathode rays possess momentum.

2. C The only correct description of the results of the Geiger and Marsden experiment (also known as the Rutherford gold foil experiment) is given in (C). This experiment showed that:

- most alpha particles went through the gold foil undeflected – this suggested that the atom was mostly empty space … so (A) and B) are incorrect
- only some alpha particles rebounded from the gold foil – this suggested a central nucleus … so (D) is incorrect.

3. D Through his experiments on the properties of cathode rays, JJ Thomson determined that cathode rays were smaller than atoms (in 1897). He was also able to measure the charge-to-mass ratio of the cathode ray particles. Originally, he called the particles 'corpuscles'. However, scientists later renamed them 'electrons'. So (D) is the answer and (A), (B) and (C) are incorrect.

[Note: The name 'electrons' came from the earlier work of physicist George Stoney, prior to Thomson's work. He proposed this term in 1891 for the 'fundamental unit quantity of electricity'.

4. A The Maltese cross apparatus showed that cathode rays travel in a straight line because a sharp shadow of the cross was produced on the glass at the end of a Crookes tube. So (A) is the answer. This experiment did not show that cathode rays consisted of a beam of electrons, although a similar apparatus was used to do this. So (B) is incorrect. It did not indicate whether the cathode rays are absorbed or reflected by the metal in the Maltese cross. So while (C) can be inferred, it was not demonstrated, and hence is incorrect. When a magnet is brought close to a Crookes tube, the shadow produced by a Maltese cross moves. So (D) is incorrect.

5. **B** A beam of charged particles will be deflected by an electric field, whereas an electromagnetic wave will not be deflected by an electric field, so (B) is the answer. Both electromagnetic waves and charged particle beams will produce the effects described in (A), (C) and (D), so these are all incorrect answers.

6. **D** Since the force due to an electric field is parallel to that field and since the force due to a magnetic field is perpendicular to that field, the two forces can only balance one another if they are perpendicular to one another. So (D) is the answer and (C) is incorrect. JJ Thomson used both magnetic and electric fields in determining the charge/mass ratio, so (A) and (B) are both incorrect.

7. **A** The magnetic field, B, is directed towards the left and the electron is moving out of the page, so the force on the electron is in a direction at right angles to both and so must be either up or down. So (B) and (D) are both incorrect. Note that v is directed into the page because q for an electron is negative, and the force is upwards and not downwards. So (A) is the answer and (C) is incorrect.

8. **C** Cathode rays are streams of electrons, travelling from left to right in the diagram. They are deflected and not produced or stopped by the charged plates labelled R, so (A) and (B) are incorrect. Having a negative charge, they are attracted upwards towards the positive plate and away from the negative plate. This deflects them vertically, as in (C), and not horizontally as in (D).

9. **D** The image shows the dark and sharp shadow of the Maltese Cross. Surrounding the shadow is the glow on the glass as it is struck by the cathode rays. This shows that the cathode rays travel in straight lines. So (D) is the answer. They do strike the glass, but there is no evidence whether or not they pass through it, so (A) is incorrect. The shadow is caused by cathode rays NOT passing through the metal Maltese Cross, so (B) is incorrect. A point source of light could produce the same pattern shown and light is not made of charged particles, so this is not evidence that cathode rays are charged particles, so (C) is incorrect.

10. **B** Cathode rays do travel in straight lines, but this apparatus does not provide direct evidence for this. So (A) is incorrect. In this apparatus, the cathode rays hit the paddle wheel causing it to rotate. Momentum is transferred from the cathode rays to the paddle wheel, so cathode rays are particles with momentum, as in (B). Cathode rays are normally produced in vacuum tubes, but this apparatus does not indicate whether or not vacuum tubes are necessary, so (C) is incorrect. This apparatus indicates cathode rays are particles and not waves, so (D) is incorrect.

11. **B** Earlier scientists failed to detect any deflection of cathode rays by an electric field, as the vacuum in their cathode ray tubes (CRT) was not good enough and so there was too much gas inside them. These gases ionised and became conducting. JJ Thomson had access to a much more efficient vacuum pump to evacuate his CRT to a low pressure and so was able to show deflection of cathode rays by an electric field. So (B) is the answer and (C) is incorrect. Extremely high voltage is need for a CRT to operate, so (A) is incorrect. Scientists did know how to produce a uniform electric field, so (D) is incorrect.

12. **A** Rutherford explained the large deflection or reflection of a small proportion of alpha particles by saying that an atom's mass was concentrated within a small volume, while the remainder of the atom was empty space. So (A) is the answer, and (B) is incorrect. The arrangement of electrons came later with Bohr, so (C) is incorrect. The neutron came later with Chadwick, so (D) is incorrect.

13. **C** Millikan's results showed that the charge on his oil drops was always a simple multiple of -1.6×10^{-19} C, which was the lowest value that he obtained. This indicates that charge is quantised, as in (C), and not continuous as in (B). Both magnetic forces and electric field strength are not charges, so (C) and (D) are incorrect.

14. **A** JJ Thomson's experiments obtained a value for the charge-to-mass ratio for a cathode ray, i.e. an electron. Millikan's experiment with oil drops showed that the charge of an electron was -1.6×10^{-19} C. Physicists were then able to combine these two findings and so determined the mass of an electron, as in (A). They did not determine the mass of an atom or a proton, so (C) and (D) are incorrect. The mass of an oil drop was determined by Millikan in his experiment as a step in determining the charge of an electron. It was not used by physicists later on when determining the mass of an electron, so (B) is incorrect.

15. The student would set up a cathode ray tube with a Maltese cross and turn it on. A sharp shadow of the cross will appear behind it on the glass, showing that cathode rays travel in a straight line.

Using the Cathode ray tube with a paddlewheel in it will result in the paddlewheel spinning. This shows that cathode rays have momentum and mass.

Bringing a bar magnet up to the cathode ray tube when on, will cause the cathode rays to deflect in the same way that negatively charged particles are deflected.

These findings all show that cathode rays behave like particles.

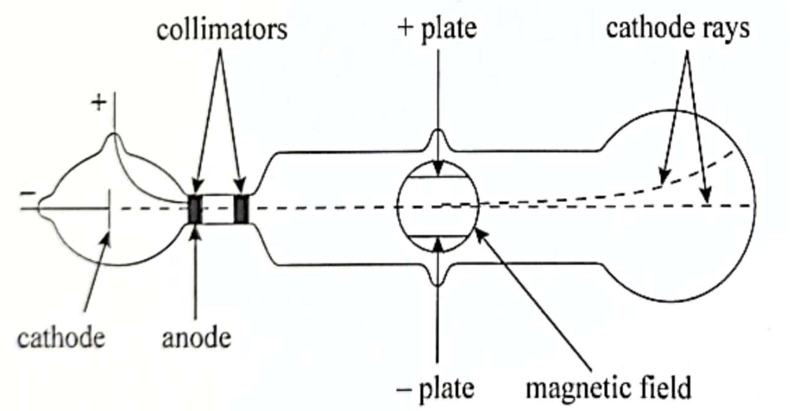
[Note: Other experiments to show that cathode rays are streams of particles include: • using a fluorescent screen, which shows that cathode rays can cause fluorescence and so they have energy; and • using pairs of electric plates in the cathode ray tube, which causes the cathode rays to bend towards the positive plate, thus showing that cathode rays carry negative charges.]

16. (a) Cathode rays can be deflected by magnetic fields and electric fields and so the q/m ratio of cathode rays can be determined, indicating the rays have mass and are particles.

(b) When the material of the cathode is changed, the cathode ray beam that emerges is the same and has the same properties.

(c) He measured the electric charge on an electron.

17.



- Pass cathode rays through collimator slits to produce a narrow beam
- Adjust magnetic field so that deflection by electric field is reversed
- Calculate e/m ratio from the electric and magnetic field strengths.

18. (a) Both γ-rays and neutrons have no charge. Neither were deflected when in the electric or magnetic fields that were being used to investigate them. Also, the physicists had not yet developed a way of measuring their mass.

(b) When the unknown radiation dislodged protons from paraffin, Chadwick realised that the protons were too heavy to have been dislodged by γ-rays and the energy of the γ-rays needed to be much higher than it was. Using the laws of conservation of energy and of momentum, Chadwick calculated that the unknown radiation had a mass close to the proton's mass and no electric charge, i.e. it was a neutral particle.

19. These experimental results can be analysed in a mathematically similar way to the method that Millikan used when analysing his oil drop experiment to find the charge of an electron. Millikan found that the charge on his oil drops was always a simple multiple of -1.6×10^{-19} C, which was the lowest value that he obtained.

In this experiment, the difference in mass between two boxes is always a multiple of the lowest value, which is 4.3 g. This suggests that the results for this difference is quantised and accurate. In this respect, it is similar to Millikan's results. However, the experiment does not indicate whether the lowest value is the mass of a single domino. Whereas Millikan looked at a single drop of oil each time to determine its charge. Also, the dominoes are in a box with mass and this box does not correspond with anything in the Millikan experiment. Further, the mass of each domino is not specified and cannot be determined, nor are the dominoes specified as being identical with the same combination of numbers. Whereas Millikan determined the mass of each oil drop.

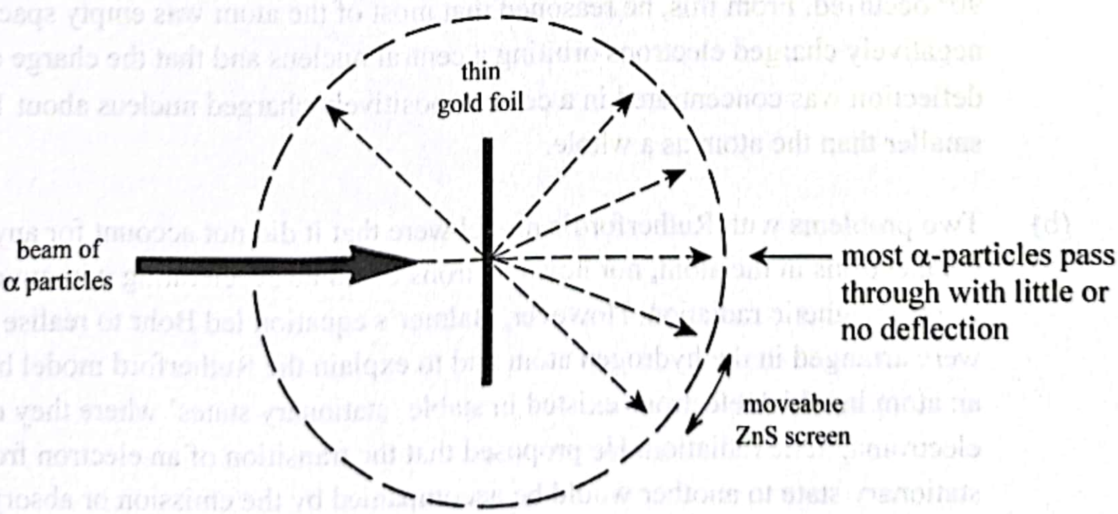
So, there are not really enough parallels to Millikan's oil-drop experiment for this to be a good model.

[Note: A 10 cent coin weighs 5.6 g, so a single domino would not weigh only 4.5 g.]

20. Chadwick determined that the unknown radiation ejected from a block of paraffin could not be γ-rays as Joliot and Curie had thought, as γ-rays did not have enough energy to eject protons. Since he knew the mass of the targets and the protons ejected, he was able to apply the laws of conservation of energy and momentum to determine that the unknown radiation was a particle with mass. He found that the particles had a similar mass to a proton, but with no charge (i.e. they had a neutral charge).

[Note: These particles were the 'neutrons' Rutherford had predicted in 1920, over a decade earlier.]

21. (a)



(b) The results showed that the mass and electric charge was concentrated in the centre of the atom in a small, positively charged nucleus and that most of the atom was empty space.

22. Most of the α-particles passed through the gold foil without being deflected at all. This indicated that the gold atoms in the gold foil were mostly empty space.

23. (a)
- Most of the α-particles passed through the gold foil without being deflected at all.
- A very small number of the α-particles were deflected by angles greater than 90° and some were actually reflected back towards their source.

(b) Rutherford proposed a nuclear atom that was mostly empty space with a tiny, positively charged nucleus in the centre, while electrons orbited the nucleus. The empty space allowed α-particles to pass through without being deflected. The positively charged nucleus in the centre accounted for why a small number of α-particles were deflected due to electrostatic repulsion and some were reflected due their collision with the nucleus.

24. (a) Neutrons are very difficult to detect as they are neutral, i.e. they have no charge.

(b) Neutrons cannot be manipulated easily because of their lack of charge. Whereas protons have a positive charge that can be measured and so can be manipulated similarly to electrons in a cathode ray tube.

25. Chadwick's discovery of the neutron led to a new model of the atom in which protons and neutrons were in the nucleus, with the electrons orbiting it. This model removed the need for Rutherford's hypothesis that some electrons needed to be in the nucleus, as well as orbiting it, to reduce the electrical repulsion between the protons.

26. (a) Using Marsden and Geiger's experiment, Rutherford found that the vast majority of α-particles were not deflected at all and that some unexpected deflections of more than 90° occurred. From this, he reasoned that most of the atom was empty space occupied by negatively charged electrons orbiting a central nucleus and that the charge causing the deflection was concentrated in a central, positively charged nucleus about 10,000× smaller than the atom as a whole.

(b) Two problems with Rutherford's model were that it did not account for any properties of the electrons in the atom, nor how electrons could be accelerating without emitting any electromagnetic radiation. However, Balmer's equation led Bohr to realise how electrons were arranged in the hydrogen atom and to explain the Rutherford model by describing an atom in which electrons existed in stable 'stationary states' where they did not emit electromagnetic radiation. He proposed that the transition of an electron from one stationary state to another would be accompanied by the emission or absorption of a quantum of electromagnetic radiation (a photon).