8

Read the passage below and answer the questions that follow.

Fig. 8.1 shows a bubble chamber which consists of a sealed chamber filled with a liquefied gas. The coils around the chamber provide a magnetic field. The pressure inside the chamber can be reduced quickly by an adjustable piston. The liquid is originally at a temperature just below its boiling point. When the pressure is reduced, the boiling point of the liquid becomes lower, so that it is less than the original temperature of the liquid, leaving the liquid superheated.

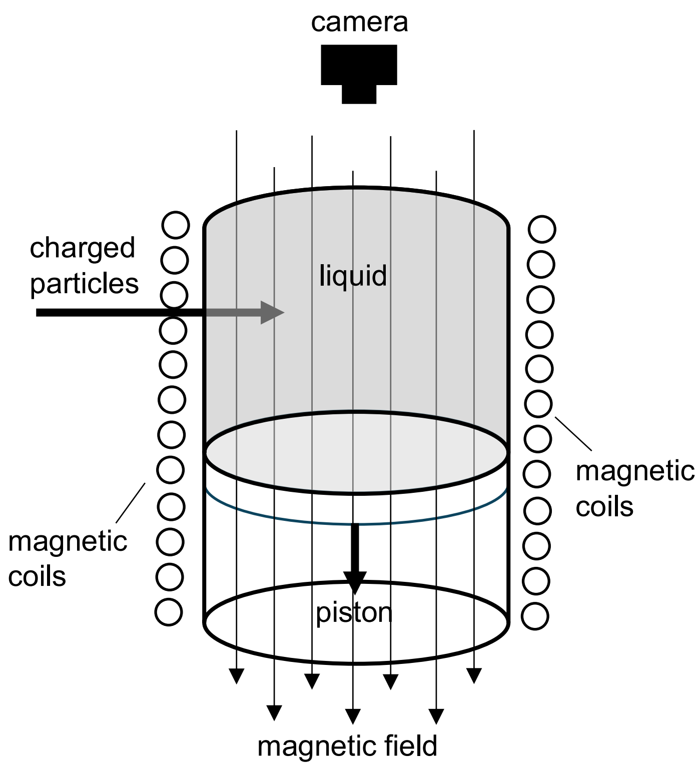


Fig. 8.1

As beams of charged particles pass through the liquid, they deposit energy by ionising the liquid atoms. This causes the liquid to boil and tiny gas bubbles are formed along the paths of the charged particles.

Some charged particles may also collide with an atomic nucleus of the liquid and form products which are charged too. These charged products will move on and ionise the liquid, causing more trails of bubbles to form.

The chamber is illuminated so that the tracks of the charged particles can be photographed. By analyzing the tracks, the charged particles can be identified and any complex events involving the particles can be studied.

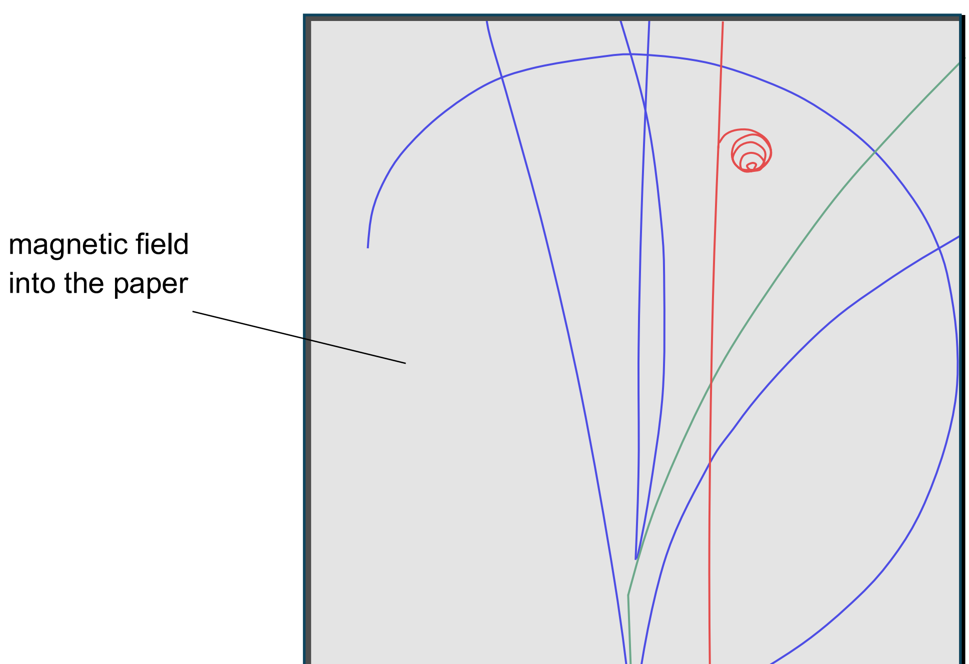
In the presence of a magnetic field, the tracks of the charged particles will be curved. The degree of curvature depends on the mass, speed, and charge of each particle.

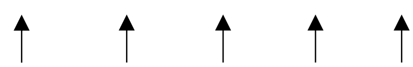
Neutral particles can be detected indirectly by applying various conservation laws to the events recorded in the bubble chamber or by observing their decay into pairs of oppositely charged particles.

Fig. 8.2 is a picture taken by the camera from a bubble chamber that is filled with liquid hydrogen. The lines show the path of the particles entering the chamber from one of the sides.

A parallel beam of K^- particles, each with an energy of 8.2 GeV and a charge of $-e$ enters from the bottom of Fig. 8.2.

The radius of any circular path made by a moving charged particle in the bubble chamber is proportional to the momentum and inversely proportional to the charge of the particle.





K^- particles entering the chamber
from the bottom

(a)

State and explain the number of positively charged particles as shown in Fig. 8.2.

………

………

……… [2]

(b)

Fig. 8.3 shows the enlarged picture of the little curly track at the top right quadrant of Fig. 8.2.

It has been proposed that this track is produced by an electron which is knocked out of the hydrogen atom by a passing K^- particle.

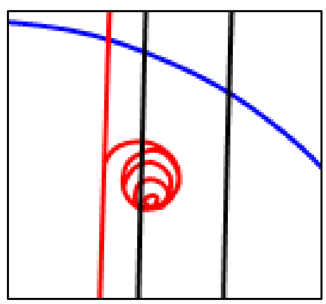


Fig. 8.3

(i)

By comparing the curly path in Fig. 8.3 with paths made by other particles in Fig. 8.2, explain whether this proposal is possible.

………..

………..

………..

………………………………………………………………………………………………… [2]

(ii)

Suggest why is this path a spiral.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………………………………………………………………………………………………… [2]

(c)

Fig. 8.4 shows a K^- particle colliding with the positively charged nucleus of a hydrogen atom at point A. The collision produced four charged particles as illustrated by the four outgoing tracks, numbered 1 to 4.

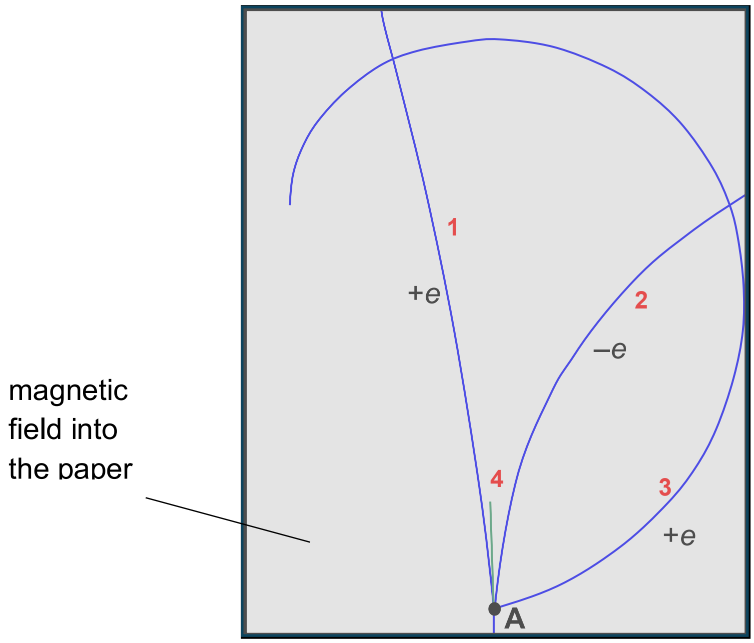


Fig. 8.4

The charges of three of the four outgoing particles after the collision are indicated beside their tracks.

(i)

Deduce the charge of the fourth outgoing particle. Justify your answer.

………..…………………………………………………………………………………….......

………..…………………………………………………………………………………….......

………..…………………………………………………………………………………….......

………..…………………………..……………………………………………………….. [2]

(ii)

State which of the outgoing particles 1 to 4 has the lowest momentum.

………..…………………………………………………………………………………….......

………..…………………………..……………………………………………………….. [1]

(d)

There is a fifth outgoing particle from the collision at point A which is neutral and does not produce any visible track. This particle eventually decays into two smaller particles at point B as shown in Fig. 8.5.

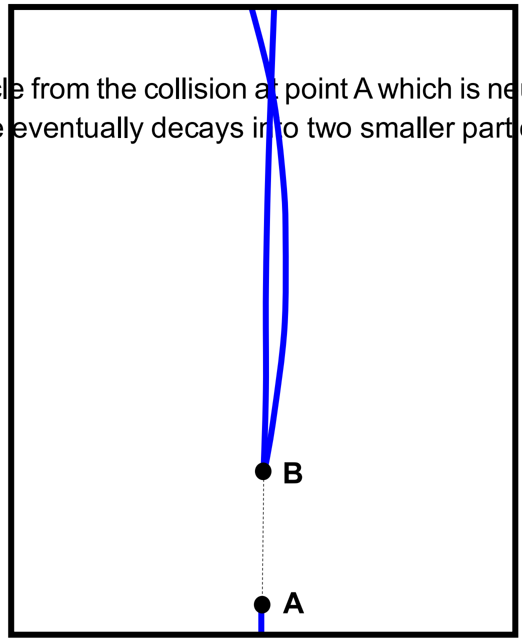


Fig. 8.5

(i)

Explain why it leaves no track.

…………..………………………………………………………………………………………….......

………..……………………………………………………………………………………........

………..…………………………..……………………………………………………….. [1]

(ii)

Deduce the charge of the two particles that are formed from the decay of the fifth particle. Explain your answer.

………..……………………………………………………………………………………........

………..……………………………………………………………………………………........

………..…………………………..……………………………………………………….. [2]

(e)

The bubble chamber is used to study the collision between a K^- particle and a stationary proton p. The total energy E and momentum in three dimensions p_x, p_y, p_z of each particle produced in a collision is governed by the formula

$$E^2 = (p_x{}^2 + p_y{}^2 + p_z{}^2)c^2 + m^2c^4$$

where m is the mass of the particle and c is the speed of light.

In a particular collision, three additional particles Ω^-, Ω^+ and K^0 are formed and the data collected are shown in Fig. 8.6 below.

Before collision

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	438.05	-13.24	0.81	1317.12
p	0.00	0.00	0.00	150.13
sum				

After collision

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	79.03	1.48	11.95	252.50
Ω^-	7.98	-0.60	2.07	33.38
Ω^+	2.02	-6.52	-1.21	30.51
p	80.46	6.85	-3.76	285.22
K^0	189.10	-8.69	-13.07	574.78
sum				

Fig. 8.6

(i)

Complete Fig. 8.6 to show

1.

the sum of the momentum in all the dimensions for the particles before and after the collision, [1]

2. the sum of the energy for the particles before and after the collision. [1]

(ii)

The sum of the total energies E before and after the collision are not equal, implying that more particles are formed but have gone undetected.

Assuming that there is only one undetected particle, determine

1.

the components of its momentum p_x, p_y, p_z and its total energy E,

p_x = ...N s

p_y = ...N s

p_z = ...N s

E = ... J [4]

2.

its mass m.

m = ... kg [2]

[Total: 20]

END OF PAPER