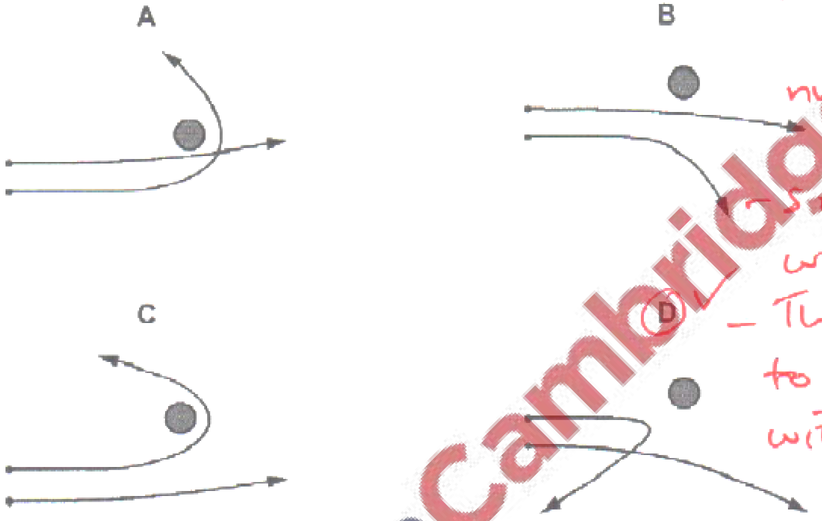
Particle Physics – 2023 Nov AS Physics 9702

1. Nov/2023/Paper_ 9702/11/No.38

Two alpha-particles with the same kinetic energy are moving towards, and are then deflected by, a gold nucleus.

Which diagram could show the paths of the two alpha-particles?



Particle	charge
α	+ve
nucleus	+ve

- so α particles will be repelled
- The closer α to the nucleus with more repulsion

2. Nov/2023/Paper_ 9702/11/No.39

Which nuclide is formed when $^{10}_{6}C$ undergoes β^+ decay?

A $^{11}_{6}C$ **B** $^{9}_{6}C$ **C** $^{10}_{5}B$ ✓ **D** $^{10}_{7}N$

$^{10}_{6}C \rightarrow ^{A}_{Z}X + ^{0}_{1}\beta^+$

$10 = A + 0$

$A = 10$ ✓

$6 = Z + 1$

$Z = 6 - 1 = 5$ ✓

A particular hadron is composed of three quarks and has zero charge.

3. Nov/2023/Paper_ 9702/11/No.40

A particular hadron is composed of three quarks and has zero charge.

What is a possible quark composition of the hadron?

A down, down, strange ← $-\frac{1}{3}e + -\frac{1}{3}e + -\frac{1}{3}e = -1e$

(B) up, down, strange ✓ ← $+\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = 0$

C up, up, down ← $+\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +1e$

D up, up, strange ← $+\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +1e$

$u \rightarrow +\frac{2}{3}e$

$d \rightarrow -\frac{1}{3}e$

$s \rightarrow -\frac{1}{3}e$

4. Nov/2023/Paper_ 9702/12/No.30

A fine mist of oil droplets is sprayed into air. As the oil droplets leave the nozzle of the spraying device they can become electrically charged.

What is not a possible value for the charge on an oil droplet?

A zero

(B) 1.0×10^{-19} C ✓

C 4.8×10^{-19} C

D 8.0×10^{-19} C

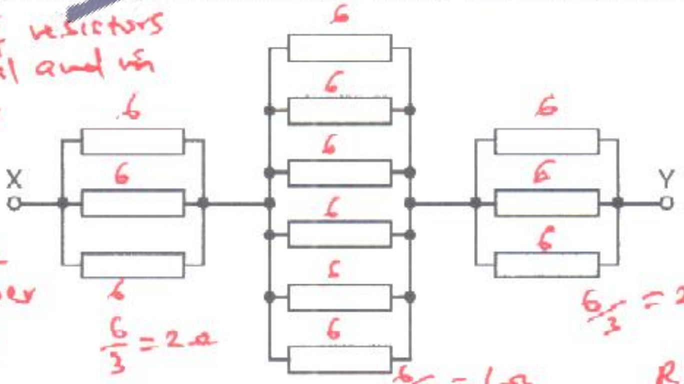
– All charge should be a multiple of 1.6×10^{-19}.
– Divide the charges by 1.6×10^{-19} to get a whole number.

$\frac{1.0 \times 10^{-19}}{1.6 \times 10^{-19}}$ = 1.6 ← not possible.

5. Nov/2023/Paper_ 9702/12/No.38

The diagram shows a network of resistors. Each resistor has a resistance of 6.0 Ω.

Remember if resistors are identical and in parallel, R_T is obtained by dividing the resistance by the number of resistors.



What is the total resistance of the network between points X and Y?

A 3.0 Ω (B) 5.0 Ω ✓ C 7.2 Ω D 18 Ω

6. Nov/2023/Paper_ 9702/12/No.39

The charge-to-mass ratio r of a particle is given by the equation shown.

$$r = \frac{\text{charge on particle}}{\text{mass of particle}}$$

The value of r is determined for an α-particle, a β^+ particle and a proton p.

Which list shows the particles in order of increasing magnitude of r from left to right?

A $\alpha \rightarrow \beta^+ \rightarrow p$

B $\alpha \rightarrow p \rightarrow \beta^+$ ✓

C $p \rightarrow \alpha \rightarrow \beta^+$

D $p \rightarrow \beta^+ \rightarrow \alpha$

$^4_2\alpha^{2+}$, $^0_1\beta^+$, $^1_1p^+$

$r_\alpha = \frac{2}{4} = 0.5$ $r_\beta = \frac{1}{0} = \infty$ $r_p = \frac{1}{1} = 1$

α, p, β^+

7. Nov/2023/Paper_ 9702/12/No.40

Which combination of up (u) and down (d) quarks forms a neutron?

A u u u B u u d C u d d ✓ D d d d

neutron = u d d

$+\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = 0$

$u \rightarrow +\frac{2}{3}e$

$d \rightarrow -\frac{1}{3}e$.

so neutral has zero charge.

8. Nov/2023/Paper_ 9702/13/No.38

The table shows the number of nucleons and the total number of particles (protons, neutrons and electrons) in neutral atoms of four nuclides W, X, Y and Z.

	number of nucleons	total number of particles
W	19	30
X	19	31
Y	21	32
Z	22	31

– isotopes have equal protons in their nucleus.
– In an atom protons = electrons.
– ∴ for isotopes, the number of electrons are equal.

Which two nuclides are isotopes of each other?

A W and X B W and Y ✓ C X and Z D Y and Z

No of electrons

W : 30 − 19 = 11
X : 31 − 19 = 12
Y : 32 − 21 = 11
Z : 31 − 22 = 9

equal, so W and Y are isotopes.

9. Nov/2023/Paper_ 9702/13/No.39

When a sample of a radioactive isotope decays by α-particle emission, the α-particles emitted have a single discrete energy.

When a sample of a radioactive isotope decays by β^- particle emission, the β^- particles emitted have a continuous range of energies.

What is the explanation for this?

A An antineutrino is emitted with a β^- particle but not with an α-particle. ✓

B An antineutrino is emitted with an α-particle but not with a β^- particle.

C The α-particles have much more energy than the β^- particles.

D The β^- particles have much more energy than the α-particles.

10. Nov/2023/Paper_ 9702/13/No.40

Some particles are a combination of three quarks.

Which combination of quarks does **not** result in a particle with a charge of either $+1.6 \times 10^{-19}$ C or zero?

charge of +e

A up, down, down ← $+\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = 0$

B up, strange, strange ← $+\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = 0$

C up, up, down ← $+\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +1e = +e$ $(1.6\times10^{-19}$ C$)$.

D up, up, up ✓

$U \rightarrow +\frac{2}{3}e$

$U\ U\ U = +\frac{2}{3}e + \frac{2}{3}e + \frac{2}{3}e$

$= +\frac{4}{3}e$

$= +1\frac{1}{3}e$

$U: +\frac{2}{3}e$

$d: -\frac{1}{3}e$

$s: -\frac{1}{3}$

11. Nov/2023/Paper_ 9702/21/No.7

(a) The results of the α-particle scattering experiment led to the development of the nuclear model for the atom.

State the results that suggested that most of the mass of the atom is concentrated in a very small region and most of the atom is empty space.

- A very small proportion of α particles are reflected back.
- A large proportion of α-particles pass straight through undeflected. [2]

(b) State the composition of γ-radiation.

electromagnetic radiation [1]

(c) Table 7.1 lists the names of three particles and possible classifications for them.

Table 7.1

particle name	classification		
	baryon	hadron	lepton
neutrino			✓
neutron	✓	✓	
positron			✓

Complete Table 7.1 by placing ticks (✓) in the boxes to indicate the classifications that apply to each particle. [2]

(d) The discovery of a particle with an unusual charge was an important step in the development of the theory of quarks. The particle is a hadron with a mass of 2.19×10^{-27} kg and a charge of $+2e$, where e is the elementary charge.

(i) Calculate the mass, in u, of the particle. Give your answer to three significant figures.

$1u = 1.66 \times 10^{-27}$ kg

$? = 2.19 \times 10^{-27}$ kg

$\frac{1u \times 2.19 \times 10^{-27}}{1.66 \times 10^{-27}} = 1.32$

mass = ... 1.32 .... u [1]

(ii) Determine a possible quark composition of a hadron with a charge of $+2e$. Explain your reasoning.

$+\frac{2}{3}e + +\frac{2}{3}e + +\frac{2}{3} = +\frac{6}{3}e$

$= 2e$

u c t

up charm top

up → $+\frac{2}{3}e$

charm → $+\frac{2}{3}e$

Top → $+\frac{2}{3}e$.

[2]

[Total: 8]

12. Nov/2023/Paper_ 9702/22/No.7

(a) In the following list, underline **all** the particles that are **not** fundamental.

antineutrino baryon nucleon positron (e^+) [1]

(b) A nucleus of thorium-230 ($^{230}_{90}Th$) decays in stages, by emitting α-particles and β^- particles, to form a nucleus of lead-206 ($^{206}_{82}Pb$).

Determine the total number of α-particles and the total number of β^- particles that are emitted during the sequence of decays that form the nucleus of lead-206 from the nucleus of thorium-230.

$^{230}_{90}Th \rightarrow {}^{206}_{82}Pb + x\,{}^{4}_{2}\alpha + y\,{}^{0}_{-1}\beta$

$230 = 206 + 4x + 0$

$4x = 230 - 206$

$x = \frac{24}{4}$

$x = 6.$

$90 = 82 + 2x - y$

$90 = 82 \times (2\times6) - y$

$y = 94 - 90$

$y = 4$

number of α-particles = 6

number of β^- particles = 4

[2]

(c) A meson has a charge of $-1e$, where e is the elementary charge. The quark composition of the meson includes a charm antiquark.

State and explain a possible flavour (type) of the other quark in the meson.

charm $= +\frac{2}{3}e$

anticharm $= -\frac{2}{3}e$

meson $= -1e$

meson = quark + antiquark

$-1 = -\frac{2}{3} + x$

$x = -1 + \frac{2}{3} = -\frac{1}{3}$.

Quark with $-\frac{1}{3}e$ are down, strange & bottom.

– So down (d), strange (s) and bottom (b) are the other possible flavour.

[2]

– So the meson could have the composition $d\bar{c}$, $s\bar{c}$ or $b\bar{c}$

[Total: 5]

13. Nov/2023/Paper_ 9702/23/No.8

(a) The nuclide $^{23}_{12}Mg$ is an isotope of magnesium that undergoes β^+ decay to form a new nuclide X according to the equation

$$^{23}_{12}Mg \rightarrow \, ^{23}_{11}X + \, ^{0}_{1}\beta^+ + \, ^{0}_{0}\nu.$$

Four numbers are missing from the equation.

(i) For the nuclide $^{23}_{12}Mg$, state what is represented by the numbers 23 and 12.

23 represents: Nucleon number

12 represents: Number of protons [2]

(ii) Complete the equation by inserting the missing numbers. [2]

(iii) State the name of the group (class) of fundamental particles to which the positron and neutrino belong.

Leptons [1]

(b) A radioactive source emits particles from its nuclei when it decays.
Fig. 8.1 shows, for the source, the variation with kinetic energy of the number of particles emitted.

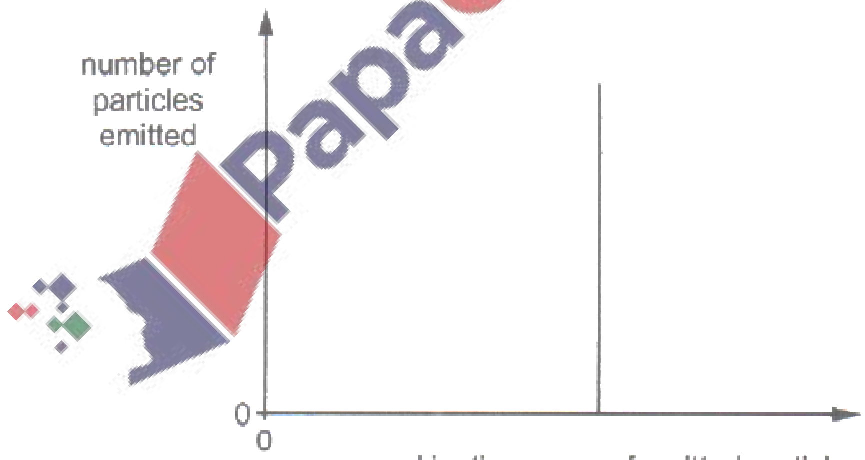


Fig. 8.1

State how Fig. 8.1 shows that these nuclei do **not** undergo beta-decay.

- There is only one single kinetic energy
if were beta decay, it will have a range of kinetic energies. [1]

[Total: 6]