1. Most α-particles passing straight through the gold foil showed that the atom is:

   ☐ entirely negative

   ☐ mostly empty space

   ☐ made only of nuclei

   ☐ a solid ball of charge

2. An α-particle is:

   ☐ a helium nucleus (2 protons + 2 neutrons)

   ☐ a single proton (hydrogen nucleus)

   ☐ a fast electron from the nucleus

   ☐ a high-energy photon

3. What is the charge on an up quark?

   ☐ $+\frac{2}{3}e$

   ☐ 0

   ☐ $+1\,e$

   ☐ $-\frac{1}{3}e$

4. Almost all of an atom's mass is in its nucleus.

   ☐ True ☐ False

5. Of the three, α radiation is the most strongly ionising.

   ☐ True ☐ False

6. A proton is made of which quarks?

   ☐ u u u

   ☐ d d d

   ☐ u u d

   ☐ u d d

7. Protons and neutrons together are called _____.

   _____

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_____

9. A neutron is u d d. What is its total charge, in units of e?

   _____

10. How many neutrons are in $^{14}_{6}\mathrm{C}$?

    _____

1. **mostly empty space**

   If most go straight through, there is little in the way – the atom is mostly empty, with the mass and charge concentrated in a tiny nucleus.

2. **a helium nucleus (2 protons + 2 neutrons)**

   An α-particle is ${}^{4}_{2}\alpha$ – a helium-4 nucleus with charge $+2e$.

3. $+\frac{2}{3}e$

   Up-type quarks (up, charm, top) carry $+\frac{2}{3}e$; down-type (down, strange, bottom) carry $-\frac{1}{3}e$.

4. **True**

   Protons and neutrons are ~1 u each; electrons are ~1/1836 u, so the nucleus holds nearly all the mass.

5. **True**

   Yes – α is the strongest ioniser (and so the least penetrating); γ is the weakest ioniser (and most penetrating).

6. **u u d**

   Proton = u u d, giving charge $\frac{2}{3}+\frac{2}{3}-\frac{1}{3}=+1$.

7. **nucleons**

   The nucleon number A counts the protons plus neutrons in the nucleus.

8. **antiparticle**

   An antiparticle has the same mass but opposite charge – the positron is $+e$ to the electron's $-e$.

9. **0**

   $\frac{2}{3}-\frac{1}{3}-\frac{1}{3}=0$ – the neutron is uncharged.

10. **8**

    $N=A-Z=14-6=8$ neutrons.

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