CIE A-Level Physics

26 - Nuclear and Particle Physics

Flashcards

How does the alpha-scattering experiment give evidence of a small and dense nucleus?

How does the alpha-scattering experiment give evidence of a small and dense nucleus?

A few alpha particles bounce back.

This wouldn't happen if the positive charge in the atom was distributed evenly throughout (as in the Plum Pudding Model), which suggests they must be hitting a dense positive charge. The fact it only happens to a very small number of alpha particles shows the nucleus must be small.

What are the main constituents of an atom?

What are the main constituents of an atom?

Proton

Neutron

Electron

How many times bigger is an atom than a nucleus?

How many times bigger is an atom than a nucleus?

Approximately 100,000 times.

What is the letter associated with a proton number?

What is the letter associated with a proton number?

Z

What is a nucleon?

What is a nucleon?

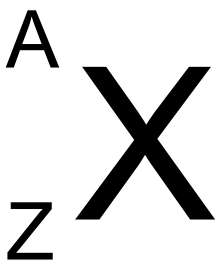
A particle that makes up the nucleus: a proton or a neutron.

What letter represents nucleon number?

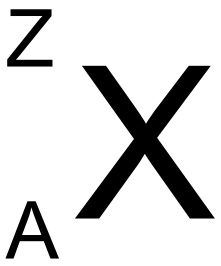
What letter represents nucleon number?

A

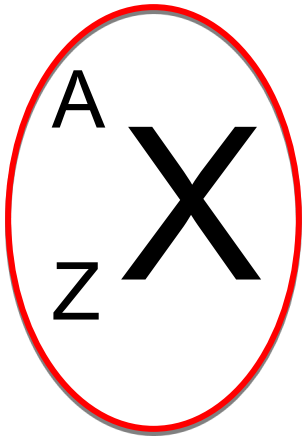
Which is the correct notation?



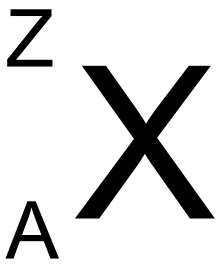
OR



Which is the correct notation?



OR



What is the definition of an isotope?

What is the definition of an isotope?

Isotopes are atoms of an element (with the same number of protons) with a different number of neutrons (and therefore a different mass number).

What is the strong nuclear force?

What is the strong nuclear force?

The force that holds the nucleus together.

It must overcome the electrostatic force of repulsion between protons, but not so much as to cause the nucleus to collapse.

Describe the range of the strong force.

Describe the range of the strong force.

Repulsive up to 0.5fm

Attractive up to 3fm

What is the equation relating radius of an atom and its nucleon number?

What is the equation relating the radius of an atom and its nucleon number?

$$r = r_0 A^{\frac{1}{3}}$$

Where r = radius, r_0 = constant (for all atoms), A = nucleon number

Which has a higher density: an atom or a nucleus?

Which has higher density: an atom or a nucleus?

A nucleus is much more dense than an atom since the atom includes a lot of empty space.

True or false?

‘Every particle has a antiparticle.’

True or false? ‘Every particle has a antiparticle.’

True.

Give a difference and a similarity between particles and antiparticles.

Give a difference and a similarity between particles and antiparticles.

Similarity - Mass

Difference - Charge (eg. for protons/anti-protons).

What is the name of the antiparticle of an electron?

What is the name of the antiparticle of an electron?

Positron.

What is a hadron?

What is a hadron?

A type of particle which is affected by the strong nuclear force.

What are hadrons made of?

What are hadrons made of?

Hadrons are made up of quarks.

What are the classes of hadrons?

What are the classes of hadrons?

- Baryon (three quarks)
- Mesons (two quarks)

What are two examples of baryons?

What are two examples of baryons?

Protons and neutrons.

What are the four fundamental forces?

What are the four fundamental forces?

1. Strong nuclear
2. Weak nuclear
3. Electrostatic
4. Gravity

Which forces are hadrons subject to?

Which forces are hadrons subject to?

It can be all 4!

(Only charged hadrons, like protons, will be subject to electrostatic forces)

What are leptons?

What are leptons?

Leptons are fundamental particles which are not subject to the strong nuclear force.

(They do still interact via the weak nuclear force)

Give some example of leptons.

Give some example of leptons.

Electron

Muon

Neutrino

And their corresponding antiparticles

What are the three types of quark?

What are the three types of quark?

Up (u)

Down (d)

Strange (s)

And their corresponding antiparticles

State the quark compositions of protons and neutrons.

State the quark composition of protons and neutrons.

Proton (uud)

Neutron (udd)

True or False? Quarks can be found on their own, in pairs or in triplets.

True or false? Quarks can be found on their own, in pairs or in triplets.

False.

Quarks are never found on their own (‘free’).

Give the charges of the up, down and strange quarks (in terms of the electron charge, e).

Give the charges of the up, down and strange quarks (in terms of the electron charge, e).

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

Down = $-\frac{1}{3}e$

Strange = $-\frac{1}{3}e$

(The charges of corresponding antiparticles are the same number, but opposite sign).

What is meant by beta minus decay?

What is meant by beta minus decay?

When a neutron turns into a proton and the atom releases an electron and an anti electron neutrino.

Which quark decays in beta minus decay?
What does it turn into?

Which quark decays in beta minus decay? What does it turn into?

A down quark turns into an up quark.

What quantities must be conserved during the decay of particles?

What quantities must be conserved during the decay of particles?

Charge, mass, baryon and lepton numbers.

(And energy - but you can't show this in a symbol equation)

What are the defining features of radioactive decay?

What are the defining features of radioactive decay?

Radioactive decay is spontaneous and random - you can't predict when an individual nucleus will decay (or which nucleus will go next).

What features of a nucleus might cause it to radioactively decay?

What features of a nucleus might cause it to radioactively decay?

- Too many or too few neutrons.
- Too heavy overall (too many nucleons).
- Too much energy.

Name 3 types of radiation.

Name 3 types of radiation.

1. Alpha
2. Beta (plus and minus)
3. Gamma

Order Alpha, Gamma and Beta radiation starting with the most ionising?

Order Alpha, Gamma and Beta radiation starting with the most ionising?

- Alpha
- Beta
- Gamma

What is an alpha particle?

What is an alpha particle?

A particle which contains two protons and two neutrons, the same as a helium nucleus.

Which type of radiation can only be stopped by lead or concrete?

Which type of radiation can only be stopped by lead or concrete?

Gamma

How far does a beta particle typically penetrate in air?

How far does a beta particle typically penetrate in air?

50cm - 1m

What materials would be needed to investigate whether a radioactive source was releasing alpha, beta or gamma?

What materials would be needed to investigate whether a radioactive source was releasing alpha, beta or gamma?

Alpha - paper.

Beta - ~5mm thick aluminium.

Gamma - thick lead sheet.

A particle with nucleon number, A, and mass number, Z, undergoes alpha decay. What are the nucleon and mass numbers of the resulting particle? (In terms of A and Z)

A particle with nucleon number, A, and atomic number, Z, undergoes alpha decay. What are the nucleon and atomic numbers of the resulting particle? (In terms of A and Z)

Nucleon number = A - 4

Atomic number = Z - 2

In beta plus decay, how does the atomic number change?

In beta plus decay, how does the atomic number change?

It decreases.

(A proton turns into a neutron and a positron, so mass is ‘constant’ but atomic number decreases).

What is the activity of a source?

What is the activity of a source?

The number of radioactive decays per second (measured in Becquerels, Bq).

In the equation $A = \lambda N$, what do each of the letters/symbols stand for?

In the equation $A = \lambda N$, what do each of the letters/symbols stand for?

A = activity

λ = decay constant

N = number of radioactive nuclei

What is the half-life of an isotope?

What is the half-life of an isotope?

The average time taken for the activity of a sample (or the number of radioactive nuclei) to halve.

What is the equation linking the activity of a sample, A, at time, t, to the original activity of the sample, A_0?

What is the equation linking the activity of a sample, A, at time, t, to the original activity of the sample, A_0?

$$A = A_0 e^{-\lambda t}$$

What isotope is commonly used to find out how old artefacts are?

What isotope is commonly used to find out how old artefacts are?

Carbon-14 (in radiocarbon dating)

What equation is used to convert mass to its energy equivalent?

What equation is used to convert mass to its energy equivalent?

$$E = mc^2$$

What occurs when a particle and antiparticle meet?

What occurs when a particle and antiparticle meet?

- Annihilation.
- When a particle and its antiparticle meet, they will annihilate each other and release two gamma rays.
- Two rays are released in order to conserve momentum.
- The mass of the particles will transform into the energy equivalent.

What is pair production?

What is pair production?

When a gamma ray has enough energy to produce a particle and its antiparticle.

Why does beta plus decay have a very low penetration?

Why does beta plus decay have a very low penetration?

The positrons will be annihilated by electrons almost immediately.

What is the mass defect?

What is the mass defect?

The difference between the total mass of all the nucleons separately, compared to the mass of the nucleus.

Why is there a mass defect?

Why is there a mass defect?

Energy is released as the nucleons bind together into a nucleus. The mass-energy equivalence means this produces a mass defect.

What is binding energy?

What is binding energy?

The energy required to separate a nucleus into its constituent parts.

(This will be the same numerical value as the energy released when the nucleus binds, and is equivalent to the mass defect).

True or false? A low binding energy per nucleon will mean that an element is more stable.

True or false? A low binding energy per nucleon will mean that an element is more stable.

False: A low binding energy per nucleon means not much energy would be required to separate the nucleus (ie. it's more likely to decay).

What is nuclear fission?

What is nuclear fission?

Where a unstable nucleus splits into 2 smaller nuclei. It often occurs with the larger nuclei.

The binding energy per nucleon increases when fission occurs therefore the overall process releases energy.

What is fusion?

What is fusion?

When two small nuclei fuse together to create a larger nuclei. The new nucleus has a larger binding energy per nucleon than the old nuclei therefore energy is released in the process.

Which process (fission or fusion) releases the most energy?

Which process (fission or fusion) releases the most energy?

Fusion releases a lot more energy per reaction.

This is because the change in binding energy is very drastic.

Why is it difficult to make fusion occur on earth?

Why is it difficult to make fusion occur on earth?

There is a large repulsion between the two positively charged nuclei, therefore a lot of energy is required to overcome the repulsion and fuse them together.

It is hard to get a material that can withstand the heat and be cost effective.

How is fission used in nuclear reactors?

How is fission used in nuclear reactors?

Rods of uranium-235 absorb neutrons and become unstable and then split into two daughter nuclei. It also releases 2 or 3 more neutrons. These then go on to be reabsorbed by another uranium-235 nucleus.

What is the purpose of a moderator?

What is the purpose of a moderator?

To slow down the neutrons so they travel slow enough to be absorbed by the uranium.

They do this through elastic collisions between the moderator and the nucleus.

Why are control rods essential for a nuclear power station?

Why are control rods essential for a nuclear power station?

They stop the chain reaction from being out of control.

They absorb neutrons so that only 1 of the neutrons released in each reaction can go on to be absorbed by another uranium.

If not then the nuclear reactor would overheat as too many reactions would happen at once.

Give an example of a material that can be used as a moderator?

Give an example of a material that can be used as a moderator?

Water.

What is a chain reaction?

What is a chain reaction?

A chain reaction is when exactly one neutron from each decay goes on to cause another decay - so the amount of energy released is constant and doesn't increase or decrease.

How is nuclear waste (eg. spent fuel rods) disposed of?

How is nuclear waste (eg. spent fuel rods) disposed of?

It is first stored in cooling ponds.

It will then be put in sealed steel containers and potentially stored deep underground or underwater.

Give one environmental benefit and risk of nuclear power.

Give one environmental benefit and risk of nuclear power.

Benefit - no release of greenhouse gas, no contribution to global warming, doesn't use fossil fuels.

Risk - leak or escape of material could be catastrophic.