INKPHYSICS FLASHCARDS

Particles

Year 12 · 22 cards · fronts and backs

Print double-sided, flipping on the long edge, and each answer lands behind its question. Cut along the card borders.

Definitions in mark-scheme wording, the equations that are not on the data sheet, each lesson's check question, and the misconceptions that lose marks. The same cards run on the website with spaced-repetition scheduling, at inkphysics.co.uk/flashcards.

DEFINITION

Define: Isotopes.

CONSTITUENTS OF THE ATOM

DEFINITION

Define: Specific charge.

CONSTITUENTS OF THE ATOM

EQUATION — NOT ON THE DATA SHEET

Specific charge:

specific charge = ?

CONSTITUENTS OF THE ATOM

CHECK YOURSELF

Calculate the specific charge of an iron-56 nucleus (Z = 26). Take e = 1.60×10^{-19} C and the nucleon mass as 1.67×10^{-27} kg.

Hint: Charge counts protons only; mass counts every nucleon.

CONSTITUENTS OF THE ATOM

SPOT THE ERROR

Say what is wrong with this claim:

Atoms of the same element are identical.

CONSTITUENTS OF THE ATOM

CHECK YOURSELF

Write the decay equation for radium-226 (Z = 88) undergoing alpha decay to radon (Rn), and check both balances.

Hint: The alpha particle takes four nucleons, two of them protons.

STABLE AND UNSTABLE NUCLEI

SPOT THE ERROR

Say what is wrong with this claim:

Positive charges can never stick together.

STABLE AND UNSTABLE NUCLEI

DEFINITION

Define: Annihilation.

ANTIMATTER AND PHOTONS

DEFINITION

The charge of a particle divided by its mass: Q/m, in $C\ kg^{-1}$.

CONSTITUENTS OF THE ATOM

DEFINITION

Atoms with the same number of protons but different numbers of neutrons: the same element with a different nucleon number.

CONSTITUENTS OF THE ATOM

CHECK YOURSELF

Charge: $Q = 26 \times 1.60 \times 10^{-19} = 4.16 \times 10^{-18}$ C.

Mass: $m = 56 \times 1.67 \times 10^{-27} = 9.35 \times 10^{-26}$ kg.

Specific charge: $Q/m = 4.4 \times 10^{7}\ C\ kg^{-1}$. Smaller than a proton's alone, because thirty neutrons added mass without adding any charge.

CONSTITUENTS OF THE ATOM

EQUATION — NOT ON THE DATA SHEET

specific charge = (Q)/(m)

CONSTITUENTS OF THE ATOM

CHECK YOURSELF

$^{226}Ra \rightarrow {}^{222}Rn + {}^{4}He$.

Nucleon check: 226 = 222 + 4. Proton check: 88 = 86 + 2, so radon has Z = 86.

Both books balance, and the element changed because Z changed: that is what decay does.

STABLE AND UNSTABLE NUCLEI

SPOT THE ERROR

Atoms of one element share a proton number but not necessarily a neutron count: isotopes are the same element with different masses. Chemically alike, nuclear-ly different.

CONSTITUENTS OF THE ATOM

DEFINITION

A particle and its antiparticle meeting and converting entirely into two photons, conserving energy and momentum.

ANTIMATTER AND PHOTONS

SPOT THE ERROR

Protons do repel electrically, but inside the nucleus the strong nuclear force overpowers that repulsion out to about 3 fm. Nuclei exist because, at nuclear distances, the strong force wins.

STABLE AND UNSTABLE NUCLEI

DEFINITION

Define: Pair production.

ANTIMATTER AND PHOTONS

CHECK YOURSELF

A slow electron and a slow positron annihilate. Find the minimum frequency of each photon produced. (Electron rest energy 0.511 MeV; $h = 6.63 \times 10^{-34}$ J s.)

Hint: One rest energy per photon; convert MeV to joules first.

ANTIMATTER AND PHOTONS

SPOT THE ERROR

Say what is wrong with this claim:

Antimatter is science fiction.

ANTIMATTER AND PHOTONS

DEFINITION

Define: The weak interaction.

PARTICLE INTERACTIONS AND EXCHANGE PARTICLES

CHECK YOURSELF

In electron capture, a proton in a nucleus absorbs an atomic electron. Write the particle equation, name the exchange particle, and explain how you know the weak interaction is responsible.

Hint: What does the proton become, and what must leave to balance the leptons?

PARTICLE INTERACTIONS AND EXCHANGE PARTICLES

SPOT THE ERROR

Say what is wrong with this claim:

When two things repel, nothing passes between them.

PARTICLE INTERACTIONS AND EXCHANGE PARTICLES

DEFINITION

Define: Hadrons.

CLASSIFICATION OF PARTICLES

DEFINITION

Define: Leptons.

CLASSIFICATION OF PARTICLES

CHECK YOURSELF

Each photon carries at least one rest energy: 0.511 MeV = $0.511 \times 10^{6} \times 1.60 \times 10^{-19} = 8.18 \times 10^{-14}$ J.

Minimum frequency: $f = E/h = 8.18 \times 10^{-14} / 6.63 \times 10^{-34} = 1.2 \times 10^{20}$ Hz.

That is gamma radiation, and detecting the two back-to-back gamma photons is precisely how a PET scanner locates the annihilation.

ANTIMATTER AND PHOTONS

DEFINITION

A single high-energy photon converting into a particle–antiparticle pair, usually near a nucleus, which recoils so momentum is conserved.

ANTIMATTER AND PHOTONS

DEFINITION

The only interaction that can change quark flavour, as when a down quark becomes an up quark and a neutron becomes a proton in beta decay; its exchange particles are the W^{+} and W^{-} bosons.

PARTICLE INTERACTIONS AND EXCHANGE PARTICLES

SPOT THE ERROR

Antimatter is routine experimental fact: every particle has an antiparticle of the same mass and opposite charge. PET scanners in hospitals work by detecting the photons from positrons annihilating with electrons.

ANTIMATTER AND PHOTONS

SPOT THE ERROR

Repulsion is carried, not conjured at a distance: the particles exchange a virtual boson — a photon for electromagnetic repulsion — which transfers the momentum that pushes them apart.

PARTICLE INTERACTIONS AND EXCHANGE PARTICLES

CHECK YOURSELF

$p + e^{-} \rightarrow n + \nu_e$: the proton becomes a neutron and an electron neutrino leaves. Charge balances: +1 - 1 = 0.

The exchange particle is the W^{+}, passed from the proton to the electron.

A proton changed into a neutron, and changing a particle's type is something only the weak interaction can do; neither the electromagnetic nor the strong interaction ever alters identity.

PARTICLE INTERACTIONS AND EXCHANGE PARTICLES

DEFINITION

Fundamental particles that do not feel the strong interaction: the electron, the muon, their neutrinos, and their antiparticles.

CLASSIFICATION OF PARTICLES

DEFINITION

Particles that feel the strong interaction: baryons, made of three quarks, and mesons, made of a quark–antiquark pair.

CLASSIFICATION OF PARTICLES

CHECK YOURSELF

A kaon decays into pions. Identify the interaction responsible and give two pieces of evidence for your answer.

Hint: What happens to strangeness, and how quickly do these decays happen?

CLASSIFICATION OF PARTICLES

SPOT THE ERROR

Say what is wrong with this claim:

Matter is just protons, neutrons and electrons.

CLASSIFICATION OF PARTICLES

CHECK YOURSELF

Using quark charges, show that the proton's charge is +1 and the neutron's is 0, then write the neutron's decay at quark level.

Hint: Add thirds, then change exactly one flavour.

QUARKS AND ANTIQUARKS

SPOT THE ERROR

Say what is wrong with this claim:

Protons and neutrons are fundamental.

QUARKS AND ANTIQUARKS

CHECK YOURSELF

A student proposes that a free proton decays: $p \rightarrow n + e^+ + \nu_e$. Audit the conservation laws, then explain what actually forbids the decay. (Rest energies: p 938.3 MeV, n 939.6 MeV, e 0.511 MeV.)

Hint: Every ledger passes. So check the one thing left.

CONSERVATION LAWS

SPOT THE ERROR

Say what is wrong with this claim:

In particle physics, anything can happen.

CONSERVATION LAWS

SPOT THE ERROR

Protons, neutrons and electrons are just the stable survivors. Accelerators and cosmic rays produce whole families beyond them: muons, pions, kaons, neutrinos — hadrons built from quarks, and fundamental leptons.

CLASSIFICATION OF PARTICLES

CHECK YOURSELF

The decay is a weak interaction.

Evidence one: strangeness changes. The kaon carries $S = \pm 1$ and pions carry $S = 0$, and only the weak interaction permits $\Delta S = \pm 1$; the strong interaction conserves strangeness exactly.

Evidence two: the decay is slow. Strong processes are effectively instantaneous, and the kaon's comparatively long life is the signature of a particle waiting for the weak interaction.

CLASSIFICATION OF PARTICLES

SPOT THE ERROR

Protons and neutrons are not fundamental: each is three quarks (uud and udd). Deep inelastic scattering finds the point-like constituents inside, and even the neutron's beta decay is really one down quark becoming an up.

QUARKS AND ANTIQUARKS

CHECK YOURSELF

Proton, uud: ⅔ + ⅔ - ⅓ = +1. Neutron, udd: ⅔ - ⅓ - ⅓ = 0. Both are whole charges, as hadrons must be.

Decay: one d becomes a u, so udd → uud + e^- + an electron antineutrino, the W^- mediating.

Charge audit at the vertex, in thirds: -1 = +2 - 3. The books balance, and the neutron's decay is one quark's change of flavour.

QUARKS AND ANTIQUARKS

SPOT THE ERROR

Far from anything happening, most imaginable reactions are forbidden. A reaction only proceeds if charge, baryon number, lepton numbers and (in strong interactions) strangeness all balance — audit the books and most candidates fail.

CONSERVATION LAWS

CHECK YOURSELF

Charge: +1 → 0 + 1 + 0 ✓. Baryon number: +1 → +1 ✓. Electron lepton number: 0 → 0 - 1 + 1 = 0 ✓. Strangeness: 0 → 0 ✓. Every quantum number balances.

Energy does not. The products carry at least 939.6 + 0.511 = 940.1 MeV of rest energy, more than the proton's 938.3 MeV, and a free proton has nothing extra to pay with.

Energy conservation forbids the decay, and the proton stays the only stable baryon. Inside a nucleus the binding-energy accounts can differ, which is why β^+ decay happens there.

CONSERVATION LAWS