# U2 - Particles and radiation

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| **What affects the stability of the isotope and why?** | No. of neutrons (i.e., the more neutrons, the less stable) ∵ the strong nuclear force can no longer hold the nucleus together. |
| **How do you find specific charge?** | Divide the charge (C) of the object by its mass (kg). |
| **What does the strong nuclear force / strong interaction do and what is it carried by?** | * Holds electrostatically repelling nucleons together. * Carried by gluons. |
| **What does strong nuclear force give rise to, to what, at which distances, and why?** | * Very short range attraction up to 3 fm. * Balanced attraction between the strong nuclear force and electrostatic force at 1.5 fm. * Very short range repulsion under 0.5 fm. * This is all between individual nucleons.     *The very short range repulsion prevents nucleons collapsing into singularities.* |
| Above 3 fm, the **strength of the strong nuclear force** drops and the **strength of the electrostatic force** takesover ∴ **decreased stability**. | |
| **Give 4 properties of alpha particles** | Highly ionising due to size; low penetration due to size; charge of +2; amu of ≃4. |
| **Why were neutrinos hypothesised?** | To account for conservation of energy and momentum in beta decay. |
| **What happens on the quark-level of beta minus decay?** | * A down quark in the nuclide decays into up quark whilst emitting a W- boson (1). * The W- boson decays into a beta minus particle and anti electron neutrino (1). |
| **What problems do beta minus and beta plus decay solve?** | * Beta minus decays solves too many neutrons. * Beta plus decay solves too many protons. |
| **Give 3 properties of gamma rays** | High frequency; very penetrating; not so ionising. |
| **What is ionisation energy defined as?** | The minimum energy required to remove an electron from its **GROUND STATE** to form an ion. |
| **What is an electron volt defined as?** | The energy of an electron when accelerated through a p.d. of 1 V. |
| **How do particles and their antiparticles differ?** | In all their properties (i.e., charge, lepton number, baryon number, and strangeness) except for rest mass. |
| **What is annihilation?** | When a particle and its antiparticle meet and annihilate converting their mass into energy in the form of photons.    *These particles are moving in opposite directions to conserve momentum.* |
| **What is the equation used for annihilation and why?** | As two particles make two photons. |
| **What is pair production?** | When a photon interacts with an atom (1) and has enough energy to produce a particle and its antiparticle.    *It should be stressed that: any surplus energy becomes kinetic energy and the photon has to interact with something as it’s massless* |
| **What is the minimum energy required of a photon to undergo pair production? What happens above this?** | The total rest energies of the particles involved. For a particle-antiparticle pair, it would be:    Above this, excess energy goes into kinetic energy. |
| **What particles are usually produced from pair production and why?** | Electron-positron pairs due to their relatively low rest mass. |
| **How does the mass of a gauge boson affect the range of its force?** | The greater its mass, the short the range of the force.  *W bosons have a mass 100x of a proton ∴ require a lot of energy ∴ can only exist for little time ∴ cannot travel far. Whereas photons with zero mass have infinite range.* |
| **What are the roles of exchange particles?** | Transfer force, transfer energy, transfer charge (sometimes). |
| **What are the 4 fundamental forces?** | Gravity, electromagnetic force, strong nuclear force, weak nuclear force. |
| **What is gravity and its force carrier?** | The mechanism by which particles with mass attract each other by exchanging gravitons. |
| **What is the electromagnetic force and its force carrier?** | When charged particles repel or attract each other by exchanging virtual photons. |
| **What does the weak force / weak interaction act between, lead to, and what is it carried by?** | * Quarks (∴ all hadrons) and leptons. * Leads to particle decay. * Carried by W+/W-/Z0 bosons.   *This is according to the AQA Physics A Unit 1 2015 Paper.* |
| **What are the 3 key points of Feynman Diagrams?** | * The only axis is time. * Momentum is preserved at each vertex. * The gauge boson must be drawn as a wiggly line. |
| **What is the Feynman Diagram for the repulsion between electrons?** | Two electrons exchange a virtual photon as they repel. |
| **What is the Feynman Diagram for beta minus decay?** |  |
| **What is the Feynman Diagram for beta plus decay?** |  |
| **What is the Feynman Diagram for electron capture?** | An electron from an inner shell is captured by the nucleus and exchanges a W- boson with a proton to form a neutron and an electron neutrino.  *This happens because the nucleus has too many protons yet not enough neutrons.* |
| **Sketch the family tree of particles** |  |
| **What does the strong force / strong interaction act between?** | Quarks (∴ all hadrons). |
| **What is quark confinement?** | Applying enough energy to quarks to “separate” them yet producing a quark-antiquark pair instead. |
| **What are the 6 leptons?** | Electrons, muons, tauons, electron neutrino, muon neutrino, and tauon neutrino. |
| **What are muons and what can they decay into?** | Heavy electrons which decay into electrons, some electron neutrinos, and some muon neutrinos as shown below: |
| **What is a hadron?** | A particle that **IS** subject to strong interaction. |
| **What hadrons and leptons don't decay and why?** | Protons, electrons, and neutrinos ∵ they're the most stable with the least rest energy. |
| **Define baryon and give the structure of 2 baryons** | * A hadron consisting of 3 quarks. * Proton with uud and neutron with udd. |
| **What is a meson?** | A hadron consisting of a quark and an antiquark. |
| **Give 2 examples of mesons** | * Pions (π+, π-., and π0). * Kaons (k+, k-, and k0). |
| **Give an example of a strange particle** | A kaon. |
| **What 3 things are unusual about strange particles?** | 1. Produced by strong interaction (∴ strangeness **IS** conserved) **YET** decay by weak interaction (∴ strangeness **IS NOT** conserved). 2. They are always produced in particle-antiparticle pairs (∴ strangeness of 0 is conserved in strong interaction). 3. They have relatively long half-lives. |
| **What do kaons decay into and by what?** | Pions by weak interaction. |
| **What is a lepton?** | A particle that **ISN'T** subject to strong interaction. |
| **What 4 properties are usually conserved in particle physics?** | Charge, baryon number, lepton number **OF EACH FAMILY**, and strangeness (only for the strong interaction).  *This is alongside energy and momentum.* |
| **How should it like when working out which particle should be used?** | *Total lepton number, muon and electron lepton number.* |
| **Define threshold frequency (f0) under the photoelectric effect** | Minimum energy required to overcome the work function |
| **What is the work function?** | The minimum energy required to remove an electron from the surface of a specific metal. |
| **What 4 observations made under the Photoelectric Effect support the particle theory over the wave theory?** | * Electrons are only emitted above a threshold frequency (f0); irrespective of intensity. * The KE (max) of emitted electrons depends on the frequency of EM radiation. * The no. of photoelectrons emitted per second depends on the intensity of EM radiation. * Low intensity EM radiation (above f0) results in the immediate emissions of electrons. |
| **Why does ‘electrons being emitted above f0 despite intensity’ support the particle theory over the wave theory?** | * Wave theory - light consists of waves with energy ∝ intensity ∴ greater intensity should cause emission of photoelectrons regardless of frequency. * Particle theory - light consists of photons with energy E = hf and the metal emits photoelectrons when f ≥ f0.   *For the wave theory, imagine shining a lot of light onto one square metre.* |
| **Why is ‘KE (max) depending on the frequency of EM’ support the particle theory over the wave theory?** | * Wave theory - energy ∝ intensity ∴ greater intensity ⇒ higher KE electrons. * Particle theory - the KE (max) depends on frequency and work function as defined by KE (max) = hf - ϕ. |
| **Why does ‘the no. of photoelectrons per second depends on the intensity of the EM radiation’ support the particle theory over the wave theory?** | * Wave theory - greater frequency ⇒ more waves arriving per second ∴ intensity should have no effect. * Particle theory - the no. of photons arriving per second depends on intensity ∵ each photon has a fixed energy and one electron absorbs a photon in a one-to-one interaction. |
| **Why does ‘low intensity EM radiation (above f0) resulting in immediate emission of electrons’ support the particle theory over the wave theory?** | * Wave theory - energy ∝ intensity ∴ lower intensity means it must take time for energy to accumulate to free an electron. * Particle theory - no. of electrons emitted ∝ intensity ∴ whilst few arrive for low intensity, theystill have sufficient energy ⇒ immediate electron emission. |
| **Why do photoelectron kinetic energies vary to a maximum?** | * Ek (max) = hf - ϕ. * Each photon’s energy is the same (due to frequency) ∴ more energy is required to remove electrons further from the surface due to more attraction. |
| **How does the photoelectric effect equation look when plotted as a line?** | The y-intercept being the work function and the x-intercept being the threshold frequency. |
| **What happens during the gold leaf experiment?** | The zinc rod/plate is negatively charged ∴ gold leaf hangs tilted. Shining UV light causes it to discharge ∴ leaf falls down. |
| **What is the stopping potential?** | Minimum p.d. required on a metal plate to attract all photoelectrons emitted from the surface back. |
| **Describe the vacuum photocell** | * The metal surface is the anode (∴ positively charged so can attract e-’s back). * Light with frequency > f0 is shone on the anode so that photoelectrons are emitted. * Applying a sufficient p.d will cause electrons to be attracted back ∴ current flows * The photocell is evacuated to prevent photoelectrons colliding with air molecules. |
| **What is the equation linking Ek (max) to stopping potential?** | *As V = E/Q, multiplying it by the charge of an electron gives J.* |
| **What’s the difference between excitation with electrons and photons?** | * An **electron** can **deliver more energy** (e.g., a 5.3 eV electron colliding with and moving another electron up by 4.9 eV before mar carrying on with 0.4 eV). * A **photon** has to **deliver** the **exact amount** (e.g., exactly 4.9 eV) as it’s absorbed. |
| **What is de-excitation?** | When an electron moves from a higher energy level to a lower energy level whilst emitting a photon of fixed frequency. |
| **What is the excitation/de-excitation amount determined by?** |  |
| **What happens in fluorescent lights?** | 1. Electrons are accelerated via a tube of mercury vapour atoms using a voltage, collide the electrons, transferring energy and thus exciting them. 2. Upon de-exciting, they emit UV photons of energy = difference in energy levels. 3. Fluorescent coating absorbs the UV photons, causes electrons to excite which upon de-exciting indirectly, emit visible photons.   *The coating has to be on the inside of the glass as glass can absorb UV too.* |
| **Why must mercury gas be at a low pressure in fluorescent lights?** | * Electrons must be able to travel a sufficient distance to gain sufficient energy required for excitations (1). * Electrons need to be able to pass through. |
| **What can you view an the spectrum of a light source using?** | A diffraction grating and spectrometer. |
| **What is a continuous spectrum?** | An emission spectrum that consists of a continuum of wavelengths. |
| **What is an emission spectrum and an absorption spectrum?** | * An emission spectrum is a spectrum of electromagnetic radiation emitted from electrons de-exciting:      * An absorption spectrum is a spectrum of electromagnetic radiation transmitted via a substance with dark vertical lines corresponding to waves absorbed. |
| **What wave-like and particle-like properties do electrons exhibit?** | * Wave-like - electrons diffract and interfere when passing through a small enough gap. * Particle-like - electrons are deflected in electric and magnetic fields. |
| **How can the wave-like nature of electrons be observed?** | 1. Fire electrons via a crystalline structure causing them to diffract onto a fluorescent screen. 2. An illuminated pattern of concentric bright and dark circles is formed corresponding to areas of constructive and destructive interference respectively.     *These are fired by accelerating them through a potential difference. A larger potential difference would mean they’re accelerated more and gain more kinetic energy leading to a smaller wavelength and thus less diffraction so closer rings.* |
| **What structure is required for electron diffraction and why?** | * Crystalline structure. * The gaps between atoms ≅ De Broglie wavelength of electron for maximum diffraction to occur. |
| **Why is light both a wave and particle?** | * It undergoes things such as refraction, diffraction, and dispersion. * Yet, also undergoes the photoelectric effect. |
| **What is the De Broglie wavelength?** | The wavelength of matter. |