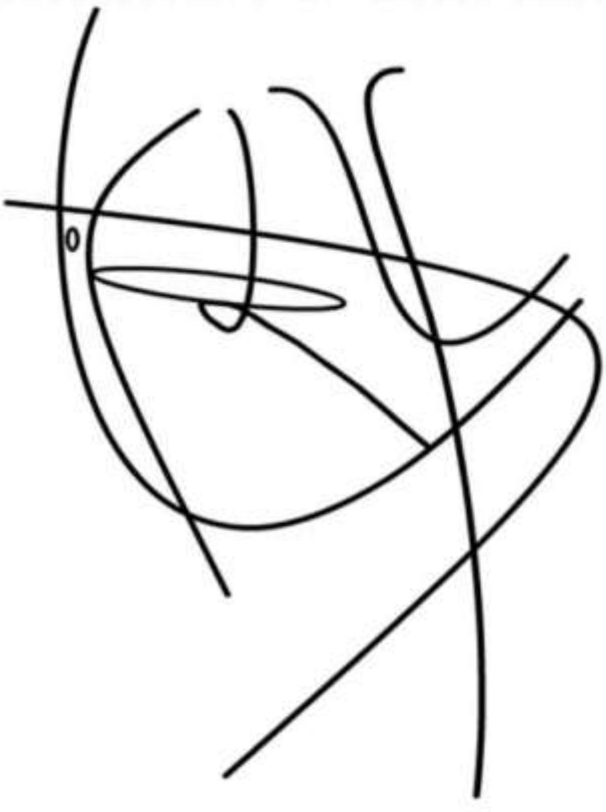
A-Level Physics Revision

Unit 1 – Particles, Quantum Phenomena & Electricity



By Daniel Powell

Foreword

This book is created to form the basis of reference or revision for AS Unit 2 for AQA Physics. It should also be appropriate for other courses as well and is a comprehensive study of the topics that usually come up in exams. The ideas are pulled together from the past 20 years of study of Physics as student and then teacher so I hope it is of use.

Please Enjoy….

Daniel Powell

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Chapter 1 Atomic Physics

1 Inside Atoms

Nucleons: Protons and Neutrons make up the nucleus. They have a mass of 1 relative to each other but an actual mass of 1.67 x 10^{-27}kg. The proton carries a charge of +1.6 x 10^{-19}C. In certain calculations you must use the actual values.

Electrons: Are negatively charged -1.6 x 10^{-19}C and have a opposite charge to that of a proton.

Isotopes: Isotopes are simply elements with more or less neutrons. This means that they can be more unstable than the ones usually found in the periodic table. Often Isotopes appear in small % so affect the relative mass of a sample. Carbon is a good example with many isotopes

C^{14} is b- emitter (5730 years $T_{1/2}$)

C^{13} is stable

C^{12} is stable

C^{11} is b+ emitter (20.3min $T_{1/2}$)

C^{10} is b+ emitter (19.2s $T_{1/2}$)

Ions: Of course ions will be trickier at A level. Instead of thinking of the removal of an electron as – -1 or the atoms charge becomes +1 to form a +1 ion i.e. Na+.

Now we think about ions as….

1.6×10^{-19}C -> +1

3.2×10^{-19}C -> +2

4.8×10^{-19}C -> +3

Specific Charge: When we think about an ion, atom or particle it has what is called a specific charge. This is a simple idea of the charge C/mass kg so should come out in Ckg^{-1}. So the specific charge on a magnesium ^{24}Mg ion is found by adding all nucleon masses which is 24 x 1.67×10^{-27}kg. Then the overall ion charge which is 3.2×10^{-19}C and dividing to produce a value of $8.04 \times 10^{6}CKg^{-1}$. You don't add all the charges as they cancel out.

What is specific charge?

This is the amount of charge per kilogram of matter….

$$\text{Specific Charge } (\text{Ckg}^{-1}) = \frac{\text{Charge (C)}}{\text{Mass (kg)}}$$

This is the specific charge on a proton….

$$\text{specific charge} = \frac{Q}{m} = \frac{1.6 \times 10^{-19}}{1.67 \times 10^{-27}} = 9.6 \times 10^{7}\ \text{Ckg}^{-1}$$

Just be clear if you are dealing with items with different masses and charges….

- Nucleus
- Ion
- particle

Periodic Table: In the periodic table all atoms have a symbol A = mass or protons + neutrons in relative form i.e. 1+2 = lithium. Z = proton number. You must learn these terms!

Periodic Table

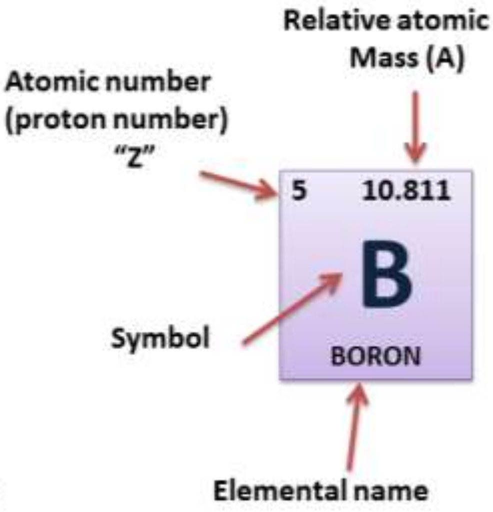
This is an example of how elements are shown on a periodic table.

It is more complex than GCSE as the relative atomic mass is shown as a decimal.

In this case the Boron occurs as 80.1% with 11 nucleons and 19.9% as 10 nucleons.

We take an average of the two weighted for 80%/20% to find the relative atomic mass of a sample found occurring naturally. This changes when the sample is pure.

We often use "A" for the total atomic mass (neutrons + protons) and "Z" for atomic number or proton number

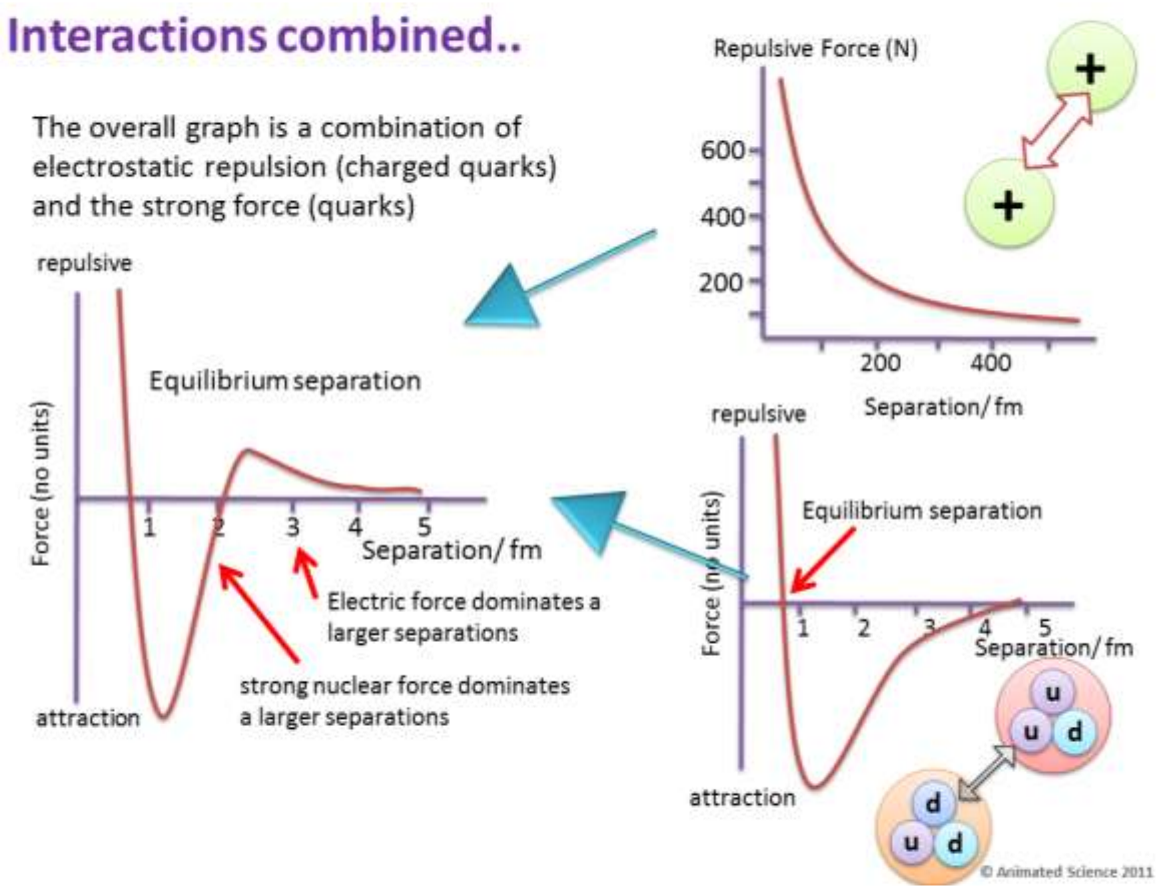


Probing the Nucleus: Rutherford did an experiment to investigate the nucleus. He fired alpha radiation at the nucleus and found that most went through and a few returned deflected at 180° or near to. The conclusion was that the nucleus was very small and very positive with a lot of empty space around it

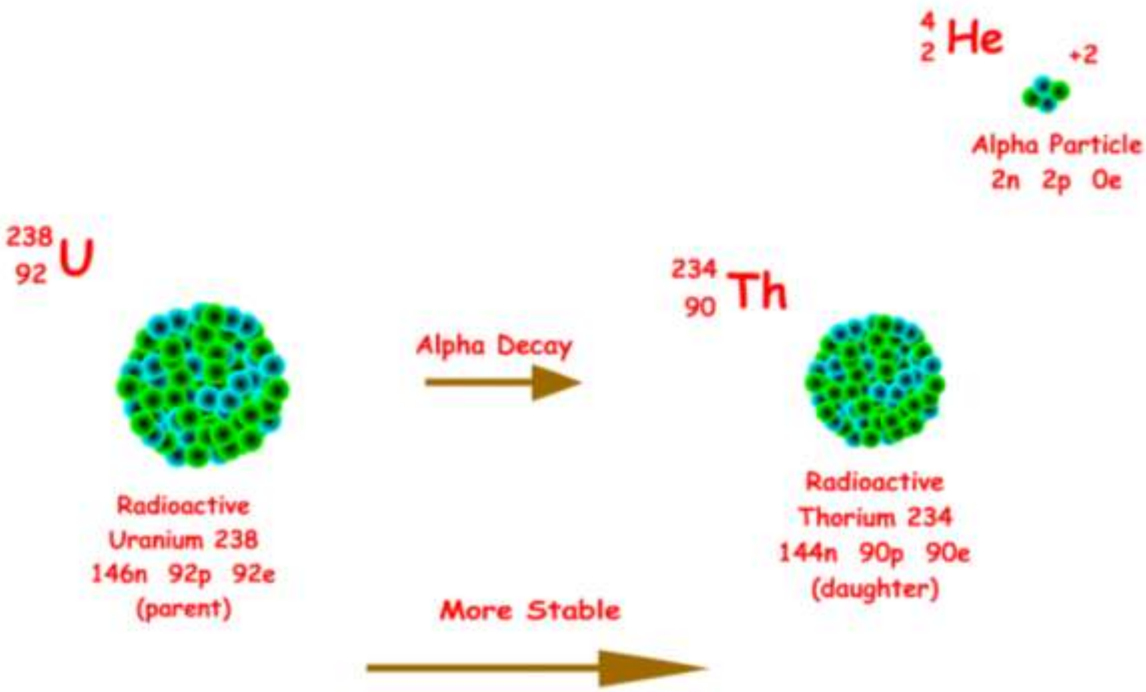
2 Nuclei

Strong Force: Acts on nucleons only as they contain quarks. It keeps the nucleus stable; short-range attraction to about 3 fm, very-short range repulsion below about 0.5 fm. This balance causes nucleons to be happy at the distance to make a stable atom.

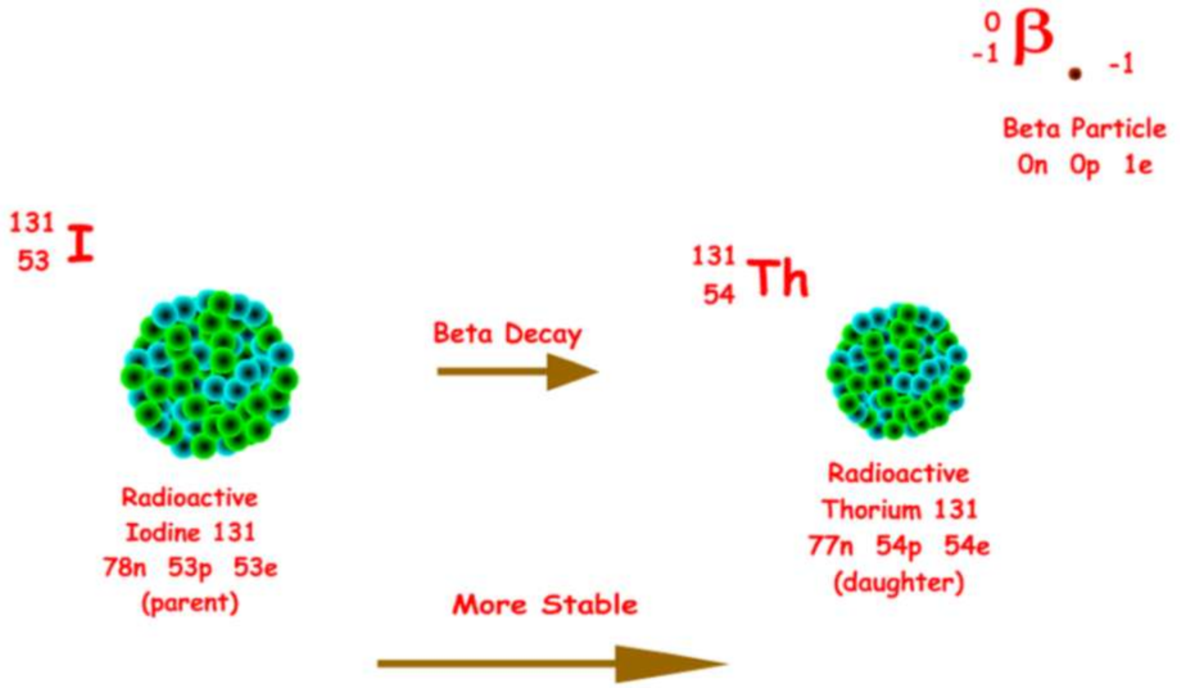
Electrostatic Force: All charged particles i.e. protons, electrons, positrons, muons etc.. either attract or repel each other. The force gets very large at small separations.



Alpha Decay: This is where 4 nucleons (2p &2n) split from the nucleus of an atom to make the atom more stable. Z & A become Z-2 & A-4. Alpha always have the same energy for a particular atom i.e. 5MeV.



Beta (β-) Decay: An atom has a nucleon decay via the weak interaction. A neutron converts to a proton and emits a β^- particle (or e-) and an electron anti-neutrino. There is symmetry for charge before and after. The particle and anti-particle share the energy of the decay differently for each emission.



Beta (β+) Decay: This is the same process as Beta (β^-) but opposite as a proton converts to a neutron and emits a beta + particle (or e+ positron) and an electron-neutrino. There is symmetry for charge before and after. The particle and anti-particle share the energy of the decay differently for each emission.

Gamma Decay: A Gamma ray (γ) is emitted from the atom which has no charge or mass.

Neutrinos: These are produced in the Sun by the weak interaction (β+ or β- decay). They have no charge or mass and are not affected by strong or electromagnetic force. They are fundamental particles. There are three types, or “flavours”, of neutrinos: electron neutrinos, muon neutrinos and tau neutrinos. Each type also has a corresponding antiparticle, called an antineutrino with an opposite chirality. You will not need the tau for AS Physics.

Neutrinos are thought to be the most numerous particle in the universe and are thought to outnumber protons and neutrons by a factor of around 1,000,000,000 (there are 100 in every cubic cm of space).

It is thought that the neutrino has **close to no mass** and carry **no charge** which leads to the difficult task of detecting them.

The first neutrinos where created at the time of the ‘Big Bang’ and are continually being produced all the time through **Beta radiation**.

Like with all the other fundamental particles the neutrino has an anti-neutrino and both interact very weakly with other particles (which is also why they are so difficult to detect).

The main difference between the neutrino and the anti-neutrino is in fact it's direction of spin. (not required for AS)

3 Photon Energy

Electromagnetic Waves: This is energy in the form of waves. The formula to express the speed that an EM wave travels in a vacuum is $c = f\lambda$. The speed is always $3.00 \times 10^{8} ms^{-1}$. We often use the suffix of nm for the wavelength visible light i.e. 500nm or 500×10^{-9}m

Photons: Electromagnetic waves are produced when a charged particle such as an electron collides with atomic electrons to make electrons change shells or very fast electrons are slowed down in matter to produce x-rays. Photons have zero mass but carry both energy and momentum. We call these waves or short bursts "photons" or wavepackets. We can think of them like particles or packets of energy containing an energy $E = hf$ (where f is the frequency of the wave, h = the plank constant 6.63×10^{-34}Js). Or as $c=f\lambda$. $E = hc/\lambda$

A simple example would be…. "what is the frequency of a 600nm EM wave?"

$c/\lambda = 3.00 \times 10^{8} ms^{-1} / 600 \times 10^{-9}m = 5.00 \times 10^{14}Hz$

What is the Energy of the wave…..

$E = hc/\lambda = (6.63 \times 10^{-34}Js \times 3.00 \times 10^{8} ms^{-1})/ 600 \times 10^{-9}m = 3.32\ 10^{-19}J$ or 2.07eV

Calculations & Maths

The known constants for these calculations are always;

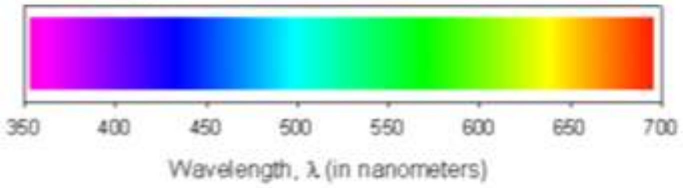
$h = 6.63 \times 10^{-34}$ Js (plank constant)

$c = 3.00 \times 10^{8}$ ms^{-1} (speed of light in a vacuum)

- Using our formulae of **$E = hf$** or since **$c=f\lambda$, $f= c/\lambda$** we could say for neatness and simplicity that;

$$E = hc/\lambda$$

- Try working out the energies for different frequencies of visible light to test out your skills. You should get a range of answers i.e. 3×10^{-19}J. Try 350nm, 590nm, 700nm



The Electron Volt: The electron volt is a very simple way of expressing a little quantity of energy. It saves us using tricky figures i.e. $3.32\ 10^{-19}$J = 2.07eV. What we do is simply divide the energy in Joules by the value of the charge on the electron or $1 \times 10^{-19}$$JeV^{-1}$.

The Electron volt....

Charge on the electron is **1e = 1.6x10^{-19} C** (eq1)

But we also know from electrical circuits; **1V = 1 JC^{-1}**

So by multiplying **equation 1** by 1V on each side we get:

1e x 1V = 1V x 1.6x10^{-19} C (eq2)

Then sub in 1JC^{-1} for the voltage part on the RHS of **(eq2)** gives us;
1e x 1V = 1JC^{-1} x 1.6x10^{-19} C

This leaves us with definition: **1eV = 1.6x10^{-19} J**
1MeV = 1x 10^{6} x 1eV

We can use this a smaller version of the joule (not a smaller version of the volt!)

Laser Beams: A laser beam is simply a lot of photons all discharged at the same time and in phase with each other. This is a property called coherence. We mean all the ups and down happen at the same time and they are of the same frequency. The power of a laser beam of energy E = hf…… P = nhf where n is the number of photons.

AQA Spec A Physics Unit 1

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