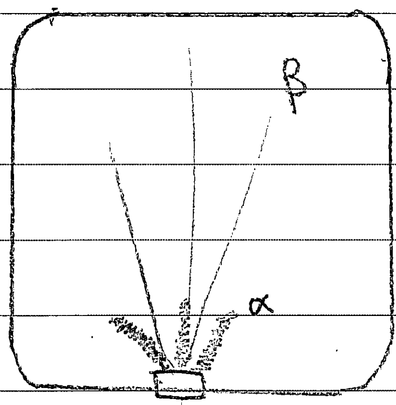
(a) i) A wilson cloud chamber is used to observe the ionisation tracks that different forms of radiation leave behind them as they move through the chamber. Alpha particles are very large and produce thick tracks as they ionise the atoms in the cloud chamber. Beta particles have less ionising ability and so create fewer nucleation centres for condensation to occur. They are longer and thinner.



ii) $^{218}_{84}Po \rightarrow \, ^{214}_{82}Pb \rightarrow \, ^{4}_{2}He \, (\alpha)$

mass of products − mass of resultants

$= 218.00897 - (213.99981 + 4.00260)$

$= 0.00656 \text{ u}$

$0.00656 \times 931.5 = 6.11064 \text{ MeV}$

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(b) $\lambda = 0.2 \times 10^{-9}$

$h = 6.626 \times 10^{-34}$

$m = 1.675 \times 10^{-27}$

$\lambda = \frac{h}{mv}$

$\lambda mv = h$

$v = \frac{h}{m\lambda}$

$v = \frac{6.626 \times 10^{-34}}{1.675 \times 10^{-27} \times .2 \times 10^{-9}}$

$v = 1977.91$ m/s

ii) Unlike other sub-atomic particles, neutrons have no charge. This means they can be fired into the nucleus of an atom without interfering with the electrons. As such, neutrons can be used to probe the atomic nuclei of various materials. Furthermore, given de Broglie's hypothesis, neutrons have a specific wavelength. This means we can observe changes in their wavelength to make observations about the energy transfers in collisions.

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(c) One of the main achievements of the Bohr model was it's ability to explain the hydrogen emission spectrum. Bohr observed the emission lines and combined this with Planck's hypothesis to come up with his first two postulates:

1) whilst in orbit, electrons occupy fixed energy levels, and are in a stable state
2) when an electron gains or loses energy according to $E=hf$, it moves up or down to a different energy level.

When electrons fall back down, they emit EMR. The magnitude of this loss of energy determines the frequency of the waves emitted. As such, Bohr's "energy levels" heavily relied upon and explained the hydrogen emission spectrum. Thus, the spectroscope was extremely important in the development of his atomic model.

If you require more space to answer parts (a), (b) and (c) of the question, you may ask for an extra writing booklet.

If you have used an extra writing booklet for parts (a), (b) and (c) of the question, tick here. ☐

(d) i) Davisson and Germer observed the interference pattern produced when they fired electrons at a nickel crystal. The pattern was evidence for diffraction, a wave property. As such, they concluded the following: Electrons do exhibit wave properties, according to De Broglie's proposal. Calculations based on the interference pattern concur with his equation for matter waves: $\lambda = \frac{h}{mv}$

ii) This experiment was extremely significant because it explained the stationary state of electron orbits. Rutherford concluded that electrons orbit in stationary states and do not lose energy, but he was unable to explain why. Similarly Bohr quantised these energy levels, $E=hf$, but was still unable to explain why electrons, as accelerating charges, did not emit energy. The Davisson - Germer experiment proved the existence of matter waves, and suggested that electrons were not accelerating charges at all, but rather standing waves, with the wavelength corresponding to the energy shell. This conclusively explained the main problem with the Rutherford - Bohr model.

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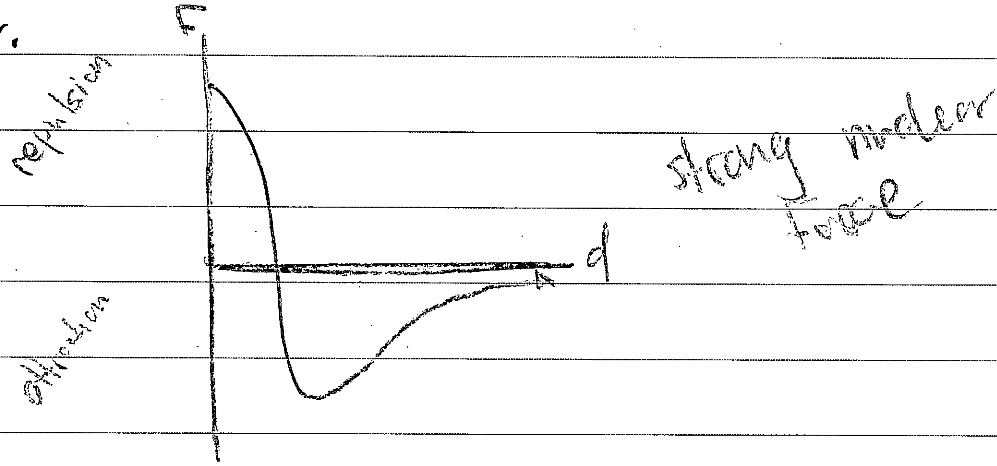
(e) By analysing collisions within the large Hadron collider, scientists have made great advances in our knowledge of subatomic particles. It is now known that matter consists of more than protons, neutrons and electrons. The discovery of quarks and leptons has revolutionised the current scientific model of the atom. The diagram below shows this information.

quark	charge	lepton	charge
up	+ 2/3	electron	-1
down	- 1/3	electron neutrino	0
strange	+2/3	muon	-1
charm	- 1/3	muon neutrino	0
top	+ 2/3	tau	-1
bottom	- 1/3	tau neutrino	0

As such, scientists now know that protons are made of two up quarks and one down quark. Conversely, neutrons are made of two down quarks and one up quark. This model has allowed the prediction of a whole range of particles, and explains them using a very simple model.

Secondly, we have advanced in our knowledge of the four fundamental forces, namely gravity, electromagnetic, strong and weak. This has greatly increased our knowledge of the binding forces in the nucleus, and explains the stability of the nucleus despite the strong repulsive forces between protons. We now know that the strong nuclear force acts between all nucleons. This explains why neutrons are necessary for the stability of the nucleus, as they hold protons apart (reducing their repulsion) and holding them together.



Finally, we have gained new knowledge of Bosons, force particles. This has brought about revolutionary understanding of the nature of forces, and why they display the properties they do.

strong force	gluons
weak force	weakons
electromagnetic	photons
gravity	gravitons ???

As a result of these three advances in knowledge of the forces and particles involved in the nucleus, our newfound understanding of the structure of matter opens up window of opportunity for advances in nuclear power, research and more.

If you require more space to answer parts (d) and (e) of the question, you may ask for an extra writing booklet.

If you have used an extra writing booklet for parts (d) and (e) of the question, tick here. ☐