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(a)(i) A nucleon is a constituent particle of the nucleus. Nucleons include protons and neutrons.

(ii) Nucleons are hadrons (protons, neutrons) and are affected by the strong nuclear force and obey Pauli's Exclusion Principle. Leptons (electrons, neutrinos), however, ~~do not obey~~ are not affected by the strong nuclear force while gauge bosons (photons, gluons, W, Z°) are not affected by the strong nuclear force and do not obey Pauli's Exclusion Principle.

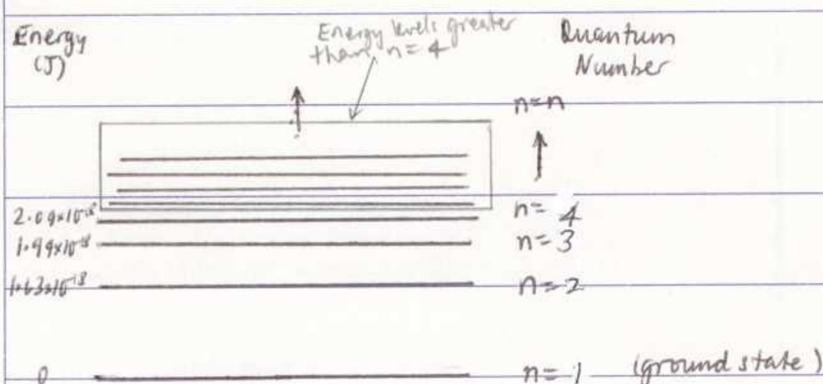
b)(i) $n = 4,\quad E_4 = 2 \cdot 04 \times 10^{-18}\,J$

$n = 3,\quad E_3 = 1 \cdot 94 \times 10^{-18}\,J$

$\therefore\quad \Delta E = E_4 - E_3 = 2 \cdot 04 \times 10^{-18} - 1 \cdot 94 \times 10^{-18}$

$\Delta E = 1 \times 10^{-19}\,J$

(ii)



For $n > 4$ the energy levels lie above the successive energy levels

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(c) Alpha particles are ionised helium nuclei, beta particles are electrons and gamma rays are highly energetic electromagnetic radiation photons. The first-hand investigation involved first determining the background count then observing the penetrating power through a range of materials including air, cardboard, aluminium foil, aluminium plate and lead plate. The method went as follows:

1. Use a geiger counter or similar device to determine the background count for 30 seconds. Perform this three times and average. This is the background count.
2. Place the alpha source 4cm away from the counter and record the count for 30 seconds. Repeat this again and average the result. Subtract the background count from this. This is the actual count rate.
3. Repeat step 2 ~~for~~ the beta and gamma source.
4. Repeat step 2 and 3 except place a piece of cardboard in front of the source.
5. Repeat step 4 for Al foil, Al plate and Pb plate.
6. Tabulate all results (actual count rate) and hence determine the relative penetrating power of each radiation.

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.(c) Thus the penetrating power of each radiation was found by first determining the background count from natural radiation sources. Then the geiger counter was used to take the count rate for 30 seconds for the alpha, beta and gamma sources in 4cm air. This was repeated twice. The same procedure was repeated except aluminium foil, aluminium plate and lead plate were placed in front of the source and the count taken. At all times the distance between the radiation source and the geiger counter was kept constant. The count rates from each test had the background count subtracted from it and this was the actual count rate. The results were tabulated and from this we were able to determine the relative penetrating power of each form of radiation. Alpha was the least penetrating as it was stopped by cardboard, beta had a penetrative power somewhere between alpha and gamma and was stopped by Al plate while gamma was the most penetrative and was partially stopped by lead plate. At all times the radioactive sources were handled with tongs and were kept at a maximum distance as possible from humans as a safety precaution.

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(c) Also the sources were kept in a lead-lined box when not in use as a further safety precaution.

(d) The Manhattan Project was a pivotal moment in human history as for the first time humanity possessed the power to destroy itself. The nuclear bomb was the result of the tireless work of scientists after President Roosevelt initiated the project at the behest of Albert Einstein, who later regretted urging Roosevelt to produce an atomic bomb. The Manhattan Project furthered scientific advances in nuclear physics which later resulted in the construction of commercial nuclear fission reactors. These nuclear reactors produced electrical energy from a sustained, controlled nuclear fission reaction. It provided an alternative to fossil fuels but also resulted in safety issues such as disposal of nuclear waste and accidents such as Chernobyl and Three Mile Island. Thus the Manhattan Project led to the development of nuclear reactors that have provided benefits and disadvantages for society. The development of the nuclear bomb also allowed

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(d) the Americans to speed up the end of World War II in an effort to save lives, which paradoxically resulted in the killing of hundreds and thousands at Hiroshima and Nagasaki. The Manhattan Project also plunged the two superpowers, the United States and the Soviet Union into a Cold War which resulted in the largest arms buildup in history. For many years society stood on the brink of nuclear annihilation as both powers stood ready to destroy each other. It wasted precious resources that could have been used to eradicate disease and hunger. The Manhattan Project resulted in the production of a nuclear weapon and with the Cold War over and the breakdown of the Soviet Union, the advent of nuclear terrorism. The attacks on America recently have sparked increased fears of nuclear terrorism in the US. Thus the development of nuclear weaponry from the Manhattan Project has resulted in benefits for society and well as major disadvantages. Mankind has the power to destroy itself and there are some who would not hesistate to use it as a terror device. The advancements in nuclear physics by the Manhattan Project has led to

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(d) some peaceful benefits and terrifying outcomes for society

(e) Chadwick is credited with the discovery of the neutron, a neutral particle first postulated by Rutherford to overcome the difficulties in atomic weight. Enrico Fermi's work led to the discovery of the neutrino later by other scientists, and also produced the world's first nuclear reactor called Chicago Pile 1.

Chadwick's work led to an increased understanding of the nucleus with his discovery of the neutron. He showed that when beryllium was bombarded by alpha particles, it was neutrons that were emitted and not gamma rays that the Curies thought at the time. By using the Laws of Conservation of Momentum and Energy he clearly showed that the particle had a mass similar to a ~~neutr~~ proton and was neutral, ie. a neutron. Chadwick's work into the neutron led to an increased understanding of the nucleus. His work also led to the use of neutrons as matter probes. Other scientists realised that the neutrons discovered by Chadwick could be used to probe matter and atoms because they were uncharged,

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(e) and thus would not interact with matter like electrons and protons, and had a suitable de Broglie wavelength which could be used for matter probes. Thus Chadwick's work on the neutron allowed other scientists to increase their understanding of the atom by being able to probe further into the atom through the use of neutrons.

Chadwick's work on the neutron also led Fermi to correctly believe that neutrons would be excellent nuclear initiators. Since they were uncharged the neutron would be able to approach the atom without repulsion and possibly cause it to split. The culmination of Fermi's work led to the development of the world's first artificial nuclear reactor that proved conclusively that atoms could indeed be split. Fermi's work also included the neutrino as first postulated by Pauli and this allowed for a greater understanding into beta decay and the weak nuclear force which governs it. The neutrino ~~is~~ a massless, neutral particle that travelled at the speed of light and had spin, momentum and angular momentum. It was postulated in order to maintain the Laws of Conservation.

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(e) Fermi's work led later to its discovery and also an increased understanding of the atom on the subatomic level. Fermi provided scientists with the basis for other work into subatomic particles such as muons and neutrinos. Chadwick's work on the neutron also increased scientists' understanding of the binding forces in the nucleus. It was found that the strong nuclear force was responsible for holding the nucleus together while neutrons added to the stability of in particular heavy atoms by increasing the strong nuclear force between nucleons while not adding to the forces of electrostatic attraction because it was a neutral particle.

Thus the advancements in science made by Chadwick and Fermi increaced our understanding of the atom through Chadwick's discovery of the neutron and Fermi's work on nuclear fission. Their work allowed other scientists to perform experiments and theorise further that resulted in further understanding of the atom,