Student 3: Low Merit
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A report to the Prime Minister's Chief Science Advisor

Fusion is a process which occurs naturally within the sun and the stars. It is when two light nuclei combine to form a heavier nucleus. Not only is this new nuclei formed, but energy is released. Controlled fusion reaction have potential to produce up to 100 times the amount of energy required to start the reaction, which is why countries around the world are researching and developing methods of controlled nuclear fusion. Nuclear energy would provide the world with an almost endless supply of energy, to meet rising demand for power. This report will include physics theories relevant to nuclear fusion, as well as other information which will help to explore the possibility of nuclear fusion reactors potentially being used in New Zealand in the future. Fusion reactions to produce large amounts of
1 energy commonly involve two dense isotopes of Hydrogen fusing to form Helium and releasing a neutron as well as a considerable amount of energy. The isotopes of Hydrogen are deuterium ($\frac{1}{2}H$) and tritium ($\frac{1}{3}H$). The equation for such a fusion reaction is $\frac{1}{2}H + \frac{1}{3}H \rightarrow \frac{4}{2}He$ + 1n (+energy). The two reactants are easily accessed, as deuterium is common, found in seawater and tritium can be produced (from a fairly common element called lithium which is found is soil) by bombarding the lithium with high energy neutrons. For a nuclear fusion reaction to occur, there are specific requirements that must be achieved in order to start a reaction. These include extremely high temperatures, high pressures and densities. Since no container on Earth can hold plasma millions of degrees hot, there are two methods that are currently used to carry out controlled fusion reactions— magnetic confinement and inertial confinement.

1 The coulombic repulsion of atoms is a barrier to controlled nuclear fusion. Positively charged atoms repel one another due to their like charges. The temperature must be very hot In order for nuclei to overcome their force of repulsion, thus the fusion reaction is thermonuclear. The nuclei must he heated millions of degrees, in fact, over 100,000,000°C, in order for deuterium and tritium to overcome their repulsive forces and fuse to form helium. This causes the gas to become extremely hot, and electrons are removed from the nucleus (the atom hence becomes ionised.) Scientists consider this to be the form of plasma, where the matter is composed of electrically charged particles. Effectively, it is the fourth state of matter. At this extremely high temperature, atoms are within very small distances from each other, and so the strong nuclear force (a very strong force which holds nucleons together) is able to overcome the force of repulsion, allowing nuclei (deuterium and tritium) to fuse and form a new nucleus. The nuclear strong force is able to hold the nucleus (helium) together, even against the huge force of repulsion between electrons or protons. However, its short range means that atoms must be extremely close together for the nuclear strong force to have an effect. By heating the atoms :deuterium and tritium) up such a high temperature, their kinetic energy increases dramatically„ and thus they move faster and this results In more collisions between atoms, with greater force, hence more opportunities for the nuclear strong force to take hold and nuclei to fuse into a denser nucleus (helium). Therefore, a higher temperature is necessary for the columbic barrier to be overcome and fusion to occur. Therefore, deuterium and tritium are able to fuse and form helium.

(2) Energy is required to separate the nucleons from a nucleus, i.e. break apart the nucleus. This is called the binding energy. The final nuclei formed in this fusion reaction ($^{4}_{2}He$) is lighter in mass than its constituent parts (nucleons from deuterium and tritium). This means that some of the mass has been released as energy. According to the equation $E=mc^2$ energy is equivalent to the change in mass which is also known as the mass defect. (The value of c remains constant, meaning energy is proportional to mass and vice versa.) Energy and mass are interchangeable, thus the binding energy is equal to the mass defect. The equation shows that any change in mass is reflected in the energy released. When deuterium ($^{1}_{2}H$) fuses with ($^{1}_{3}H$) tritium), they form Helium ($^{4}_{2}He$) which is heavier than its constituent parts. This mass is, thus, not completely lost, but released as energy. Therefore, the more mass lost, the greater the binding energy ($E=mc^2$). Because Helium is lighter than deuterium and tritium summed, it has a greater binding energy per nucleon (as $E=mc^2$) and thus it is more stable.