Student 1: Low Excellence

Note: This student evidence comes from student work related to the task FAQs. The following is a snippet of the complete report that was written by the student.

Sometimes you hear that radioactive substances have been used in medicine. Why don't they cause cancer in patients?

If a radioactive substance is to be used inside the body for imaging (eg PET scanning) or for diagnosis (like some thyroid treatments) it always has a short half-life so that the body is exposed to radiation for as short a time as possible. Half-life is the time it takes for a mass of radioactive substance to decay to half. Because radioactive substances have an exponential decay, after 5 half-lives, the mass will have decayed to $\frac{1}{2^5}$, which is $\frac{1}{32}$ of what it was at the start. A small as possible mass is used in the first place so after 5 half-lives there is not much left to cause any damage. [1] However, you have to have a half-life that gives enough time to do the treatment, if it was only a few seconds you wouldn't even get it to the patient before it was all decayed out. A half-life of a few hours seems to be the best.

When a radioactive atom decays it produces either an electron (beta decay) or an alpha particle (alpha decay). In both, the atomic number of the atom changes because charge will have been lost from the atom. If the new atom has a different atomic number it must be a different substance. [2] It is important that this new substance is not radioactive too, otherwise the danger will still continue.

What does ionising ability mean?

For a particle to ionise an atom it needs to supply the atom with sufficient energy to overcome the energy holding the electron in the atom. This can be done by either knocking it out or by "eliminating" an electron from the shells around the atom. This is ionising radiation. Alpha particles, because of their relatively high (+2) charge and their relatively high physical mass (2 × proton + 2 × neutron) and therefore size, can very easily knock out and absorb an electron from an atom and so ionise the atom. A beta particle (an electron) is about 8000 times smaller than an alpha particle but it travels a lot faster. It will still ionise as it is charged and has a reasonably high energy but will not ionise as well as an alpha particle. A gamma ray has no mass (rest mass), is not charged and has a velocity of the speed of light. The chances of it interacting with an atom are reduced but possible. If gamma radiation hits an outer electron of an atom sometimes the electron gains enough energy from the gamma photon to be removed from the atom and so the atom becomes ionised. Therefore gamma rays have high penetration ability but little ionising ability compared to alpha and beta particles [3]

How do the radioactive decays cause the reactor to heat up and make electricity?

When there is a nuclear reaction heat is produced. One of the reactions that might happen is:

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{55}Cs + {}^{95}_{37}Rb + 3{}^{1}_{0}n + energy$$

If you calculate the total rest mass of the reactants you will find it is more than the total rest mass of the products. Einstein said that the mass of the nucleons in a nucleus can be changed into energy and vice versa ($E = mc^2$) and so when a nucleus is split into two other nuclei some mass is changed into energy or energy into mass. In this case mass is lost so the lost mass has been changed into energy that has been released. Part of the energy will be e/m radiation but there will also be a lot of heat released.[4] The heat from fission reactions is used to heat up water to make the water pumped through the reactor into steam a little bit like the radiator of a car removes the heat from the chemical reactions in the engine. The hot steam goes through turbines connected to electric generators to create electricity. If for some reason the water cannot flow to remove heat then the reactor will melt.