6 **(a)** A possible fusion process which has been suggested for the generation of energy is represented by the following equation:

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n$$

Rest mass of proton $= 1.67357 \times 10^{-27}$ kg

Rest mass of neutron $= 1.67496 \times 10^{-27}$ kg

Rest mass of $^{2}_{1}H$ $= 3.34454 \times 10^{-27}$ kg

Rest mass of $^{3}_{2}He$ $= 5.00835 \times 10^{-27}$ kg

(i) Using the data above, calculate the energy released.

energy released = ………………………….. J [2]

(ii) The total kinetic energy of the helium nucleus, neutron and the energy of radiation for the reaction is found to be more than the answer in **(i)**.

Suggest a reason for this difference.

……..…………………………….………………………………………………………

……..…………………………….…………………………………………………….. [1]

(b) In order to achieve nuclear fusion, the particles involved must first overcome the electric repulsion to get close enough for the attractive strong nuclear force to fuse the particles. This requires extremely high temperatures.

Consider a proton "gas" at high temperature and assume a proton is a sphere of radius $r \approx 1 \times 10^{-15}$ m. Two protons are moving towards each other with the same kinetic energy *K* as shown in Fig. 6.1.

Fig. 6.1

(i) Calculate the value of *K* which is just enough to bring the two protons to 'just touch' one another as seen in Fig. 6.2 so that the nuclear force can come into action. Assume that the 2 protons are initially far apart

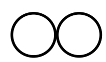

Fig. 6.2

K = ………………………….. J [2]

(ii) If the proton "gas" behaves like an ideal gas, determine the temperature of the proton "gas" for the protons to have an average kinetic energy as that calculated in **(b)(i)**.

temperature = ………………………….. K [1]

(c) Beryllium nuclei when bombarded by alpha particles may undergo nuclear reactions. One such reaction is

$$^{9}_{4}\text{Be} + ^{4}_{2}\text{He} \rightarrow ^{12}_{6}\text{C} + \text{X}$$

(i) State what is meant by the binding energy of a nucleus.

……..……………………….………………………………………………………………

……..……………………….………………………………………………………………

……..……………………….…………………………………………………………... [1]

(ii) Identify particle X and explain why it is not taken into consideration in the calculation of energy released when using the binding energy approach.

……..……………………….………………………………………………………………

……..……………………….………………………………………………………………

……..……………………….…………………………………………………………... [1]

(iii) The binding energy per nucleon of Beryllium-9 and Helium-4 are approximately 6.4763 MeV and 7.0819 MeV respectively and that of Carbon-12 is 7.6885 MeV.

Calculate the net energy released during this process.

energy released = ………………………….. J [3]