8 **(a)** State the principle of conservation of momentum.

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

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

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

(b) In a collision between a neutron and a uranium nucleus, the force that the neutron exerts on the uranium nucleus varies with time as shown in Fig. 8.1.

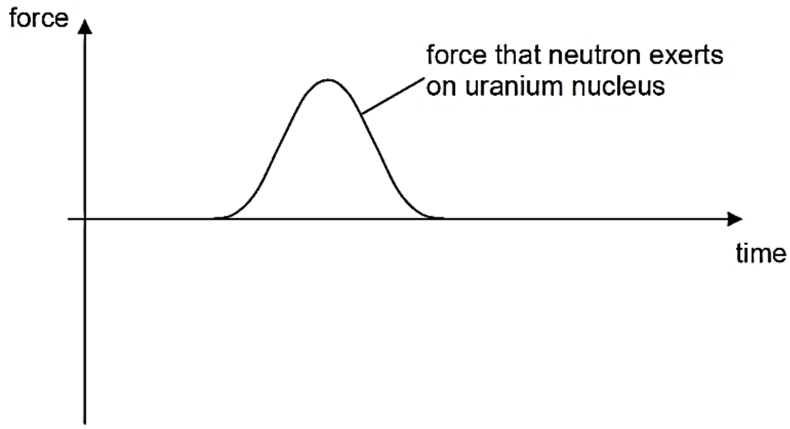

Fig. 8.1

(i) Sketch on Fig. 8.1, a graph of the force that the uranium nucleus exerts on the neutron. [1]

(ii) Explain how your answer to **(b)(i)** is consistent with **(a)**.

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…………………………………………………………………………………….. [2]

(c) In 1914, James Chadwick showed that the energies of the beta particles emitted for a radioactive source had a distribution of energies rather than with a distinct single value of energy.

Figure 8.2 shows the energy spectrum for beta particles emitted during the decay of Bismuth-210 ($^{210}_{83}Bi$). The intensity (vertical axis) indicates the number of beta particles emitted with each particular kinetic energy (horizontal axis).

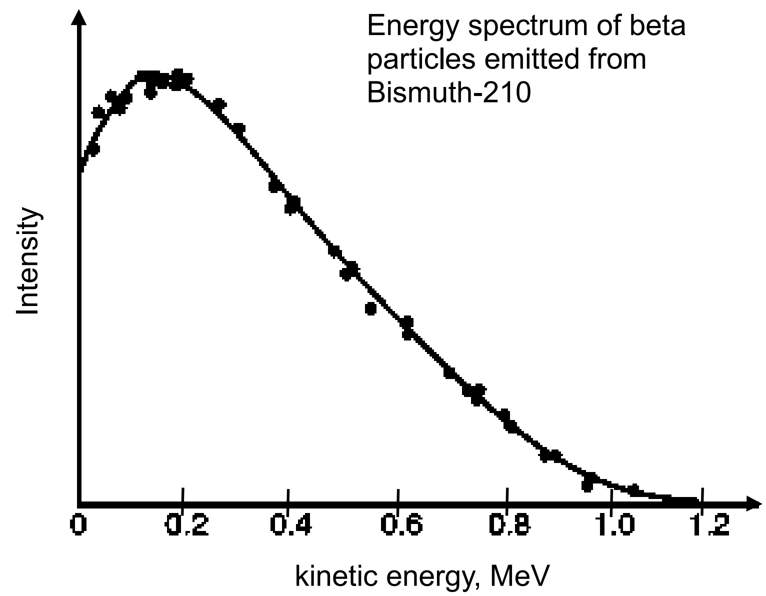

Fig. 8.2

(i) **1.** From Fig.8.2, determine Q, the maximum possible energy of the beta particle emitted.

Q =……………………… MeV [1]

2. Hence calculate the maximum speed of the beta particle.

maximum speed =……………………… m s^{-1} [1]

3. A Bismuth ${}^{210}_{83}\text{Bi}$ nuclide, decays into Polonium (chemical symbol: Po), emitting a beta particle with the maximum possible energy in the process.

Using your answer in **(c)(i)1.**, determine the mass of the resultant Polonium nucleus, in terms of *u*, and express your answer to 3 decimal places. (mass of a ${}^{210}_{83}\text{Bi}$ nucleus is 209.939 *u*; mass of proton m_p is 1.00729 *u*; mass of neutron m_n is 1.00867 *u*).

mass=…………………… *u* [3]

(ii) From Fig. 8.2, identify the most probable energy for the beta particle.

most probable energy value = ………………… MeV [1]

(iii) The continuous spectrum of kinetic energy values of the emitted beta particles presented a problem to physicists up to 1930s. If a stationary nucleus decayed into a beta particle and a stable daughter nucleus only, it should lead to a distinct single value of energy for the emitted beta particle.

Explain, using conservation of linear momentum and energy, how the continuous spectrum of beta particle energies gave rise to this problem.

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…………………………………………………………………………………………..

………………………………………………………………………………………… [2]

(iv) Suggest what was proposed by physicists to resolve the problem in **(c)(iii)**.

…………………………………………………………………………………………

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

(d) Radioactive isotopes are often introduced into the body through the bloodstream. Their spread through the body can then be monitored by detecting the appearance of radiation in different organs. Iodine-131 ($^{131}\mathrm{I}$), a beta emitter with a half-life of 8.04 days, is one such tracer. Suppose a scientist introduces a sample of $^{131}\mathrm{I}$ with an activity of 375 Bq into the body and watches it spread to the organs.

(i) Define decay constant.

…………………………………………………………………………………………..

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

(ii) Assuming that all of the $^{131}\mathrm{I}$ atoms in the sample went to the thyroid gland, calculate the decay rate in the thyroid 2.5 weeks later. Assume that none of the $^{131}\mathrm{I}$ is eliminated by the body through physiological means.

decay rate = …………………….. Bq [3]

(iii) Calculate the mass of $^{131}\mathrm{I}$ required to produce an activity of 375 Bq.

mass = …………………………….. kg [3]

[Total: 20]

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