Tutorial Questions Nuclear Physics

Question 1

a. The mass of a proton is 1.6726×10^{-27} kg. Express this in terms of the unified atomic mass constant (u).
b. The mass of a neutron is 1.008665 u. Express this in kg.

Question 2

Because mass and energy can be thought of as equivalent, the masses of atomic particles are sometimes given in energy units. For example, the mass of an electron is 0.51 MeV. Calculate the mass of an electron:

a. in kg, and
b. in terms of u.

Question 3

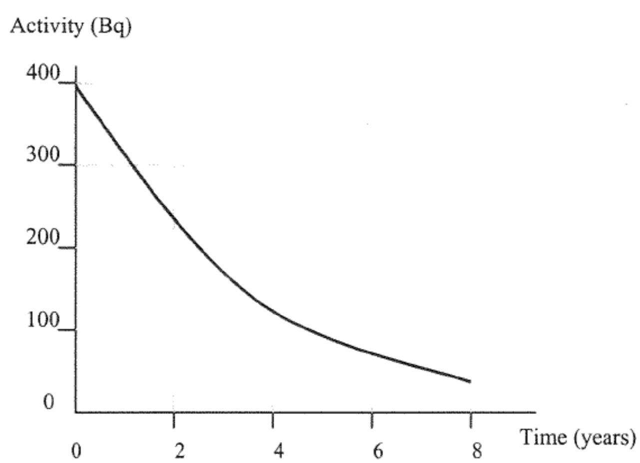
A sample of carbon-15 initially contains 500000 undecayed nuclei. If the decay constant for this isotope of carbon is $0.30\ s^{-1}$, what is the initial activity of the sample?

Question 4

A sample consists of 1000 undecayed nuclei of a nuclide whose decay constant is $0.2\ s^{-1}$. What would the activity of this sample be? What would you expect its activity to be after 1 s?

Question 5

The figure below shows the decay of a radio-isotope of caesium, ${}^{134}_{55}Cs$. Use the graph to determine the half-life of this nuclide, and hence find the decay constant.



Decay graph for a radio-isotope of caesium

Question 6

A radiographer calculates that a patient is to be injected with a tracer containing 1 x 10^{18} atoms of iodine-131 in order to monitor the activity of his thyroid. If the half-life of iodine-131 is 8 days, calculate

a) the radioactive decay constant
b) the initial activity (disintegrations per second)
c) the number of undecayed atoms of iodine-131 after 24 days.
d) the total activity after 3 days.

Question 7

In an experiment to measure the half-life of radon-220, the initial ionisation current is 1.0 x 10^{-9} A. Assuming that each α-particle is emitted with an energy of 6.3 MeV, and that creating an ion-pair from the molecules of air in the chamber requires 30 eV, calculate

a) the initial velocity of the emitted α-particle
b) the number of ion-pairs produced per second
c) the number of α-particle emitted per second
d) the number of atoms of radon-220 initially present in the chamber.

Mass of an α-particle = 6.8 x 10^{-27} kg
Charge on an α-particle = 3.2 x 10^{-19} C
Charge on an electron = 1.6 x 10^{-19} C
Half-life of radon-220 = 55 s

Question 8

Uranium nuclei when bombarded by neutrons may undergo nuclear reactions. One such reaction is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Kr +$$

(a) **(i)** Complete the equation for this nuclear reaction.

(ii) Name this type of nuclear reaction.

(b) The binding energy per nucleon of Uranium-235 is approximately 7.5 MeV and that of Barium-144 and Krypton-90 is approximately 8.5 MeV.

(i) Estimate the energy change in this nuclear reaction.

(ii) Suggest two forms of energy into which the energy in **(i)** is transformed during a reaction of this type.

Question 9

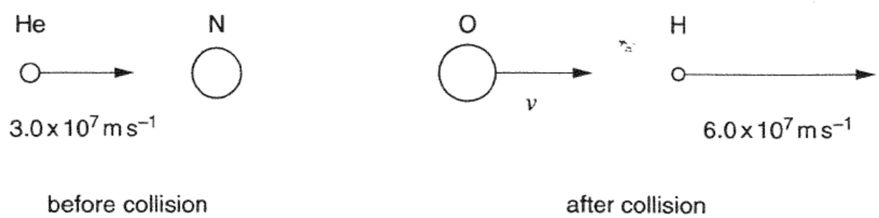
A collision takes place between an α-particle travelling at $3.0 \times 10^7\,m\,s^{-1}$ and a stationary nitrogen nucleus. It results in the following nuclear reaction.

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

The masses of the nuclei involved are listed below.

$^{14}_{7}N$	13.9993 *u*
$^{4}_{2}He$ (α-particle)	4.0015 *u*
$^{17}_{8}O$	16.9947 *u*
$^{1}_{1}H$ (proton)	1.0073 *u*

The particles move in a straight line, as shown in Fig. 7.1. The speed of the proton after the collision is $6.0 \times 10^7\,m\,s^{-1}$.



(a) State the number and type of particles which form an α-particle.

(b) Calculate the small change in mass, in kilograms, which takes place in this nuclear reaction.

(c) Use your answer to **(b)** to calculate the minimum kinetic energy needed by the α-particle to cause the nuclear reaction.

(d) Use the principle of conservation of momentum to calculate v, the velocity of the oxygen nucleus after the collision.