# Tutorial : Nuclear Reactions

1. Consider Rutherfords experiment in the case where an alpha particle of energy 4.8 MeV rebounds back on its original trajectory from a gold foil. Use arguments based on the conservation of energy to show that the mass of the atom must be concentrated in a dense positively charged nucleus whose diameter is smaller than 100 fm, whereas the diameter of the atom is about an angstrom

2. It is desired to study the first excited state of $^{16}$O, which is at an energy of 6.049 MeV. (a) Using the $(\alpha, n)$ reaction on a target of $^{13}$C, what is the minimum energy of incident alphas which will populate the excited state ? (b) In what direction will the neutron travel ? (c) If it is desired to detect the neutrons at 90° to the incident beam, what is the minimum $\alpha$ energy that can result in the excited state being populated ?

3. The (n,p) reaction can be regarded as equivalent to $\beta^+$ decay in that the same initial and final nuclei are involved. Derive a general expression relating the $Q$ value of the (n,p) reaction to the maximum energy release in $\beta^+$ decay. Find several examples to verify your derived relationship.

4. The $Q$ value for the reaction $^{9}$Be(p,d)$^{8}$Be is $559.5 \pm 0.4$ keV. Use this value along with the accurately known masses of $^{9}$Be, $^{2}$H and $^{1}$H to find the mass of $^{8}$Be.

5. Compute the $Q$ values of the reactions (a) $^{6}$Li + p $\longrightarrow$ $^{3}$He + $^{4}$He; (b) $^{59}$Co + p $\longrightarrow$ n + $^{59}$Ni; (c) $^{40}$Ca + $\alpha$ $\longrightarrow$ n + $^{43}$Ti

6. Make a list of at least 5 features of the Compound Nucleus type of reaction mechanism.

7. The radioactive isotope $^{15}$O, which has important medical applications (see Krane Chap 20), can be produced in the reaction $^{12}$C($\alpha$,n). (a) The cross section reaches a peak when the laboratory incident energy of the $\alpha$ particles is 14.6 MeV. What is the excitation energy of the compound nuclear state ? (b) The reaction cross section at the above incident energy is 25 mb. Assuming a carbon target of 0.10 mg/cm$^2$, an $\alpha$ particle incident beam current of 20 nA, compute the $^{15}$O activity that results after 4.0 min of reaction.

8. What should be the incident energy of a beam of protons to be Coulomb scattered by gold nuclei ?

9. Alpha particles of energy 8.0 MeV are incident at the rate of $3.0 \times 10^7$ per second on a gold foil of thickness $4.0 \times 10^{-6}$ m. A detector in the form of an annular ring is placed 3.0 cm from the scattering foil and concentric with the beam direction; the annulus has an inner radius of 0.50 cm and an outer radius of 0.70 cm. What is the rate at which the scattered particles strike the detector.

10. Give the compound nucleus resulting from protons bombarding an aluminium target and mention at least five different ways for this compound nucleus to decay.