Group III : Nuclear Fusion

Profile : Nuclear Fusion

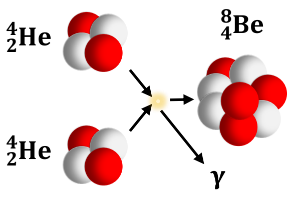
Nuclear fusion refers to nuclear reactions in which two atomic nuclei "**fuse**" to form one or more new nuclides. As we know, nuclear fusion does not take place under natural conditions on Earth (unlike radioactive nuclear conversions such as beta conversion). This is because a physical force "prevents" nuclei from fusing: The two atomic nuclei have positive charges (Protons) and actually **repel each other** due to the **Coulomb force**. However, if the ambient temperature and pressure are high enough - that is, if the distance between the nuclides is low and the energy of the nuclides is high enough - the Coulomb barrier can be overcome and fusion can occur. A natural environment in which this is possible is stars. For example, in our Sun, hydrogen nuclei fuse to form helium (The so-called **Hydrogen Burning**). Examples of possible reactions are

$$^{2}_{1}\mathrm{H} + ^{1}_{1}\mathrm{H} \rightarrow ^{3}_{2}\mathrm{He} + \gamma$$

Or another example:

$$^{3}_{2}\mathrm{He} + ^{3}_{2}\mathrm{He} \rightarrow ^{4}_{2}\mathrm{He} + ^{1}_{1}\mathrm{H} + ^{1}_{1}\mathrm{H}$$

In fusion reactions, there are always **two atomic nuclei** on the left side of the equation. On the right side there is at least one daughter nucleus. A wide variety of other particles can be released, such as here a gamma quantum (**Photon**, denoted by γ). Often the daughter nucleus is also radioactive can undergo further nuclear conversions.



An important nuclear fusion in stars is the fusion of two helium-4 nuclei. Here a beryllium nucleus is formed and gamma radiation is released.

In A Nutshell

- ✓ The overall reaction is generally $^{A_1}_{Z_1}X_1 + ^{A_2}_{Z_2}X_2 \rightarrow ^{A_3}_{Z_3}Y + \ldots$
- ✓ Occurs at: **High Temperatures & Pressure**
- ✓ Radiation released: ***different***

Expert Task | Fusion in the Laboratory

In 1917, Ernest Rutherford succeeded in performing a fusion reaction in the laboratory. He irradiated a gas of **Nitrogen** $^{12}_{7}\mathbf{N}$ mit accelerated **Helium Nuclei** $^{4}_{2}\mathbf{He}$. The reaction produced a **daughter nucleus** and a **single proton** $^{1}_{1}\mathbf{p}$.

a) Write the reaction equation. Use the conservation of mass number and proton number and the nuclide table to find the daughter nucleus (the formula in the Nutshell box can help you).

b) Make conjectures to answer the following question:

Although this fusion reaction was observed as early as 1917 and today a wide variety of nuclear fusions can be carried out with the help of particle accelerators, it is not yet possible to use nuclear fusion as an effective energy source. How can this be?

Home Group Task

What to explain:

- Write down the reaction equation of the fusion of two helium-4 nuclei (there is only one daughter nuclide and a photon released). Using the equation, briefly summarize nuclear fusion and its properties.

What you have to find out:

- The resulting isotope of the Rutherford reaction from task a) is radioactive. Use the nuclide map to set up the subsequent Conversion equation with the help of Group 1.