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Research Article

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Extraction of Tritium from ceramic breeder material

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ABSTRACT

The Fusion reactors will use deuterium and tritium as fuel since this reaction takes place at relatively low temperature. Tritium is not available in nature, it must be produced in the fusion reactor blanket which surrounds the plasma zone. The lithium bearing compound is available in plenty in earth's crust and by absorbing neutron, lithium produces tritium two reactions. So by designing the lithium blanket, more than one tritium atom per fusion reaction can be produced. In the absence of thermonuclear reactions, the (D,T) neutrons which are energetic 14-MeV neutrons, are produced in the accelerator based neutron generators. In order to ensure that sufficient amount of tritium would be produced in the future fusion reactor blankets, experiments are carried out to irradiate the lithium assembly using the available neutron source and measurements are done to estimate the tritium breeding. Also, it is required to extract the tritium produced in the lithium blanket. This work consists of designing of tritium extraction system.

Keywords: Fusion, tritium breeding.

INTRODUCTION

As fusion energy research progresses over the next several decades, and ignition and energy production are attempted, the fuel for fusion reactors will be a combination of deuterium and tritium. From a safety point of view, these are not the ideal materials. The reaction of deuterium plus tritium produces alpha particles and 14.1 MeV neutrons. These neutrons are used to breed the tritium fuel, but also interact with other materials, making some of them radioactive[8]. While the decay of tritium produces only a low energy beta, tritium is difficult to contain. Additionally, being an isotope of hydrogen, the tritium can become part of the hydrocarbons that compose our bodies.

All nuclear power stations in operation today rely on fission – the splitting of large atomic nuclei, in particular the very heavy elements like uranium and plutonium [13]. Most nuclear power stations are fuelled by uranium.

An alternative approach to have usable energy production depends on nuclear fusion. The basis of this is the release of energy when very light nuclei are brought together to form more stable heavier ones [6]. Fusion research holds out the promise of providing a clean, sustainable energy supply to contribute to the increasing needs of our civilization. Nuclear fusion is the process that powers the sun and other stars. Research into nuclear fusion to generate electricity is ongoing despite of huge technical challenges.

Background of fusion

Nuclear reactions are different from chemical reactions in that they involve the protons and neutrons in the nucleus, rather than electrons. Like chemical reactions, nuclear reactions can involve either a net absorption or a net release of energy. To achieve a release of energy in a fusion reaction, smaller, less stable nuclei must be joined together to form a more stable nucleus[7]. The energy associated with binding, the initial components is greater than that associated with the reaction products, and it is this energy difference that is released during fusion. Interestingly, these small differences in binding energy are reflected in the observable masses of the various reaction components; via Albert Einstein's famous equation describing the equivalence of mass and energy: $E = mc^2$. This states that energy = mass × (speed of light)^2 . That is, the components after the reaction actually weigh less than those before the reaction and the mass difference is released as energy [14]. Einstein's equation gives an indication of the scale of the proportionality between mass and energy, and it explains why very small changes of mass in nuclear fuel can release a great deal of usable energy.

3. Fusion Reactions

Fusion is a potential energy source with a major advantage of having an almost unlimited fuel supply. The next generation fusion reactors will be based on the deuterium-tritium (D&T) reaction .Since it is the easiest fusion reaction to achieve [15]. The reacting nuclei must collide hard and often to undergo fusion. The requirements of multiple, high-energy collisions of fuel nuclei are met in a hot, dense plasma.

This is the reaction between the heavy isotopes of hydrogen, deuterium (D), and tritium (T) which on fusion yields an alpha particle (^{4}He) and a neutron and 17.6MeV of energy, viz [4].

$$^{2}D + {}^{3}T \text{ -» } {}^{4}He + {}^{1}n + 17.6\text{ MeV}$$

The released energy is taken up by the two new particles in inverse proportion to their masses. That is, one fifth is taken up by the kinetic energy of the helium nucleus and four-fifths by the kinetic energy of the neutron[1-5].

As an electrically neutral particle, the neutron is unaffected by any magnetic fields. These fast neutrons are emitted in all directions and are the primary means by which energy leaves the fusion reactor. Many of these neutrons would leave the reactor on its outer edge and come to rest in a component known as "the blanket".

This contains material designed to slow down the fast neutrons and in doing so become heated. This heat is, in turn transferred to a medium such as high-pressure helium or steam. This hot, high-pressure gas can be used to drive an electricity-generating turbine. Some modules of the power-station blanket would include lithium, which reacts with the fast neutrons to generate tritium, one of the two fuels required for the reaction.

In this way a fusion power station could produce one component of its own fuel.

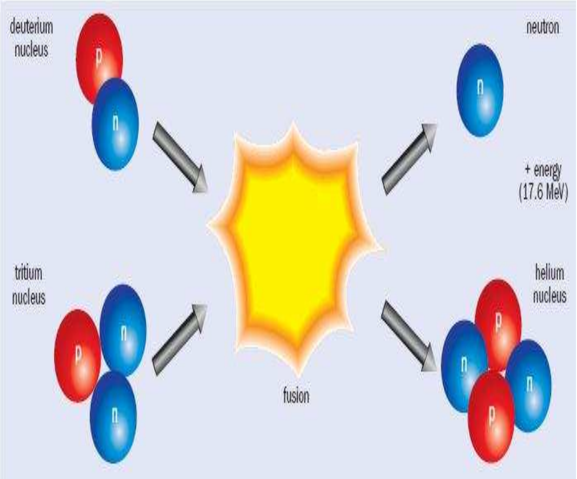


Fig. 1 The fusion reaction

Operation of a power plant with the (DT) fuel cycle requires introduction of an essentially continuous supply of deuterium and tritium into the reactor chamber[8]. Deuterium is readily available as heavy water (D_2O) from which deuterium can be separated by simple electrolysis. Since the earth's waters contain about 1013 metric tons (t) of deuterium, there is an essentially unlimited supply of deuterium available for all nations.

But naturally occurring tritium is in-sufficient in quantity and concentration for use as a fuel. It is only 10-16% of total Hydrogen found on earth[14]. However, tritium can be produced from lithium by the following nuclear reactions:

$$^{6}\mathrm{Li} + n \to {}^{4}\mathrm{He} + T + 4.8\,\mathrm{MeV}$$
$$^{7}\mathrm{Li} + n \to {}^{4}\mathrm{H} + n + T + 2.5\,\mathrm{MeV}$$

4. Lithium bearing ceramics for tritium production

Interest in the use of solid lithium-based materials as tritium breeders for fusion blankets has grown since the late 1970s. Ceramic lithium compounds are used as breeder for fusion blanket because of more favorable physical characteristics for the severe operating conditions of high temperatures and intense neutron fluxes. Lithium-containing ceramics such as Li2O, γ-$LiAlO_2$,Li_4SiO_4, Li_2ZrO_3 and Li_2TiO_3 have been considered as candidates for tritium breeding materials in D–T fusion reactors of the ITER test blanket module (TBM) for DEMO reactor [1-5]. The tritium breeder blanket in the fusion reactor serves two primary functions: breeding tritium and converting the released energy into sensible heat, both of which are critical to fusion power development [11]. Principal requirements to be fulfilled by the breeder material are to 1) breed and release tritium, 2) possess physical and chemical stability at high temperature, 3) display compatibility with other blanket components, and 4) exhibit adequate irradiation behavior. Because of their overall desirable properties, lithium-containing ceramics are recognized as attractive tritium breeding materials for fusion reactor blankets [12].

The sample material is irradiated and then it is measured by liquid scintillation counting. By this technique we can measure the tritium produced in the sample material.

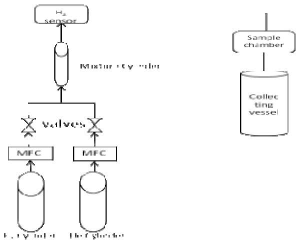
An extraction system is designed to extract the tritium produced in a sample material by irradiation process.

5. Extraction System [10]:

AIM: To extract tritium from ceramic material $LiAlO_2$

APPARATUS:

Hydrogen And Helium Cylinders , Mass Flow Controllers, Valves, Mixture Cylinder, Hydrogen Sensor, Heated Insulated Pipe, Chamber For Sample ,standard ¼" Pipes.



Procedure

Hydrogen and Helium Cylinder are attached with mass flow controller (MFC). Ni-leak is attached with Hydrogen cylinder (through which only hydrogen pass).

Send both the gases in to a chamber where they can mix properly. (Helium is Heavier then Hydrogen). Hydrogen sensor ids being used to measure the amount of hydrogen.

Send that gas mixture into the another chamber in which sample ($LiAlO_2$) is kept, from which tritium is to be extracted[10]. Before sending the gas mixture in to the chamber heat the chamber up to 1000°C.

After some time hydrogen is come out with tritium in HT form.

Send that directly in to the water.Tritium is dissolved in water and tritiated water is formed.

CONCLUSION

By the extraction system we can extract out the tritium which is produced by irradiation in the sample.

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