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Investigation of hydrogen isotopes interaction processes with lithium under neutron irradiation

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HIGHLIGHTS

- The experiments on study of helium and tritium generation and release processes under neutron irradiation from lithium saturated with deuterium are described in paper.
- The values of relative tritium and helium yield from lithium sample at different levels of neutron irradiation is calculated.
- It was concluded that the main affecting process on tritium release from lithium is its interaction with lithium atoms with formation of lithium tritide.

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ABSTRACT

The paper describes the experiments on study of helium and tritium generation and release processes from lithium saturated with deuterium under neutron irradiation (in temperature range from 473 to 773 K). The diagrams of two reactor experiments show the time dependences of helium, DT, T_2, and tritium water partial pressures changes in experimental chamber with investigated lithium sample. According to experimental results, the values of relative tritium and helium yield from lithium sample at different levels of neutron irradiation were calculated. The time dependences of relative tritium and helium yield from lithium sample were plotted.

It was concluded that the main affecting process on tritium release from lithium is its interaction with lithium atoms with formation of lithium tritide.

1. Introduction

Tritium and deuterium will be used in fusion reactors as a fuel. If deuterium exists in nature in the form of heavy water, tritium can be obtained only by artificial way, for example, during neutron irradiation of ^{6}Li. Therefore, lithium is a row material for fusion reactions. By the way, lithium is the lightest metal and has unique physical and thermophysical characteristics whereby it is considered as a material of heat-transfer agent of blanket in fusion reactors and as plasma facing material. The effectiveness of lithium utilization was confirmed in experiments on T-10, T-11 M, TFTR, CDX-U facilities [1–3].

Nevertheless, the quantity of studies related to determination of tritium generation and release parameters from lithium under neutron irradiation is not enough. That is why the study of lithium behavior under conditions close to its real work conditions in fusion reactors namely under simultaneous exposure of neutron irradiation, temperature and hydrogen isotopes is the actual target of this investigation. In current work the ratio of tritium release rate to its generation rate in lithium sample under different experimental conditions was defined.

2. Experimental part

2.1. Object of investigations

Chemical composition of lithium is presented in Table 1. The mass of lithium sample was 1.25 g. Before experiments the lithium sample was saturated with deuterium to simulate the impact that

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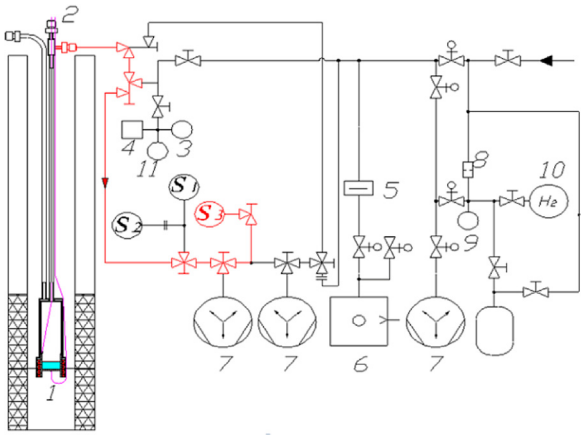

Fig. 1. Experimental facility with ampoule device: 1—ampoule's body; 2—cooling case; 3—heater; 4—liquid lithium sample; 5—thermocouples; 6—heat insulation; 7—nitrogen supply pipe.

the presents of other hydrogen isotopes have on the mechanism of tritium generation and release from lithium. During application of lithium as plasma facing material, the lithium will adsorb other gases in vacuum vessel, such as deuterium from the plasma or its fueling systems, because of lithium's high absorption ability in liquid state. The presence of dissolved deuterium in lithium sample will prohibit (in some degree) from tritium dissolution (lithium tritide formation) in sample under neutron irradiation. This procedure consists in following: after annealing at 973 K the lithium sample was saturated with deuterium (it was in gaseous state) at temperatures from 473 to 773 K up to concentration of D/Li = 0.015 (which was determined by deuterium pressure drop in working chamber).

2.2. Experimental facility

The experiments were carried out at LIANA facility at the IVG1.M research reactor located in Kurchatov, Kazakhstan. Detailed description of experimental facility and reactor ampoule device (Fig. 1) with investigated sample is given in Ref. [4].

2.3. Reactor experiments

The technique of reactor experiments consists in the following:

- before reactor start-up the lithium sample was heated to required temperature and the mass-spectrometer measuring system of partial gases pressures in an experimental ampoule device was powered on;
- then, at the investigated reactor power level using cooling system the sample's temperature was stabilized on required level;
- when fluxes of released helium and tritium came to a quasis-tationary level the lithium sample had been heated to the next investigated temperature level;
- after taking of kinetic dependences of gas release from lithium sample for all predetermined sample temperatures the IVG.1M reactor was set to the next level of thermal power, and the new cycle of mass-spectrometer measurements was carried out;

Table 1
Chemical composition of metallic lithium of LE-1 brand (lithium content at least 99.9%).

Impurities, not above, %								
Na	K	Ca	Mg	Mn	Fe	Al	SiO_2	$N\text{-}NO_2$
0.04	0.005	0.03	0.02	0.001	0.005	0.003	0.01	0.05

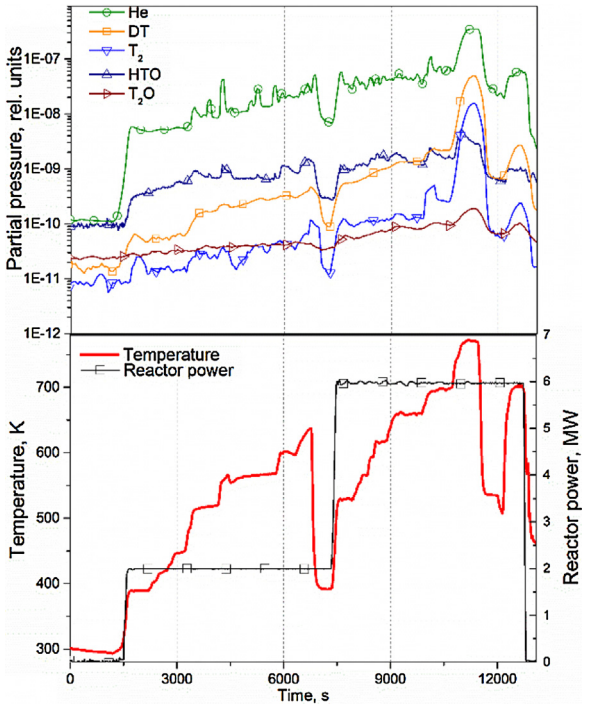

Fig. 2. The diagram of reactor experiment with lithium sample at the power level 2 and 6 MW.

- after that the reactor power was reduced.

The experimental conditions were the following: residual pressure in measuring system is 10^{-5} Pa; temperature range of investigated sample from 353 to 723 K; reactor power 2 and 6 MW. The neutron flux in reactor core center at the reactor power level 1 MW is 2.5×10^{13} 1/(cm^2 s), and 58% from it—thermal neutrons.

3. Results and analysis

3.1. Results of experiments

Fig. 2 presents the diagram of the first reactor experiment on lithium sample irradiation on reactor power 2 and 6 MW.

As can be seen from the graph, after the beginning of exposure on 2 MW the helium began release actively, and helium flux from lithium is directly proportional to the reactor thermal power. The relation of average flux of helium release from sample at the reactor power level 6 MW to average flux of helium release at 2 MW (at 523 K and 600 K) is ~3. The dependence of helium release from reactor power level is clear—the generation of helium atoms in lithium increases with reactor power level increasing. The growth of helium release with temperature increasing is associated with dissolved helium transfer processes acceleration in lithium sample.

Tritium is released as DT, HTO, T_2 molecules and as tritium water T_2O, but noticeable peaks of tritium release at higher temperatures are not observed. Tritium release as HT molecule is not taken into account because the total amount of deuterium dissolved in lithium are more than two orders higher than hydrogen amount in lithium.

At low temperatures tritium release is lower than sensitivity threshold of measuring system. At the reactor thermal power 6 MW and lithium temperatures higher than 700 K the peaks of tritium release in the form of molecules of DT and T2 are observed. And relative (not absolute) increase of T2 molecules release is higher than DT release.

We suppose that quantitatively it can be explained by following:

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