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Results of neutron irradiation of liquid lithium saturated with deuterium

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HIGHLIGHTS

- The results on neutron irradiation of liquid lithium saturated with deuterium at the IVG.1M research reactor are described.
- At temperatures below 573 K the efficiency coefficient of tritium release is well described by the expression $K = 0.015\ exp(-14/RT)$, and above 623 K – $K = 10^9\ exp(-144/RT)$.
- The T_2 molecules contribution into the overall tritium release becomes apparent at temperatures higher than 673 K and increases with the temperature rise.

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ABSTRACT

This paper describes the results on neutron irradiation of liquid lithium saturated with deuterium at the IVG.1 M research reactor. The neutron flux at the reactor core center at 2 MW was 5 10^{-13} cm^{-2} s^{-1}. The efficiency coefficients of helium and tritium release from lithium saturated with deuterium were calculated. The tritium interaction with lithium atoms (formation and dissociation of lithium tritide) has an effect on tritium release. An increment of sample's temperature results in tritium release acceleration due to rising of the dissociation rate of lithium tritide. At temperatures below 573 K the efficiency coefficient of tritium release is well described by the expression $K = 0.015\ exp(-14/RT)$, and above 623 K – $K = 10^9\ exp(-144/RT)$. The T_2 molecules contribution into the overall tritium release becomes apparent at temperatures higher than 673 K and increases with the temperature rise.

1. Introduction

Lithium has a unique physical and thermophysical properties that offer possibilities of its use as a material of plasma facing elements in the future fusion reactors [1]. Liquid lithium is also considered as a tritium-breeding material, because it has high tritium breeding ratio, high thermal conductivity and small viscosity [2]. Experiments with liquid lithium have been successfully carried out during past 15 years on the T-10, T-11M, FTU, CDX-U, NSTX, TJ-II and TFTR fusion facilities and their results confirmed the stability and working ability of in-vessel target plates based on liquid lithium [3–5]. However liquid lithium has a significant disadvantage in contact with the hydrogen isotopes – the formation of hydrides [6]. Particularly, the formation of lithium tritide blocks the release of tritium generated in lithium under neutron irradiation. Pre-saturation of lithium with deuterium allows to reduce the possibility of lithium tritide formation under neutron irradiation.

This study investigated the influence of deuterium dissolved in lithium on the processes of tritium release from lithium under neutron irradiation.

2. Experimental part

2.1. Lithium sample and its saturation with deuterium

The investigated sample was made from lithium of LE-1 brand (m = 0.85 g). Chemical content of lithium is presented in Table 1. The ^6Li content in sample was 7.52%. Before conduction of in-pile

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Table 1
Chemical content 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

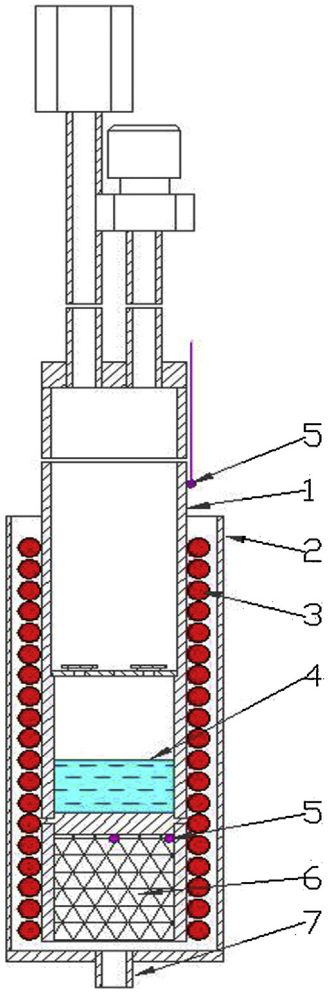

Fig. 1. Reactor ampoule device: 1–ampoule's case (12Cr18Ni10Ti); 2–cooling housing (12Cr18Ni10Ti); 3–ohmic heater; 4–sample; 5–thermocouples; 6–thermal insulation; 7–nitrogen supply.

experiments the lithium sample had been saturated with deuterium in order to reduce the sorption properties of lithium and prevent the formation of lithium tritide during tritium migration to the sample's surface. Lithium sample was saturated with deuterium up to concentration of D/Li = 0.015 under temperature of 623 K, and deuterium pressure of 100 Torr. The total amount of deuterium absorbed by liquid lithium over the course of the saturation experiment was $1.6{\cdot}10^{-3}$ mol.

2.2. Experimental facility and reactor ampoule device

The experiments were carried out at LIANA experimental facility located at the IVG.1 M research reactor in Kurchatov, Kazakhstan.

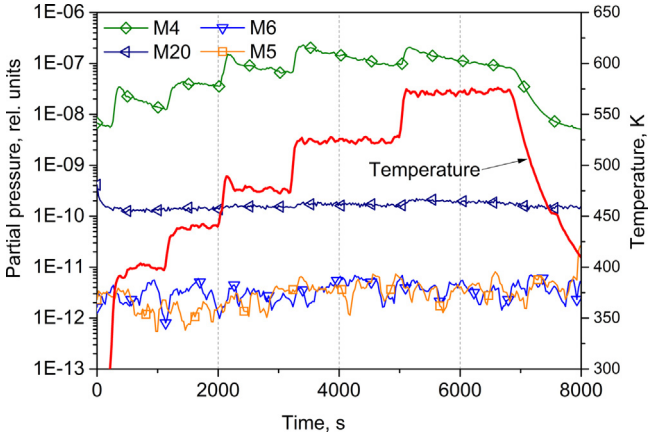

Fig. 2. Diagram of TDS-experiment with lithium sample saturated with deuterium.

More detailed description of the experimental facility is given in [7]. A special ampoule device was designed for the experiments with lithium sample (see Fig. 1). The investigated lithium sample was placed in the ampoule device where it was saturated with deuterium, then the TDS-experiment and the experiments on neutron irradiation of saturated lithium sample were performed sequentially. For temperature control and maintenance the ampoule device was equipped with two thermocouples, ohmic heater, and cooling system. The neutron flux in the core center of the IVG.1 M reactor is presented in Table 2.

2.3. Results of TDS-experiment

After lithium saturation procedure the TDS-experiment was performed with simultaneous mass-spectrometric registration of the gases released from sample. The temperature of lithium sample was varied from 323 K to 573 K, heating step was 50 K. The diagram of TDS-experiment is given in Fig. 2.

Results of TDS-experiment showed that the increase of sample's temperature caused insignificant change of partial pressure of D_2 (M4 on graph) released from lithium. The average level of D_2 was just about the same during the whole heating process. The partial pressure of deuterium water (M20) hadn't changed during the experiment. It can be assumed that the deuterium associated with free lithium atoms and located in lithium as a lithium deuteride.

2.4. Technique of reactor experiments

Right after the TDS-experiment the neutron irradiation experiments were performed using the method of mass-spectrometric registration of gases released from the investigated sample. The experimental conditions are presented in Table 3. The duration of experiments was about 3 h.

Table 3
Conditions of reactor experiments.

Parameter	Value
Residual gas pressure in measuring channel	10^{-5} Pa
Sample's temperature range	353–723 K
Reactor power	2 MW

Table 2
Neutron flux in the IVG.1 M core center at the power level 6 MW.

Energetic group	0-0.67 eV	0.67 eV–0.10 MeV	0.10–10.00 MeV	Integral flux
Neutron flux, $1/(cm^2\ s)$	$0.87{\cdot}10^{14}$	$0.42{\cdot}10^{14}$	$0.22{\cdot}10^{14}$	$1.50{\cdot}10^{14}$

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