MEASUREMENT OF THE RATIO OF ISOTOPES AND MOLECULAR FRACTIONS IN A MIXED HYDROGEN-DEUTERIUM NEUTRAL BEAM [[1]](#footnote-1)\*)

DOI: 10.34854/ICPAF.2021.48.1.057

1Deichuli P., 1Brul A., 1Davydenko V., 1Ivanov A., 2Osin D., 3Magee R.

1Budker Institute of Nuclear Physics, Novosibirsk, Russia, pdeichuli@yandex.ru
2Tokamak Energy Ltd., Abingdon, OX14 4SD, United Kingdom
3Tri Alpha Energy Ltd, 92610, Foothill Ranch, CA, USA

Injection of high-power atomic beams is widely used in controlled fusion experiments to heat plasma and maintain current. In some cases, the injection of beams from a mixture of deuterium and hydrogen is of great interest [1].

This paper describes experiments on obtaining a powerful atomic beam from a mixture of hydrogen and deuterium with an arbitrary set ratio of isotopes. Direct measurement of the content of each isotope in a mixed beam is a rather complex task. Therefore, it is very tempting to measure the isotope content using a simple non-contact method of Doppler beam spectroscopy. This paper analyzes these possibilities and discusses the results of corresponding experiments with a high-power hydrogen-deuterium beam.

The beam of an ion source operating on a mixture of isotopes, along with hydrogen ions H+, H2+, H3+, H2O+ and deuterium D+, D2+, D3+, D2O+, the new hybrid ions HD+, H2D+, HD2+ and HDO+ present. Accordingly, after neutralization and dissociation of molecular ions in the gas target of the injector, which is usually the case in the practice of obtaining atomic beams for controlled fusion purposes, the radiation of the beam is a set of Doppler shifted lines (H,D)α groups of particles with different velocities. In addition, the deuterium lines have an additional isotopic shift, which for the Ha-Da pair is about 1.72 Å.

In the primary ion beam, there are 12 varieties of ions, which in the observed region of the spectrum correspond to 16 radiation lines. It is shown that the spectrum can be reduced to 12 completely resolvable lines – 6 lines each in the hydrogen and deuterium parts of the spectrum. Note that is easier to separate the peaks of a slow heavy impurity when observing "after", when the isotope shift and Doppler shift are combined. This is quite possible even for a low-energy beam (15 keV).

When analyzing the obtained spectra, we used a procedure for calculating the content of molecular fractions in the beam, similar to the standard one, see, for example, [2]. The presence of new lines due to the contribution of new ion varieties was taken into account and corresponding conversion coefficients were introduced. In addition to the beam fractions with energies E, E/2, E / 3, E / 18 for hydrogen and E, E / 2, E/3, E/10 for deuterium, it is necessary to take into account the fractions E/4, E/5 and (E/18+E/19) for the hydrogen part of the spectrum and the fractions 2E/3, 2E/5 and (2E/19+E/10) for the deuterium part.

Of particular interest in the spectrum of a mixed beam are the emission lines of half-energy hydrogen and full-energy deuterium. For these lines, the cross-sections of the processes that determine their intensity are the same, and there is no contribution from processes involving hybrid ions, and, what is the best part, having the same Doppler shift, these lines are resolvable, due to the isotope shift. This makes it possible to measure the ratio of isotopes in the ion source beam, if the compositions of molecular fractions in mono-isotope beams are known. The results of measurements of the isotope ratio are compared with measurements of the neutron yield of the DD reaction.

Referens

1. Ryutov D.D. Private communication.
2. Uhlemann R., Hemsworth R.S., Wang G., and Euringer H. // Rev. Sci. Instrum. 1993. V. 64, P. 974. [doi: 10.1063/1.1144100](https://doi.org/10.1063/1.1144100).
1. \*) [abstracts of this report in Russian](http://www.fpl.gpi.ru/Zvenigorod/XLVIII/Mu/ru/BQ-Deichuli.docx) [↑](#footnote-ref-1)