EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Status Report to the ISOLDE and Neutron Time-of-Flight Committee

Prototype Target Tests with the ISOLDE Tape Station

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T.M. Mendonca[1], A. Gottberg[1], on behalf of:

IS509: E. Noah[2], R. Catherall[1], F. Plewinski[3], T. Stora[1], E. Wildner[1],
IS540: T. Stora[1] and the ENSAR ActILab collaboration

1 CERN, Geneva, Switzerland
2 University of Geneva, Switzerland
3 ESS AB, Lund, Sweden

Abstract

In this report, a summary of two prototype target units tested in 2012 is presented. The results obtained during the experimental campaigns for IS509 (Production and release of gas and volatile elements from sodium-based targets) and IS540 (UCx prototype target tests for ActILab-ENSAR) are described.

Experiments and remaining shifts: IS509 - 6 shifts, IS540 – 6 shifts

Experimental details

Yields and time-dependant release characteristics were measured by using the ISOLDE tape station that is equipped with a beta particle detector and an HPGe.

The yield measurements have been performed by measuring the activity implanted on the tape. The activity was sampled at regular intervals after switching off the proton beam allowing the measurement of the release curves. The extraction efficiency was obtained from integration of the release curves, which are approximated by a four parameter function [1]

$$P(t) = \frac{1}{N}\left(1 - e^{-\frac{ln2\cdot t}{t_r}}\right)\left(\alpha\, e^{-\frac{ln2\cdot t}{t_f}} + (1-\alpha)e^{-\frac{ln2\cdot t}{t_s}}\right) \quad (1)$$

where P(t) is the probability of release of a particle, t_r, t_f and t_s are, respectively, the exponential rise, fast fall and slow fall times and α is a weighting factor between the slow and fast components. The factor 1/N is used for normalizing P(t) to unity for $t \rightarrow \infty$. To obtain the yield of a certain isotope, the release curve is integrated, being the normalized yield expressed in units of ions/μC.

In some cases where beam compositions are well known and the intensity exceeds 10^6 pps, one or several faraday cups, typically the ones in the separator's focal plane (YGPS.FC490, YHRS.FC490) and in the CA0 section (YCA0.FC68), are used.

Specific for IS509: A prototype target unit, inspired from the standard ISOLDE static units, has been designed, constructed and tested on-line in order to investigate its use as a high power target for the production of neutrino beam [2]. The target material consisted of a binary fluoride system, NaF:LiF (39:61% mol.), with melting point at 649ºC. The release and production yields of the radioisotopes of interest have been assessed at the ISOLDE tape station. Proton beam settings for molten metal targets at ISOLDE, those of the staggered extraction mode ('STAGISO'), were used with extraction intervals of 16 and 20 μs to decrease damaging effects of shock waves on the target container [3]. In addition, the proton Gaussian beam size has been set to 4.2x4.4 mm FWHM, larger than standard beam sizes to reduce the energy density of the proton beam. The radioactive beams of interest have been investigated as a function of the target temperature and proton beam intensities. The target unit has been kept above its melting point during the experimental run.

Specific for IS540: Within the framework of ActiLab in FP7-ENSAR: Integrating R&D on ISOL UC targets, several uranium carbide target materials are under development. The material tested here was synthesized from a fine-grained uranium dioxide powder together with multiwall carbon nanotubes that are believed to act stabilizing on the overall structure of the matrix at high temperatures. For the detection of long-lived isotopes, collections into Al foil were performed in GLM or GHM, followed by an offline analysis using a Saarbruecken-owned HPGe detector situated in the solid state laboratory or using, if dispensable, the detector setup of the ISOLDE tape station. If available independent measurements are performed by experimental setups that are installed and ready to receive beam. In this way the collection experiment for AMS measurements at LA2 (IS541) has provided yields that were extracted from precise activity measurements of their samples for the yield of ^{11}Be [4].

Status report for IS509

Title: Production and Release of Gas and Volatile Elements from Sodium-based Targets

Spokesperson: E. Noah

Accepted isotopes: ^{18}Ne, ^{19}Ne, ^{10}C, ^{11}C, ^{15}C

Performed studies:

A prototype static molten fluoride salt target (#478) has been designed, constructed and tested [5,6] in order to validate its use as target material for future facilities for neutrino oscillation physics such as the Beta Beams [7]. An important step towards the validation of the molten salt target was performed within the IS509 experiment, where a systematic study of the production and release of low-Z elements. Primary focus has been given to the production and release of ^{18}Ne as a baseline ion for the Beta Beams project [8].

The production yields and release properties of several low-Z elements has been investigated as a function of the target temperature, which has been varied between 700 and 770ºC. Moreover, the proton beam intensity has been also changed, ranging between $1x10^{12}$ and $6x10^{12}$ protons per pulse. The analysis of the data showed an increase in the ^{18}Ne and ^{19}Ne both with target temperature and proton intensity. A maximum yield of $5.7x10^{4}$ ions per μC of incoming beam has been measured at 770ºC [5,6]. Furthermore, the release parameters of neon allowed the first determination of the diffusion coefficient of this element in molten fluoride salts [9]. The measured diffusion coefficient is found to be in the order of 10^{-9} m^2/s [10] in good agreement with the values for Xe or Kr in molten salts. In addition, the obtained coefficient is found to be eight orders of magnitude higher than the one found in solid targets, such as CaO or Al_2O_3, where this value is of the order of 10^{-17} m^2/s [10,11].

The yields of carbon isotopes have been also assessed as a function of the target temperature and proton beam intensity. An increase on ^{11}C yields has been observed in both monoxide and dioxide forms, being the highest value observed for carbon in the monoxide form. A record yield of $7.7x10^{8}$ ions/μC for ^{11}C [5,6] has been measured showing an improvement by two orders of magnitude in comparison to the best reported values [12]. Furthermore, in the case of ^{15}C it is also observed a small improvement of the yield by a factor of 1.5. The present results open the possibility of the use of molten fluoride targets as production unit for the ISOLDE physics program. In addition, the obtained ^{11}C intensities are relevant for the production of radiotracers for positron emission tomography expanding the possible applications of this type of targets to medical physics.

Future plans with <u>available</u> shifts:

(i) Envisaged measurements and requested isotopes

Following the results obtained in the experimental campaign carried out in June 2012, the molten salt target could be used as a production unit for physics with carbon beams. The available shifts could be allocated prior to the physics runs.

Different studies are envisaged for the available shifts as summarized below:

Systematic yield measurements and reproducibility of the carbon beams and complementary data for neon release. The first subject would allow confirming the best operating conditions for the production of high intensity carbon beams. In addition, the feasibility of the use of such type of targets in the production of medical isotopes will be investigated.

Complementary studies on neon release parameters would be needed for completeness of the study of the diffusion behaviour of this element in molten fluoride salts. The temperature dependence of the diffusion coefficient will be systematically investigated.

The test of different fluoride compositions, such as $NaF{:}ZrF_4$, would allow a comparison in the performance of such targets in the production of ^{18}Ne. Furthermore, accounting for the use of Zr in the target, the measured beams could be expanded to medium mass elements, such as Kr. Following the calculated cross-section for Kr, an improvement by a factor of 10 in ^{72}Kr yield is expected.

In summary, the requested isotopes for the available shifts are: ^{18}Ne, ^{19}Ne, ^{11}C, ^{15}C, ^{72}Kr.

(ii) Have these studies been performed in the meantime by another group?

No. Molten salts have been used at ISOLDE in the 1970's in the production of Sb beams. Due to the various challenges in constructing such units (corrosion behaviour of the salts, thermal instability), this type of targets was not further used.

(iii) Number of shifts (based on newest yields) required for each isotope.

Isotope	yield (/uC)	target – ion source	Shifts (8h)
^{11}C	-	NaF:LiF – VD7	2
^{15}C	-	NaF:LiF – VD7	0.5
^{18}Ne	-	NaF:LiF – VD7	1
^{19}Ne	-	NaF:LiF – VD7	1
^{72}Kr	-	NaF:ZrF4 – VD7	2.5

Total shifts: 6

Status report for IS540

Title: UCx Prototype Target Tests for ActILab-ENSAR

Spokesperson: Thierry Stora

ActILab is an FP7 JRA that focuses on the synthesis, operation and characterisation of novel actinide matrixes for ISOL applications. Within the ActiLab collaboration a uranium carbide material was developed and produced at ISOLDE and its online performance is under investigation in IS540. Uranium dioxide powder, as used for the production of conventional UC_x ISOLDE production targets, was ground in 2-propanol suspension employing consecutive cycles of a high impact tungsten carbide ball mill [13]. In this way a reduction of average particle size form 18 µm down to 160 nm was achieved. The fine powder was then mixed with multiwall carbon nanotubes following the molar ratio of 6 between uranium dioxide and carbon. The resulting powder was pressed and calcined at 1800°C in a vacuum oven, before it was inserted into target unit #498 that was equipped with a bulk Re ionizer tube in conventional target geometry resulting in a target mass thickness of approx. half the value of conventional UC_X targets due to a lower resulting density of the material. UC_X target materials were already previously synthesized with carbon nonotubes within EURISOL-DS Task #3 in collaboration between CERN and INFN [14] using conventional micrometric UO_2. This material was then tested online at ISOLDE for different alkali beams but no improvement could be observed in the past.

The beamtime in December 2012 lasted 5 shifts (from December 12, 10am to December 13, 6pm). The yield of a series of isotopes, Be (A = 11), Na (A = 26, 30), Cs (A = 142, 144, 148), has been assessed at different target temperatures. However, reproducibility was poor due to fluctuations in transmission through ISCOOL and instabilities of tape station operation. It is therefore that no time-dependent release curve could be recorded. In addition only limited data could be found reliable, including the yield of ^{30}Na at different target temperatures and the yield of ^{11}Be as it was confirmed by IS541 [15].

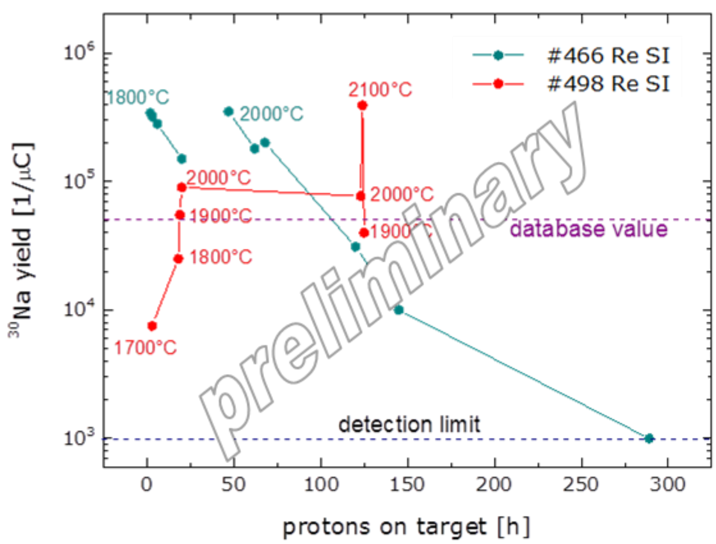

Fig. 1: Comparison between typical ^{30}Na yields as function of proton irradiation time for a conventional UC_X target (#466) and for the nanostructured target material (#498) used in IS540 (preliminary data).

Despites the technical difficulties record yields of ^{11}Be of $1 \cdot 10^8$ μC^{-1} were found and $3 \cdot 10^7$ pps at 2 µA proton current were staidly delivered to the IS541 experiment for several days using a high resolution setup of the HRS for the suppression of isobaric ^{11}Li, that was causing the intensity decrease.

In addition to increased yields of ^{11}Be, higher intensities of Cs beams and an enhanced stability of exotic sodium beams over time (Fig. 1) were measured; both observations shall be confirmed and the characteristics for more isotopes shall be gathered during further online tests.

Future plans with available shifts:

The remaining 6 shifts shall not be used. Instead we will ask for a TISD beamtime in the beginning of the 2014 online period in order to confirm the improvement of yields that was indicated by the data from IS540 and IS541. Complementary online tests of this material are foreseen in ALTO-IPNO in spring 2014. Depending on the outcome of these two tests, meaning if intensity losses for users seem unlikely, the material shall be used in chosen target units throughout 2014 and 2015 in order to test the reproducibility and to build up operation expertise.

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Appendix

IS509:

Publications

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- T.M. Mendonca, R. Hodak, V. Ghetta, M. Allibert, D. Heuer, E. Noah, S. Cimmino, M. Delonca, A. Gottberg, M. Kronberger, J.P. Ramos, C. Seiffert, T. Stora, Submitted to NIMB.
- T.M. Mendonca, R. Hodak, V. Ghetta, M. Allibert, D. Heuer, E. Noah, T. Stora, in preparation.

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- Gottberg, T. Mendonca, T. Stora, ISOLDE Newsletters 2013. Available from: <http://isolde.web.cern.ch/isolde/default2.php?index=index/scienceindex.htm&main=science/newsletters.php>.
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