Study of near-barrier Fusion and transfer of ^{6}Li with ^{194}Pt

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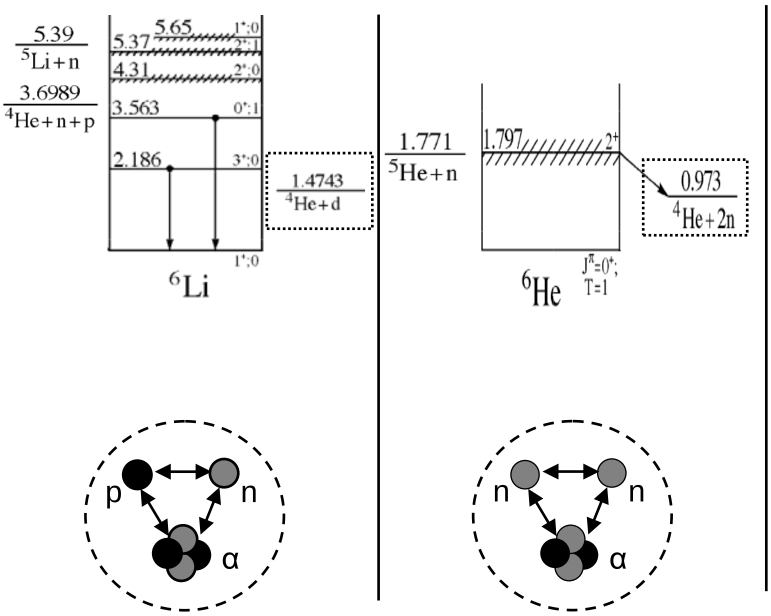
1.Motivation

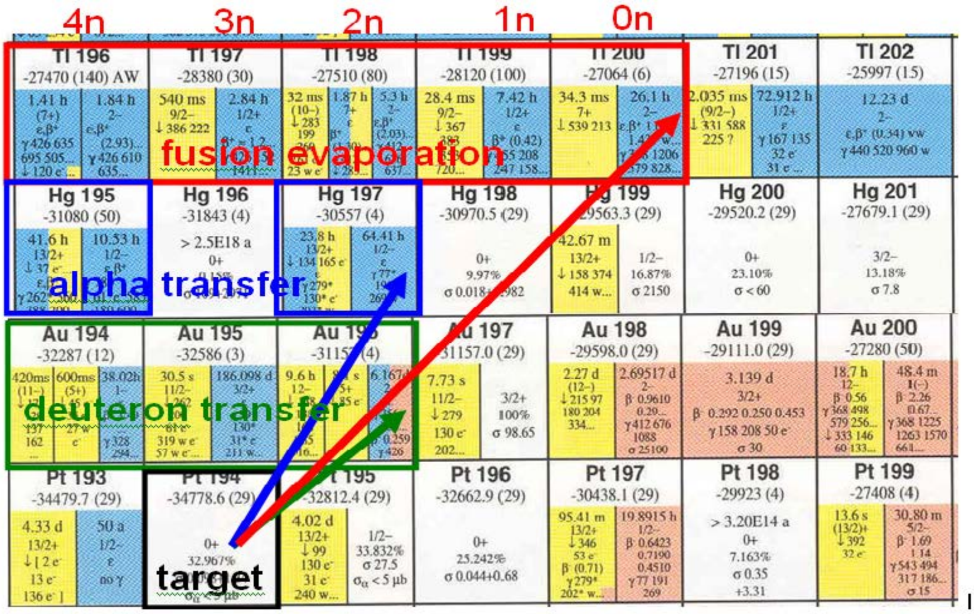
Reaction with slightly bound nuclei started to be studied intensively with the occurrence of radioactive beams. These fragile objects behave, even at low energies, differently from stable, solidly bound nuclei. One of their particularities is the fact that when approaching another nucleus it is possible that the Coulomb field close to the barrier is enough to break them apart. This process takes place in the vicinity of the target nucleus, so we have to account for the complex (Coulomb plus nuclear) interaction of at least three objects. As a result, one may obtain a classical complete fusion but also an incomplete fusion with only a part of the bombarding nucleus, the breakup fusion process. Especially interesting for such kind of studies are the slightly bound nuclei that have a pronounced cluster structure.
The present experiment proposes to measure the fusion evaporation cross section for ^{6}Li on ^{194}Pt with the aim of comparing the results with those using a ^{6}He projectile. A sensible enhancement of fusion cross section at sub barrier energies is expected (see e.g. Yu. E. Penionzhkevich et al. PRL **96,** 162701 (2006)). There are many common features of ^{6}Li and ^{6}He as can be seen from the scheme below.



In particular, the (alpha, d) cluster structure of 6Li is well known with S_{α}=1.48MeV. The radius of ^{6}Li (between 2.32 and 2.45fm) is about 10% higher than the systematic. Studies of momentum distributions for breakup residues of ^{6}Li and ^{6}He lead to similar results.

2.Experimental Set-up

In the experiment, foils of separated isotope ^{194}Pt with a thickness of 3 microns will be irradiated with a ^{6}Li beam of various energies. The Pt foils will alternate with Al foils of 5 microns. After irradiation, the foils will be placed in a special device for measuring their activation, existent in our Lab. The device is composed of two face to face clover detectors in a closed geometry in order to increase the detection efficiency. The Pt foils will be measured with the aim of identifying the number of produced isotopes of Tl from which we can determine the fusion-evaporation cross section for each channel. The figure below indicates the expected isotopes and their lifetimes:



A special simulation program was written and used for optimizing the composition of the stack of foils, the energies of the ^{6}Li beam and their intensity and the periods of irradiation/measure. The request below is resulting from these simulations. For the production cross sections, the PACE program has been used for near barrier energies. For energies deep under barrier we used as a guide the results from a measurement on a neighboring isotope ^{198}Pt (A. Shrivastava et al. Phys Rev. Lett. 103, 232702 (2009)). Compared to this experiment, the measurement on the ^{194}Pt has the advantage of accessing both in complete and incomplete fusion channels radioactive nuclei that are suitable for measurement by activation.

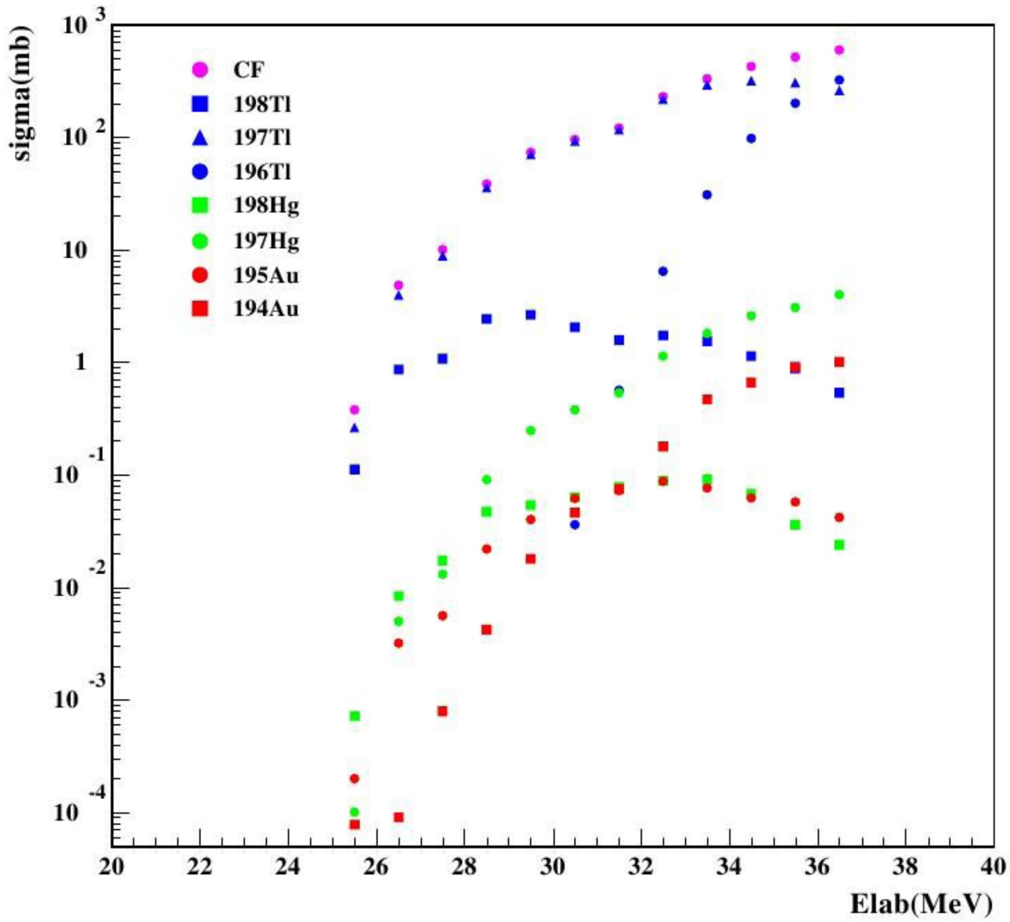
A new technique for decreasing the background of the measurements (and therefore increase the quality of data) will be used. This technique will use in the device for measuring the activation, a LEP detector instead of one clover, allowing to record the coincidences between gamma rays and X rays of a given isotope (A. Lemasson et al., Nucl. Instrum. Methods Phys. Res., Sect. A 598, 445 (2009)). Besides making a comparison of ^{6}Li and ^{6}He, as pointed out by Shrivastra et al. will be interesting to make another similar measurement but with a bound incoming projectile like alpha particle. This study will make the object of a subsequent proposal. Meanwhile, the channels with alpha transfer will be studied already in the present experiment together with the deuteron (loosely bound nucleus) transfer.

3. Estimated production rates and beam tine request

The 8.5MV on Tandem terminal is customary in our Lab. With this voltage ^{6}Li ions may be accelerated to 34MeV. Besides, an additional irradiation at 29.5Mev will be necessary as will result from the tables below. At both energies it is possible to obtain intensities of 10enA or $2x10^{10}$ part/sec.

A model calculation for the cross section of various open channels is given in the following figure.

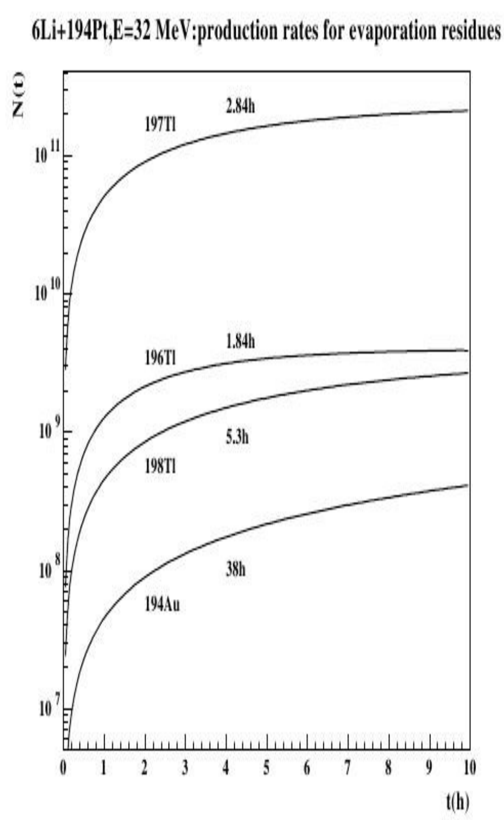
6Li+194Pt, experimental(PACE4) fusion evaporation cross sections

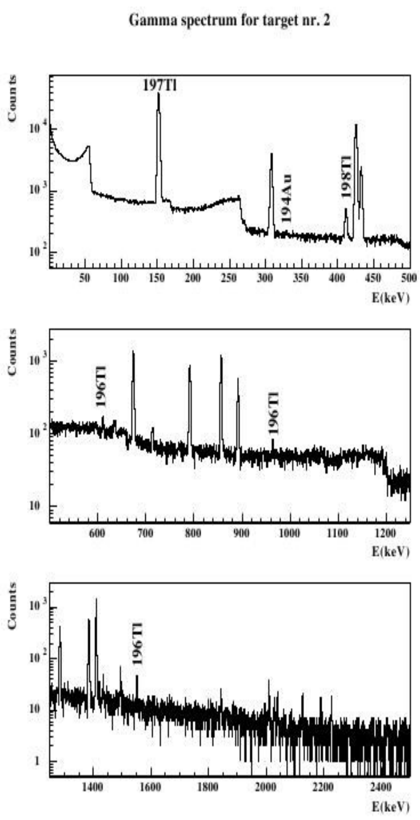


For 34MeV beam energies, the corresponding incident energies on each of the 6 foils of the stack will be: 34., 31.8, 29.5, 27.1, 24.5 and 21.7 respectively while for the incident energy of 29.5MeV the energies will be: 29.5, 27.1, 24.5, 21.7, 17.7 and 15.3 MeV respectively. The following table shows the estimated production rates (in part/sec) for various reaction channels on the foils of the stack for the E=34MeV and I=10enA:

CF	0.33109E+08	0.16403E+08	0.66486E+07	0.10339E+07	0.90025E+04	0.75679E+01
198Tl	0.88373E+05	0.13269E+06	0.18054E+06	0.95910E+05	0.33823E+04	0.11818E+02
198Tl	0.25039E+08	0.15657E+08	0.63831E+07	0.92759E+06	0.58237E+04	0.31624E+01
196Tl	0.75892E+07	0.41815E+06	0.77413E+03	0.97744E+00	0.79692E-03	0.37743E-06
198Hg	0.52714E+04	0.67486E+04	0.45595E+04	0.16055E+04	0.17919E+02	0.19612E-01
197Hg	0.20155E+06	0.80139E+05	0.24541E+05	0.17068E+04	0.12696E+01	0.24493E-04
195Au	0.48528E+04	0.65711E+04	0.40093E+04	0.58110E+03	0.43009E+01	0.19594E-02
194Au	0.51163E+05	0.12450E+05	0.25570E+04	0.91803E+02	0.56593E+01	0.38046E+01

The following figure (left) shows the time evolution of the production rates in the case of few reaction channels of major interest.





From the data presented above, the simulation program leads to the shape of the measured gamma spectra for a period of irradiation of 2 hours, pause of one hour and activation measurement one hour as a possible scenario (the second foil in the stack is shown) which is shown in the right side figure above.

Another possible (and more realistic) scenario would be: 3h irradiation, 0.5 h transfer to the activation measuring station, 3h measurement and another hour for the transfer back to the beam line. In this case, an irradiation- measure cycle will take about 1UT. Considering that the X-gamma coincidence is a new unexplored technique in our Lab for activation measurements and the subsequent loss of statistics in this case, we propose to measure for the E=29.5MeV twelve cycles, three clover-clover and 9 LEP-clover. One day will be reserved for recomposing the stack and change the energy to the maximal 34MeVwith may be a necessary conditioning of the accelerator tubes. After that, another 6 cycles will be measured in these conditions, two with clover-clover configuration and 4 with LEP-clover configuration.

In total we require 21UT of beam time with the specified characteristics.