Contribution ID: **14** Type: **Poster**

Mass measurement and spectroscopy of 190-Re using the Q3D magnetic spectrograph

Monday, 2 May 2022 19:20 (20 minutes)

The neutron-rich isotope rhenium-190 lies in the mass ≈170-190 region of the nuclide chart; a region known for the occurrence of a large number of metastable, isomeric nuclear states [1]. The formation of these states is caused by significant quadrupole deformations and are named K-isomers, due to the large angular momentum projection, K, on the nuclear deformation axis. These K-isomers are deformation aligned states and therefore experience hindered decays into the nuclear states with significantly different K values or those which are rotationally aligned. Therefore, these high-K states commonly have long lifetimes which can form astrophysical waiting points at low energies [2].

Rhenium-190 is already known to exhibit an isomeric state, most recently observed by Reed *et al.* [2] at the Experimental Storage Ring (ESR) at GSI. This isomeric state has a half-life of $t_{1/2}$ = 3.2 ± 0.2 h, an excitation energy of 204 ± 10 keV and a spin-parity of I = (6−). As rhenium-190 lies on the decay path of nuclei populated in the astrophysical rapid neutron capture process (known as the *r*-process), it is possible that this state is an astrophysical waiting point. To support astrophysical network calculations, such as the Brussels Nuclear Library (BRUSLIB) [3], and to reduce decay-energy uncertainties dominating over uncertainties in the reaction rate it would be beneficial to reduce the uncertainty in the excitation energy of the isomeric state in rhenium-190. An investigation into the energy-level scheme in rhenium-190 may also lead to the discovery of further isomeric states, as currently the level scheme for this nuclei is quite poorly known, with only five states (including the ground state) currently reported.

This presentation will detail an experiment performed at the Q3D magnetic spectrograph at the Maier-Leibnitz Laboratory (MLL) in Munich. The isotopes rhenium-190 and iridium-192 were produced by bombarding targets of osmium-192 and platinum-194, respectively, with an 18 MeV polarised deuteron beam and measuring α-particle ejectiles.

An energy calibration was produced by comparing the well known energy levels in the iridium-192 spectrum to the measured peak positions. This calibration was used to obtain the difference in Q-values for the reactions 192Os(d,α)192Re and 194Pt(d,α)192Ir. As the values for the masses of platinum-194, osmium-192 and iridium-192 are well known, this difference enabled measurement and publication of the atomic mass of rhenium-190 to a significantly higher precision than previously published [4].

The current stage of the project involves investigating the energy, spin and parity of the observed excited states in rhenium-190. The spin and parity of the states will be investigated by comparing the intensity of the peaks in the rhenium-190 spectrum detected at a variety of angles to Distorted-Wave Born Approximation calculations of the differential cross sections for different spin/parity configurations. Through this, it is anticipated that uncertainties in the properties of the I = (6−) isomeric state can be reduced. The current state of the analysis will be presented.

[1] P. M. Walker and G. D. Dracoulis. Energy traps in atomic nuclei. *Nature*, **399**, 35–40 (1999).

[2] M. W. Reed et al. Long-lived isomers in neutron-rich Z=72-76 nuclides. *Phys. Rev. C*, **86**, 054321 (2012).

[3] Y. Xu et al. Databases and tools for nuclear astrophysics applications BRUSsels Nuclear LIBrary (BRUSLIB), Nuclear Astrophysics Compilation of REactions II (NACRE II) and Nuclear NETwork GENerator (NETGEN). *Astronomy and Astrophysics*, *549*, **A106** (2013).

[4] M.R. Griffiths et al. Mass Measurement of Re-190. *J. Phys. G: Nucl. Part. Phys*, **47**, 085104 (2020).

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Session Classification: Poster Session On Site