# Spectroscopic Studies of $^{18}$O, $^{19}$O and $^{20}$O using the ($^{7}$Li,p)-Reaction

T. Dorsch [a], H.G. Bohlen [a], W. von Oertzen [a], Tz. Kokalova [a], C. Wheldon [a], T. Faestermann, R. Hertenberger, R. Krücken, M. Mahgoub, M. Milin [b], and H.-F. Wirth
[a] Hahn-Meitner-Institut Berlin GmbH, Glienicker Str. 100, 14109 Berlin, Germany
[b] Ruđer Bošković Institute, Bijenicka 54, HR 10002 Zagreb, Croatia

Detailled knowledge of the structure of the neutron-rich oxygen isotopes with A≥19 is still missing, and in $^{18}$O the (6p4h)-band is also not yet known. We have therefore started the investigation of the A= 18, 19, 20 oxygen isotopes using the ($^{7}$Li,p)-reaction on $^{12}$C, $^{13}$C, $^{14}$C targets, respectively.

The measurements have been performed at the Q3D magnetic spectrograph of the Maier-Leibnitz-Laboratory, Garching, at an incident energy of 44.0 MeV and a scattering angle of 10°. Since we wanted to cover a range of about 20 MeV excitation energy, it was necessary to measure the reaction on the three carbon targets and a $V_2O_5$ target at ten different magnetic field settings. The latter target was used to be able to identify contamination lines resulting from $^{16}$O (it turned out, that the oxygen content was negligible in the carbon targets).

The spectra have been calibrated using the known states of $^{18}$O, and the same calibration could also be used for the $^{19}$O and $^{20}$O spectra. For each isotope the ten measured pieces of spectra were joined precisely together in the overlap region, and the counting rate was adjusted to a common scale. As an example the full spectrum for $^{18}$O is shown in Fig. 1, however, the presented analysis is still preliminary. Similar spectra were obtained also for $^{19}$O and $^{20}$O. The relatively large value of about 44 keV for the energy resolution is related to the energy-loss of the incident $^{7}$Li in the targets, which had thicknesses between 70 and 100 $\mu$g/cm$^2$.

In the analysis of the spectra the states above particle thresholds have been fitted with Breit-Wigner line shapes. The flat background observed in the central panel of Fig. 1 is described as a 3-body phase-space distribution (blue) of the three particles $p$ (detected), $n$ and $^{17}$O (both not detected). Also a 4-body phase-space distribution ($p + n + n$ + $^{16}$O) contributes (lower panel, pink line; the green line is the sum of both phase-space distributions). Since the $^{13}$C and $^{14}$C targets contained some $^{12}$C, the $^{18}$O spectrum measured on the $^{12}$C target was used in these two cases in the fit also as background contribution.

In this analysis a large number of states is observed, in the case of $^{19}$O and $^{20}$O about two times more than previously known. This is shown in Table 1, where the total number of known states [1,2,3] is compared to the number of states from our result, the latter is split also into the parts of previously known and unknown states. The interpretation of these results in terms of band structures has been started. In addition, further measurements at larger scattering angles are planned with the aim to determine characteristic shapes of angular distributions for spin and parity assignments.

| number of states in: | $^{18}$O | $^{19}$O | $^{20}$O |
|---|---|---|---|
| known [1,2,3] (total) | 117 | 55 | 29 |
| observed now in total | 101 | 102 | 60 |
| from these: known | 78 | 43 | 23 |
| new | 23 | 59 | 37 |
| Q-value [MeV] | +8.40 | +7.41 | +6.84 |
| obs. $E_x$-range [MeV] | 0−20.9 | 0−20.6 | 0−20.2 |

Table 1: Summary of the total number of states in $^{18}$O, $^{19}$O and $^{20}$O known from the literature ($2^{nd}$ line) and observed in the ($^{7}$Li,p) reaction of the present work ($3^{rd}$ line). In the latter case it is also specified, how many states were previously known and how many are new states. In the last two lines the reaction Q-values and the observed ranges of excitation energies are given for each isotope.

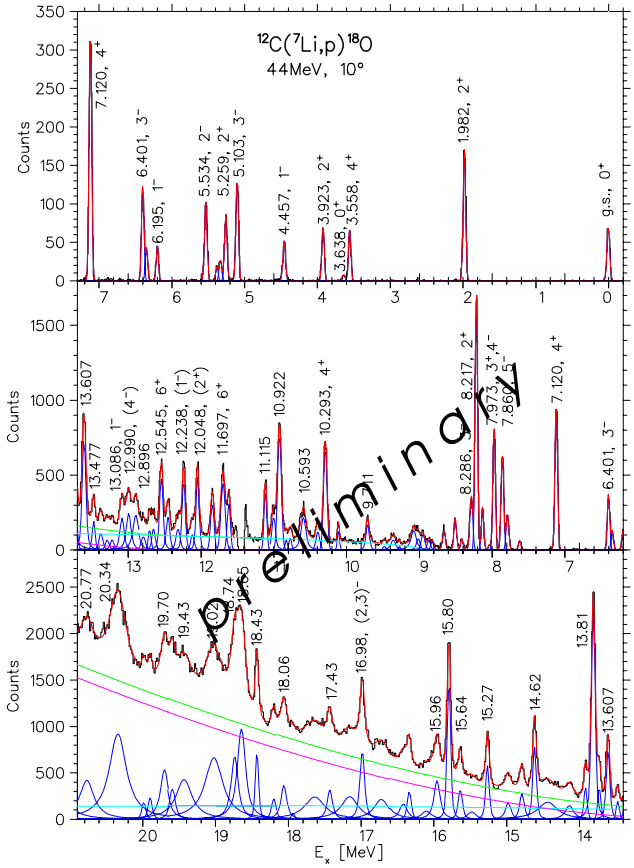


Fig. 1: Spectrum of the $^{12}$C($^{7}$Li,p)$^{18}$O reaction measured at 44.0 MeV incident energy and at $\theta_{Lab}$= 10°. Shown spin and parity assignments were taken from the literature. The spectrum in the upper panel is scaled down by a factor of three.

## References

[1] F. Ajzenberg-Selove, Nucl. Phys. **A475** (1987) 1
[2] D.R. Tilley *et al.*, Nucl. Phys. **A636** (1998) 249
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