Beta Decay of ^{22}O

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The study of light nuclei far from stability has been recently renewed by the possibility of production through the projectile fragmentation of intermediate energy heavy ion beams at GANIL. The results presented here have been obtained with the Projectile Fragments Isotopic Separation (PFIS) method developed at the LISE spectrometer.

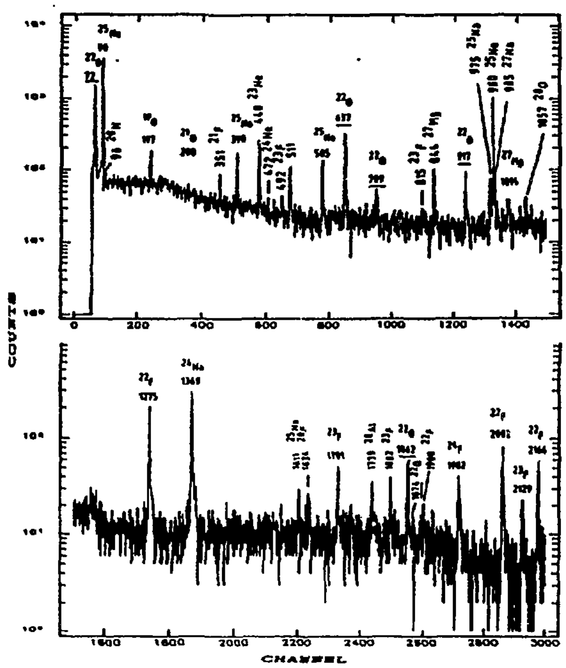
^{22}O is a Tz = 3 nucleus and is the first in a series of seven such nuclei in the sd shell extending from ^{22}O to ^{24}Mg. Although the half life of ^{22}O was previously measured by Murphy et al.[1], the present study is the first beta-gamma spectroscopy on this neutron rich nucleus. Five gamma lines have been attributed to the β decay of ^{22}O with a measured half life of $T_{1/2}$ = (2.25±0.15)s and a partial decay scheme has been established.

THE EXPERIMENT

The ^{22}O nuclei were produced as fragments of a 60 MeV/n ^{40}Ar beam interacting with a thick Be target. They were selected among all the produced nuclei with the LISE separator. Details about the performance of the spectrometer and the Projectile Fragments Isotopic Separation method are fully given in [2] and [3] respectively. With the used experimental conditions, the ^{22}O nuclei were collected on a mylar catcher foil at the rate of 23 nuclei/s.

The detectors consisted of two NaI and one Ge detector triggered either by a plastic beta detector or by NaI-Ge coincidences. Details about the experimental set-up, the detector calibrations and the gamma ray analysis can be found in ref [4].

Most of the contaminants transmitted with ^{22}O by LISE have well-known decay schemes and are easily identified in the gamma spectrum (fig. 1).



Gamma spectrum measured in coincidence with the β decay of nuclei during beam-off periods. The LISE line has been optimized for ^{22}O. Lines are identified by energy in keV and parent source. The six observed gamma lines of ^{22}O are underlined.

Figure 1

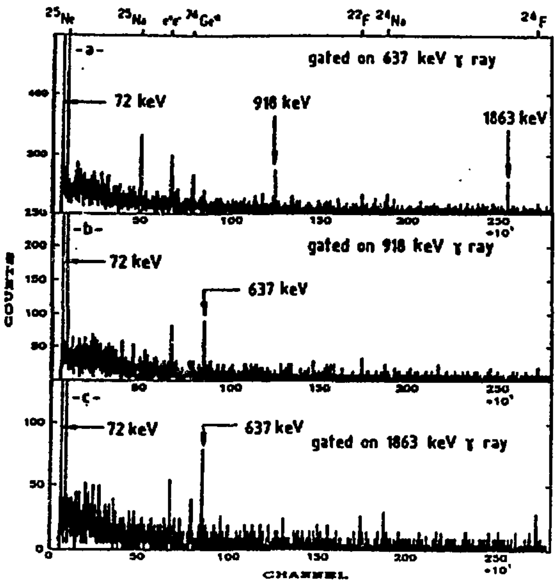
Energy (keV)	Relative intensity[a]	Half-life (s)
71,6 (2)	102 (33)	2,33 (15)
637,4 (2)	100 (7)	2,23 (25)
709,6 (3)	13 (3)	3,30 (120)
918,0 (2)	34 (4)	1,75 (29)
1862,6 (3)	56 (7)	2,17 (48)
1874,2 (10)	9 (4)	

a) Intensities normalized to 100 for the 637keV γ ray and not corrected for summing effect.

Energies in keV, relative intensities and half-lives of the beta-delayed gammas observed in the decay of ^{22}O. Numbers in parentheses represent the uncertainty in the last digit(s).

Table 1

In table 1 the energies and intensities of the β-delayed gammas are given as observed in the decay of ^{22}O. The NaI-Ge coincidence spectra are presented in fig. 2. The uppermost plot in fig. 2 shows the spectrum gated on the 637 keV ray illustrating the coincidence of the line with the 72,918 and 1863 keV γ rays while the 710 keV is not observed. Fig. 2b and c give the spectrum gated on the 918 and 1863 keV γ rays, respectively, illustrating their mutual non-coincidence.

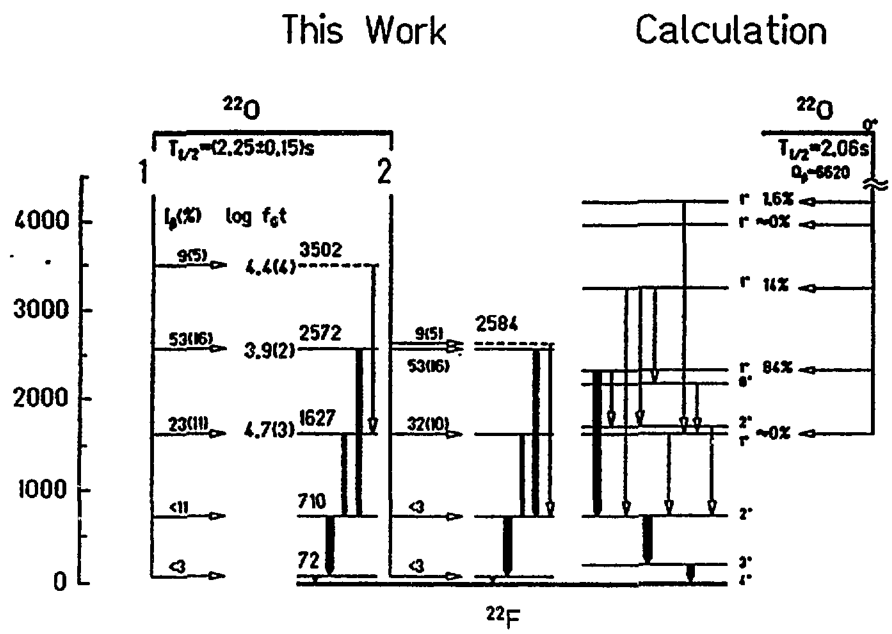


Coincidence data illustrating γ-γ coincidence relationships among some of the deexcitation γ rays of ^{22}F resulting from ^{22}O β decay. The ^{22}O γ lines are indicated by an arrow. The contaminants are identified by parent source on the upper scale.

Figure 2

THE ANALYSIS

The excited levels of ^{22}F were first studied by Stockes et al. [5] using charge exchange reaction. All the deexcitation γ rays observed in the present work can be fitted into the lowest experimental levels except the 72 keV line. The coincidence data and the high intensity observed for the 72 keV and 637 keV, imply the existence of a second excited state at 710 keV. From these data alone it is however impossible to decide whether the first excited state is at 72 keV or 637 keV. More recently ^{22}F has been reinvestigated by Orr et al. [6] to provide additional reaction data. Indeed a 72 keV first excited state has significant consequence for the analysis of charge-exchange reactions since they cannot get sufficient energy resolution to separate the ground and 72 keV states. As far as excitation energies are concerned this implies a systematic shift of all the measured values. From the analysis in ref. [6] it followed that the observed "ground state peak" was predominantly due to the 72 keV level. Consequently the values from change-exchange studies have been re-interpreted. The presence of a ground state and first excited state doublet in ^{22}F is thus definitely settled.



Partial decay scheme of ^{22}O. The two proposed schemes deduced from this work differ only in the placement of the 1874 keV transition. Excitation energies are in keV. Only those experimental levels that are firmly established are shown as straight lines. On the right side is shown the β decay of ^{22}O calculated by Brown and Zhao on the basis of Wildenthal's wave functions. Only levels that are pertinent to the β decay and γ transition higher 1% are shown.

Figure 3

The relative β branching I_{β} to excited states in ^{22}F deduced from the γ ray intensities presented in this work is shown on the left side in fig. 3. Since the 1874 keV line was not observed in coincidence data, the branchings, including summing corrections, were calculated assuming several possibilities for this γ transition (to the 710 keV and 1627 keV levels). The two possible decay schemes are presented in fig.3. The logfot values for the allowed transitions quoted in this figure have been calculated using the tabulations of Gove and Martin [7]. The theoretical decay scheme of ^{22}O calculated by Brown and Zhao [8] on the basis of Wildenthal's wave functions [9] is presented on the right side in fig. 3.

Concerning the γ decay scheme, there are clearly similarities between experiment and calculations :

i) the decay of the first 2^+ state is exclusively through the first 3^+ state.

ii) the major gamma branching ratios are associated to the cascade $1^+(2) \rightarrow 2^+(1) \rightarrow 3^+(1) \rightarrow {}^{22}F$ ground state.

iii) the transition from the second to the first 1^+ excited states is not expected and not observed in the experiment.

On the contrary, the decay of the proposed level at 3502 keV is not expected by the calculation as far as this level is associated to the theoretical third 1^+ level, since the predicted branch (not shown on the theoretical level) is very small. The possibility that the observed 1874 keV line may feed the 710 keV level (i.e. level scheme number 2) would imply the existence of two 1^+ states close together (2572-2584), one of which would be like the "intruder" state discussed for ^{20}O decay in [10].

The most striking disagreement between theory and experiment concerns the β feeding of the 1^+ first excited state at 1627 keV. The shell model predicts a very weak β decay branch to this state whereas, experimentally, this branch carries ~ 30% of the total strength. As suggested by Orr et al. [6] the probable explanation of this discrepancy may be found within the shell model wave functions. Indeed the lowest 1^+ state in ^{22}F has only a very small $1d^6_{5/2}$ component while this branch is dominant for the ^{22}O ground state and the second 1^+ state in ^{22}F.

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