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BETA DECAY OF ^{22}F

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1. Introduction

In the last years the interest in the properties of nuclei far from the region of beta stability has strongly increased. However, the experimental information about the neutron-rich isotopes of light elements is still poor, and therefore, new measurements of masses and half-lives and the studies of decay properties of these nuclei are very useful.

In 1965 Vaughn et al.[1] reported on the production of ^{22}F in the reaction $^{22}Ne(n,p)^{22}F$. On the basis of the decay scheme and the measured beta end-point energy of 11.2 ± 0.6 MeV they determined a mass excess $\Delta = 4.5 \pm 0.6$ MeV for ^{22}F.

In 1969 Stokes and Young[2] deduced from the kinematics of the reaction $^{22}Ne(t,\ ^{3}He)\ ^{22}F$ a mass excess value of 2.828 ± 0.030 MeV.

In the present work we have investigated the beta decay of ^{22}F and the following gamma de-excitation. New data on the decay scheme of ^{22}F are obtained.

2. Experimental Procedure

The experiment has been performed using the mass separator EMSONHIB[3]. The separator operates on-line with the 310-cm heavy ion cyclotron of the JINR at Dubna.

The ^{22}F nuclei were produced in the two-nucleon-transfer reaction $^{181}Ta(^{22}Ne,^{22}F)$. The ^{22}Ne ion beam, accelerated to 174 MeV, bombarded a 20 μm thick metallic tantalum target. Separated nuclear reaction products were collected on a 100 μm thick aluminium foil. Beta and gamma detectors were placed directly behind the collecting foil of the mass separator.

Beta particles were detected in a $dE/dx-E$ scintillation spectrometer consisting of a plastic scintillator (0.5 mm thick, 35 mm in diameter) and a 70 x 70 - mm stilbene crystal. The energy calibration was performed with ^{207}Bi , ^{144}Pr , ^{23}Ne and ^{20}F electron emitters /4/ under exactly the same conditions as those for the measurement of the ^{22}F spectrum (short-lived nuclei of ^{23}Ne and ^{20}F were also produced in the $^{181}Ta+^{22}Ne$ multinucleon-transfer reaction). The operation of the detecting system up to 10.4 MeV was checked by beta particles from the ^{16}N decay.

The gamma spectrum was measured by a 30-cm^3 Ge(Li) detector. The gamma rays /5/ from a ^{226}Ra source and the background gamma lines from the reaction $^{56}Fe(n,\gamma)$ (ref. 6) were used for the calibration.

Ions with mass number 22 were collected on the catcher of the mass separator. As shown by Artukh et al. /7/ , the cross section for the formation of ^{22}O , ^{22}Na and ^{22}Mg are much smaller than that for ^{22}F. Of all produced nuclei with $A = 22$, the radioactivity of ^{22}F was measured preferentially. Due to the large cross section for the one-nucleon-transfer reaction $^{181}Ta(^{22}Ne,^{21}F)$, a small amount of ^{21}F was separated in form of HF molecular ions. Background spectra were measured without interrupting the target irradiation and with the switched-off mass separator.

The half-life measurement was performed under the pulsed operating conditions of the cyclotron and the separator. In this measurement only gamma quanta of $E_\gamma > 0.7$ MeV were recorded in order to eliminate the gamma rays of ^{21}F. Beta particles were absorbed in 6 mm of lead.

3. Experimental Results and Discussion

The beta spectra of ^{22}F and the background are shown in the upper part of fig. 1. In the beta spectrum we do not observe the intense (33%) beta transition of 11.2 ± 0.6 MeV reported by Vaughn et al. /1/

In the lower part of fig. 1 the Fermi-Kurie plots of ^{20}F and ^{22}F are shown. Since our measurements were carried out at a small distance between the scintillation detector and the collecting foil, the Fermi-Kurie plots are not straight lines. Figure 1 shows that the difference between the end-point energies of ^{20}F and ^{22}F is very small. The maximum beta energy $E_\beta = 5.419 \pm 0.013$ MeV (99.8%) of ^{20}F is well known /8/. Therefore, we are able to determine the maximum beta energy of ^{22}F with high accuracy. From a least square fit to the Fermi-Kurie plots we derived the ^{22}F maximum beta energy $E_\beta = 5.5 \pm 0.1$ MeV.

The measured gamma spectrum is shown in fig. 2. All gamma transitions fit into the known level scheme /9/ of ^{22}Ne with the exception of the 1.90-MeV line. The gamma intensities obtained agree with the branching ratios reported by Kutschera et al. /10/

The decay curve of ^{22}F is shown in fig. 3. The half-life, determined by means of a least square fit procedure, is 4.2± 0.1 sec.

The proposed decay scheme of ^{22}F is showm in fig. 4. The beta decay of ^{22}F leads to the excitation of the 5.52-MeV (4^+), 6.35-MeV (6^+) and 7.54-MeV levels in ^{22}Ne. The beta branching ratios given in table 1 were determined under the assumption that all the states of ^{22}Ne excited by the beta decay of ^{22}F de-excite through the 1.28-MeV level. The missing intensities of about 16% in the total sum of beta branching intensities may be due to beta transitions to higher excited states of ^{22}Ne de-exciting by high-energy gamma transitions for which the Ge(Li) detector efficiency is too small. On the other hand, the excessive intensity of the 1.28-MeV transition cannot be caused by the contribution of the decay of long-lived ^{22}Na, because the background spectrum (fig. 2) does not contain its 1.28-MeV line. The background spectrum was measured immediately after the end of the gamma measurement.

All the values of $\log ft$ (table 2) calculated using the tables of Dzhelepov et al. /11/ are within the empirical range for allowed transitions. This result and the proposed decay scheme allow us to assign a spin and parity value of 5^+ to the ground state of ^{22}F. Consequently, the 5.64-MeV level of ^{22}Ne with a spin and parity of 2^+ or 3^+ can not be excited by an allowed beta transition. According to our gamma measurement we suggest the existence of a 7.54-MeV level which decays to the 5.64-MeV level by the 1.90-MeV gamma transition.

The proposed decay scheme and the measured maximum beta energy of $E_\beta = 5.5 \pm 0.1$ MeV lead to the value of $Q_\beta = 11.0 \pm 0.1$ MeV.

On the basis of the ^{22}Ne mass excess $\Delta = -8.025$ MeV (ref. 12) we obtained for the mass excess of ^{22}F the quantity $\Delta = 3.0 \pm 0.1$ MeV. This result agrees fairly well with the value 2.828 ± 0.030 MeV reported by Stokes and Young /2/.

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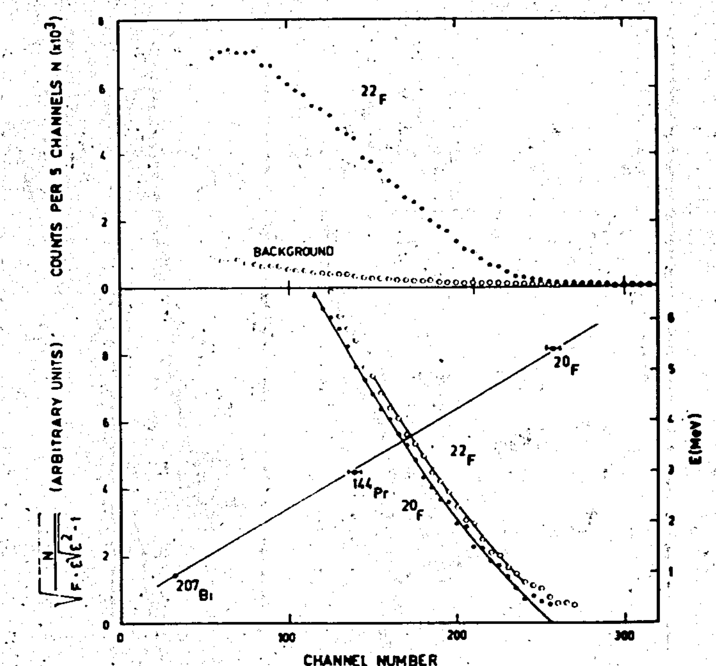


Fig. 1. Spectra of the ^{22}F beta decay and the backgro part). Fermi-Kurie plots of the ^{22}F and ^{20}F beta spect with the energy calibration (lower part).

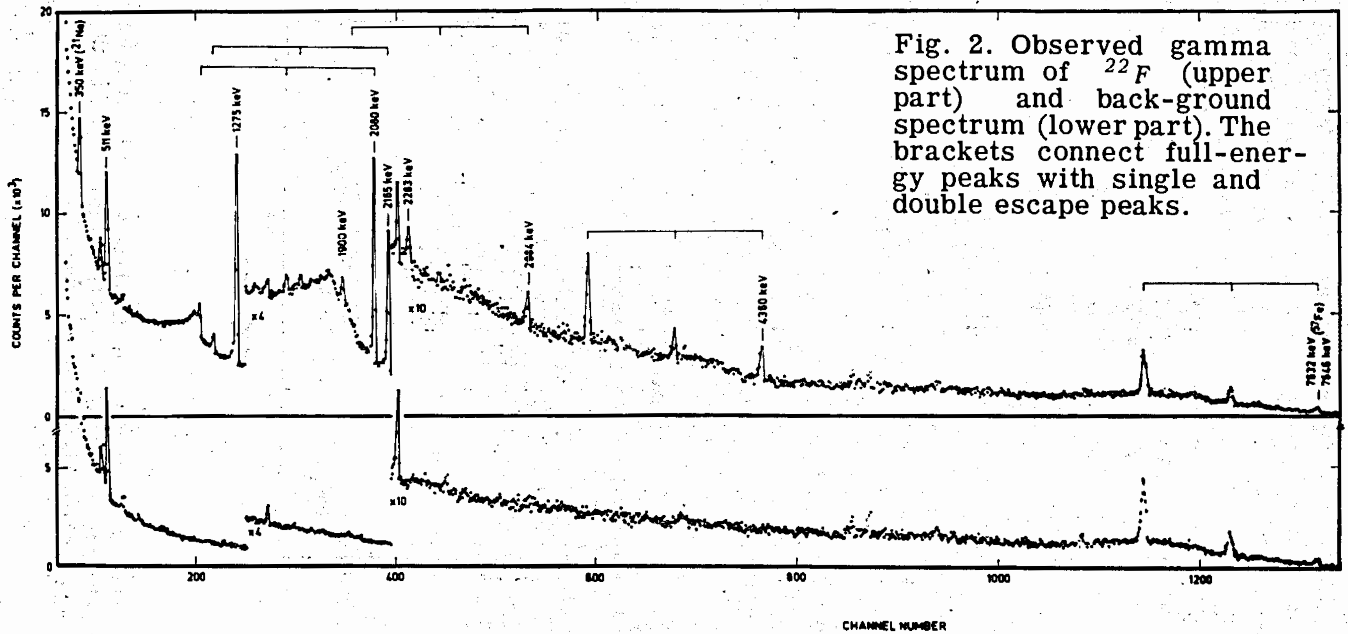
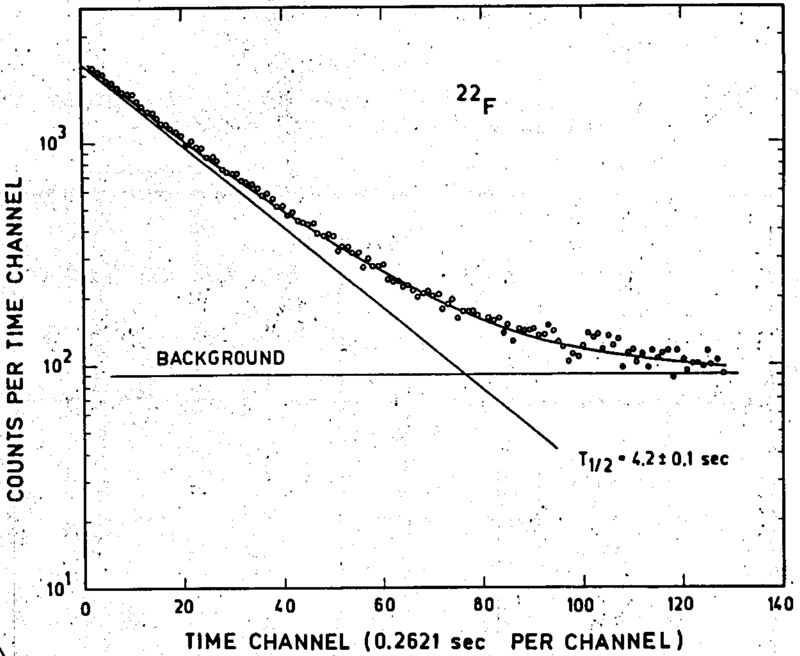


Fig. 2. Observed gamma spectrum of ^{22}F (upper part) and back-ground spectrum (lower part). The brackets connect full-energy peaks with single and double escape peaks.

Fig. 3. Decay curve of ^{22}F.



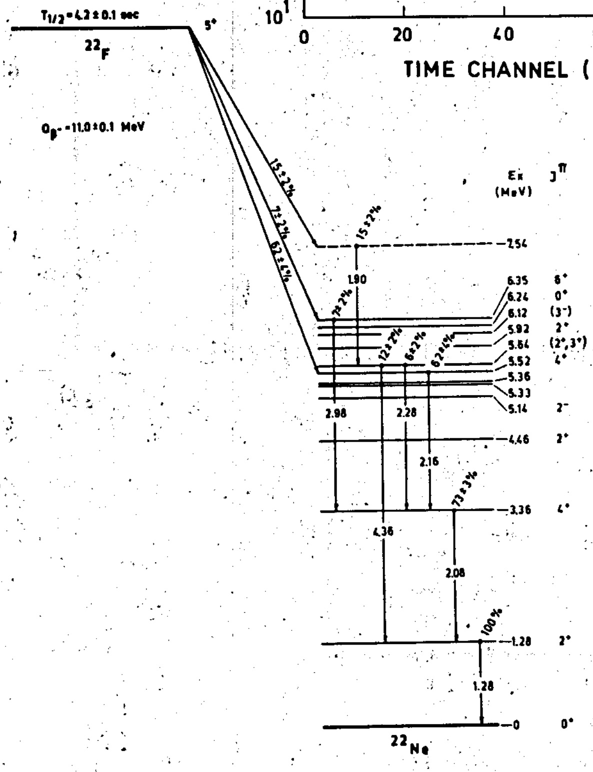


Fig. 4. Decay scheme of ^{22}F.

Table 1

Energies and relative intensities of gamma transitions following the beta decay of ^{22}F

E_γ (keV)	Relative intensities (%)
1275 ± 5	100
1900 ± 5	15 ± 2
2080 ± 5	73 ± 3
2165 ± 5	62 ± 4
2283 ± 5	6 ± 2
2984 ± 5	7 ± 2
4360 ± 5	12 ± 2

Table 2
Characteristics of the ^{22}F beta decay

^{22}Ne level (MeV)	J^{π}	Beta end-point energy (MeV)	Beta branching ratio (%)	log ft
5.52	4^+	5.5 ± 0.1	62 ± 4	4.8
6.35	6^+	4.6 ± 0.1	7 ± 2	5.4
7.54	-	3.5 ± 0.1	15 ± 2	4.5