Beta-ray branching in the decay of ^{20}F

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Measurements on the γ-ray spectrum from 11-sec ^{20}F resulted in an energy of 3332.51(19) keV for the cascade γ ray from the ^{20}Ne 4.97-MeV state and a β-branching intensity to this level of $0.90(4)\times10^{-4}$ per decay. The corresponding $\log f_0t$ value is 7.16(2), and the excitation energy of the ^{20}Ne state is 4966.51(20) keV.

[RADIOACTIVITY ^{20}F; measured E_γ, I_γ; Ge(Li) detector; deduced E_x, β branching, and $\log f_0t$ value.]

As part of a program of more precisely defining the properties of nuclei in the $A\sim20$ region, for comparison with theoretical nuclear structure calculations, we have reinvestigated the β decay of ^{20}F. This activity is known[1] to decay with a half-life of 11.00(2) sec almost 100% by an allowed $2+\rightarrow2+\beta$ transition to the ^{20}Ne first-excited state whose excitation energy has now been determined[2] to be 1633.674(15) keV. A very weak additional β-ray branch was found some years ago at Brookhaven[3] and was measured with improved accuracy a few years later by Gallmann *et al.*[4] That branch was a non-unique first-forbidden β decay leading to the known $J^\pi=2^-$ state of ^{20}Ne at 4.97 MeV with a branching intensity of 1.7(3) $\times10^{-4}$ per decay. An energy value of 3334.3(7) keV was measured for the cascade γ ray. The corresponding ^{20}Ne excitation energy has been quoted[1] as 4967.9(7) keV.

In the present work the ^{20}F activity was produced in the $^{19}F(d,p)^{20}F$ reaction using deuterons of 2.0 MeV from the BNL 3.5-MV Van de Graaff. A target consisting of 2 mg/cm^2 of CaF_2 evaporated onto a thin Ni backing was clamped in a "rabbit" for transport to a remote Ge(Li) detector. With an irradiating beam current of ~25 nA the total initial counting rate in the detector was $\sim10\,000$/sec. Sources were counted for 11 sec and returned for a new irradiation of 8-sec duration. In order to determine both the energy and relative intensity of the 3333-keV γ ray of ^{20}F, a weak source of ^{56}Co was placed adjacent to the rabbit line. The ^{56}Co line at 1771.351(16) keV, along with the various lines from 3201.962(16) to 3451.152(17) keV, provided excellent references for both energy[5] and intensity[6] determinations.

Figure 1 shows a portion of a spectrum obtained in a 29-h accumulation of $^{20}F+{}^{56}Co$ radiations. Random summing of the 1633.602-keV γ rays produced a peak at 3267 keV, but the shape of this line was not suitable for energy analysis. An efficiency function, based on a least-squares fit of the intensities of the ^{56}Co γ rays, was used to derive the ratio of 3333/1634 γ-ray intensities for ^{20}F. Since the 3333-keV transition is a cascade[1] to the 1634-keV level, a correction had to be made for coincidence summing in the Ge(Li) detector, an effect which removes counts from the 3333(0) peak. This correction was established by measuring the β rays from the sample (above 2-MeV β energy), using a plastic scintillator, both in singles and in coincidence with the complete γ-ray spectrum. The ratio of these yields gave a total absolute efficiency of the Ge(Li) detector for γ rays of 1634 keV of 1.48(10)% in the geometry used. When this correction was included, along with the 99.4(2)% branching[1] of the 4.97-MeV state via the 3333-keV γ ray, the fractional β branching of ^{20}F to the 4.97-MeV state

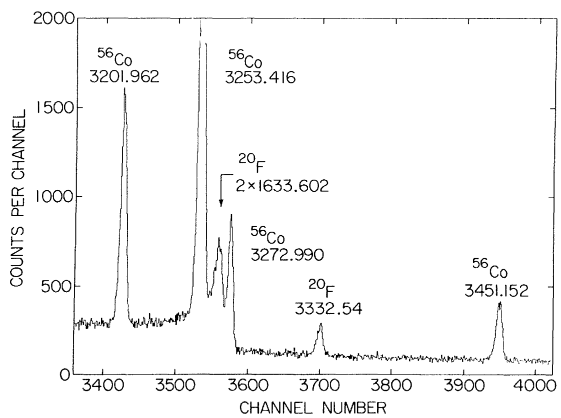

FIG. 1. Gamma-ray spectrum of ^{20}F plus a ^{56}Co reference source in the region of the ^{20}F γ ray of 3333 keV. γ-ray energies are in keV. A digital offset of 3328 channels was used and the energy dispersion was 0.476 keV/channel.

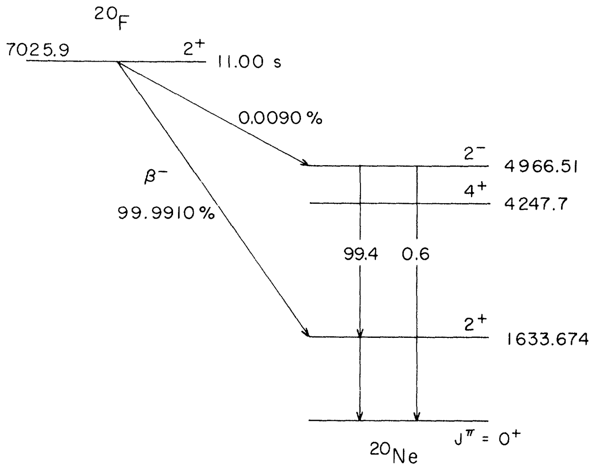

FIG. 2. Decay scheme of ^{20}F. New information from the present work includes the β-branching intensity to the 4.97-MeV level of ^{20}Ne and the excitation energy of that state.

was found to be $0.90(4)\times10^{-4}$ per decay. A possible correction for the removal of counts from the 1634-keV peak due to γ-bremsstrahlung coincidence summing was shown to be negligible.

The energy of the ^{20}F γ ray, based on the data of Fig. 1 averaged with the results of another run of 23 h at a different gain setting, was $E_\gamma = 3332.54(19)$ keV. These analyses used the peak-fitting program SAMPO[7] and a least-squares polynomial fit to the energies of the ^{56}Co γ-ray peaks. By including the recoil correction and adding the excitation energy of the ^{20}Ne first-excited state, the excitation energy of the higher ^{20}Ne state is 4966.51(20) keV.

Figure 2 shows the decay scheme of ^{20}F including the branching and excitation energy cited above. Additional details on ^{20}F decay, such as upper limits on β-ray branches to other ^{20}Ne states, are given in Ref. 1.

For calculating the $\log f_0 t$ value of the weak branch the β-decay energy was obtained from the Q_β of 7025.9(8) keV for ^{20}F quoted in the literature[1] together with the above value for the ^{20}Ne excitation energy. A value of $f_0 = 118.2(2)$ was obtained for the branch to the 4.97-MeV level. Combining this with the partial half-life based on the ^{20}F half-life of 11.00(2) sec and the β branching of $0.90(4)\times10^{-4}$ a $\log f_0 t$ value of 7.16(2) would be obtained if the transition were allowed.[8] A theoretical calculation of this non-unique first-forbidden rate is included in a comprehensive treatment of all known first-forbidden β decays in $A < 37$ nuclei.[9]

The present values for the energy and relative intensity of the 3333-keV γ ray of ^{20}F are both more accurate than previous determinations by a factor of ~ 4. In both instances the differences of approximately two standard deviations of the older values[4] suggest that the previous assigned errors may have been too small.

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[8] We follow the convention of quoting $\log f_0 t$ values for non-unique first-forbidden β decays even though this procedure has no theoretical justification.

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