

ASTROPHYSICAL ASPECTS OF RADIATIVE CAPTURE OF PROTONS BY  $^{19}\text{F}$ 

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The particles that are most effective in causing nuclear reactions in astrophysical processes are those pairs having energies in the region  $\Delta E$  near  $E_0$ . The energy  $E_0$  is called the most effective energy for thermonuclear reactions and can be calculated from the relation  $E_0 = 1.22 (Z_1^2 Z_2^2 AT_6^2)^{1/2}$  keV, where  $T_6$  = temperature in millions of degrees. The main line of nucleosynthesis during helium burning is found to consist of the reactions:  $3\ ^4\text{He} \rightarrow\ ^{12}\text{C}$ ;  $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$  and  $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$ . Thus  $^{20}\text{Ne}$  can be synthesized through the radiative capture of alpha particle by  $^{16}\text{O}$ . The helium burning starts at about  $T = 10^8$  °C, for which  $E_0 = 246$  keV and 4.97 MeV state in  $^{20}\text{Ne}$  would serve as the dominant resonance in  $^{16}\text{O} + \alpha$  reaction. But the spin and parity of the state ( $2^-$ ) cannot be formed from  $^{16}\text{O}(0^-)$  and  $^4\text{He}(0^-)$ . Thus 4.97 MeV state is "invisible" to the  $^{16}\text{O} + ^4\text{He}$  channel and near  $T = 10^8$  °C the  $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$  reaction will be nonresonant. As the temperatures increases a nonresonant reaction rate changes into a resonant rate and higher-lying resonances of the type  $J(-)^J$  will come into play. At the temperatures higher than  $T \cdot 10^9$  °C a new type of nuclear reaction becomes important and many nuclei become subject to photodisintegration. Around  $T = 1.3 \cdot 10^9$  °C the rate of the  $\gamma + ^{20}\text{Ne} \rightarrow ^{16}\text{O} + ^4\text{He}$  reaction becomes greater than the rate for the reaction  $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$  where upon the  $^{20}\text{Ne}$  is effectively disintegrated. The photodisintegration rates for  $^{20}\text{Ne}(\gamma, \alpha)^{16}\text{O}$  are related in a very simple way to the rate of the inverse reaction-radiative capture of protons by  $^{19}\text{F}$ .

At low proton energies resonance from the  $^{19}\text{F}(p, \gamma)^{20}\text{Ne}$  reaction have been observed at several proton energies. Spin and parity of these capturing states is  $J(-)^{J+1}$ . These states cannot contribute to the synthesis of  $^{20}\text{Ne}$  nuclei, since they are "invisible" to the  $^{16}\text{O} + ^4\text{He}$  reaction channel. But at a temperatures greater than  $T = 2 \cdot 10^{10}$  °C they may be important for destruction of  $^{20}\text{Ne}$  nuclei if gamma-transitions to the ground state in  $^{19}\text{F}(p, \gamma)^{20}\text{Ne}$  reaction are sufficiently strong. Although photon capture into a  $J(-)^{J+1}$  state cannot directly lead to the alpha-particle breakup to the states of  $^{16}\text{O}$ , it can do so indirectly following a gamma-ray transition to a  $J(-)^J$  state in  $^{20}\text{Ne}$ . It is therefore of interest to measure the partial widths of gamma transitions to the ground and first excited state in proton capture by  $^{19}\text{F}$ . Kane<sup>(1)</sup> has been performed the search for the 13.51 MeV ( $1^+$ ,  $E_p = 668$  keV) ground state transition in the  $^{19}\text{F}(p, \gamma)^{20}\text{Ne}$  reaction ( see Fig. 1). The search was made using 3"X3" NaI(Tl) crystal, but the origins of gamma-ray counts in the high-energy part of spectrum cannot be satisfactory established. The presence of these counts may be due: to the pile-up effect, to the addition of 13.51-1.63 MeV and 1.63-0 MeV transitions, to the multiplier defect and to the tails of remote resonances or to nonresonant proton capture. The checking of these possibilities introduces severe experimental difficulties into investigation of gamma-decay scheme of 13.51 MeV and other  $J(-)^{J+1}$  states in  $^{20}\text{Ne}$ . The good energy resolution of Ge(Li) detector facilitates the detection of high-energy gamma-rays, due to an improved signal-to-noise ratio, when compared to NaI crystal. The results of our measurements of the  $^{19}\text{F}(p, \gamma)^{20}\text{Ne}$  reaction at  $E_p = 668$  keV are shown in Fig. 2. The presence of gamma-ray transition to the ground state is clearly established and  $\Gamma_\gamma$  value of 0.06 MeV is obtained. The investigations of the other  $J(-)^{J+1}$  states in  $^{20}\text{Ne}$  are in progress.

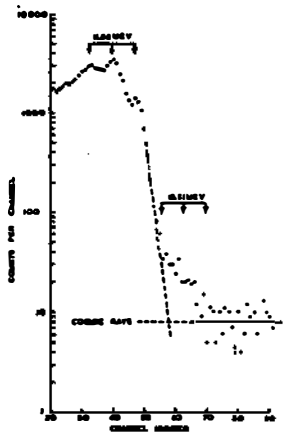


FIG. 1

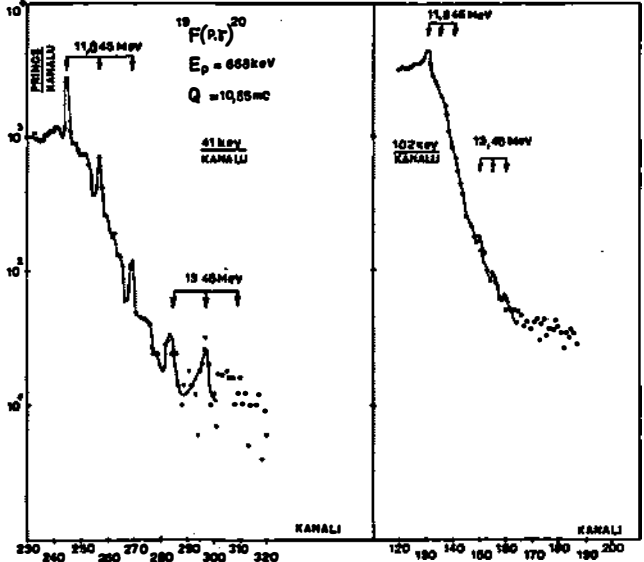


FIG. 2

References

1) J.V.Kane, R.H.Pixley, D.H.Wilkinson, Phys. Rev. 120(1960)952