The $^{19}\mathrm{F}(\alpha,\mathrm{p})^{22}\mathrm{Ne}$ and $^{23}\mathrm{Na}(\mathrm{p},\alpha)^{20}\mathrm{Ne}$ reactions at energies of astrophysical interest via the Trojan Horse Method

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^{19}F production and destruction pathways in astrophysic environment is crucial: it is, in fact, the least abundant element in the 12$\leq$A$\leq$56 mass range, and therefore fluorine abundance can me used to test the models. ^{19}F presence is observatively confirmed for low-mass AGB stars ($\mathrm{M} = 2 \div 4\,\mathrm{M}_{\odot}$), and model failed to reproduce the observed abundance. This fact is probably due to extra mixing problems, but further investigations from a "nuclear" point of wiew were needed: in AGB environment, in fact, ^{19}F can be destroyed via $^{19}\mathrm{F}(\mathrm{p},\alpha)^{16}\mathrm{O}$ [1] and $^{19}\mathrm{F}(\alpha,\mathrm{p})^{22}\mathrm{Ne}$ [2, 3]. About the second of the two, there are no direct measurement due to the presence of the Coulomb barrier: for a low-mass AGB star, in fact, at the typical range of temperature ($2 \cdot 10^8 \leq \mathrm{T} \leq 4 \cdot 10^8$ K) the Gamow window for the reaction lies between 150 and 1200 keV, so far below the barrier (3.81 MeV in this case), while the cross-section measured via direct methods arrives down to 660 keV in the center-of-mass reference frame [4]. For those reason a measurement of the $^{19}\mathrm{F}(\alpha,\mathrm{p})^{22}\mathrm{Ne}$ was attempted using the Trojan Horse Method, that has proven to be really useful to investigate reactions between charged particles or between charged particles and neutrons in the entrance channel at energies of astrophysical interest. The experiment was performed at Ruđer Bošković Institute, with a 6 MeV $^{6}\mathrm{Li}$ beam impinging on a $^{7}\mathrm{LiF}$ target, with the aim to trigger the $^{6}\mathrm{Li}(^{19}\mathrm{F},\mathrm{p}^{22}\mathrm{Ne})^{2}\mathrm{H}$ reaction. Using the THM, from the three-body reaction above, we were able to isolate the quasi-free contribution coming from the $^{19}\mathrm{F}(\alpha,\mathrm{p})^{22}\mathrm{Ne}$, and the absolute-units cross section was determined [2, 3]. Using the *Modified R-matrix* formalism, we were also able to determine the resonances strenght, and the evaluated rate has shown to be higher by a factor of almost 5 with respect to what already present in literature. An evaluation of the astrophysical impact of this new reaction rate was also performed adopting the NEWTON code for AGB star nucleosynthesis calculation in order to study fluorine production and destruction. In particular, calculations for three stellar models of 1.5, 3, and 5 M$_{\odot}$ and solar metallicity were performed.

Another reaction of great interest in AGB nucleosynthesis is the $^{23}\mathrm{Na(p,\alpha)^{20}Ne}$, that is cosidered to have great importance in intermediate-mass AGB stars ($\mathrm{M} = 4 \div 8\,\mathrm{M}_{\odot}$), and could be strongly related to the wide known Na/O anticorrelation in globular clusters [5]. This reaction is also of great importance because it represents, along with the ^{23}Na(pγ)^{24}Mg reaction, the turning point between the NeNa and MgAl cycles. Both have the result to fuse hydrogen into helium, and for a mass number 20≤A≤40, both (p,α) and (p,γ) channels are open at the temperatures typical of H$-$burning, so those kind of reaction will compete. H$-$burning in the mass range A≥20 is important to understand Ne, Na, Mg and Al abundances observed in stars: the relative isotopic abundance depends on the temperature and density conditions inside the H$-$burning region of a certain star. One of the NeNa and MgAl cycles can be active if the reaction rate branching ratio $\mathrm{B_{p\alpha/p\gamma}} = \mathrm{N_A}\langle\sigma\nu\rangle_{\mathrm{p}\alpha}/\mathrm{N_A}\langle\sigma\nu\rangle_{\mathrm{p}\gamma}$ is large enough. About NeNa$-$cycle, at temperature $\mathrm{T} \sim 6 \cdot 10^6$ K, $^{22}\mathrm{Ne}$ is entirely transformed in $^{23}\mathrm{Na}$. An extra production of this element is predicted at temperatures higher than $35 \cdot 10^6$ K, reaching 60% at $\mathrm{T} \sim 60 \cdot 10^6$ K. This extra production is provided by $^{20}\mathrm{Ne}$ reaction. In the end $^{23}\mathrm{Na}$ starts burning at $\mathrm{T} \geq 60 \cdot 10^6$ K [6].

$^{23}\mathrm{Na(p,\alpha)^{20}Ne}$ has not been studied at astrophysical energies with direct methods in the energy range of astrophysical interest. Here the Gamow window lies bwetween 50 keV and 200 keV, while the Coulomb barrier is at 2.57 MeV. Several states of $^{24}\mathrm{Mg}$ were however studied [7], via the $^{23}\mathrm{Na(^3He,d)^{24}Mg}$ transfer reaction at 20 MeV. Two resonant states at 37 keV and 138 keV were found: the former had a too low cross section to be studied (but uncertainties were reduced by a factor of 515), and the latter is still the bigger source of uncertainties (circa a factor of 12) in the temperature region near $\mathrm{T} \sim 70 \cdot 10^6$ K. From those facts is clear how even a slight reduction of the uncertainties is critical. For the $^{23}\mathrm{Na(p,\alpha)^{20}Ne}$ reaction, the Trojan Horse Metod was applied using the brand new $^{23}\mathrm{Na}$ beam delivered at Laboratori Nazionali del Sud. The beam collided with a $\mathrm{CD_2}$ target, with the aim to induce the $^{23}\mathrm{Na(d,\alpha\,^{20}Ne)n}$ three-body reaction. We were able to select data coming from the quasi-free contribution of the reaction of interest. An evaluation of the arbitrary-units differential cross-section at the energies of astrophysical interest was also performed. This energy interval corresponds to $50 \leq \mathrm{E} \leq 200$ keV in the range of temperature proper of intermediate-mass AGB stars ($20 \cdot 10^6 \leq \mathrm{T} \leq 80 \cdot 10^6$ K) .

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