Relation between the $^{16}O(\alpha,\gamma)^{20}Ne$ capture reaction and its reverse $^{20}Ne(\gamma,\alpha)^{16}O$ photodisintegration reaction in stars and in the lab

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The astrophysical reaction rates of the $^{16}O(\alpha,\gamma)^{20}Ne$ capture reaction and its reverse $^{20}Ne(\gamma,\alpha)^{16}O$ photodisintegration reaction are dominated by a few narrow resonances. Only at very low temperatures direct capture plays a significant role [1].
Usually the reaction rate of photodisintegration reactions is calculated from the reaction rate of the corresponding capture reaction using the detailed balanced theorem. This is only valid for nuclei which are thermalized, i.e., the occupation probability scales with $\exp(-\Delta E/kT)$. For the nuclei under consideration one finds first excited states at $E_x = 6049$ keV for ^{16}O and $E_x = 1634$ keV for ^{20}Ne. At first view, contributions of thermally excited states seem to be negligible. And, indeed, the reaction rates of the $^{16}O(\alpha,\gamma)^{20}Ne$ capture reaction in the lab and under stellar conditions are identical [1].
However, for the inverse $^{20}Ne(\gamma,\alpha)^{16}O$ photodisintegration reaction one finds a significant contribution of the thermally populated first excited state at $E_x = 1634$ keV in ^{20}Ne. Consequently, the reaction rates of the $^{20}Ne(\gamma,\alpha)^{16}O$ photodisintegration reaction are different in the lab and under stellar conditions. It is shown that the detailed balance theorem remains valid for the reaction rates under stellar conditions.
Photodisintegration rates in the lab have been measured recently using a quasi-thermal photon spectrum from bremsstrahlung [2], and a quasi-thermal photon spectrum with superior quality has been suggested using high-energy synchrotron radiation [3]. Direct (γ,α) experiments using quasi-thermal photon spectra are difficult in most cases because one has to measure a continuous α-particle energy spectrum. In contrast, the $^{20}Ne(\gamma,\alpha)^{16}O$ photodisintegration reaction is an unique test case for (γ,α) reactions because the dominance of a few narrow resonances leads to a discrete α-particle energy spectrum. The well-known strengths of these resonances in the capture reaction may help in the calibration of the new quasi-thermal photon sources.

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