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Chlorine and sulfur in nearby planetary nebulae and H II regions

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Abstract. We derive the chlorine abundances in a sample of nearby planetary nebulae (PNe) and H II regions that have some of the best available spectra. We use a nearly homogeneous procedure to derive the abundance in each object and find that the Cl/H abundance ratio shows similar values in H II regions and PNe. This supports our previous interpretation that the underabundance we found for oxygen in the H II regions is due to the depletion of their oxygen atoms into organic refractory dust components. For other elements, the bias introduced by ionization correction factors in their derived abundances can be very important, as we illustrate here for sulfur using photoionization models. Even for low-ionization PNe, the derived sulfur abundances can be lower than the real ones by up to 0.3 dex, and the differences found with the abundances derived for H II regions that have similar S/H can reach 0.4 dex.

Keywords. H II regions, ISM: abundances, planetary nebulae: general

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Recently, we derived in a homogeneous way the oxygen abundances for five H II regions and eight planetary nebulae (PNe) of the solar neighborhood (closer than 2 kpc), using available spectra of high quality (Rodríguez & Delgado-Inglada 2011). We used collisionally excited lines and recombination lines of oxygen, finding that in both cases the abundances derived for the PNe are ~ 0.2 dex above those calculated for the H II regions. We compared the resulting abundances with those found for the Sun, B stars, and the diffuse interstellar medium (ISM). A good agreement can be reached for the results implied by collisionally excited lines if the H II regions have about a quarter of their oxygen atoms deposited in an organic refractory dust component. This dust component was previously proposed to explain the pattern of oxygen depletion in the diffuse and dense ISM (Jenkins 2009; Whittet 2010). Oxygen is the element for which the derived abundances are more reliable, but the abundances of the other elements could provide further evidence on this issue. Here we present results for chlorine and sulfur.

Figure 1 shows the chlorine abundances calculated using the physical conditions derived previously (see Rodríguez & Delgado-Inglada 2011) and the intensities of [Cl II] λ9124, [Cl III] $\lambda\lambda$5517, 5537, and [Cl IV] λ8046 or [Cl IV] λ7530. [Cl II] lines were not available for the PNe with $O^+/O^{++} < 1$, but the Cl^+ concentration is small in high ionization objects. On the other hand, [Cl IV] λ8046 (used for the H II regions) was not in the wavelength range observed for the PNe, whereas [Cl IV] λ7530 (used for the PNe), which arises from the same upper level, is weaker and probably blended with a C II line in the H II regions. The [Cl IV] lines were outside of the observed ranges for two PNe (one has a lower limit in the figure; the other one falls below the plotted range), and unobserved in the low-ionization objects, where the contribution of Cl^{3+} should be negligible. Chlorine is not expected to be further ionized in our sample objects. Because of the small differences in the procedures used to derive Cl/H in the different objects, the comparison is less reliable than in the case of oxygen, but the results in the figure suggest that nearby H II

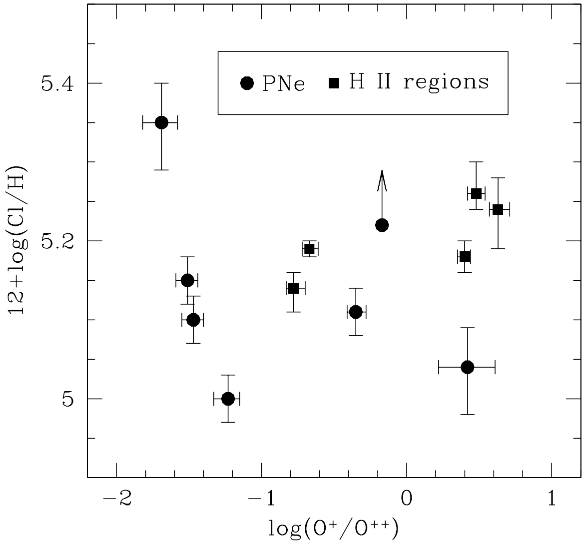

Figure 1. Chlorine abundances for the sample nebulae as a function of O^+/O^{++}.

regions and PNe have similar abundances of chlorine. This supports the idea described above that oxygen is more depleted in H II regions than in PNe.

Besides oxygen and chlorine, the abundances of sulfur, neon, and argon are not expected to be modified during the evolution of the PNe progenitor stars and can also be derived using optical spectra. However, in order to derive the abundances of these elements we need to study the bias introduced by the ionization correction factors (ICFs), which is likely to be different in H II regions and PNe. We use sulfur to illustrate this issue, since the same ICF is generally applied for this element in H II regions and PNe. The ICF was originally derived by Stasińska (1978) for H II regions, and was later adopted by Kingsburgh & Barlow (1994) for PNe. We calculated a series of photoionization models with Cloudy (Ferland *et al.* 1998), ionized by either O-type stars (Pauldrach *et al.* 2001) or evolved stars (Rauch 2003). The models have metallicities similar to those in our sample objects, electron densities around 2000 cm^{-3}, and either plane-parallel geometry (for the H II regions) or spherical geometry (for the PNe). We analyzed the predicted spectra to derive physical conditions and ionic and total abundances following the same procedure we would use for real objects. We compared the derived sulfur abundances with the input ones, finding that for the model H II regions the derived abundances are larger by up to ~ 0.1 dex, whereas for the model low-ionization PNe, like those in our sample, the derived abundances can be higher by ~ 0.05 dex or lower by ~ 0.3 dex. Hence, extreme care will be needed to achieve meaningful comparisons of the sulfur abundances.

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