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PLANETARY NEBULAE AND THE INTERSTELLAR MEDIUM

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Planetary nebulae (PN) are recognized sources of enrichment of He and heavier elements in the interstellar medium (ISM). It has long been known that PN differ in chemical composition from the Sun and similar stars (see reviews by Peimbert 1978, Aller 1984, and by Kaler 1985 and references therein cited). Zuckerman and Aller (1986) find 62% of their sample of 68 PN with reasonably determined C/O ratios to have C/O > 1, as compared with 61% of the sample used in the present study wherein all determinations based on C II λ4267 are excluded. PN may be copious sources of interstellar C, soot, and silicate grains. In their sample of 41 PN, Aller and Czyzak (1983) noted that N also tends to be more abundant than in the Sun. Torres-Peimbert (1986) concludes that PN constitute an important N source for the ISM. On the other hand, many workers have noted that O is less abundant than in the Sun. If fluctuations, ΔT_ε, in electron temperature, T_ε, are significant, traditionally derived ionic abundances found from collisionally excited lines will have to be increased (Peimbert 1967; Dinerstein et al. 1985; Zuckerman and Aller 1986). Application of corrections required knowledge of ΔT_ε. It is generally believed that stars in the mass range range 2 to 5 M(sun) manufacture C and N in the CNO cycle and C-burning, but that Ne and heavier elements are not affected by nuclear processes occurring in PN progenitors.

Our objective here is to examine a larger sample of PN. In addition to available published data, we include some 40 objects largely concentrated towards the galactic center and anticenter regions. All were observed with the Lick 3^m telescope and image tube scanner (Aller and Keyes in preparation). Abundances of C, N, O, Ne, Cℓ, and Ar are determined by a procedure in which theoretical models are used to obtain ionization correction factors (ICF). Of the 106 PN here discussed, 66 are N-rich and 40 are N-poor, N-rich being defined as objects wherein A(N) = log N(N) > 7.99 on the scale log N(H) = 12.00. The C-sample, which is dependent on IUE observations, is much smaller. Table 1 lists the mean abundances for C, N, and O and their ranges defined as $\log[\langle N(el)\rangle \pm \sigma]$ and the ratios Ne/O, etc., both for the entire galactic volume surveyed and the "solar neighborhood," here defined as containing those objects for which 8.0 < R < 9.0 kpc. R is the galactocentric distance; we adopt R(sun) = 8.5 kpc. There appear to be no significant differences between the average compositions in our neighborhood and the average taken over the entire observable portion of the galaxy.

Plots of Ne/H and O/H ratios with R suggest a gradual decline as R increases but the effect is largely smothered under a huge scatter. Some of the spread is certainly due to errors of observation, inadequacies of the models, uncertainties in the ICF factors, and inaccuracies in atomic parameters for the $3p^n$ configurations. Much of the dispersion must come from the intrinsic spread between "high Z" and "low Z" objects. The PN must be separated into population types for a more refined treatment. In both the Ne and O plots, the points most widely scattered with respect to the mean trend tend to pertain to N-rich objects. The overall means show an engaging comparison with solar values. See Table 2.

Conclusion. If we allow for uncertainties in solar abundances of Ne, S, Ar, and especially Cℓ, there is a reasonable fit between solar and PN abundances. In the PN, however, the O abundance is "too low," while N and C are enhanced. If agreement for O is forced by choosing an appropriate ΔT_ε fluctuation, then Ne, S, Cℓ, and Ar are all "overabundant" in the PN. Is it possible that O is often destroyed to form C and N, as appears to have happened in NGC 6537?

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Table 1. Elemental Abundances for C, N, O, Ne, S, Cℓ, and Ar
$A(\text{element}) = \log\{N(\text{element})/N(H)\} + 12.00$

Entire Galaxy	Range	n	8.0 < R < 9.0 kpc	Range	n
A(C) = 8.71	(8.26-8.93)	(26)	8.89	(8.3 -9.2)	(8)
A(N) = 8.26	(7.36-8.53)	(106)	8.22	(7.72-8.42)	(19)
A(O) = 8.65	(8.40-8.80)	(106)	8.71	(8.59-8.83)	(18)
Ne/O = 0.223	± 0.066	(100)	0.24	± 0.07 (18)	(18)
S/O = 0.0224	± 0.012	(91)	0.024	± 0.017 (14)	(14)
Cℓ/O = [0.44	± 0.25] × 10^{-3}	(61)	[0.48	± 0.25] × 10^{-3}	(8)
Ar/O = [0.68	± 0.37] × 10^{-2}	(96)	[0.53	± 0.18] × 10^{-2}	(15)

n = number of objects in each sample.

Table 2. Comparison of Solar and PN Logarithmic Abundances

Element	C	N	O	Ne	S	Cℓ	Ar
Sun	8.67*	7.99*	8.92*	8.05+	7.23+	5.5 ± 0.4	6.57+
PN	8.71	8.26	8.65	8.00	7.00	5.3	6.48

*Lambert, D.L., 1978, M.N.R.A.S., 182, 249; (+) Aller, L.H., 1986, in press.

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