NEW DETECTIONS OF METAL-BEARING MOLECULES IN IRC+10216: FROM CHEMISTRY TO NUCLEOSYNTHESIS

L. M. ZIURYS

Chemistry Dept., Arizona State Univ., Tempe, AZ 85287-1604

1. Introduction

The carriers of the metallic elements in interstellar gas are at present uncertain. If these elements exist as atoms, they are likely to be a major contributor to the electron density and the main source of neutralization for complex molecular ions. On the other hand, metals might be condensed onto grains. Certainly there are large depletions of these elements in diffuse gas, but do they apply to dense material as well? Alternatively, the metallic elements could be contained in simple molecules. It has been postulated that these elements should be inert in cold gas, but in actuality, few gas-phase reactions involving metals have been studied experimentally.

Detection of metal-containing molecules in interstellar gas was first accomplished in 1987, when the halide species AlCl, KCl, NaCl, and AlF were observed towards the circumstellar shell of the late-type carbon star IRC+10216 by Cernicharo and Guélin (1987). Very recently, MgNC was also discovered in this source (Guélin et al. 1986; Kawaguchi et al. 1993), as well as NaCN by Turner et al. (1994). These limited detections have already raised questions concerning metal chemistry. For example, all six species have been found only in IRC+10216, where they have a curious distribution. The halide species are found in the inner envelope, where the temperatures and densities are quite high and equilibrium chemistry occurs. In contrast, MgNC, a free radical, is found only in the *outer* envelope (Guélin et al. 1993). In this region, temperatures and densities are much lower and are similar to those found in molecular clouds. Under these conditions, the metallic elements are predicted to be inert.

2. New Studies of Magnesium-Bearing Molecules

The curious results for MgNC have prompted new laboratory and observational studies of MgCN, MgCCH, and $MgCH_3$. MgCN is the metastable isomer of MgNC and lies $\sim$ 700 K higher in energy. The MgNC/MgCN system is analogous to the HCN/HNC isomer pair. MgCCH and $MgCH_3$ are relevant because of the large abundances of HCCH, CCH, and other carbon chains, as well as methane, found in IRC+10216. Measurement of the rotational spectrum of these radicals has been recently carried out by Anderson, Steimle, and Ziurys (1994) for MgCN and Anderson and Ziurys for MgCCH (1994) and $MgCH_3$ (1995).

Ziurys, Guélin, and collaborators subsequently have been conducting astronomical searches for these radicals towards IRC+10216. Initially, for MgCN, the $N = 11 \rightarrow 10$ and $N = 10 \rightarrow 9$ transitions were detected towards this object using the NRAO 12m telescope, although the $N = 10 \rightarrow 9$ lines were partially contaminated by C_6H. These transitions were subsequently confirmed using the IRAM 30m antenna (Ziurys et al. 1995). The $N = 9 \rightarrow 8$ lines were observed as well, although they are blended with cyclic C_3H (see Fig. 1).

The IRAM spectra have double-horned shaped line profiles, which indicates that MgCN, like MgNC, must arise from the outer envelope of IRC+10216. In this region, the column density of MgCN is $N_{tot} \sim 10^{12}$ cm^{-2}, which implies a MgNC/MgCN ratio of about 22/1. This ratio is very low, considering the metastable nature of MgCN, and indicates that non-equilibrium, low temperature chemistry is producing these species.

Searches for the MgCCH and $MgCH_3$ radicals, using the 12m and 30m telescopes, have thus far proved unsuccessful. Upper limits to the column densities of these two species are $N_{tot} < 10^{12}$ cm^{-2}.

Magnesium has three stable isotopes with a relative abundance ratio of ^{24}Mg: ^{25}Mg: ^{26}Mg = 7.9:1:1.1. Through a joint laboratory/observational effort, several transitions of both ^{25}MgNC and ^{26}MgNC have been identified in the outer envelope of IRC+10216 (Guélin et al. 1995). The astronomical measurements have enabled the first accurate determination of the Mg isotope ratio in an AGB star, which was found to be very close to solar. The three isotopes are produced in the Mg/Al cycle, which also produces ^{26}Al. The near solar ratio puts constraints on the nucleosynthesis occurring in IRC+10216, as well as suggests that AGB stars may not be a good source of ^{26}Al.

3. Conclusions

The recent detections of metal-bearing molecules certainly have altered the past view of their chemistry. Magnesium-containing molecules appear to be

Figure 1. Spectra of MgCN observed towards IRC+10216 using the IRAM 30m telescope.

forming via cold, non-equilibrium chemistry. Why they are not observed in molecular clouds is thus surprising. Also, the pattern of detected species is not easily explained. Finally, observation of ^{26}MgNC and ^{25}MgNC in IRC+10216 suggests that determination of other metal isotope ratios in AGB stars may be possible, leading to a better understanding of nucleosynthesis.

References

Anderson, M.A., Steimle, T.C., and Ziurys, L.M. 1994, ApJ, **429**, L41
Anderson, M.A., and Ziurys, L.M. 1994, ApJ., **439**, L25
Anderson, M.A., and Ziurys, L.M. 1995, ApJ, **452**, L157
Cernicharo, J. and Guélin, M. 1987, A & A, **183**, L10
Guélin, M., Cernicharo, J., Kahane, C., and Gomez-Gonzales, J. 1986, A & A, **157**, L17
Guélin, M., Lucas, R., and Cernicharo, J. 1993, A & A, **280**, L19
Guélin, M., et al. 1995, A & A, **297**, 183
Kawaguchi, K., Kagi, E., Hirano, T., Takano, S., and Saito, S. 1993, ApJ, **406**, L39
Turner, B.E., Steimle, T.C., and Meerts, L. 1994, ApJ, **426**, L97
Ziurys, L.M., Apponi, A.J., Guélin, M., and Cernicharo, J. 1995, ApJ, **445**, L47