Abstract. We have constructed a chemical reaction model in a contracting interstellar cloud including 104 species which are involved in a network of 557 reactions. The chemical kinetic equations were integrated as a function of time by using gear package. The evolution of the system was followed in the density range 10^{-10^7} particles cm^{-3}. The calculated fractional abundances of the charged species are in good agreement with those given by other investigators. The charge density has been followed in diffuse, intermediate and dense regions. The most dominant ionic species are metallic ions, HCO^+ and H_3^+ in the shielded regions and atomic ions H^+, C^+, Si^+, He^+, S^+ and metal ions in the diffuse and intermediate regions. The abundances of negatively charged ions were found to be negligible. The results of the calculations on the different metallic ions are interpreted.

1. Introduction

Ionized particles play an important role in interstellar chemistry and the dynamics of the interstellar gas, because the ions mediate the coupling of the neutral gas to the magnetic field.

The fractional ionization is relatively low in molecular or dark clouds. The degree of ionization in molecular clouds is intricately related to various processes, e.g., ionization of H_2 and He by cosmic ray (Solomon and Werner, 1971), formation and dissociative recombination of molecular ions (Herbst and Klemperer, 1973) charge transfer between molecular ions and metallic atoms (Oppenheimer and Dalgarno, 1974b), radiative recombination of metallic ions, recombination of ions on grains, and of electrons to grains (Umebayashi and Nakano, 1980). Photoionization, adsorption of ions and capture of electrons on grain surface, recombination of ions and electrons due to grain-grain collisions, desorption of charged particles off grain surface, recombination due to association reaction and negative ions (El Nawawy et al., 1992).

Many observational efforts have been made to derive the density of charged particles in interstellar clouds (e.g., Van Dishoeck et al., 1992; Petrie et al., 1991; Balm and Jura 1992; Vladilo et al., 1993; Phillips et al., 1992; Turner 1993 and Heck et al., 1993). On the other hand, the physical parameters affecting the charge state, in diffuse and dense interstellar clouds, have been followed by many authors

Reactions of charged particles with grains have been neglected in this work. They have been treated in detail by Hasegawa and Herbst (1993).

The metal abundance is a potentially important contributor to the electron abundance in clouds (Graedel et al. 1982). In the previous model calculations the metal abundance was an important factor in determining the chemistry through its influence on the abundance of polyatomic ions, especially H_3^+. From observation of molecules and molecular ions it is possible to place some limits on the electron abundance in clouds (Langer, 1985 and Dalgarno and Lepp, 1984) and given a model of the contribution of the metals to the electron abundance, a limit on the metal abundance is defined. Note, however, that if polycyclic aromatic hydrocarbons (PAHS) are abundant (\chi(PAHS) > 10^{-8}) they will play a more important role in the electron balance than will the metals (Lepp and Dalgarno, 1988). In the current work we neglect the effect of PAHS.

The objective of this work is to develop a time dependent model which describes the ion chemistry of the less complex carbon, nitrogen, oxygen and sulphur bearing molecules during contraction of a magnetized gas cloud. The model also take proper account of the effects of metallic elements and neutral grains. The details of the physical and chemical scheme, the numerical method of solution, the rate coefficients and the abundances of nitrogen- and carbon-bearing species were presented earlier in part (I), Amin et al. (1995a). The abundances of oxygen-, chlorine- and sulphur-bearing molecules are given in part (II), Amin et al. (1995b). The reaction scheme was compiled by Amin (1994). In this paper we specifically aim to obtain a detailed distribution of the charged particles in a contracting interstellar cloud and follow its evolution from the low neutral densities of \( n = 10^{-3} \) cm up to the protostellar densities of \( n = 10^7 \) cm\(^{-3}\).

2. Results

Figures 1-5, represent the fractional abundances of the important atomic ions and molecular ions, respectively. From these figures, we can represent the fractional abundance of electrons by the equation

\[ X(e) = a n^{-0.5}, \]

where \( a = 5 \times 10^{-3} \) in the diffuse part and \( 2 \times 10^{-4} \) in a highly dense cloud. Figure 6 shows a comparison between the predictions of the above relation of electron density based on time dependent calculations and those based on steady