



Ionic charge states of solar energetic particles: a survey of interplanetary shock related events

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The ionic charge of solar energetic particles (SEP) is an important parameter for the diagnostic of the plasma conditions of the source. Furthermore, the acceleration and transport processes depend significantly on velocity and rigidity, i.e. on the mass and ionic charge of the ions. In recent years, improved instrumentation on SAMPEX, SOHO and ACE providing ionic charge measurements over an extended energy range and for a large range of particle intensities, have changed our view completely. These measurements showed that the mean ionic charge, Q , of heavy ions in the energy range $\sim 0.2 - 0.6$ MeV/amu increases with energy in all flare related, ^3He - and Fe-rich (*impulsive*) events, indicating a source location in the low corona. Event averages of Q in interplanetary shock related (*gradual*) events show a large variability, with Q increasing often at high energies. In this paper we present a survey of ionic charge observations for time periods around the shock passage, obtained with the SEPICA instrument onboard the ACE spacecraft during 1997 - 2000. We analyzed all interplanetary shock related events where SEPICA data are available. We find for 36 out of 39 events for iron in the energy range 0.18 - 0.25 MeV/amu average ionic charge states of $Q_{Fe} \sim 9 - 11$, with no significant variation with energy. Two of the other three events show high charge states ($Q_{Fe} \sim 16$) at 0.18 - 0.25 MeV/amu, with an increase by 3 - 4 charge units at energies of 0.35-0.43 MeV/amu, similar to the observations in Fe-rich and ^3He -rich events. The interplanetary shock related ionic charge states will be compared with solar wind charge states and with ionic charge states during the onset phase of the SEP events. The implications of the energy dependence of the ionic charge states on possible sources contributing to the accelerated population (e.g. solar wind, suprathermal particles, contributions from Fe-rich impulsive events) will be discussed in this paper.