The condensation temperatures of the elements:A reappraisal

BERNARD J.WOOD; DUANE J. SMYTHE

[1]Department of Earth Sciences, University of Oxford OX1 3AN, U.K. bernie.wood@earth.ox.ac.uk; duane.smythe@earth.ox.ac.uk

We re-calculated the condensation temperatures of the elements from a solar gas at 10^{-4} bar. The calculations highlighted three areas where currently available estimates of condensation temperature could be improved. One of these is the nature of mixing behavior of many important trace elements when dissolved in major condensates such as silicates, Fe-rich metals and sulfides. Nonideal solution of the trace elements can alter (generally lower) condensation temperatures by up to 500 K. Secondly, recent measurements of the halogen contents of CI chondrites (Clay et al. 2017) indicate that the solar system abundance of chlorine is significantly overestimated and this affects the stabilities of gaseous complexes of many elements of interest. Finally, we have attempted to improve on previous estimates of the free energies of chlorine-bearing solids since the temperature of chlorine condensation has an important control on the condensation temperatures of many trace elements. Our result for the 50% condensation temperature of chlorine, 472 K is nearly 500 K lower than the result of [1] and this means that the HCl content of the solar gas at temperatures < 900 K is higher than previously estimated.

We based our calculations on the program PHEQ [2] which we modified to perform condensation calculations for the elements H, O, C, S, Na, Ca, Mg, Al, Si, Fe, F, Cl, P, N, Ni and K by free energy minimisation. Condensation calculations for minor elements were then performed using the output from PHEQ in conjunction with relevant thermodynamic data. We made explicit provision for nonidealities using information from phase diagrams, heat of solution measurements, partitioning data and by using the lattice strain model for FeS and ionic solids and the Miedema model for solutions in solid Fe. We computed the relative stabilities of gaseous chloride, sulfide and hydroxide species of the trace elements of interest and used these, as appropriate in our condensation calculations. In general, our new 50% condensation temperatures are similar to or, because of the modifications noted above, lower than those of Lodders [1]

[1] Lodders (2003) *Astrophys. Jour.* 591,1220-1247

[2] Wood&Hashimoto(1993) Geochim.Cosmochim.Acta 57, 2377-2388.

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