Metallothermic Scandium Production –

A Thermochemical Study

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ABSTRACT

Scandium became one of the important rare earth metals of today as its application in modern technology increases, especially as alloying element for strengthening aluminium in aerospace industry[1–3]. Nevertheless its high price impedes even further increase due to small concentration in ores and quite complicated production techniques.

First scandium was produced by electrolysis from $ScCl_3$ in chloride electrolyte resulting in not satisfying purity and multiple purification steps[4, 5]. Desired purity was obtained by metallothermy from $ScCl_3$ and ScF_3 with different reduction agents and additives [6–8] but still requiring additional purification steps and using expensive raw materials.

All known publications depict solely experimental results and all methods are based on empirical indications. Considerations concerning possible reduction mechanisms, explanations for the possible concentration ratios of charge components, as well as reasons for the choice of temperature ranges, are neglected.
In order to determine those data for multicomponent systems, "Klärkreuze" method[9] is done, supported by *FactSage®* software. This method divides the concentration triangle with connections of quasi-binary tie lines into sectional triangles building the series of secondary subsystems displaying equilibrium conditions of basic substances[10]. This partition of a ternary systems is called triangulation[11] and of quaternary tetraedration[12], which allows conclusions about possible reactions, concentration ranges in which these reactions occur and possible products forming in multicomponent systems.

In this study, reaction mechanisms during reduction of Sc_2O_3 and ScF_3 by Ca and Al are determined, as well as the possible temperature and concentration ranges of these reactions. At first, all possible tie lines and sections between all examined elements, respectively congruent melting components, were calculated. Subsequently, all possible tie lines and sections between elements, congruent and incongruent melting compounds were calculating depending on the formation temperature. This allowed for the determination of quasi-binary tie lines and sections. The conditions for maximum ensured Sc yield from expensive Sc compounds are listed to compare potentials of Sc production processes.

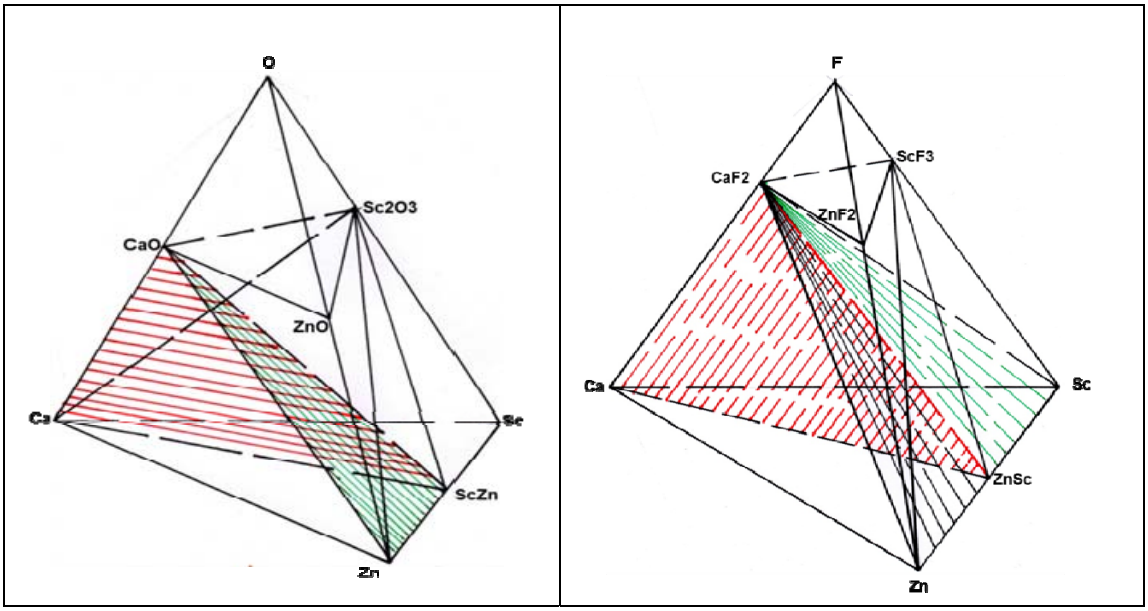

Figure 1: Tetraedration and subsystems of the Sc-Ca-Zn-O (left) and Sc-Ca-Zn-F (right) system at T > 1300 K without consideration of $CaZn_2$, $CaZn_5$, $CaZn_{11}$ with quasi-binary planes (red and green marked) as faces shared by two sub-systems

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