

DISSOLUTION OF CHROMITE IN LIQUID SLAGS: EMPIRICAL RELATIONSHIPS

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ABSTRACT

The dissolution of chrome ore in liquid slags was studied by using the rotating cylinder technique. The chrome ore in this study is from the LG-6 of the Bushveld Complex of South Africa and the slag compositions are representative that of the ferrochromium production and stainless steelmaking. The experiments were done under Ar atmosphere at 1600°C and the cylinders of chromite were rotated in the liquid slags at 100 rpm. The dissolution process was measured by the chemical analysis of the samples taken from the melt at predetermined time intervals and the SEM-EDAX investigation on the partially reacted samples of chromite, solidified slag and the crucibles containing the charge.

Based on a statistical model, empirical relations between the slag composition and chromite dissolution were determined under two different levels of reducing conditions over a large range of slag compositions. Different reducing conditions were achieved by using graphite and molybdenum crucibles. The slag composition range chosen in this study is (Mass per cent) SiO₂: 35-50, Al₂O₃: 5-30, MgO: 5-30, CaO: 5-35.

1. INTRODUCTION

Ferrochromium is currently produced predominantly by the smelting of chromite ore in submerged-arc electric furnaces. The economics of the process largely depend on the grade and melting behavior of the ore and the slag properties.

Previous studies¹⁻⁶ indicate that the chromium in the discard slags are mainly in the form undissolved chrome ore and the metal droplets. In plants that experienced high chromium losses (more than 11 per cent) it was found that more than 60 per cent of the chromium in the slag was in the form of undissolved or partly altered chromite particles. On a South African submerged-arc furnace, *Van der Colf*⁷ determined that the chromium recovery averaged 73.2 per cent, chromium losses being 17.2 per cent as oxide, 2.17 per cent as metallic inclusions and 7.43 per cent as dust and other losses.

Information on the dissolution behavior of chrome ore in liquid slags is necessary in minimizing the Cr losses to slag towards a more economically feasible process and making possible that the low grade chrome ores can be used to produce a saleable ferrochrome metal. Although the kinetics of the chromite ore and solid Cr_2O_3 reduction has been investigated extensively in the past, the number of studies with chromite in molten slags is limited. Therefore, this work is believed to make an important contribution in understanding the dissolution behavior of chromite in a wide range of slag compositions at temperatures representative that of high carbon ferrochrome production and stainless steel making.

2. EXPERIMENTAL PROCEDURE

The empirical relations between the slag chemistry and the chromite dissolution under reducing conditions were established. The effect of different levels of reducing conditions were tested by using graphite and molybdenum crucibles under argon, the chromite cylinders were rotated at 100 rpm and the slag temperature was 1600°C. In the experiments, the rotational speed of 100 rpm was chosen because it was the lowest rotational speed that a proper alignment could be obtained.

Because of the large number of slag components and their comparatively large range, the experimental work was based on a statistical model. Statistical designing of experiments has the advantages that the experiments become more efficient and economical and the individual and the joint effects of different factors on the response can be evaluated together. A total number of 20 different slag compositions were used to define the response surface, i.e. chromite dissolution.

The data generated according to the statistical model was fitted in a quadratic equation of the type:

$$Y(X) = \beta_0 + \sum_{i=1}^4 \beta_i X_i + \sum_{i=1}^4 \beta_{ii} X_i^2 + \sum_{i=1}^4 \sum_{i < j}^4 \beta_{ij} X_i X_j \quad (1)$$

Where,

Y =Response ('Per cent Dissolution')

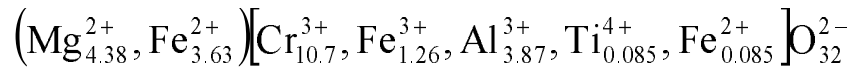
β_0 =Intercept,

β_{ij} =Parameter for X_i ,

X_i =Mass Percent (X_1 =SiO₂, X_2 =Al₂O₃, X_3 =MgO, X_4 =CaO).

The experimental method consisted of submersing rotating chromite cylinders in a liquid slag melt, of appropriate composition, held in a graphite or molybdenum crucible. Approximately 350 g of slag was charged in the crucible to allow sufficient volume for the total immersion of chromite cylinders. The dissolution was measured by the chemical analysis of the samples obtained from the slag melt at predetermined time intervals.

The chromite cylinders were prepared from tabled and pulverised LG-6 chromite ore from the Bushveld Complex of South Africa. The chemical analysis of the ore is given in Table 1. By using the number of moles of cations per 32 moles of oxygen, the chemical formula of the sintered chromite was calculated to be⁸:



Where round and square brackets represent tetrahedral and octahedral sites respectively. The method of calculation is given elsewhere⁹.

Pulverised chrome ore with no binders was pressed in a steel mould under a uni-axial pressure of 6 tons to obtain fresh cylinders with 15,6 mm in diameter and 17-19 mm in length. This was followed by sintering in the induction furnace under argon, at a flow rate of 2200 cm³/min, at 1200°C for 2 hours. The density of the cylinders was 3.6 g/cm³. The cylinders, which had any cracks after sintering, were rejected. Subsequent to sintering, the cylinders were drilled and attached to an alumina + stainless steel rod assembly by using alumina cement. The rod assembly attached to the chromite cylinder was rotated along its axis at a controlled speed determined by using a hand tachometer. The chromite cylinder could be raised or lowered by about 20 cm so that it could be removed or immersed into the melt. The gas-tight reaction chamber kept under a slightly positive pressure was continuously flushed by dried UHP argon gas at 2200 cm³/min during the experiments. For the temperature measurements, a type B (Pt-6% Rh/Pt-30% Rh) thermocouple was used.

Master slags were prepared from chemically pure SiO₂, Al₂O₃, MgO, and CaO powders mixed at appropriate proportions. The mixtures contained in a graphite crucible were melted in a high frequency induction furnace to provide homogenisation and to increase the density of the samples. The molten slags were poured into cast iron moulds for solidification and solidified slags were then finally ground to powder form. The final slag compositions in the experiments were achieved by the addition of necessary amount of fresh powders to the master slags.

The reaction chamber heated by 50 kW, 3 kHz induction unit consists of a fused silica tube 500 mm long, with an external diameter of 120 mm and an internal diameter of 106 mm. The lower end of the tube is closed. The top end is closed by a water-cooled brass plate, with an O-ring between the silica tube and the brass plate to ensure gas-tightness. A graphite crucible was used as the heating element. Depending on the desired level of reducing conditions in the chamber, graphite or molybdenum crucibles of 85 x 50 mm was placed in the graphite tube for melting. A graphite cover 2.5-cm thick was used as a radiation shield. The space between the heating element and silica tube at the periphery and bottom was packed by lampblack for insulation. This arrangement is shown in Figure 1.

As the chromite cylinder dissolves in the liquid slag, SiO₂, Al₂O₃, MgO, CaO, total Fe, and total Cr contents of the slag change. The change in the total chromium content of the slag with time is taken as a basis in the measurement of the dissolution process. At a given time t , during the dissolution of chromite in the liquid slag, the 'Per cent Dissolution' is simply defined as the percentage of total chromium mass from the starting chromite cylinder released into the slag.

The chromium mass in the slag at a given period is determined by the chemical analysis of the slag samples. Thus, the 'Per cent Dissolution' is given by the formula:

$$\text{PercentDissolution} \sim = \frac{(M)_{\text{slag},t} (\%Cr)_{\text{slag},t} + \sum_{i=1}^n (M)_{\text{sample},i} (\%Cr)_{\text{sample},i}}{0.3407(M)_{\text{cylinder}}} \quad (2)$$

Where, $(M)_{\text{slag},t}$ is the slag mass (g), $(\%Cr)_{\text{slag},t}$ per cent chromium in the slag at time t , $(M)_{\text{sample}}$ sample mass (g), $(\%Cr)_{\text{sample},i}$ per cent chromium in a particular sample and $(M)_{\text{cylinder}}$ is the initial mass of the cylinder (g). There is 34.07 per cent elemental chromium in the sintered chromite.

It was evident from the metallic formations rich in Cr, Fe and Si found in the solidified slag samples and on the crucible walls after the experiments that a certain amount of reduction took place. Therefore, Equation 2 represents the dissolution and reduction behaviour of chromite in liquid slags.

3. EMPIRICAL RELATIONS BETWEEN THE SLAG COMPOSITION AND THE CHROMITE DISSOLUTION.

The discussions presented here is based on the calculations obtained from the statistical model. The experimental data for one set of experiments at each particular period was employed in Equation 1 to obtain values of β . This means that, when constructing the 'Per cent Dissolution' versus 'Time (min)' curves for each series of experiments there is one equation of the type given by Equation 1 for each particular period, i.e. 5, 10, 15, 30, 45, 60, 75 and 90 minutes.

The per cent dissolution versus time curves for some of the experiments completed by using graphite crucibles shown in Figure 2. The same trend was observed in all the experiments conducted by using graphite and molybdenum crucibles. Apart from the considerable changes in the chromite dissolution with changing slag composition, the general trend observed in almost all of the experimental points is that a rapid introduction of chromium from the chromite cylinder into the slag phase occur within the first 15 minutes of the experiments. After this period, some chromium removal from the slag occurs due to the reduction taking place on the graphite crucible walls. Although to a lesser extend some metallization also took place when Mo crucibles were used.

In the following, the effect of MgO/CaO, MgO/Al₂O₃, Al₂O₃/CaO and the basicity ratio of the slag on the chromite dissolution is discussed. The discussions are based on the results obtained after 15 minutes of reaction time, because at this period, in almost all the experiments the chromite dissolution was at its maximum. The empirical relationships were obtained from the plots of slag composition vs. chromite dissolution data calculated from the statistical model. A comparison for two different levels of reducing conditions on the chromite dissolution is also made. The reducing conditions were affected by using graphite and molybdenum crucibles.

A complete description of the relationship between the slag composition at different levels of the slag components and the chromite dissolution is too extensive. Therefore, here only a summary of the results will be made and a detailed description of the relationships can be found elsewhere⁹.

3.1. MgO/CaO of the Slag vs. Chromite Dissolution

Figure 3 is given as an example to the plots of chromite dissolution vs. slag composition. The empirical relationships discussed in the following are based on similar plots that were obtained at different levels of the slag components. The response surface shown in Figure 3 illustrates the change in chromite dissolution with changing SiO_2 , CaO and MgO/CaO of the slags with 20 per cent Al_2O_3 and 15 per cent MgO. The SiO_2 and CaO contents of the slags changed to compensate the change in the MgO/CaO. The increasing MgO/CaO (0.5→1.1) and SiO_2 concentration (35→50) in this slag had an adverse effect on the chromite dissolution.

The discussions relevant to the effect of MgO/CaO ratio of the slag on the chromite dissolution at the first 15 minutes of reaction time at different levels of the slag components are summarized in Table 2. In this table '+' and '-' signs are used to indicate an increase or a decrease in a given slag component respectively. For example, in slags with constant MgO and SiO_2 at different levels, an increasing MgO to CaO ratio implies a decrease in the component CaO (-) and an increase in the amount of Al_2O_3 (+) component as it is the only oxide to compensate the decrease in the CaO concentration. The net result of this is an increase in the chromite dissolution indicated by a (+) sign.

Al_2O_3 content of slag plays a dominant role in improving the chromite dissolution with increasing ratio of MgO/CaO. A decrease or an increase in the alumina content (in the range 16 to 22 per cent) is reflected on the per cent dissolution values in the same direction.

The effect of increasing MgO content of the slag (in the range 12 to 30 per cent) on the dissolution of chromite is positive when this increase is compensated by a decrease in the CaO content. However, when this increase in the MgO is provided by a decrease in the Al_2O_3 content, the effect becomes negative, i.e. the chromite dissolution decreases.

The chromite dissolution decreases with increasing SiO_2 contents of the slags contained in graphite crucibles. The levels of SiO_2 and CaO have a minor effect on the effect of MgO/CaO on the chromite dissolution. Although higher MgO contents in the slag results in higher dissolution values, the comparatively low levels of MgO strengthens the effect of MgO/CaO on the dissolution indicated by steeper curves obtained at these low levels of MgO.

3.2. $\text{Al}_2\text{O}_3/\text{CaO}$ Ratio of the Slag vs. Chromite Dissolution

Increasing the Al_2O_3 to CaO ratio of slag causes an increase in the per cent dissolution values of chromite. This means that in slags with constant SiO_2 and MgO increasing Al_2O_3 concentration and decreasing CaO concentration favors the chromite dissolution. In slags with constant SiO_2 and Al_2O_3 to compensate the changes in the $\text{Al}_2\text{O}_3/\text{CaO}$ of the slag, the MgO contents of the slag increase and the CaO contents decrease.

Figure 4 shows the $\text{Al}_2\text{O}_3/\text{CaO}$ versus per cent dissolution curves in slags with a MgO content of 15 per cent and fixed SiO_2 concentrations of 35 to 50 per cent. At comparatively low levels of Al_2O_3 to CaO ratios (and lower SiO_2 concentrations) the per cent dissolution values are more sensitive to changes in the $\text{Al}_2\text{O}_3/\text{CaO}$ indicated by the higher slope of the curves as the SiO_2 content decrease from 50 to 35 per cent. Based on the plots constructed with same principles as Figure 4, the results on the effect of $\text{Al}_2\text{O}_3/\text{CaO}$ of the slag on the chromite dissolution are summarized in Table 2.

The per cent dissolution values for chromite increase with an increase in the Al_2O_3 content of the slag. This effect presents itself even when the MgO concentrations are decreasing. Although lower CaO levels favor the dissolution of chromite, an increase in the SiO_2 content dominates

and counteracts this effect causing a decrease in the chromite dissolution. In overall, increasing MgO concentrations in the slag phase causes an increase in the chromite dissolution.

3.3. MgO/Al₂O₃ of the Slag vs. Chromite Dissolution

The results on the effect of MgO to Al₂O₃ ratio of the slag on the dissolution of chromite for 15 minutes of reaction time are summarized in Table 2.

1. Decreasing Al₂O₃ in the slag when combined with an increase in the CaO content results in a decrease in the chromite dissolution.
2. The strong negative effect of decreasing Al₂O₃ suppresses the positive effect of increasing MgO content on the chromite dissolution, and in overall, a decrease in the alumina concentration in the slag causes a decrease in the chromite dissolution.
3. Increasing MgO content in the slag when combined with a decrease in the CaO concentration causes an increase in the chromite dissolution.

3.4. Slag Basicity vs. Chromite Dissolution

Based on the previous discussions, increasing the Al₂O₃ content of the slags results in an increase in the chromite dissolution. Chromite dissolution is also improved by a decrease in the CaO, which is the strongest network modifier in this slag system. The opposite effect of these two components on the dissolution of chromite may lead to the suggestion that Al₂O₃ does not behave basic. On the other hand, an increase in the MgO content of the slag, which is also a basic oxide, results in an increase in the chromite dissolution. From these observations it can be suggested that the chromite dissolution in the slags under study here is not a simple function of the slag basicity or any other specific ratio of the slag constituents, but it is rather affected by each individual component in a characteristic way at certain levels of these components.

Assuming that Al₂O₃ behaves acidic, the basicity can be defined as:

$$B = [(CaO + MgO) / (Al_2O_3 + SiO_2)] \quad (3)$$

The definition of basicity by Equation 3 allows the analysis of the following:

1. Slags with constant SiO₂ and MgO, changing Al₂O₃ and CaO.
2. Slags with constant SiO₂ and CaO, changing Al₂O₃ and MgO.
3. Slags with constant MgO and Al₂O₃, changing SiO₂ and CaO.

In general it was observed that increasing the basicity ratio of the types 1 and 2 slags caused a decrease in chromite dissolution and increasing the ratio in slags with constant MgO and Al₂O₃ (type 3 slags) in the contrary resulted in an increase in the chromite dissolution.

The slag basicity ratio, when alumina is assumed to behave basic, becomes:

$$B = [(CaO + MgO + Al_2O_3) / SiO_2] \quad (4)$$

The definition of basicity by Equation 4 allows the analysis of the effect of following types of slags on the chromite dissolution:

1. Slags with constant Al₂O₃ and MgO with changing CaO and SiO₂.

2. Slags with constant Al_2O_3 and CaO with changing MgO and SiO_2 .

In these slags, SiO_2 content was changed (35 to 50 per cent), because the basicity ratio does not change unless there is a change in SiO_2 .

An increase in the basicity ratio caused an increase in the chromite dissolution in both types of slags. In slags type 2, the chromite dissolution increased with increasing basicity ratio up to a certain limit, a further increase in the basicity ratio beyond this limit caused the chromite dissolution to decrease. Figure 5 is given as a typical example to the effect of slag basicity ratio on the dissolution of chromite in slags with two components constant and SiO_2 and the fourth component changing. At relatively low basicity ratios, an increase in the SiO_2 content of slags had a negative effect on chromite dissolution which is opposite of the observation relatively high basicity ratios. At the basicity ratio of 0.9, per cent dissolution decreased from 50 to 15 per cent and at the basicity ratio of 1.71, per cent dissolution increased from 35 to 85 per cent.

In slags with fixed Al_2O_3 and MgO contents (type 1 slags), chromite dissolution increased with increasing basicity ratio. Figure 6 illustrates the typical effect of the slag basicity on the per cent dissolution of chromite in slags with 20 per cent Al_2O_3 and 15 per cent MgO . An increase in the basicity ratio from 1 to 1.86 caused the per cent dissolution to increase from 17 to 86 per cent. The increase in the basicity ratio in the given range was performed by an increase in the CaO content from 15 to 30 per cent and a decrease in the SiO_2 content from 50 to 35 per cent.

The discussions based on the effect of basicity ratios, defined by Equations 3 and 4, on the dissolution of chromite are summarized in Table 2.

When alumina was assumed acidic, a relationship between the slag basicity and the chromite dissolution could not be established. However it was determined that the chromite dissolution increases with increasing ratios of the following slag components,

1. Al_2O_3 to CaO
2. Al_2O_3 to MgO
3. CaO to SiO_2

When alumina was assumed basic, there seems a more consistent relationship between the slag basicity and the chromite dissolution. The chromite dissolution increase with increasing basicity when the increase in the basicity is provided by an increase in the ratios of CaO to SiO_2 or MgO to SiO_2 . The chromite dissolution increases with increasing MgO to SiO_2 ratios when MgO is changing between 5 and 16 per cent. At higher MgO concentrations, however the chromite dissolution decreases with increasing MgO/SiO_2 .

3.5. The Effect of Reducing Conditions on the Chromite Dissolution.

Molybdenum crucibles were used to provide a basis for the comparison of the effect of the level of reducing conditions on the chromite dissolution in the liquid slags. Indicated by the equilibrium oxygen partial pressures in Equations 5, 6 and 7, the use of graphite crucibles provide stronger reducing conditions compared to the molybdenum crucibles.



$$\Delta G^\circ = -RT \ln K = -112877 - 86.514 T = -274917.722 \text{ J(at } 1600^\circ\text{C)}^{10}$$

If it is assumed that the $P_{\text{CO(g)}}=1$ atm, then $P_{\text{O}_2} = 4.63 \times 10^{-16}$ atm, and;



$$\Delta G^\circ = -RT \ln K = -578229 + 166.523 T = -266311.421 \text{ J (at } 1600^\circ\text{C)}^{10}$$

If $a_{\text{MoO}_2(s)}=1$ atm, then $P_{\text{O}_2} = 3.73 \times 10^{-8}$ atm. And for the reaction;



$$\Delta G^\circ = -RT \ln K = -18410 - 33.89 T = -81886 \text{ J (at } 1600^\circ\text{C)}^{10}$$

$$P_{\text{O}_2} = 7.7 \times 10^{-5} \text{ atm for a } P_{\text{MoO}_2(g)} = 0.01 \text{ atm}$$

The seemingly higher chromite dissolution at higher oxygen partial pressures can be explained by the fact that, chromite dissolution and the reduction of Cr, Fe and Si oxides take place simultaneously, which start after a certain period when their activities reach a critical value in the liquid slag. The per cent dissolution values in this study, calculated by using Equation 2, are an indication of the total chromium content of the slag phase at a given period. The lower chromium content of the slag under stronger reducing conditions is because the reduction of chromium oxide in slag starts earlier than that of with higher oxygen partial pressures.

The effect of slag basicity on the dissolution of chromite in slags contained in molybdenum crucibles is summarized in Table 2.

4. CONCLUSIONS

Both the processes, the dissolution of chromite and the reduction of oxides in a liquid slag system, involve a complex array of ionic movements and mass transport of elements. This makes it difficult to establish the controlling factors in determining the extent of chromite dissolution in a given slag composition under certain conditions. However, in the light of the observations in this study it is likely that under reducing conditions the chromite dissolution is initiated more easily in an acid slag than it is in a basic slag. But the extent and the rate of this process is determined by the removal of reaction products from the reaction sites at the vicinity of the chromite particles exposed to the liquid slag. And, a basic slag offers an easier ionic movement than an acid slag, therefore it is expected that in a basic slag the extent of chromite dissolution would be higher than an acid slag.

A detailed and more quantitative summary of the relationships between the slag composition and the chromite dissolution is given in Table 3. The arrows (\rightarrow) indicate the direction of change in the concentration of a given oxide in the slag phase. From Table 3, the per cent dissolution values (in graphite crucibles) increase with increasing ratios of the following slag components,

1. MgO to CaO
2. Al_2O_3 to CaO
3. Al_2O_3 to MgO
4. CaO to SiO_2
5. MgO to SiO_2 , when $39 < \text{SiO}_2 < 50$ and $5 < \text{MgO} < 16$, and
6. SiO_2 to MgO, when $35 < \text{SiO}_2 < 39$ and $16 < \text{MgO} < 20$

And, for molybdenum crucibles, the chromite dissolution increases with increasing ratios of the following slag components:

1. CaO to Al_2O_3
2. MgO to Al_2O_3
3. CaO to SiO_2

The effect of changes in the ratios of CaO and MgO to Al_2O_3 content of the slag on the per cent dissolution is different for graphite and molybdenum crucibles. An increase in the ratio of Al_2O_3 to MgO or CaO causes an increase in the per cent dissolution when graphite crucibles are used. Whereas, an increase in the same ratio causes the per cent dissolution values to decrease in molybdenum crucibles. The effect of stronger reducing conditions in graphite crucibles compared to the molybdenum crucibles, becomes more pronounced with increasing Al_2O_3 to CaO (or MgO) ratios in the slag. The effect of the level of reducing conditions on the per cent dissolution is not affected considerably by CaO to SiO_2 ratio of the slag. The per cent dissolution values increase with increasing CaO to SiO_2 ratios of the slag in both the graphite and molybdenum crucibles.

5. ACKNOWLEDGEMENTS

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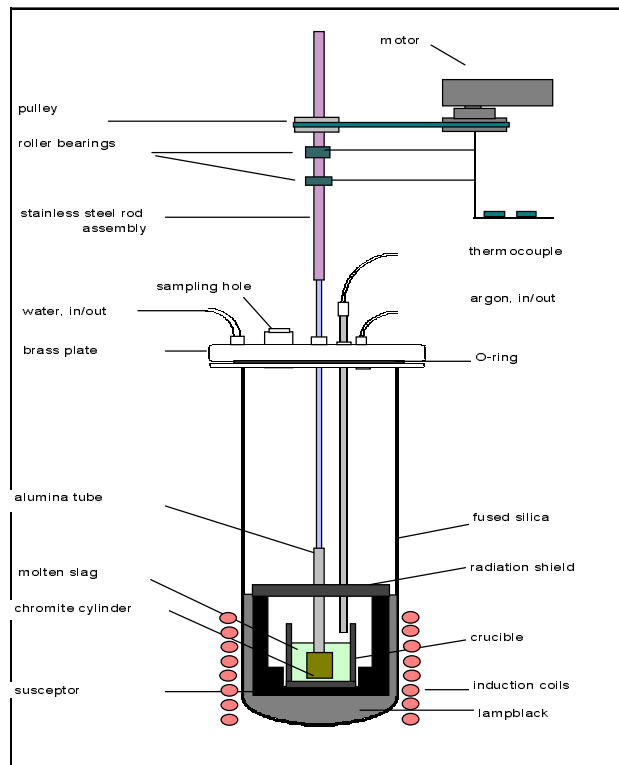


Fig. 1. Schematic representation of the reaction chamber. The arrangement of the graphite tube for electrical conduction, radiation shield, crucible containing the charge and the lampblack insulation.

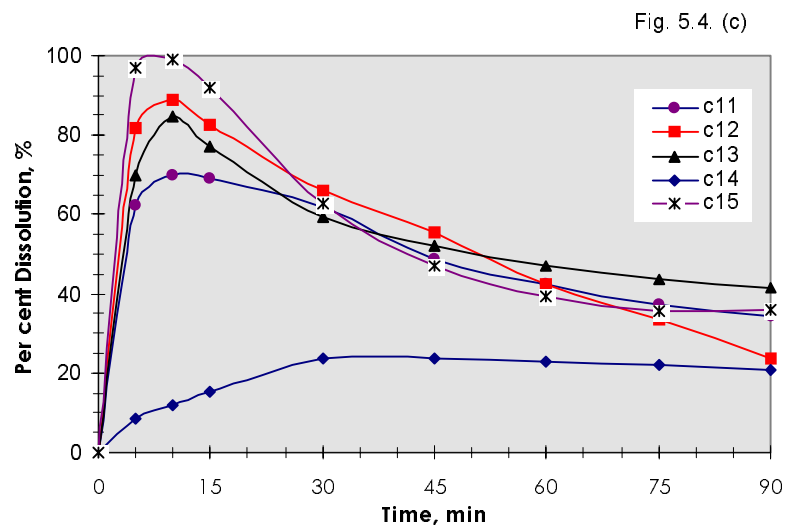


Fig. 2. The effect of slag composition on the dissolution of chromite as a function of time at 1600°C and 100 rpm. The compositions of the slags C11-C15 contained in graphite crucibles are given in Table 3.

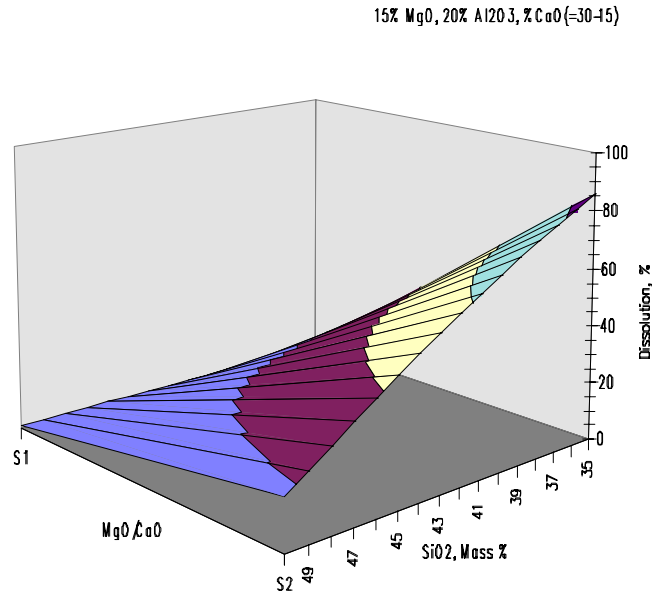


Fig. 3. Per cent dissolution of chromite as a function of the MgO/CaO and the SiO₂ content of the slags containing 15 per cent MgO and 20 per cent Al₂O₃ (S1=0.5, S2=1.0). 1600°C and 100 rpm, 15 minutes after immersion.

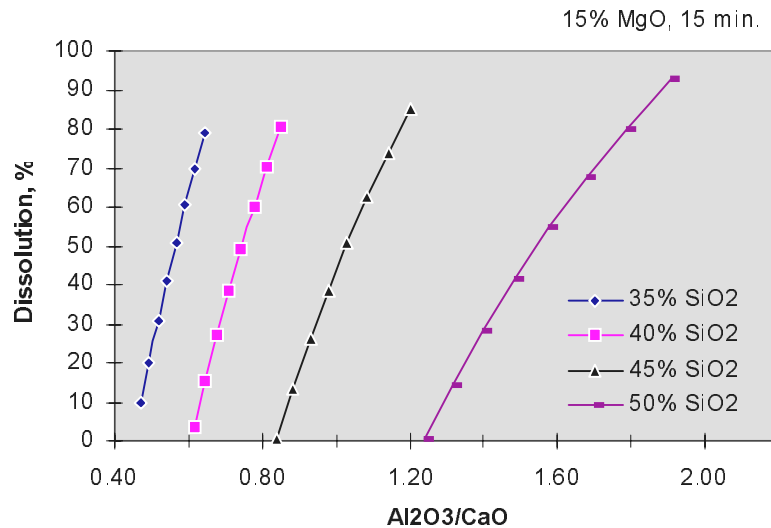


Fig. 4. Per cent dissolution of chromite as a function of the Al₂O₃/CaO ratio of the slags containing 15 per cent MgO and 35, 40, 45 and 50 per cent SiO₂ at 1600°C and 100 rpm, 15 minutes after immersion.

Series:	35% SiO ₂	40% SiO ₂	45% SiO ₂	50% SiO ₂
Al ₂ O ₃ , %	16-21	17-22	19-22	19-23
CaO, %	34-29	28-23	22-18	16-12

20% Al₂O₃, 20% CaO, SiO₂=35-50, 15 Minutes

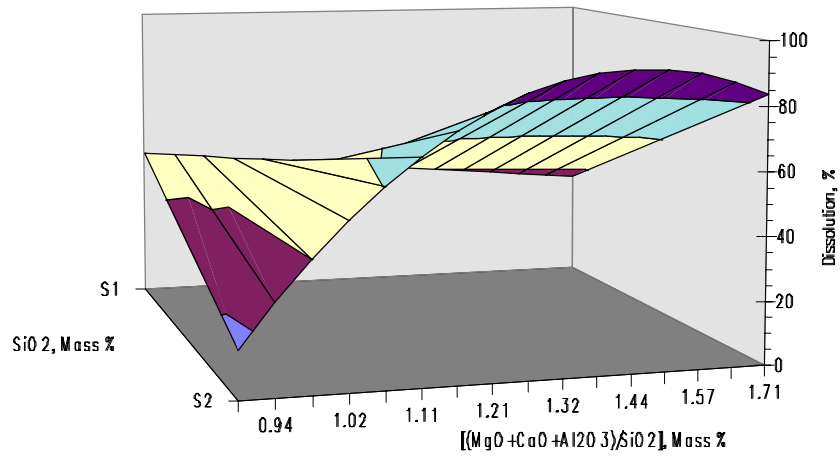


Fig. 5. Basicity and SiO₂ content of slags versus per cent dissolution of chromite in slags containing 20 per cent Al₂O₃ and 20 per cent CaO (S1= 35, S2= 50). 1600°C and 100 rpm, 15 minutes after immersion.

20% Al₂O₃, 15% MgO, SiO₂=35-50, 15 Minutes

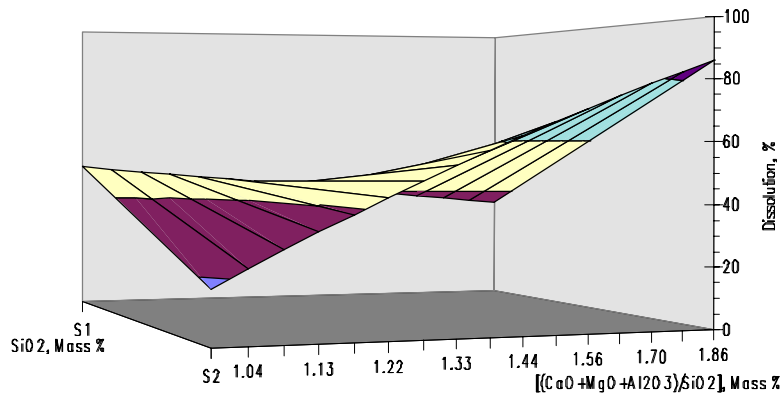


Fig. 6. Basicity and SiO₂ content of slags versus per cent dissolution of chromite in slags containing 20 per cent Al₂O₃ and 15 per cent MgO (S1= 35, S2= 50). 1600°C and 100 rpm, 15 minutes after immersion.

Table 1. Chemical analysis of the as received, pulverised and sintered chromite.

	Component, mass %							
Chromite	Fe ₂ O ₃ *	FeO	Cr ₂ O ₃	Al ₂ O ₃	SiO ₂	TiO ₂	MgO	CaO
As received	23.3	17.5	49.7	12.9	2.6	0.42	10.9	<0.2
Pulverised	24.2	18.2	49.7	12.9	2.8	0.42	10.7	0.19
Sintered	24.3	18.2	49.8	12.1	2.8	0.41	10.8	0.20

* Total Fe is calculated as Fe₂O₃.

Table 2. The summary of discussions on the effect of the ratios of different slag components on the chromite dissolution in slags contained in graphite crucibles at 1600°C, under argon. The cylinders of chromite were rotated at 100 rpm..

	Component, Mass %				
(Al ₂ O ₃ /CaO of Slag)	SiO ₂	Al ₂ O ₃	MgO	CaO	Dissolution, %
+	Constant	+	Constant	-	+
+	Constant	Constant	+	-	+
+	Constant	+	-	Constant	+
+	+	Constant	Constant	-	-
(MgO/Al ₂ O ₃) of Slag	SiO ₂	Al ₂ O ₃	MgO	CaO	Dissolution, %
+	Constant	-	Constant	+	-
+	Constant	-	+	Constant	-
+	Constant	Constant	+	-	+
(MgO/CaO) of Slag	SiO ₂	Al ₂ O ₃	MgO	CaO	Dissolution, %
+	Constant	+	Constant	-	+
+	Constant	Constant	+	-	+
+	Constant	-	+	Constant	-
+	+	Constant	Constant	-	-
Basicity R ₁	SiO ₂	Al ₂ O ₃	MgO	CaO	Dissolution., %
-	Constant	+	Constant	-	+
-	Constant	+	-	Constant	+
+	-	Constant	Constant	+	+
+	+	Constant	Constant	-	+
+	+	Constant	Constant	-	+
+	+	Constant	Constant	-	+
Basicity R ₂	SiO ₂	Al ₂ O ₃	MgO	CaO	Dissolution., %
+	-	Constant	Constant	+	+
+	-	Constant	+	Constant	+
+	-	Constant	+	Constant	-
Experiments in Molybdenum Crucibles					
Basicity	SiO ₂	Al ₂ O ₃	MgO	CaO	Dissolution, %
+	Constant	-	Constant	+	+
+	-	Constant	Constant	+	+
+	Constant	-	+	Constant	+

Table 3. Summary of discussions on the effect of slag composition on the per cent dissolution of chromite in slags contained in graphite and molybdenum crucibles at 1600°C, under argon. Chromite cylinders were rotated at 100 rpm.

Graphite Crucibles				
SiO₂	Al₂O₃	MgO	CaO	Dissolution, %
35→50	20	15	30→14	—
44	12→30	24→6	20	+
42,44,46	29→13	5→25	20	—
40	16,18,20,22	10→22	28→22	+
40	7→21	16,20,24,30	27→20	+
47.5	30→11	5→30	12,14,16,18	—
40	16→23	15	29→22	+
35,40,45,50	20	10→19	30→10	+
40	16,18,20,22	10→22	28→22	+
40	2→21	16,20,24,30	28→20	+
35,40,45,50	15→22	15	35→13	+
35→50	20	12,14,16,18	33→12	—
40	22→17	15	23→28	—
44	30→12	6→24	20	—
35→50	18,20,22	15	32→13	—
50→39	20	5→16	20	+
39→35	20	16→20	20	—
Molybdenum Crucibles				
35,40,45,50	30→12	15	5→35	+
40	30→9	5,15,20,25	9→35	+
50→35	20	5,10,15,20	10→35	+
50→35	15,20,25,30	15	5→35	+
40	30→5	5→35	12,16,20,25	+
35	30→15	15→30	20	+
40	30→10	10→30	20	+
45	30→10	5→25	20	+
50→35	15,20,25,30	15	5→35	+
50→35	20	5,10,15,20	10→35	+

Table 4. The compositions of the slags used in experiments C11-C15 shown in Figure 4.

Exp. No.	Component, Mass Per cent			
	SiO ₂	Al ₂ O ₃	MgO	CaO
C11	47.03	12.65	6.38	33.95
C12	30.86	23.01	16.84	29.29
C13	50.22	18.28	14.62	16.88
C14	40.79	31.10	14.16	13.95
C15	49.89	8.81	15.75	25.55