Phosphorus Distribution Between Carbon Saturated Iron at 1350°C, and Lime-based Slags Containing Na_2O and CaF_2

Willem Hendrik van Niekerk[1] and Rian Johannes Dippenaar[2]
[1]Manager, Technology Development, Heavy Minerals Project, Iscor Ltd., PO Box 9229, Pretoria, Republic of South Africa
[2]Department of Material Science and Metallurgical Engineering, University of Pretoria, Pretoria, 0002, Republic of South Africa

1. INTRODUCTION

Dephosphorization of hot-metal is inhibited by the presence of silicon in the metal phase and is commercially only viable at low silicon levels[1], preferably below 0,2% silicon[2]. Most blast furnaces produce hot metal with higher silicon contents and dephosphorization of hot metal is therefore not common practice. On the other hand, a process such as the COREX is capable of consistently producing hot metal with very low silicon contents. Silicon levels of 0,1%, and even lower, have been attained[3-5]. Consequently, hot metal produced by the COREX process is ideally suited for the external removal of phosphorus.

Dephosphorization only, or the simultaneous removal of sulphur and phosphorus from hot metal can be achieved with a soda-ash treatment. As a result, the thermodynamic properties of Na_2O-SiO_2 slags have been studied extensively[6-10]. However, due to various difficulties encountered with the use of this reagent, particularly its environmentally unfriendly nature, soda-ash is used on an ever diminishing scale. A lime-based reagent, provided it possesses a high efficiency of sulphur and phosphorus removal, may be used as an inexpensive alternative.

Various studies[7,11-14] have shown that small additions of Na_2O significantly enhance the ability of lime-based slags to dephosphorize liquid iron. Simeonov and Sano[11] reported a ten-fold increase in the equilibrium phosphorus distribution ratio (L_P) at 1300°C when a 2,6 per cent addition of Na_2O is made to a CaO-CaF_2-SiO_2-MnO slag. Pak and Fruehan[13] observed a five fold increase in the phosphorus partition coefficient, for a 5 weight per cent addition of Na_2O to a CaO saturated CaO-FeO_T-SiO_2 slag at 1600 °C. Muraki, Fukushima and Sano[14] obtained similar results with Na_2O additions to the CaO-SiO_2-CaF_2 system.

Na_2O additions to lime-based slags improve their ability to absorb phosphorus, mainly because Na_2O is a stronger basic oxide than CaO. An increase in basicity causes a decrease in the activity coefficient of P_2O_5. Turkdogan and Pearson[15] proposed the following empirical relationship between the activity coefficient of P_2O_5 and the composition of slags, as a function of temperature:

$$\log \gamma_{P_2O_5} = -1.12 \cdot (22 \cdot N_{CaO} + 15 \cdot N_{MgO} + 13 \cdot N_{MnO} + 12 \cdot N_{FeO} + 31 \cdot N_F - 2 \cdot N_{SiO_2}) - 42{,}000 / T + 23.58 \quad (1)$$

Other investigators[12,16,17] derived expressions similar to equation (1), but incorporated an additional term (N_{Na_2O}) to account for the effect of Na_2O. These expressions all indicate that Na_2O exerts a stronger influence on γP_2O_5 than CaO.

The phosphate capacity ($C_{PO_4^{3-}}$), which is perhaps the most effective measure of the thermodynamic dephosphorizing capability of slags, is improved by both a higher basicity and a lower activity coefficient of P_2O_5, as shown in equation (3).

For application at low hot-metal temperatures, additions of fluxes (such as CaF_2) may be required to ensure that the lime-based slags remain fluid during hot-metal treatment. However, the effect of CaF_2 on the phosphate capacity of slags has not been uniquely defined

mainly because from a thermodynamic point of view, CaF_2 may influence the activity of FeO as well as the activity coefficient, γP_2O_5 in the slag.

It is generally accepted[18-21] that CaF_2 increases the activity coefficient of FeO and consequently enhances dephosphorization. With regard to its effect on the activity coefficient of P_2O_5, it follows from the work of Turkdogan and Pearson[15], equation (1), that CaF_2 (shown in the equation as N_F) causes a significant decrease in γP_2O_5. Other investigators reported a similar effect of CaF_2 on P_2O_5 albeit not to the same extent. Kor[22] suggested a coefficient of 20 for N_F in equation (1), while Kawai et al[23] proposed a coefficient of 9. The fact that the value of γP_2O_5 is significantly lowered by the addition of CaF_2 to a lime based slag can be explained if the phase relationships in the CaF_2-CaO-P_2O_5 ternary system[24] is taken into account. As shown in Figure 1, a stable calcium fluoride phosphate [$CaF_2.3Ca_3(PO_4)_2$], which melts congruently at 1650°C, can form. The formation of this phase will reduce the activity coefficient of P_2O_5 considerably.

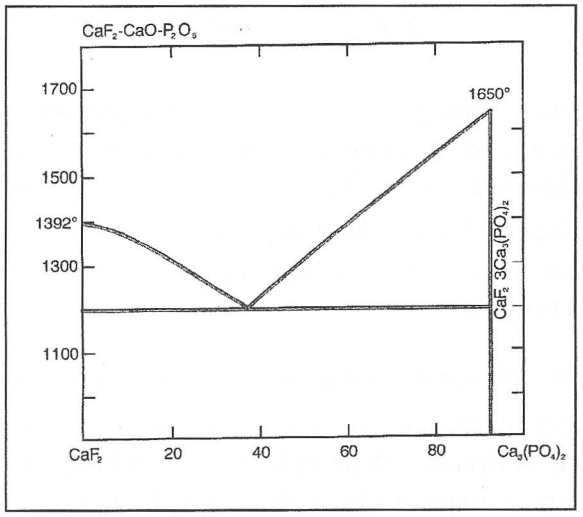

Figure 1 - Phase diagram for the CaF_2 - $Ca_3(PO_4)_2$ system [24].

Unfortunately, not all previous studies confirmed this decrease in γP_2O_5 by additions of CaF_2 to lime-based slags. Simeonov and Sano[11] for example found that an increase in CaF_2 content increased the value of γP_2O_5. However, the FeO content of the slag they used was very low and they explained the observed increase in γP_2O_5 by a decrease in the basicity of the slag since the strong base CaO is replaced by CaF_2.

Previous researchers have all shown, as indicated above, that additions of Na_2O to lime-based slags improve their ability to dephosphorize liquid iron, but the contribution made by CaF_2 has as yet not been quantified. Furthermore, very little thermodynamic data on lime-based slags containing CaF_2 as well as Na_2O at hot-metal temperatures, are available. Consequently, before a lime-based reagent for dephosphorization of hot metal can be developed, the influence exerted by Na_2O and CaF_2 respectively, on dephosphorization need to be clarified.

In the present study experiments were firstly performed in the Na_2O-SiO_2 and the CaO-Na_2O-SiO_2 systems, so that the effect of Na_2O on dephosphorization could be substantiated, followed by a study of selected slags in the system: CaF_2-CaO-Na_2O-SiO_2. This was done with a view to establish the combined effect of CaF_2 and Na_2O on dephosphorization in lime-based slags, and also to establish if stable fluoride phosphates form in lime based slags which also contains Na_2O.

2. THEORETICAL CONSIDERATIONS

Wagner[25] proposed that the equilibrium phosphorus distribution between liquid iron and slag be formulated as follows:

$$\tfrac{1}{2}P_2(g)+\tfrac{5}{4}O_2(g)+\tfrac{3}{2}O^{2-}(slag)=PO_4^{3-}(slag) \quad (2)$$

He defined the phosphate capacity ($C_{PO_4^{3-}}$) as follows:

$$C_{PO_4^{3-}}=\frac{(\%PO_4^{3-})_{slag}}{P_{P_2}^{1/2}\cdot P_{O_2}^{5/4}}=K_{PO_4^{3-}}\cdot a_{O^{2-}}^{3/2}/f_{PO_4^{3-}} \quad (3)$$

where P_{P_2} and P_{O_2} respectively represent the equilibrium partial pressures of phosphorus and oxygen. The phosphorus content in the slag is given by $(\%PO_4^{3-})_{slag}$ and the activity coefficient of the phosphate ion by $f_{PO_4^{3-}}$. The equilibrium constant for reaction (2) is represented by $K_{PO_4^{3-}}$ and the activity of oxygen ions in the slag by $a_{O^{2-}}^{3/2}$.

The expression for the phosphate capacity (equation 3) can be reformulated to improve its ease of application by considering the behaviour of phosphorus and oxygen at infinite dilution in liquid iron (reactions 4[26] and 5[27]).

$$\tfrac{1}{2}P_2(g) = \underline{P}$$
$$\Delta G^\circ = -157{,}700 + 5.4T \quad (J/mol) \qquad (4)$$

$$\tfrac{3}{4}O_2(g) = \tfrac{3}{2}\underline{O}$$
$$\Delta G^\circ = -342{,}800 + 19.48T \quad (J/mol) \qquad (5)$$

By combining reactions (4) and (5), a single equilibrium constant can be obtained.

$$K_{4\&5} = \frac{a_{\underline{P}} \cdot a_{\underline{O}}^{5/2}}{P_{P_2}^{1/2} \cdot P_{O_2}^{5/4}} \qquad (6)$$

where $a_{\underline{P}}$ and $a^{5/2}{}_{\underline{O}}$ are the activities (1 wt per cent standard state) in liquid iron of phosphorus and oxygen respectively.

The numerical value of $K_{4\&5}$ is given by equation (6a).

$$\ln K_{4\&5} = 60{,}200/T - 2.99 \qquad (6a)$$

Substitution of equation (6) into equation (3) yields:

$$C_{PO_4^{3-}} = \frac{(\%PO_4^{3-})_{slag}}{a_{\underline{P}} \cdot a_{\underline{O}}^{5/2} / K_{4\&5}} \qquad (7)$$

Finally, $(\%PO_4^{3-})_{slag}$ is converted to $(\%P)_{slag}$, $a_{\underline{P}}$ is replaced by $\%\underline{P}.f_{\underline{P}}$ and logarithms are taken to yield:

$$\log C_{PO_4^{3-}} = \log L_P + \log\left(MM_{PO_4^{3-}} / MM_P\right) - \log f_P - \log a_{\underline{O}}^{5/2} + \log K_{4\&5} \qquad (8)$$

with f_P the Henrian activity coefficient of phosphorus in liquid iron (1 wt per cent standard state) and $(MM_{PO_4^{3-}} / MM_P)$ the ratio of the molar masses of phosphate and phosphorus, which is equal to 3.07.

The activity coefficient (f_P) is determined by means of the following equation:

$$\log f_P = e_P^C \cdot \%C + e_P^P \cdot \%P \qquad (9)$$

By using the interaction parameters proposed by Hadrys et al[28] and The Steelmaking Data Sourcebook[26] respectively, the following relationship is obtained at 1600 °C:

$$\log f_P = 0.126 \cdot \%C + 0.054 \cdot \%P \qquad (9a)$$

If it is assumed that the interaction parameters used in equation (9a) are an inverse function of temperature[26], the equation can be reformulated for application at 1350 °C:

$$\log f_P = 0.145 \cdot \%C + 0.062 \cdot \%P \qquad (9b)$$

3. EXPERIMENTAL

The experimental apparatus and method have been described in detail elsewhere[29]. Briefly, slag (2g) and carbon-saturated iron (4g) were equilibrated in carbon crucibles in a silicon-carbide, resistance-heated tube furnace at 1350°C under a carbon monoxide atmosphere (1 atm). Phosphorus was added to the metal in the form of FeP, whereas P_2O_5 was used to introduce phosphorus into the slag phase.

In the case of the CaO-Na_2O-SiO_2-CaF_2 system, the phosphorus contents of the metal and slag phases were adjusted relatively closely to the respective equilibrium values, as determined in a preliminary study. It was consequently possible to shorten the time to attain equilibrium for the distribution of

phosphorus between slag and metal. It is imperative that this procedure be used, because the composition of these Na_2O containing slags in contact with carbon saturated iron changes rapidly with time.

The temperature was controlled by a Pt/Pt-10%Rh thermocouple at 1350 ±4 °C. Before entering the furnace the CO gas was passed through a purifying train containing Na_2O, P_2O_5 and $MgClO_4$.

On completion of each experimental run the crucible was quenched in a stream of argon gas. The slag and metal phases were crushed and analysed chemically. The phosphorus content in the metal was determined by a photometric method, similar to the molybdivanadophosphoric acid method.

In a separate experimental trial, the formation of fluoride phosphate compounds were studied. Lime and sodium based mixtures, each containing P_2O_5 and in some cases CaF_2 were prepared. These were heated in a pure iron crucible under an argon atmosphere to a temperature of 1400°C for approximately 20 minutes. The resultant slags were cooled down rapidly, crushed and analysed by XRD.

4. RESULTS AND DISCUSSION

4.1 (Na_2O - SiO_2) system

The phosphorus partition ratios between carbon saturated iron and selected Na_2O-SiO_2 slags are given in Table I.

The phosphate capacity for the (Na_2O-SiO_2) system, calculated by assuming that P_{CO} = 1 atm and by computing the activity of carbon for each individual case (based on the actual carbon content), is illustrated in Figure 2 together with data previously reported by Inoue and Suito[7].

There is evidently good agreement between the results of the present study and that of Inoue and Suito[7]. Consequently, the significant increase in the phosphate capacity of (Na_2O-SiO_2) slags by the addition of Na_2O, as reported in previous studies, is confirmed by the present work.

Table I Experimental data for the phosphorus partition ratio of Na_2O-SiO_2 slags

Exp	Slag Analysis (w/o)			Metal Analysis (w/o)		Time (min)	L_p
	Na_2O	SiO_2	P	C	P		
PO33	46.2	53.8	0.10	4.29	0.18	15	0.56
KP1A	21.5	78.5	0.014	4.03	0.33	120	0.04
KP2A	22.5	77.5	0.011	3.92	0.39	120	0.03
KP1B	28.5	71.5	0.025	4.06	0.31	100	0.08
KP2B	30.4	69.6	0.019	4.21	0.25	100	0.08
KP3A	39.2	60.8	0.06	4.20	0.32	45	0.19
KP3B	39.2	60.8	0.039	4.13	0.25	45	0.16
KP4A	47.9	52.1	0.20	4.36	0.26	12	0.77
KP4B	47.9	52.1	0.22	4.31	0.27	12	0.81
KP5A	56.7	43.3	0.64	4.42	0.05	5	12.8
KP5B	56.8	43.2	0.78	4.38	0.05	5	15.6

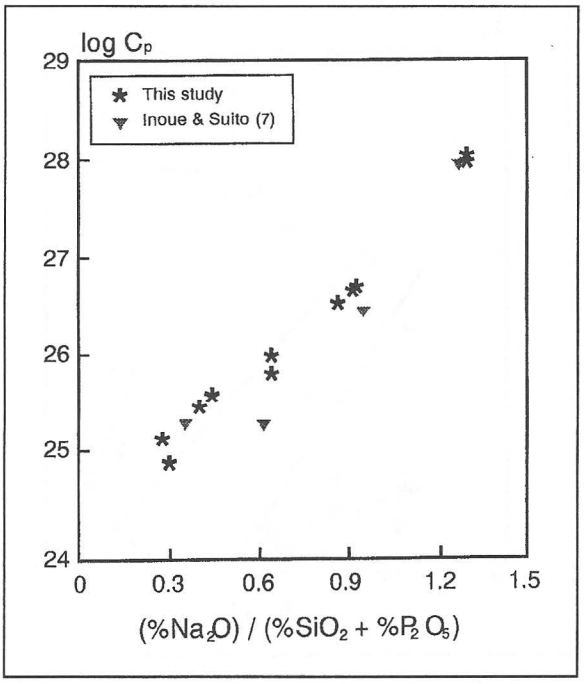

Figure 2 - The phosphate capacities of Na_2O-SiO_2 slags at 1350 °C calculated from the actual activity of carbon, but assuming that P_{CO} = 1 atm.

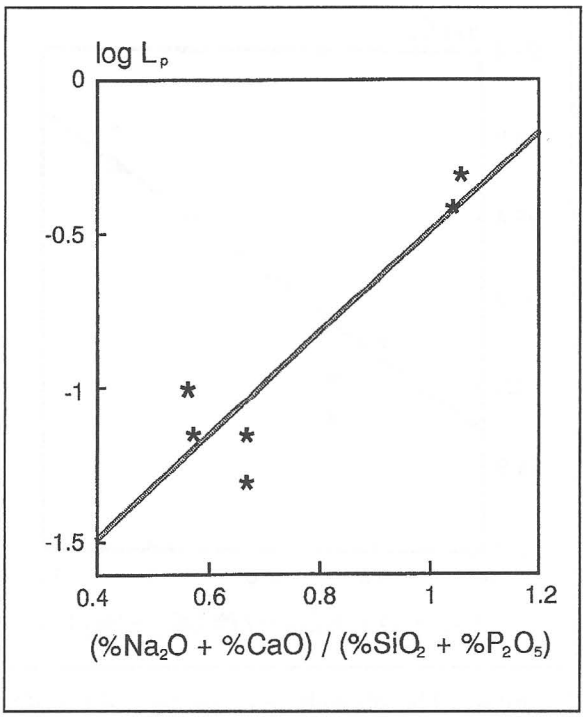

Figure 3 - The influence of basicity on the phosphorus partition ratio of (Na_2O-SiO_2-CaO) slags at 1350 °C.

4.2 (Na_2O - SiO_2 - CaO) system

The phosphorus partitioning between carbon-saturated liquid iron and selected (Na_2O-SiO_2-CaO) slags is shown in Table II.

The experimentally determined phosphorus partition ratios and the calculated phosphate capacities are illustrated in Figure 3 and Figure 4 respectively.

Although only six data points were obtained in this study, the ability of Na_2O to increase the partition ratio and phosphate capacity in lime-based slags at 1350 °C, previously found by Pak and Fruehan[13] at 1400 °C, is confirmed.

Table II Experimental data for the phosphorus partition ratio of Na_2O-SiO_2-CaO slags

Exp	Slag Analysis (w/o)				Metal Analysis (w/o)		L_p	Origin of Phosph.
	Na_2O	SiO_2	CaO	P	C	P		
KP6A	17.7	59.8	22.5	0.018	3.80	0.34	0.053	metal
KP6B	17.4	59.9	22.7	0.022	3.56	0.33	0.067	metal
KP7A	12.3	63.9	23.8	0.037	3.77	0.36	0.103	metal
KP7B	12.7	63.8	23.5	0.023	3.74	0.31	0.074	metal
PO7	21.9	48.8	29.3	0.06	3.52	0.15	0.400	metal
PO8	21.8	48.5	29.7	0.11	3.35	0.23	0.478	slag

* Equilibration time 20 minutes

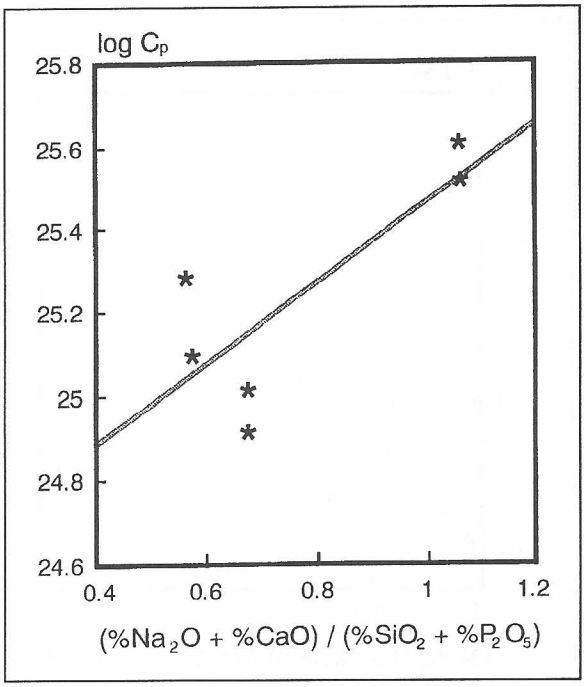

Figure 4 - The phosphate capacities of (Na_2O-SiO_2-CaO) slags at 1350 °C.

4.3 (CaO-Na_2O-SiO_2-CaF_2) system.

The results are given in Table III.

The influence of CaF_2, at different basicities ($[CaO+Na_2O]/[SiO_2+P_2O_5]$), on the phosphorus partition ratio and phosphate capacity is illustrated in Figures 5 and 6 respectively. Similar results are obtained when *optical basicity* is used as a measure to express the basicity of these slags.

It is evident from both these figures that the basicity of the slag is an important parameter to be considered for the evaluation of the efficient removal of phosphorus from liquid iron. It is also clear from Figures 5 and 6 that CaF_2 exerts a strong negative influence on the partition ratio and phosphate capacity of these slags. For example:

The phosphate capacity (logarithm) of a slag with basicity ($[CaO+Na_2O]/[SiO_2+P_2O_5]$) = 1,61 decreases from 27 to 25,5 with an increase in CaF_2 content from 20% to 40%.

In order to explain this effect of CaF_2 on the phosphate capacity, the activity coefficient of

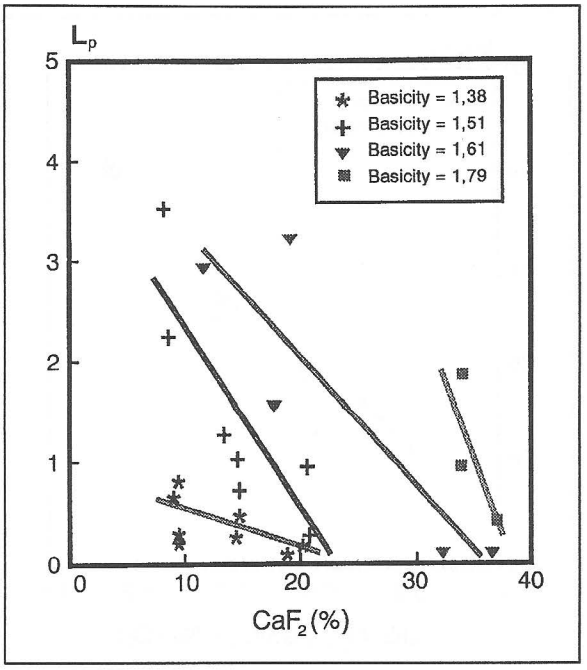

Figure 5 - The influence of basicity and CaF_2 content on the phosphorus partition ratio of lime-based slags at 1350 °C.

P_2O_5 was evaluated. The phosphorus equilibrium between slag and metal can be represented in its simplest form by the following equation:

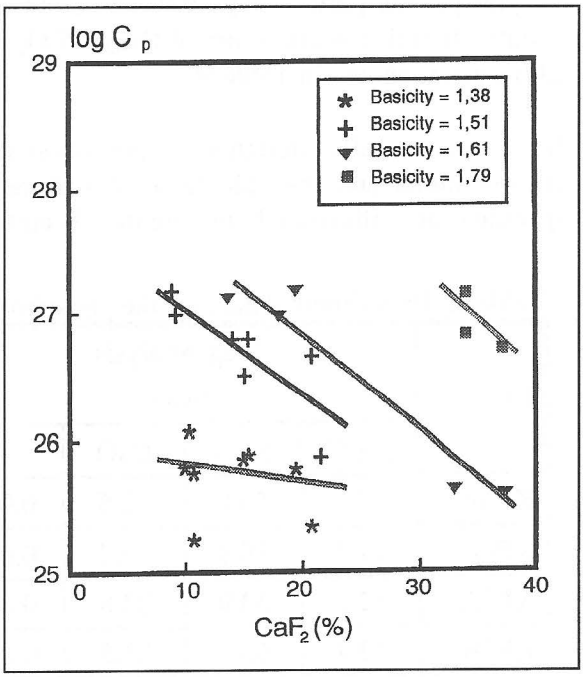

Figure 6 - The influence of basicity and CaF_2 content on the phosphate capacities of lime-based slags at 1350 °C.

Table III Experimental data for lime-based slags containing CaF_2 and Na_2O, equilibrated with carbon saturated iron.

Exp	Slag Analysis (w/o)					Metal Analysis (w/o)		Time Min	Origin*
	Na_2O	SiO_2	CaO	CaF_2	P	P	C		
PO9	16.0	36.0	34.7	8.9	0.27	0.12	4.14	10	M
PO10	15.6	35.7	38.2	8.4	0.46	0.13	4.09	10	S
PO11	14.6	33.4	36.7	13.7	0.22	0.17	4.15	10	M
PO12	15.0	32.9	36.5	13.5	0.40	0.14	4.14	10	S
PO13	14.8	31.2	33.8	17.9	0.20	0.12	4.24	10	M
PO14	14.7	30.3	34.0	19.5	0.37	0.12	4.16	10	S
PO15	12.3	22.7	30.0	34.1	0.14	0.14	4.26	10	M
PO16	11.8	22.8	30.0	34.2	0.29	0.15	4.29	10	S
PO17	7.6	38.5	43.5	9.6	0.03	0.18	3.50	20	M
PO18	7.4	38.8	40.1	9.7	0.06	0.29	3.92	20	S
PO19	7.0	36.1	44.3	14.7	0.04	0.11	3.80	20	M
PO20	6.9	36.1	41.6	14.3	0.05	0.24	4.00	20	S
PO21	6.5	33.4	39.2	20.2	0.02	0.19	3.76	20	M
PO22	6.6	33.2	40.0	18.9	0.02	0.32	4.44	20	S
PO23	5.2	25.8	35.1	32.6	0.02	0.25	4.18	20	M
PO25	11.3	37.6	40.2	9.5	0.15	0.22	3.71	15	M
PO26	11.3	37.3	39.8	9.1	0.15	0.26	3.52	15	S
PO27	10.2	35.0	38.2	14.8	0.13	0.17	4.09	15	M
PO28	10.2	34.6	38.4	15.0	0.19	0.18	4.22	15	S
PO29	8.2	31.5	38.0	21.1	0.03	0.18	4.12	15	M
PO30	8.4	31.2	37.6	20.8	0.17	0.17	4.11	15	S
PO31	8.0	24.2	30.3	36.8	0.02	0.24	4.13	15	M
PO32	8.9	23.9	28.1	37.2	0.12	0.25	4.46	15	S

* M: Metal side, S : Slag side

$$2[\underline{P}]_{Fe} + 5[\underline{O}]_{Fe} = (P_2O_5)_{slag} \qquad (10)$$

with

$$\Delta G^\circ = -705{,}456 + 556.5T \quad (J/mol)^{(30)} \qquad (10a)$$

The equilibrium constant for reaction (10), K, is given by:

$$K = \frac{N_{P_2O_5} \cdot \gamma_{P_2O_5}}{\left(f_{\underline{P}} \cdot \%P\right)^2 \cdot a_{\underline{O}}^5} = 4.32 \times 10^{-7} \qquad (10b)$$

at $1350^\circ C$

Table IV Experimental results of the study on the formation of complex fluoride phosphate compounds

Exp.	Slag Analysis (w/o)				Species present
	Na_2O	CaO	CaF_2	P_2O_5	
A	60	0	0	40	N_3P, N_2P, P_2O_5
B	48	0	20	32	N_3P, P_2O_5, NaF, C_2P
C	55	0	9	36	N_3P, P_2O_5, NaF
D	59	0	9	32	N_3P, P_2O_5, NaF
E	0	51	0	49	C_3P, C_2P
F	0	46	9	45	$CaF_2.3C_3P$, C_3P, CaF_2, P_2O_5
G	0	40	20	40	$CaF_2.3C_3P$, CaF_2, P_2O_5
H	40	20	20	20	CaO, NaF, N_3P
I	20	40	20	20	CaO, CaF_2, NaF, $CaF_2.3C_3P$

with;

N_2P : $Na_4P_2O_7$ N_3P : Na_3PO_4

C_2P : $Ca_2P_2O_7$ C_3P : $Ca_3P_2O_8$

$CaF_2.3C_3P$: $CaF_2.3Ca_3(PO_4)_2$

The only unknown in equation (10b), γP_2O_5, is calculated and shown in Figure 7 as a function of the CaF_2 content at constant basicity, where basicity is again defined as the ratio: $([CaO+Na_2O]/[SiO_2+P_2O_5])$.

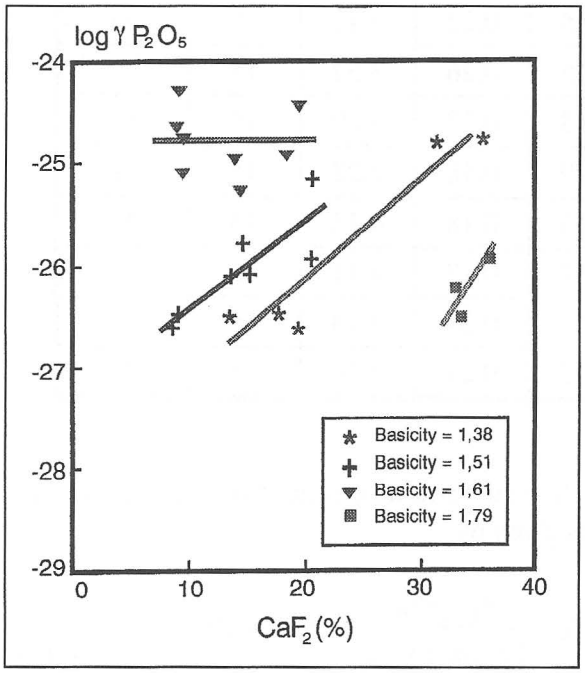

Figure 7 - The activity coefficient of P_2O_5 in (CaO-Na_2O- SiO_2-CaF_2) slags at 1350°C as a function of the CaF_2 content.

It follows from Figure 7 that γP_2O_5 increases with CaF_2 additions to the slag, especially at high basicities. This result seems to be in contradiction with the findings of previous studies[15,19,22,23], where it was reported that dephosphorization is enhanced thermodynamically by the addition of CaF_2 to the slag. However, the well established fact[6,11,30] that an increase in basicity lowers γP_2O_5, is confirmed by this study as shown in Figure 8.

The findings of this study are furthermore in agreement with those of Simeonov and Sano[11]. The common denominator between this study and that of Simeonov and Sano[11], which incidentally distinguish them from the other studies, is that the slags studied, contained Na_2O but not FeO. The effect of CaF_2 in FeO-containing slags is to increase the activity of the FeO[18-21]. This corresponds to a higher oxygen potential and consequently enhanced dephosphorization as shown by equation (10). Accordingly, it may be that

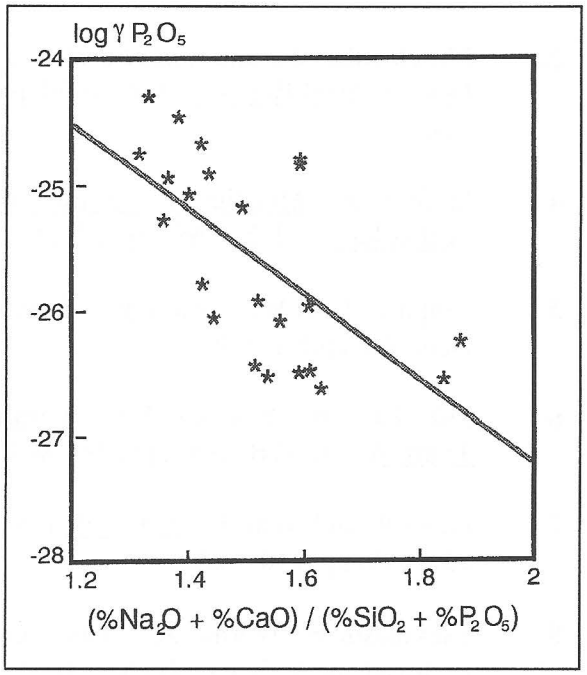

Figure 8 - The effect of basicity on the activity coefficient of P_2O_5 in (CaO-Na_2O-SiO_2-CaF_2) slags at 1350 °C.

previous researchers[15,19,22,23] observed an increase in the FeO activity rather than a decrease in γP_2O_5 due to the presence of CaF_2 in their slags. However, it is clearly shown in Figure 1 that a stable calcium fluoride phosphate does exist in the CaF_2-CaO-P_2O_5 slag system. The existence of this compound strongly suggests that phosphorus in CaF_2-CaO-P_2O_5 slags is stabilised by the formation of $CaF_2.3Ca_3(PO_4)_2$ and that the observed effect of FeO is probably a different issue. Consequently, the fact that phosphorus was not stabilised in the present study, still remains to be explained. The difference between the slag system shown in Figure 1 and those slags where a decrease in phosphate capacity was observed, Figure 6, is that the slags in the latter case contained a significant fraction of Na_2O. Consequently, the question arises if stable calcium fluoride phosphate phases also form in the slag system used in this study which also contains Na_2O. For this reason an attempt was made to confirm the existence of a $CaF_2.3Ca_3(PO_4)_2$ phase and to establish whether similar stable phases will form in slags which contain Na_2O. The results of this study are summarised in Table IV.

These results confirm that stable calcium fluoride phosphate compounds, as is indicated by the phase diagram depicted in Figure 1, form in the slag system under consideration; lime based slags without Na_2O additions (Slags F & G). However, in Na_2O based slags without CaO (Slags B to D), the only fluoride specie present is NaF. No sodium fluoride phosphate could be detected in these slags. In the case of the sodium containing lime-based slags, it also seems that the formation of NaF occurs in preference to sodium phosphate compounds. The partial (Slag I) or complete absence (Slag H) of sodium fluoride phosphate compounds in these slags probably explains why the presence of CaF_2 in sodium containing lime-based slags impedes dephosphorization whereas it enhances dephosphorization in sodium-free lime-based slags where stable compounds are formed.

This is an important finding because it does shed some light on the controversies referred to and indicates that dephosphorization will only be enhanced by CaF_2 in those slags where stable phosphates are formed. Stable fluoride phosphates formed in the absence of Na_2O-containing slags. Consequently, CaF_2 enhances dephosphorization in slags where a

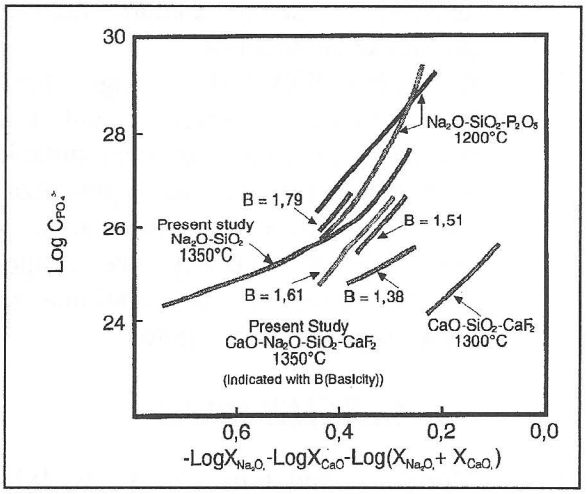

Figure 9 - The phosphate capacities of different slag systems (after Pak and Fruehan[6]).

CaF_2 - phosphate complex forms, but decreases the phosphate capacity in the absence of CaF_2 - phosphate formation when it merely serves to dilute the slag.

Finally, the phosphate capacities determined in this study are shown in Figure 9, together with those of other systems.

It follows that the lime-based slags investigated in this study posses high phosphate capacities. These slags were specifically chosen because of their low melting points, and they should therefore be suitable for dephosphorization of hot metal at relatively low temperatures. In addition, it was shown previously[31] that these slags have high sulphide capacities which should make them particularly suitable for simultaneous desulphurization and dephosphorization of COREX iron.

5. CONCLUSIONS

1. Additions of Na_2O increase the phosphate capacity of silicate and lime-based slags considerably.
2. Additions of CaF_2 to Na_2O containing lime-based slags increase the activity coefficient of P_2O_5, and therefore decrease the phosphate capacity thereof. This is probably due to the absence of stable sodium fluoride phosphate compounds.
3. (CaO-Na_2O-SiO_2-CaF_2) slags have high phosphate capacities and low melting points, yielding them suitable as effective reagents for dephosphorization, and even desulphurization, of hot metal at relatively low temperatures. However, CaF_2 additions to these slags should be limited.

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