Chloride Capacities of CaO–SiO₂–Al₂O₃(–FeO, MgO, MnO) Slags and Their Application in the Incineration Processes

Makoto MIWA and Kazuki MORITA

Department of Materials Engineering, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-8656 Japan.

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Thermodynamic properties of chlorine in the CaO–SiO₂–Al₂O₃(–FeO, MgO, MnO) and CaO–SiO₂–FeO slags have been investigated. The experiments were carried out under relatively high oxygen partial pressure, using gas–slag equilibrium, controlling both P_{O_2} and P_{Cl_2} simultaneously ($P_{O_2}=10^{-5}$ – 10^{-13} atm, $P_{Cl_2}=10^{-7}$ – 10^{-10} atm at 1 673 K) by flowing gas mixture of H₂, CO₂, HCl and Ar gases, and the solubility of chlorine in the 40mass%CaO–40mass%SiO₂–20mass%Al₂O₃ slag was found to vary in proportion to $P_{O_2}^{-1/4}$ and $P_{Cl_2}^{1/2}$, which was the same relationship observed in the reducing conditions. Accordingly, chloride capacity (C_{Cl^-}) is used to evaluate ability of slags to absorb chlorine. The C_{Cl^-} values were observed to increase with increasing slag basicity, and showed a reasonable relationship with that of $C_{S^{2-}}$. Based on the result obtained in the present study, chlorine distribution during incineration with slags was predicted quantitatively.

KEY WORDS: iron- and steelmaking slags; gas–slag equilibrium; chlorine; solubility of chlorine; chloride capacity; sulfide capacity; slag basicity; incineration.

1. Introduction

Ecological problems have recently been treated in iron- and steelmaking processes, as is seen in the development of waste plastic injection into a blast furnace.¹⁾ However, we have to consider more effective utilization of such a high temperature mass production system as iron- and steelmaking processes for the waste management. In the near future, even the waste containing chlorine such as polyvinyl chloride (PVC) should be treated, but we have to overcome the problem of dioxine and HCl generation. In order to predict the generation of such toxic gases, the behavior of chlorine in high temperature furnaces must be predicted and the evaluation of chlorine gas absorption into slags becomes very important. From this viewpoint, Hirosumi and Morita²⁾ clarified that chlorine dissolves into the slag as Cl[–] ion in low oxygen partial pressure, and they defined the ability of slags to capture chlorine as follows.

$$C_{Cl^-} = \frac{(\text{mass\%Cl}^-)P_{O_2}^{1/4}}{P_{Cl_2}^{1/2}}$$

However, the previous research was conducted under strongly reducing conditions where oxygen partial pressure is much lower than that of waste incineration. Seeing that sulfur exists as sulfate at higher oxygen partial pressure for instance, chlorine could dissolve as oxychloride such as ClO[–], ClO₃[–], etc.

In the present study, by measuring the chlorine concentrations at various compositions of the CaO–SiO₂–Al₂O₃(–FeO, MgO, MnO) and CaO–SiO₂–FeO slags in comparatively high oxygen partial pressure ($P_{O_2}=10^{-5}$ – 10^{-13} atm),

the dissolution mechanism of chlorine into molten slags has been clarified and the ability of slags to capture chlorine has been evaluated in terms of chloride capacity, C_{Cl^-} .

Finally, based on the result obtained in this study, chlorine distribution during incineration with slags was predicted quantitatively.

2. Experimental

A SiC resistance furnace with a fused mullite tube (53 mm ID and 1 000 mm length) was employed and experimental temperature (1 673 K) was controlled by a proportional-integral differential (PID) controller and kept within ± 1 K with a Pt–6%Rh/Pt–30%Rh thermocouple. Schematic sketch inside the furnace is drawn in Fig. 1.

During experiments, the atmosphere was controlled by flowing a gas mixture of CO₂, H₂ and HCl at a rate of 50–100 Ncm³/min. P_{O_2} was controlled by fixing initial P_{CO_2} and P_{H_2} according to Eqs. (1) and (2), assuming their final P_{CO} equals to P_{H_2O} . On the other hand, P_{Cl_2} was controlled by the final P_{HCl} and P_{H_2} according to Eqs. (3) and (4), when Eq. (1) is in equilibrium state.

$$\Delta G_1^\circ = 33\,500 - 29.4T \text{ [J/mol]}^{(3)} \dots \dots \dots (2)$$

$$\Delta G_3^\circ = 94\,200 + 6.41T \text{ [J/mol]}^{(3)} \dots \dots \dots (4)$$

In order to control partial pressures of gas species precisely, capillary mass flow units were used. In the gas pu-

rification system, H_2SO_4 and $\text{Mg}(\text{ClO}_4)_2$ were used to remove H_2O , and soda lime were used to remove CO_2 .

The slag samples were prepared by mixing CaO calcined from CaCO_3 , reagent grade SiO_2 , Al_2O_3 , FeO , MgO and MnO . About 3 g of slags were charged into crucibles, then kept in a hot zone of the furnace. The materials of crucible were selected according to the slag systems and the atmosphere of experiment. Iron crucible was used for FeO containing slags, and Ni crucible was used when oxygen partial pressure was less than 10^{-11} atm, while platinum crucibles in the other cases. The experimental time was determined to be 24 h, which were confirmed enough for the equilibrium attainment by the preliminary experiments. Just before taking out the samples, the experimental gas mixture was switched to Ar gas for 1 min. The samples were withdrawn and quenched in the flushing Ar gas and subjected to chemical analyses.

The Ca, Al, Fe, Mg and Mn contents of the slags were determined by inductively coupled plasma (ICP) emission spectrometry at the wavelengths of 318, 396, 238, 279 and 258 nm, respectively, while SiO_2 and total chlorine contents by gravimetry and silver nitrate titration.

The slag compositions were corrected so that the total of contents of CaO , SiO_2 , Al_2O_3 , FeO , MgO and MnO may become 100 mass%. Namely, the chlorine contents are excluded in representing the slag compositions after the experiments.

Fig. 1. Schematic cross section of the experimental apparatus.

3. Results and Discussion

3.1. Chlorine Dissolution into Molten Slag

In order to investigate the behavior of chlorine in molten slags in comparatively high oxygen partial pressure, the relationship between the solubility of chlorine in the slag, (mass%Cl), and P_{Cl_2} , as well as that between (mass%Cl) and P_{O_2} , was investigated. The 40mass% CaO –40mass% SiO_2 –20mass% Al_2O_3 slag was selected with P_{Cl_2} and P_{O_2} , ranging from approximately 10^{-10} to 10^{-7} atm and 10^{-13} to 10^{-5} atm, respectively at 1 673 K. Experimental conditions and results are summarized in Table 1.

As seen in Fig. 2, there is a linear relationship between $\log P_{\text{O}_2}$, and $\log(\text{mass}\%\text{Cl})/P_{\text{Cl}_2}^{1/2}$, and the slope of the line is close to $-1/4$. Accordingly, the solubility of chlorine in the slag is considered to be in proportion to $P_{\text{O}_2}^{-1/4}$ and $P_{\text{Cl}_2}^{1/2}$. Based on this result, the dissolution mechanism of chlorine into the slag at the present experimental condition can be described as Eq. (5) and the dissolution mechanism of chlorine is the same as that under the reducing conditions reported by Hirosumi *et al.*²⁾

This means that chlorine also dissolves into the slag as Cl^- ion and oxychloride ions may not be stable in such high oxygen partial pressures. Henceforth, chloride capacity C_{Cl^-} defined by Hirosumi *et al.*²⁾ as Eq. (6) are brought into use as an ability of chlorine absorption in the present work.

Fig. 2. Relationship between oxygen partial pressure, chlorine partial pressure and concentration of chlorine in the slag at 1 673 K.

Table 1. The C_{Cl^-} values for the CaO – SiO_2 – Al_2O_3 slags together with gas compositions at 1 673 K.

No.	Temp.(K)	Ingoing gases (atm)				P_{O_2} (atm)	P_{Cl_2} (atm)	Slag composition (mass%)				C_{Cl^-}
		HCl	H ₂	CO ₂	Ar			CaO	SiO ₂	Al ₂ O ₃	Cl	
1-1	1673	0.042	0.571	0.029	0.358	6.38E-13	8.98E-10	36.8	43.3	19.9	1.23	36.9
1-2	1673	0.062	0.333	0.067	0.538	1.25E-11	4.05E-09	37.9	42.1	20.0	0.49	16.9
1-3	1673	0.066	0.259	0.109	0.566	7.42E-11	7.35E-09	38.7	42.2	19.1	0.99	34.0
1-4	1673	0.042	0.406	0.189	0.363	9.42E-11	2.01E-09	39.3	39.9	20.8	0.57	39.9
1-5	1673	0.025	0.259	0.501	0.215	4.36E-09	3.57E-09	38.0	41.8	20.2	0.30	40.4
1-6	1673	0.028	0.202	0.526	0.244	9.32E-09	8.12E-09	37.7	42.1	20.2	0.43	47.2
1-7	1673	0.014	0.072	0.791	0.123	2.43E-07	2.64E-08	38.3	43.2	18.6	0.34	46.1
1-8	1673	0.011	0.034	0.862	0.093	1.41E-06	7.66E-08	39.8	41.4	18.8	0.34	42.3
1-9	1673	0.014	0.022	0.844	0.120	3.22E-06	2.90E-07	40.7	40.7	18.6	0.45	35.7
1-10	1673	0.006	0.019	0.926	0.050	5.53E-06	7.80E-08	41.2	39.6	19.2	0.52	54.7

Table 2. The C_{Cl^-} values for the CaO–SiO₂–Al₂O₃–FeO, MgO, MnO slags together with gas compositions at 1 673 K.

No.	Temp.(K)	Ingoing gases (atm)				Po ₂ (atm)	PCl ₂ (atm)	Slag composition (mass%)						C _{Cl⁻}	
		HCl	H ₂	CO ₂	Ar			CaO	SiO ₂	Al ₂ O ₃	FeO	MgO	MnO		Cl
2-1	1673	0.056	0.128	0.336	0.480	9.46E-09	6.82E-09	38.8	40.9	20.0	0.3			1.04	46.2
2-2	1673	0.056	0.119	0.343	0.482	1.18E-08	7.39E-09	39.5	40.0	19.8	0.7			1.04	44.3
2-3	1673	0.022	0.731	0.054	0.192	1.46E-12	1.86E-10	37.5	40.3	19.5	2.7			0.55	44.6
2-4	1673	0.022	0.752	0.039	0.188	6.76E-13	1.74E-10	38.2	40.5	17.7	3.6			0.73	50.2
2-5	1673	0.039	0.561	0.060	0.339	3.20E-12	6.67E-10	36.5	39.5	19.0	5.0			0.95	49.2
2-6	1673	0.020	0.265	0.540	0.175	5.01E-09	4.73E-10	36.2	37.4	18.1	8.3			0.33	56.7
2-7	1673	0.028	0.054	0.690	0.229	3.38E-07	1.44E-07	38.9	39.9	19.6		1.6		0.78	49.8
2-8	1673	0.025	0.059	0.707	0.209	2.95E-07	1.03E-07	37.8	40.7	18.4		3.1		0.70	50.6
2-9	1673	0.041	0.075	0.543	0.341	1.00E-07	1.29E-07	37.7	36.6	18.8		6.8		0.98	48.7
2-10	1673	0.029	0.089	0.646	0.236	9.89E-08	5.13E-08	37.1	37.3	18.7		6.9		0.61	47.4
2-11	1673	0.030	0.081	0.639	0.250	1.19E-07	6.87E-08	36.2	35.7	18.2		9.9		0.74	52.8
2-12	1673	0.031	0.249	0.464	0.256	3.97E-09	5.11E-09	38.4	39.1	20.0			2.4	0.48	53.6
2-13	1673	0.032	0.244	0.460	0.264	4.09E-09	5.63E-09	38.5	39.3	19.7			2.6	0.47	50.3
2-14	1673	0.028	0.255	0.486	0.231	4.19E-09	4.17E-09	37.5	38.0	19.4			5.1	0.48	59.5
2-15	1673	0.028	0.258	0.484	0.230	4.02E-09	4.02E-09	36.1	37.1	19.8			7.1	0.57	72.2
2-16	1673	0.031	0.248	0.463	0.258	3.99E-09	5.24E-09	36.5	37.2	18.5			7.8	0.57	62.4

Fig. 3. Effects of FeO, MgO and MnO addition to the 40mass%CaO–40mass%SiO₂–20mass%Al₂O₃ slag on C_{Cl^-} at 1 673 K.

$$C_{Cl^-} = \frac{(\text{mass}\%Cl^-)P_{O_2}^{1/4}}{P_{Cl_2}^{1/2}} = \frac{K_5 a_{O^{2-}}^{1/2}}{f_{Cl^-}} \quad \text{.....(6)}$$

Here, K_5 is the equilibrium constant of Eq. (5), $a_{O^{2-}}$ is the activity of oxide ion, and f_{Cl^-} is the activity coefficient of chloride ion in the slag, respectively.

3.2. Effects of FeO, MgO and MnO Addition on C_{Cl^-}

The effects of FeO, MgO and MnO addition to the 40mass%CaO–40mass%SiO₂–20mass%Al₂O₃ slag on its C_{Cl^-} were investigated. Experimental conditions and results are summarized in **Table 2**. **Figure 3** shows the change in C_{Cl^-} values with FeO, MgO and MnO content of the final slags. They slightly increased by FeO, MgO and MnO addition because of the increase in the slag basicity, although they increased drastically when Na₂O was added.²⁾ However, the extent of the effect also implies the change in activity coefficient of chlorine in the slags seeing that MgO addition showed the smallest effect.

3.3. CaO–SiO₂–FeO Slag System

For the CaO–SiO₂–FeO system, Fe crucibles were used to determine the activity of iron oxide according to Eq. (7). Hence, the FeO content of the slag was controlled by changing oxygen partial pressure.

Fig. 4. Relationship between a_{FeO} Calculation and a_{FeO} Experiment.

$$\Delta G_7^\circ = 232\,000 - 45.6T \text{ [J/mol]}^3) \quad \text{.....(8)}$$

The activities of iron oxide calculated from the above equation (a_{FeO} Calculation) were compared with those estimated from the experimental slag composition and the values at 1 873 K after Ban-ya and Hino⁴⁾ (a_{FeO} Experiment) as shown in **Fig. 4**. Regular solution approximation was employed in extrapolating their data to those at 1 673 K, which would be reasonable according to their findings.⁴⁾ Since both values were in good agreement, the reaction between Fe–FeO was considered to be in an equilibrium state. Slight discrepancy at higher FeO activity could be explained by the error in the temperature extrapolation or the effect of dissolved OH[−] ion due to the higher partial pressure of H₂O.

The obtained values for C_{Cl^-} are listed in **Table 3** and iso-capacity contours are drawn in the isothermal cross section of the CaO–SiO₂–FeO system at 1 673 K (**Fig. 5**). As seen in the figure, C_{Cl^-} increases as the CaO and FeO content increases, and decreases with the SiO₂ contents. Herewith, the effect of slag composition on the C_{Cl^-} value was investigated using some indexes in order to reproduce the experimental results as precisely as possible. Although

Table 3. The C_{Cl^-} values for the CaO–SiO₂–FeO slags together with gas compositions at 1 673 K.

No.	Temp.(K)	Ingoing gases (atm)				P _{O₂} (atm)	P _{Cl₂} (atm)	Slag composition (mass%)				C _{Cl⁻}
		HCl	H ₂	CO ₂	Ar			CaO	SiO ₂	FeO	Cl	
3-1	1673	0.039	0.525	0.103	0.333	1.21E-11	6.80E-10	24.8	50.4	24.8	0.53	38.2
3-2	1673	0.043	0.486	0.096	0.374	1.22E-11	8.90E-10	42.1	42.1	15.8	1.31	81.9
3-3	1673	0.033	0.548	0.135	0.284	1.99E-11	4.93E-10	24.0	46.5	29.5	0.39	37.4
3-4	1673	0.029	0.582	0.141	0.249	1.93E-11	3.68E-10	38.7	38.1	23.2	0.83	90.4
3-5	1673	0.029	0.581	0.140	0.250	1.90E-11	3.72E-10	28.2	42.2	29.6	0.56	61.0
3-6	1673	0.031	0.546	0.160	0.264	3.03E-11	4.32E-10	35.0	35.0	30.0	0.79	88.9
3-7	1673	0.039	0.481	0.145	0.335	3.26E-11	7.40E-10	22.7	43.1	34.2	0.61	53.2
3-8	1673	0.036	0.505	0.149	0.310	3.09E-11	6.19E-10	25.3	35.9	38.8	0.72	68.1
3-9	1673	0.029	0.509	0.209	0.252	6.87E-11	4.22E-10	18.9	36.2	45.0	0.40	55.6
3-10	1673	0.031	0.489	0.213	0.267	8.04E-11	4.84E-10	32.1	29.9	38.0	0.68	92.1
3-11	1673	0.035	0.467	0.198	0.301	7.47E-11	6.23E-10	23.8	35.7	40.4	0.59	69.4
3-12	1673	0.027	0.680	0.057	0.236	1.88E-12	2.91E-10	26.3	52.4	21.3	0.55	37.4
3-13	1673	0.028	0.669	0.057	0.245	1.93E-12	3.18E-10	29.0	57.8	13.2	0.52	34.4

Fig. 5. The values and iso capacity contours of C_{Cl^-} for the CaO–SiO₂–FeO slags at 1 673 K.

Fig. 6. Relationship between C_{Cl^-} and slag compositions for the CaO–SiO₂–Al₂O₃–FeO slags at 1 673 K.

the use of a simple basicity index was initially tried, a little modification brought a better relationship. Accordingly, the following index with the cross term of $X_{AlO_{1.5}}X_{FeO}$ has been introduced;

$$B = \frac{X_{CaO} + \alpha X_{FeO}}{X_{SiO_2} + \beta X_{AlO_{1.5}} + \gamma X_{AlO_{1.5}} X_{FeO}} \quad \text{.....(9)}$$

where α , β and γ are parameters, which shows the effectiveness of FeO and Al₂O₃ compared with CaO and SiO₂. The parameters were determined to be 0.67, 0.67 and –5, respectively by a trial and error method so that C_{Cl^-} could hold for the CaO–SiO₂–FeO and (40mass%CaO–

Fig. 7. Sulphide capacity ($-\log C_{S^{2-}}$) for the CaO–SiO₂–FeO slags at 1 823 K. (Reported by Pierre *et al.*⁶⁾)

40mass%SiO₂–20mass%Al₂O₃)–FeO slags. **Figure 6** shows the relationship between C_{Cl^-} and B and the fitted straight line can be expressed as Eq. (10).

$$C_{Cl^-} = -7.2 + 60B$$

$$= -7.2 + \frac{60X_{CaO} + 40X_{FeO}}{X_{SiO_2} + 0.67X_{AlO_{1.5}} - 5X_{AlO_{1.5}}X_{FeO}} \quad \text{.....(10)}$$

3.4. Comparison with Sulfide Capacities

Sulfur dissolves into molten slags as S^{2-} ion under reducing conditions. Based on the dissolution reaction, Eq. (11), sulfide capacity ($C_{S^{2-}}$) has been defined as Eq. (12)⁵⁾ as the capability of slags to absorb sulfur.

$$C_{S^{2-}} = \frac{(\text{mass}\% S^{2-}) P_{O_2}^{1/2}}{P_{S_2}^{1/2}} = \frac{K_{11} a_{O^{2-}}}{f_{S^{2-}}} \quad \text{.....(12)}$$

The $C_{S^{2-}}$ values for the CaO–SiO₂–Al₂O₃ slags have been measured by Pierre *et al.*⁶⁾ at 1 823 K as shown in **Fig. 7**. Although $C_{S^{2-}}$, as well as C_{Cl^-} , increases as the slag basicity increases, $C_{S^{2-}}$ seems to be more sensitive to the composition of slags when compared with C_{Cl^-} in **Fig. 5**.

Incorporating Eq. (6) into Eq. (12), the relationship be-

Fig. 8. Relationship between C_{Cl^-} (1673 K) and $C_{S^{2-}}$ (1823 K) for the CaO-SiO₂-FeO slags.

tween C_{Cl^-} and $C_{S^{2-}}$ can be derived as Eq. (13).

$$\log C_{Cl^-} = \frac{1}{2} \log C_{S^{2-}} + \log \frac{K_5}{K_{11}^{1/2}} + \log \frac{f_{S^{2-}}^{1/2}}{f_{Cl^-}} \quad \text{.....(13)}$$

Accordingly, if the last term of the right hand side of Eq. (13) is constant regardless of the slag composition, C_{Cl^-} is expected to change in proportion to $C_{S^{2-}}^{1/2}$.

Figure 8 shows the relationship between observed C_{Cl^-} and the $C_{S^{2-}}$ from Fig. 7 in logarithmic scale. Although there is a temperature difference of 150 K, a good linear correlation is observed between $\log C_{S^{2-}}$ and $\log C_{Cl^-}$ with a slope of approximately 1/2 which was predicted from Eq. (13).

3.5. Prediction of Chlorine Distribution during Incineration with Slags

Based on the result obtained in the present study, the chlorine distribution between gas and slags can be estimated when chlorine containing waste is incinerated with slags. For example, when $P_{O_2} = 10^{-10}$ atm, $C_{Cl^-} = 40$ and (mass%Cl⁻) = 1, P_{Cl_2} becomes 10^{-8} atm. In the practical incineration processes, however, chlorine in the gas phase is considered to exist mainly as HCl originated from H₂O or as chlorides of the heavy metals according to Eqs. (14) and (17), and the equilibrium partial pressures of HCl and PbCl₂ can be derived from Eqs. (16) and (19) as functions of the partial pressure of H₂O and activity of PbO, respectively.

$$P_{\text{HCl}} = \frac{(\text{mass\%Cl}^-) P_{\text{H}_2\text{O}}}{C_{\text{Cl}^-}} \cdot K_{15} \quad \text{.....(16)}$$

$$P_{\text{PbCl}_2} = \frac{(\text{mass\%Cl}^-)^2 a_{\text{PbO}}}{C_{\text{Cl}^-}^2} \cdot K_{18} \quad \text{.....(19)}$$

Here, the equilibrium constants K_{15} and K_{18} can be derived from the standard Gibbs energies of formation for H₂O and HCl, and PbO and PbCl₂, respectively.³⁾ When 1 t of the slag ($C_{Cl^-} = 40$) is equilibrated with 100 Nm³ of atmospheric

Fig. 9. Effect of $P_{\text{H}_2\text{O}}$ on the distribution of chlorine estimated for 1 t of the slag ($C_{Cl^-} = 40$) equilibrated with 100 Nm³ gas phase at 1673 K.

Fig. 10. Effect of a_{PbO} on the distribution of chlorine estimated for 1 t of the slag ($C_{Cl^-} = 40$) equilibrated with 100 Nm³ gas phase at 1673 K when the chlorine content of the slag is 1.0, 0.5 and 0.1 mass%.

gas at 1673 K, chlorine distributions between gas and slag phases can be estimated as shown in Figs. 9 and 10 as functions of $P_{\text{H}_2\text{O}}$ and a_{PbO} , respectively. In Fig. 10, (mass%Cl⁻) denotes the final chlorine content of the slags and the lower chlorine content of the slag will provide higher fractional distribution of chlorine to slag phase. As seen in the figures, more chlorine is absorbed into the slag with reduction of $P_{\text{H}_2\text{O}}$ and a_{PbO} , suggesting that dehydrating pretreatment of waste and prevention of heavy metal contamination are very effective for immobilizing chlorine into slag phase in the incineration processes. This also means that the hydration will distribute most of chlorine to gas phase producing chlorine free slags, followed by HCl recovery from the exhaust gas. Thus, the present results are supportive in predicting the behavior of chlorine between gas and slags during incineration processes quantitatively.

4. Conclusions

The solubility of chlorine in the molten CaO-SiO₂-Al₂O₃(-FeO, MgO, MnO) and CaO-SiO₂-FeO slags have been measured under relatively high oxygen partial pressure by a gas-slag equilibration technique, yielding the following results:

(1) The solubility of chlorine in the slag is in proportion to $P_{\text{O}_2}^{-1/4}$ and $P_{\text{Cl}_2}^{1/2}$, showing that chlorine dissolves into

the slag as Cl^- ion, and C_{Cl^-} is used to evaluate the ability of chlorine absorption into slags, defined by Hirosumi *et al.*²⁾ as;

$$C_{\text{Cl}^-} = \frac{(\text{mass}\% \text{Cl}^-) P_{\text{O}_2}^{1/4}}{P_{\text{Cl}_2}^{1/2}}$$

(2) The C_{Cl^-} value for the $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3$ slags increases by FeO, MgO and MnO addition.

(3) For the $\text{CaO-SiO}_2\text{-FeO}$ slags, the C_{Cl^-} value increases as the CaO and FeO contents increase, and decreases as the SiO_2 content increases.

(4) The C_{Cl^-} values for the $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3\text{-FeO}$ slags at 1 673 K were approximated in terms of the following empirical equation:

$$C_{\text{Cl}^-} = -7.2 + \frac{60X_{\text{CaO}} + 40X_{\text{FeO}}}{X_{\text{SiO}_2} + 0.67X_{\text{AlO}_{1.5}} - 5X_{\text{AlO}_{1.5}}X_{\text{FeO}}}$$

(5) The C_{Cl^-} value is less sensitive to the slag composition than that of $C_{\text{S}^{2-}}$. There is a good linear correlation between $\log C_{\text{S}^{2-}}$ and $\log C_{\text{Cl}^-}$ with the slope of approximately

1/2 which is consistent with the value predicted from their definitions with an assumption.

(6) Based on the result obtained in the present study, quantitative prediction of chlorine distribution during incineration with slags was performed.

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