A integrated route for CO_2 capture in the steel industry and its conversion into $CaCO_3$

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Abstract

This work proposes the transformation of CO_2 into calcium carbonate utilizing steel slag and waste heat generated in the steel industry. Laboratory scale experiments showed that near 95 wt. % of NaCl and NH_3 necessary to the mineral carbonation can be regenerated, therefore minimizing costs.

Introduction

The steel production is one of the major CO_2 emitting industrial processes. The main carbon dioxide source is the blast furnace, whose exhaust gases contain between 14 and 33 % of CO_2. This work proposes a new approach to capture and transform CO_2 into carbonates using some steps of the Solvay process, in which ammoniated brine reacts with CO_2 producing mainly solid $NaHCO_3$ and aqueous NH_4Cl. In a second step, the latter reagent is used to leach Ca^{2+} from steel slag and the former reacts with the leachate, producing high purity $CaCO_3$ and, at the same time, enabling reactants reclamation (Figure 1).

Results and Discussion

Table 1: Matrix of Composite Central Design (CCD) of capture of CO_2 by ammoniated brines.

Tests	Factors		Response	
	NH_3 (wt. %)	NaCl (wt. %)	$NaHCO_3$ mass (g)	Time to capture 50% of CO_2 (min)
1	5	5	0	7.9
2	5	20	4.57	6.3
3	15	5	NH_4HCO_3	54.3
4	15	20	6.13	35.7
5	10	1.93	NH_4HCO_3	31.4
6	10	23.08	7.17	23.0
7	2.95	12.5	0.92	5.4
8	17.05	12.5	NH_4HCO_3	60.8
9	10	12.5	2.91	17.4
10	10	12.5	3.01	23.4
11	10	12.5	2.87	16.7
Solvay	8	26	8.85	6.3
Extra 1	10	24	7.10	11.4
Extra 2	5	27	6.28	4.4

We concluded the best ammoniated brine concentration, which maximizes NH_4Cl and $NaHCO_3$ formation, is that of the Solvay process, 26 wt. % NaCl and 8 wt. % NH_3. We have observed, in the absence of HCO_3^-, the mother liquor that is rich in NH_4Cl was able to extract 22 wt. % of the Ca^{2+} cations present in the steel slag and 2 wt. % of the initial NH_3 was recovered. In the best case, more than 89 wt. % of the Ca^{2+} present in the solution was transformed into $CaCO_3$. It was achieved with a $NaHCO_3/Ca^{2+}$ molar ratio of 2:1, during 20 min at ambient temperature or 10 min at 60 °C.

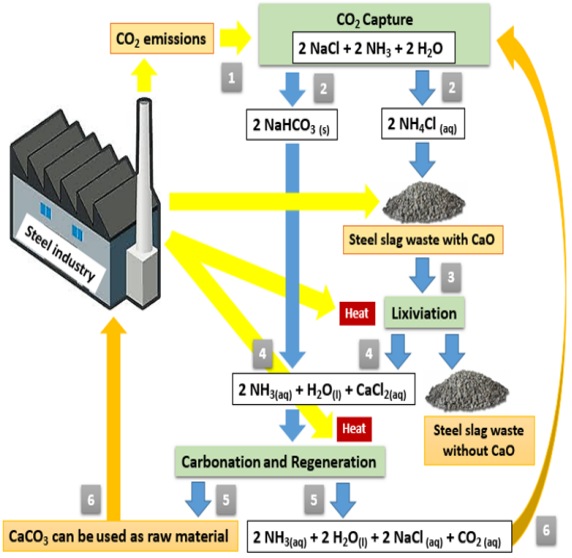

Figure 1. CO_2 capture cycle flowchart, including lixiviation, carbonation and reagents regeneration.

Conclusions

In the present work, we have proposed a new route for CO_2 capture and mineralization by a modified Solvay process. Most of the starting materials are regenerated and several leaching and $CaCO_3$ precipitation cycles are possible.

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