Flue Gas Cleaning by Ionic Liquids - Fundamental Chemistry and Industrial Application

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Introduction

Emission of acidic gases such as NOx, SOx, and CO2 from, e.g. energy production by fossil fuels in power plants, ships and other industrial sources is a major concern in relation to atmospheric pollution and climate changes. Therefore, these gases have to be effectively removed from flue gases. Presently this is mainly achieved by relatively energy intensive and resource demanding technologies such as selective catalytic reduction (SCR) of NOx with ammonia, by gypsum formation after SO2 wet-scrubbing while organic amines are being used as absorbents in CO2 scrubbers. This leads to concern about, e.g. intensive energy requirements for desorption, corrosion of steel pipes and pumps, CO2 absorption capacity and thermal decomposition of the amine. In this work, we demonstrate how ionic liquids (ILs) can be tuned by design to absorb the particular gas, e.g. SOx, NO, NO2 and CO2

Results and Discussion

Reversible absorption has been obtained for several different ILs at different temperatures and flue gas compositions. Furthermore, different porous, high surface area carriers like meso porous silica and titania have been applied as supports for the anions to obtain Supported Ionic Liquid-Phase (SILP) absorber materials. Figure 1.

![Figure 1. Principle of SILP materials.](image)

These materials benefit from low mass transport resistance of the often highly viscous ionic liquids by the distribution of the liquid as a thin film on the high surface area carriers like mesoporuous silica and titania. ILs at different temperatures and flue gas compositions. The results show that CO2, NO, NO2 and SO2 can be reversibly and selectively absorbed using different ILs, and SILP absorbers are promising materials for industrial flue gas cleaning. Absorption/desorption dynamics can be tuned by temperature, pressure, gas concentrations and the properties of the porous carrier.

The mechanism of absorption seems to be remarkably different depending on the gas and the type of ionic liquid chosen for the absorption process. Thus CO2 seems to be absorbed by our applied amino acid based ionic liquids in the form of covalent bonded carbamate species stabilized by internal hydrogen bonding. SO2 is absorbed by strong coordination to Lewis basic anions like chloride in our selected ionic liquid, while NO is transformed by a catalytic process assisted by strong Lewis bases, present in the ionic liquid, to nitric acid (Figure 2) eventually changing the ionic liquid anion to nitrate by evaporation of the protonated original anion of the selected ionic liquid. Figure 2. NO absorption capacity at room temperature given as produced HNO3 in various ionic liquids vs. time. (Gas composition: 7% NO, 2% H2O, 7% O2, balance N2).

In addition physical absorption of the gases contributes more or less to the total absorption capacity of the ILs where the chemically-like absorption mechanisms described above, however, seem to dominate.

Significance

The absorption/desorption process may be performed by shaping the SILP absorber material in honeycomb structures as the traditional deNOx catalyst used in power plants today, leading to optimized gas diffusion and low pressure drop of the passing flue gas. Installed as a traditional rotating heat exchanger it will facilitate desorption by elevation of the temperature in a smaller side channel and make it possible to desorb the gases in concentrated form. In the case of CO2, this gas may be disposed of by pumping it to underground exhausted gas or oil pockets while SO2 might be further processed to commercial grade sulfuric acid in the traditional catalytic oxidation process forming SO3 by oxidation with air. Finally, NO is already converted to nitric acid of commercial grade by the absorption process and the acid may therefore be desorbed by heating and condensed easily again and stored for further handling e.g. via unloading by ships in a convenient harbour.

References


