Phase-separation-based CO_2 capture from air and catalytic CO_2 conversions using base polyoxometalates

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Reducing atmospheric CO_2 levels and converting CO_2 into valuable chemicals are critical for a sustainable society. Here, we report a CO_2 capture system from air based on liquid–solid phase separation between amines and carbamic acid, combined with catalytic CO_2 fixation using basic metal oxide clusters. Diamines bearing an aminocyclohexyl group achieved >99% CO_2 removal under 400 ppm CO_2 flow. Isophorone diamine (IPDA) exhibited the highest performance, forming solid carbamic acid and reacting with CO_2 at an approximately 1:1 molar ratio, even in water. The captured CO_2 was completely released at 333 K under N_2 flow due to the low-temperature decomposition of carbamate species. IPDA showed excellent durability, maintaining > 99% efficiency over 100 h and a high capture rate of 201 mmol h^{-1}/mol_{amine}, demonstrating its potential for practical applications. For CO_2 conversion, group V polyoxometalate clusters were investigated due to their CO_2 activation ability. The $[Nb_{10}O_{28}]^{6-}$ cluster catalyzed CO_2 fixation with amines via electron donation from basic surface oxygen sites, as supported by DFT calculations. Additionally, $[M_6O_{19}]^{8-}$ clusters showed similar activity. Nb_6O_{19}-modified Pt nanoparticles further exhibited catalytic activity for N-formylation of piperidine, highlighting the potential of bifunctional catalysts.

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