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Research Article

BETTER ADSORBING CAPACITY OF CPM-5 IN THE LIGHT OF ITS EQUILIBRIUM KINETICS

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ABSTRACT

The adsorption equilibrium kinetics is one of the important factor in evaluating the stability of the adsorbent for the gas adsorption application, because it controls the time of a fixed bed adsorption system and has an impact on the amount of adsorbent required.

The adsorption equilibrium kinetics of CO_2 on CPM-5 was measured at two different temperatures of 298 K and 318 K using Freundlich adsorption isotherm. CPM-5, a MOF is highly porous having high specific surface area, high thermal and chemical stabilities &low densities was found to be better adsorbent for the adsorption of CO_2 gas. The amount of CO2 adsorbed was calculated by weighing CPM-5 before and after experiment.

INTRODUCTION

The release of harmful greenhouse gases (such as CO_2, CH_4 and N_2O) in to the environment is a growing concern for the world climate change. About 60% of global warming attributed to CO_2 emissions.[1] Fossil fuel power plants are the largest potential source of CO_2 emission. About three-quarters of the increase in atmospheric carbon dioxide is attributed to burning fossil fuels. The current levels of CO_2 concentration in the atmosphere have increased by more than 35% since the industrial revolution.[2]

In this regards, scientists are trying to develop effective systems for CO_2 removal from fuel gas by combining the high capacity and selectivity, fast kinetics, mild conditions for regeneration, and tolerance to moisture with minimal cost.

Adsorption in porous adsorbents is considered as an alternative viable approach for CO_2 capturing. Adsorption into solid porous adsorbents is an attractive technology to improve or substitute the current CO_2 adsorption technologies due to their high CO_2 adsorption capacities, simple and easy to control process, low energy consumption, and superior energy efficiency.

Many adsorbents have been developed and studied for CO_2 capturing such as zeolites, activated carbons, modified meso-porous silica; however the common drawbacks of these conventional adsorbents are: high energy consumption for regeneration, low productivity and low CO_2 capacities. New porous materials Metal Organic Frameworks with higher adsorption capacity and selectivity are needed to improve the CO_2 separation and storage process.

Metal-Organic Frameworks

Metal organic frameworks (MOFs) have emerged as a new class of crystalline porous materials. Metal organic frameworks are crystalline solids consisting of metal ions (normally called nodes) linked by organic ligands (as linkers).[3]These materials are rigid organic linkers to form one dimensional, two dimensional and three dimensional networks, which is porous. Metal ions generally used for synthesis of MOFs are Zn^{2+}, Ca^{2+}, Cu^{+}, Cu^{2+}, Al^{3+} In^{3+} etc. and organic linkers are Phthalic acid, Isophthalic acid, Terephthalic acid, Trimesic acid, Benzene tri benzoate (BTB) etc.

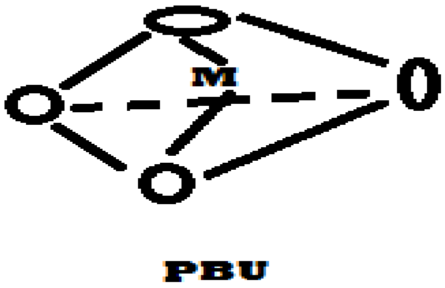

Figure-1

On co-ordination of carboxylates group to a metal centre may results in many different secondary building units (SBUs)[4] to form one dimensional, two dimensional and three dimensional

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networks. The secondary building units (SBUs) are designed by the four MO_4 primary building units (PBUs). The octahedral geometry of the $[M_4O(O_{12})]$ is designed by the four MO_4 tetrahedral shairing.[5]

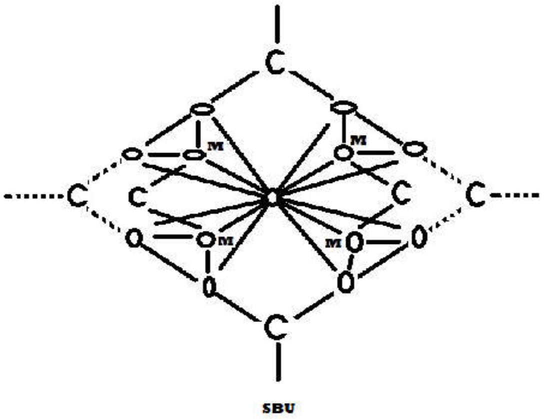
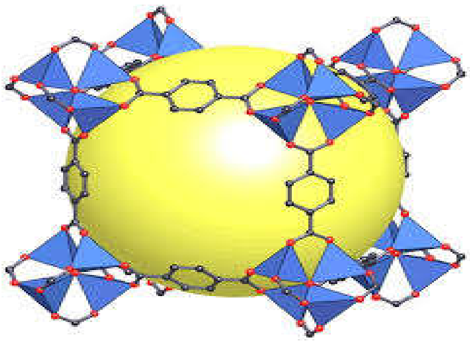


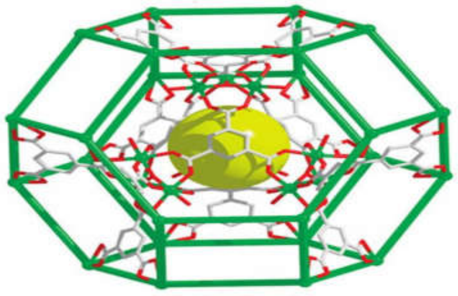
Figure-2

These SBUs connected with an aromatic ring (organic linkers) to design different types of MOFs.[6]



MOF-5

Figure-03



CPM-5

Figure-04

MOFs are renowned materials having remarkable high specific surface area[7,8], highly divers' structural chemistry and controlled pore size and shape[9]. The metal organic framework that is studied in the present work is CPM-5, which is a highly porous indium based metal organic framework with a surface area of 2187 m^2/g. CPM-5 consists of In_3O clusters as metal centre connected by 1, 3, 5 benzenetricaboxylic acid (Trimesic acid) (H_3BTC) as a linear organic linker. In addition, CPM-5 has unique cage-based porous structures which contribute to a high CO_2 uptake capacity.

Experimental

The adsorption equilibrium kinetics is one of the important factor in evaluating the stability of the adsorbent for the gas adsorption application, because it controls the time of a fixed bed adsorption system and has an impact on the amount of adsorbent required.

From the Freundlich adsorption isotherm-

$$\mathbf{x/m = K\, C_i^{1/n}}$$

where,

x/m is the adsorbed amount (mol/g), 'Ci' is the equilibrium concentration (mol/dm^3)

The constant 'K' and 'n' were estimated from the experimental data of CO_2 adsorption isotherm using the intercept and slope of a Linear Freundlich plot of ln (x/m) VslnCi.

Table -1

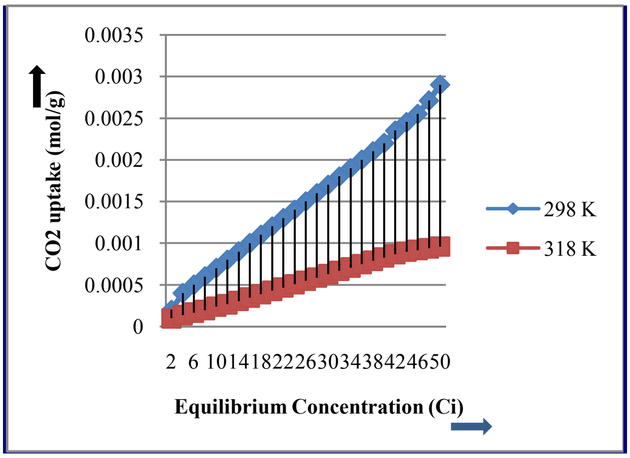
Equilibrium concentration (Ci)	CO_2 uptake (mol/g)	Temperature (K)
2	0.0002	298
4	0.0004	298
6	0.0005	298
8	0.0006	298
10	0.0007	298
12	0.0008	298
14	0.0009	298
16	0.0010	298
18	0.0011	298
20	0.0012	298
22	0.0013	298
24	0.0014	298
26	0.0015	298
28	0.0016	298
30	0.0017	298
32	0.0018	298
34	0.0019	298
36	0.0020	298
38	0.0021	298
40	0.0022	298
42	0.0023	298
44	0.0024	298
46	0.0025	298
48	0.0027	298
50	0.0029	298

Table-2

Equilibrium concentration (Ci)	CO_2 uptake (mol/g)	Temperature (K)
2	0.00010	318
4	0.00014	318
6	0.00017	318
8	0.00020	318
10	0.00024	318
12	0.00027	318
14	0.00031	318
16	0.00035	318
18	0.00039	318
20	0.00043	318
22	0.00047	318
24	0.00051	318
26	0.00055	318
28	0.00059	318
30	0.00063	318
32	0.00067	318
34	0.00071	318
36	0.00075	318
38	0.00079	318
40	0.00083	318
42	0.00087	318
44	0.00090	318
46	0.00092	318
48	0.00094	318
50	0.00096	318

The adsorption equilibrium kinetics of CO_2 in CPM-5 was measured at two different temperatures of 298 K and 318 K. the amount of CO_2 adsorbed was calculated by weighing CPM-5 before and after experiment.

K is theisothermal equilibrium constant and ‘n’ are constant for a given adsorbent and adsorbate at a particular temperature.



Figure

RESULTS AND DISCUSSION

The CO_2 adsorption equilibrium at temperatures 298 K and 318 K are plotted in the above figure. It was observed that the maximum amount of CO_2 adsorbed is 0.0029 mol/g and 0.00096 mol/g at 298 K and 318 K respectively[10,11].

Finally, CPM-5 showed unique adsorption properties. Therefore, it can be considered as an attractive adsorbent for the separation of CO_2 from fuel gases.

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