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Investigation of Surface Absorption of Mercaptan from Gas by Mezo- Pore SBA-15

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Abstract: *Selective adsorption of sulfur compounds is one of the most widely used methods, the most important advantages of this method are the desulphurisation reaction at low temperature and pressure, which reduces the cost of refining operations. In this study, SBA-15 mezo pore absorbent with co-precipitation. different methods such as: ICP, BET, XRD were used to check the physical and chemical properties and the absorbent action to remove gas-Iso propyl-mercaptan (IPM). Various experiments were carried out to remove the mercaptan gas by adsorbent discontinuously. Then, the effect of effective absorption parameters such as temperature, contact time, and initial gas concentration were studied. The maximum absorption was achieved in condition, contact time is 50 minutes, and temperatyre is 298 k, With, initial concentration of 500 ppm. For determining the most suitable absorption isotherm, Temkin, Langmuir, Freundlich adsorption isotherm have been studied. The relationships between Freundlich Temkin, Langmuir isotherms for adsorbents were investigated. The result of this study showed that isotherm temperature with Langmuir is more consistent with experimental data ($R^2 = 0.99$). The results showed that the adsorbent have a good ability to remove Iso propyl mercaptan gas.*

Keywords: *Removal of Iso propyl mercaptan- SBA-15(Santa Barbara Amorphoue Type matrial)- Adsorbent- adsorpation isotherm*

INTRODUCTION

Gas liquids containing different sulfur compound have high amount of mercaptan. Mercaptan is poisonous material group which methyl and ethyl-mercaptan are abundant types from low molecular weight to heavy chained hydro-carbon typeLow weight mercaptan is poisonous, corrosive and odorous. In addition, they produce dangerous poisonous Sulfur di oxide by burning. Sulfur dioxide burning causes pollutant, acid raining, corrosion of equipment and facilities, refinery catalyst damage (Boniek, 2014) One of ordinary method for chemical de-sulfur is to use hydrogen. In this method, sulfur compounds transform to hydrogen sulfide and carbon under high pressure and temperature using non homogenous metal catalysts. Hydrogen sulfide is gas type and will be separated easily from other products. But there are many problems in this method: 1- high cost for supply high temperature and pressure of hydrogen sources 2- heterocycle aromatic compound containing sulfur such as Thioufen and di-benzo Thioufen are resistant to this method Therefore other methods should be found to remove sulfur (Bhasarkar, 2015; Martínez et al., 2015) Adsorption process is better in comparison with other methods due to low cost, high flexibility, easy design and construction, high sensitivity to poisonous material.It refines the gas for re-use without making poisonous material (Zhu, 2013; Sarkar, 2014). Iso-propyl –mercaptan is colorless liquid which smells like (2- propanethiol C_3H_8S) causes nausea, headache or vertigo. High concentration of vapor phase causes scald and eye pain, nose and

respiratory canal pain. This is a high poisonous compound which is hazardous for environment. Also it is hazardous for industrial pipeline due to corrosion and should be separated from its carrier gas (Shin, 2011).

Research Method

Plonric acid 99% from Sigma Aldrich as surfactant active material, HCl 32% Merc Co, Tetra ertho Silicat Merc Co as silicon source, Ethanol 99% Merc, Nitrate zinc 99% Merc were used.10 gr of Plornic acid (p123) is added to 250 mL of distillated water to be solved to change its color like milk. Then 2N hydrogen chloride (18.5 ml) is stirred and added to change the color from milky to limpid. Then 22.5 mL of Tetra ertho silicate is added to solution with sequence of drops. Produced suspension is stirred under 312 K (40˚ C) for 24 hours and under 373 K (100˚C) for 20 hrs. Produced solid will be filtered under strainer paper and then it is washed by distillated water to be dried under room temperature. At last it will be calcified under 823 K (550 ˚C) for 5 hrs (Issa M.E.I-Nahhal et al., 2017).

X ray diffraction

X-ray diffraction of SBA-15 (figure 1 part a) shows crystal faces (100), (110), (210) which represents high order hexagonal structure. Peak (100) shows a pore order in SBA-15.

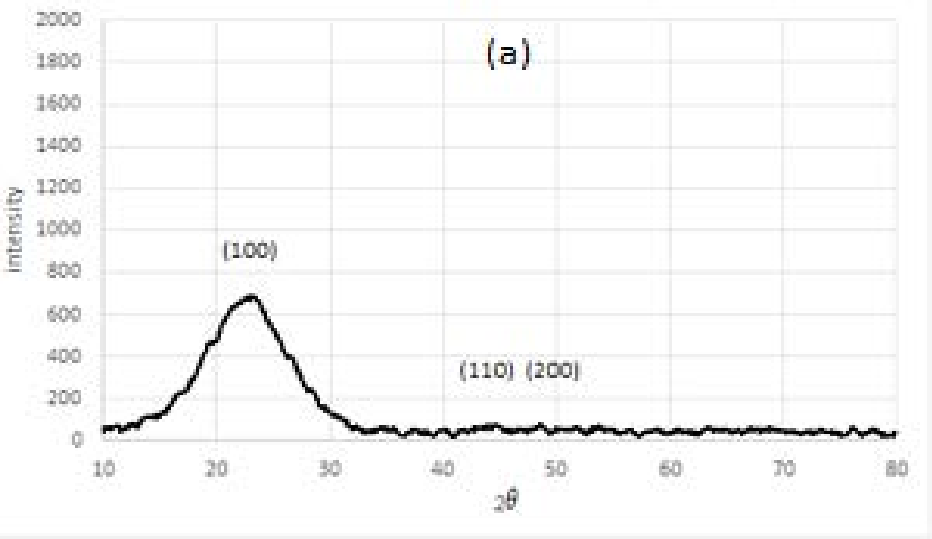


Figure 1. XRD pattern of SBA-15 (a)

porosity diffraction

To study porosity type, specific surface area, diameter and volume of pores in SBA-15 in absorbent tool and de-absorbent nitrogen are used. Measurement was performed at 77 K temperature and sample was de-gassed at 300C temperature. Plot of absorb and de-absorb of SBA-15 nitrogen is isotherm plot of IV according to IUPAC classification which proves mezzo pore compound. Hysteresis loop existence between absorb and de-absorb branches is due to capillary liquids through the pores of mezzo porosities which are trapped due to liquefaction of gas among cylindrical pores. Delay is one of mezzo pore specifications during de-absorb. (Evaporation happen in low pressure). Isothermal absorption plot IV is related to mezzo-pores. In addition, residual is H_1 type in this plot. Specific shape of each loop is due to its specific loop. H_1 loop is due to uniform pores with narrow distribution. Total volume and pore diameter average is calculated by BET curve. High percent shows that high are of absorbent is related to pores.

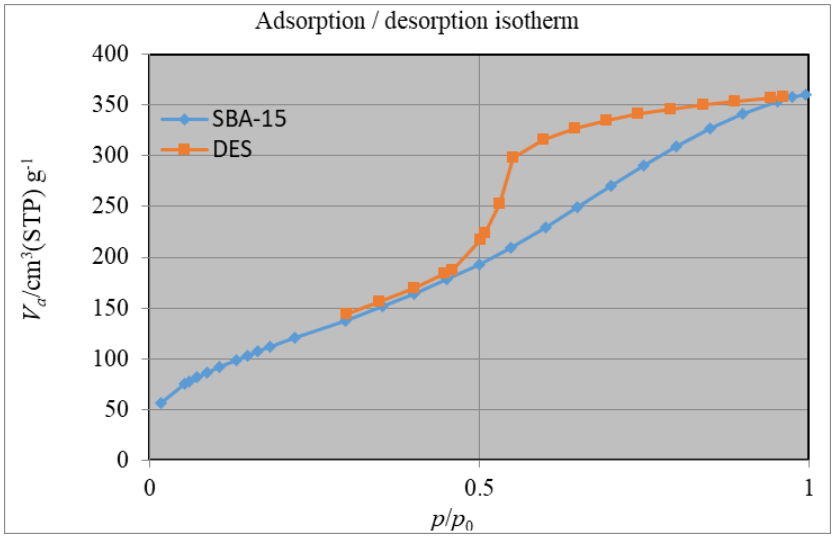


Figure 2. Adsorption / desorption isotherm SBA- 15

Table 1. Nitrogen Absorbent and de-absorbent specification.

Sample	S_{BET} (m^2g^{-1})	V_{total} (cm^3g^{-1})	APD (nm)
SBA-15	438/24	0/55661	8/08

Results and Analysis

In this work, and optimize effective parameters on mercaptan gas surface absorption by SBA-15 to get highest amount of removing mercaptan isopropyl gas, proper results and repeatability, experimental parameters include following items (just one of them will be changed).

Temperature effect:

Temperature of absorbent plays an important role, especially on surface absorption and its capacity. Temperature effect on type and its behavior for absorbent show pollutant gas absorbent extremely depends on temperature for all samples. 1 gram of absorbent is placed on specified tank. After activation, suitable temperature (25 and 50C) will be used and controlled by temperature controller. Therefore, temperature is the first parameter which is considered in study of surface absorption process

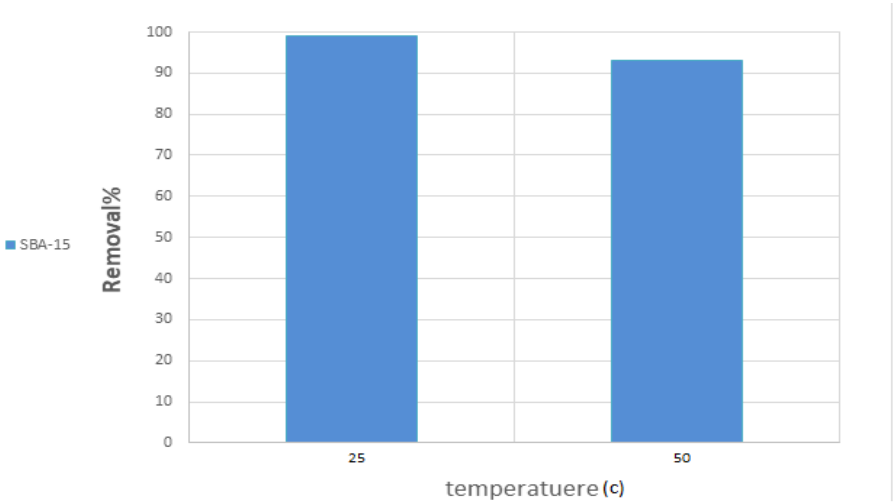


Figure 3: Plot of IPM remove percentage ratio for SBA-15 absorbent in different loading

Time effect

1 gram of absorbent is poured on absorption tank and gas absorption from 0 to 100th minutes (25˚Cand 50˚C) was studied. Maximum gas remove is for Mercaptan iso propyl. Results are shown in following plots.

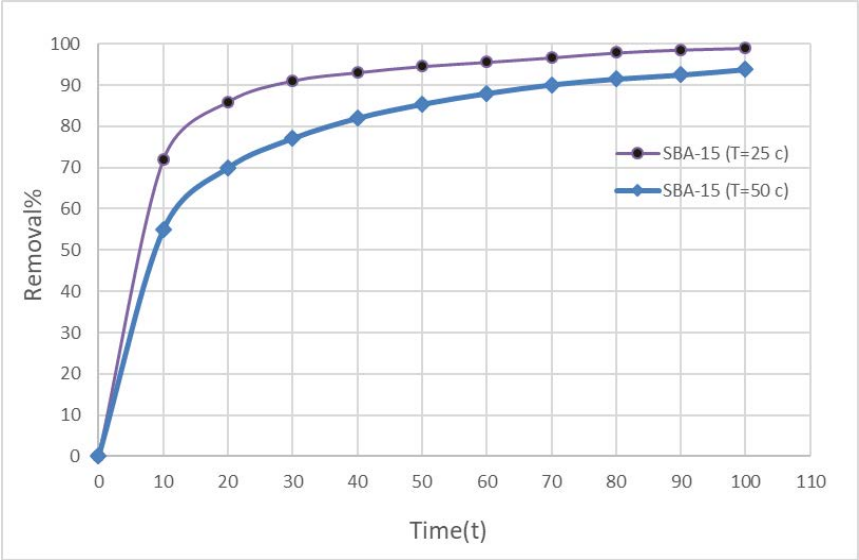


Figure 4. Time to mercaptan iso propyl remove percent during the time at25˚C and50˚C

Study of initial concentration of mercaptan isopropyl

To study effect of initial concentration, injected gas to absorption tank according to input pressure are 500, 1000, 1500, 2000, 2500 respectively.

Absorption of mercaptan isopropyl was studied for two temperatures, 25 and 50C.

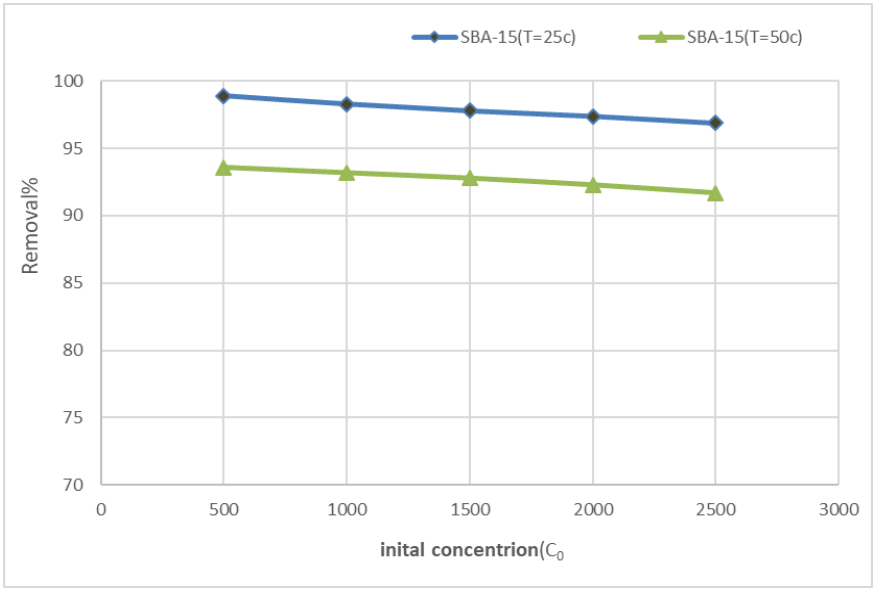


Figure 5. IPM gas removes percentage respect to initial concentration gas 25˚Cand 50˚C

Absorption Iso-therm plot.

To study absorption behavior on removing pollutant and plot of isotherm according to different articles and literature, different experiments were used.

Most of such methods include Batch type. One of these methods include application of initial concentration as constant and variable absorbent as m.

Other method is usage of constant absorbent (m) and initial concentration as variable. Therefore, since second method is more compatible to our condition, second method was used to plot isotherm. In this section, to study absorbent behavior of absorbent and determination prediction of absorbent, Temkin, Langmuir, Freundlich was used.

- **Langmuir**

Langmuir 1918 was the first person who presented organized theory kinetic-oriented for surface absorb on plat surface. In this theory, continuous process of molecule bombard on plate and molecule repelling on surface was occurred in so as molecule gathering rate to be zero on the equilibrium at the plate.

Langmuir linearization

$$\left(\frac{x}{m}\right) = q_{max}\left(\frac{b.C_e}{1+b.C_e}\right)$$

To plot Langmuir iso thermo, two linear form of Langmuir isotherm line, mentioned in literature, was used.

First method of linearization:

$$\Rightarrow \frac{1}{x/m} = \frac{1}{q_e} = \left(\frac{1}{q_{max}.b}\right)\left(\frac{1}{C_e}\right) + \frac{1}{q_{max}}$$

In first mode, Langmuir constants will be obtained after plotting $(1/q_e)$ vs $(1/C_e)$, and specification of origin coordination, slope.

$(1/q_{max}.b)$ as slope and 1/qmax as origin.

Second method of linearization:

$$\Rightarrow \frac{C_e}{q_e} = \left(\frac{1}{q_{max}}\right)C_e + \frac{1}{q_{max}.b}$$

For this type, after plotting C_e/q_e versus Ce and specification of orgin and slope, Langmuir 2 isotherm will be obtained.

$(1/q_{max})$: slope and $1/q_{max}$ b : width of origin

In addition two parameters, q_{max} and b, other parameter, RL exist which determine absorb isotherm.

RL= 1/1+b*C0

In this relation, C0 is maximum sovled concentration in gas phase. RL is constant parameter and dimensionless which be determined by Eq.5-4.

- **Freundlich Isotherm**:

Freundlich isotherm is one of the first equation which is used to descript of equilibrium data. Isotherm equation is as follows:

$$\left(\frac{x}{m}\right) = K_f.C_e^{1/n}$$

In which, (x/m) is partial absorption. K and n are Freundlich isotherm constants and dependent on temperature. Parameter n is usually greater than 1 and the bigger n, more non linearity obtained.

K_f shows capacity of absorption by absorbent. (1/n) shows absorption intensity.

Freundlich linearization

$$\left(\frac{x}{m}\right) = K_f.C_e^{1/n}$$

Linearization :

$$log\left(\frac{x}{m}\right) = log(q_e) = \log(K_f) + \frac{1}{n}\log(C_e)$$

Therefore, it is possible to plot $log(q_e)$ vs $\log(C_e)$, Freundlich isotherm constants will be obtained by specification of width of origin and slope.

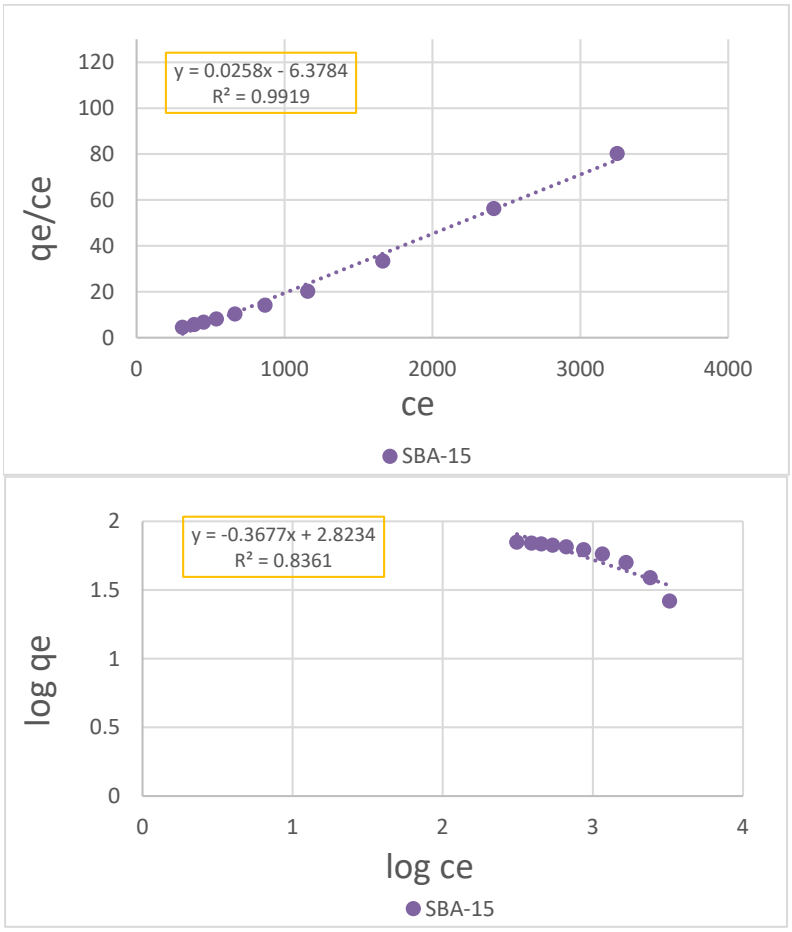
- **Temkin Isotherm**

Following supposition of Absorption Energy of Temkin isotherm is a relation of surface coverage.

$$\frac{x}{m} = A + BLOGCE$$

In this relation, A and B will be isotherm coefficient. In 1985 studies, it was specified that isotherm will be used in a limited range of ionic concentration.
Linear relation of isotherm has a line form. Therefore this form will be used.

$$\frac{x}{m} = q_e = A + BLOGCE$$



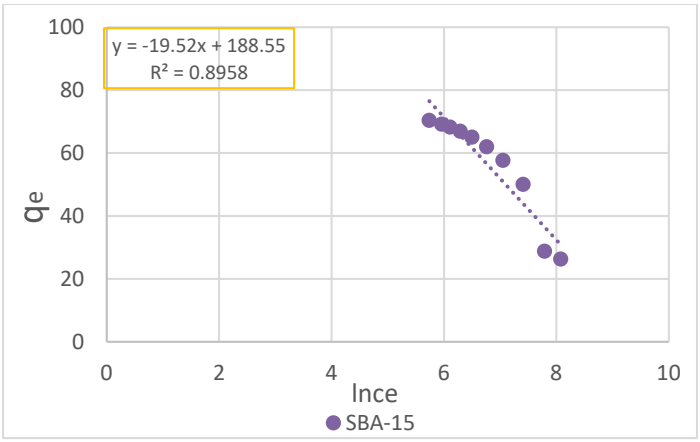
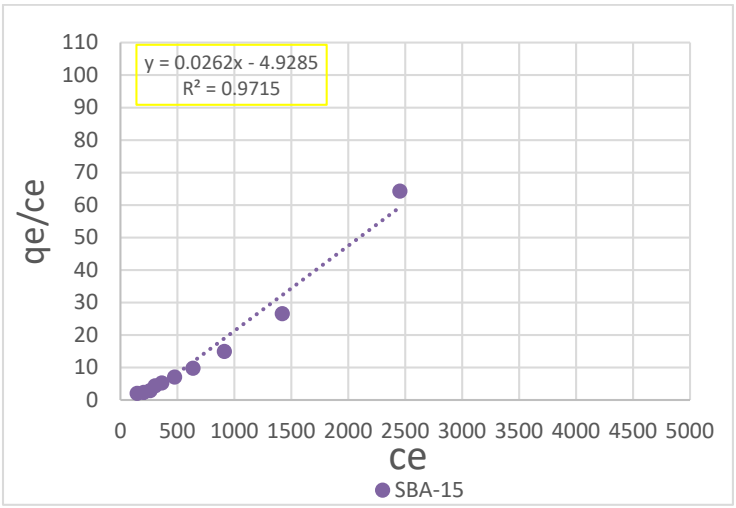
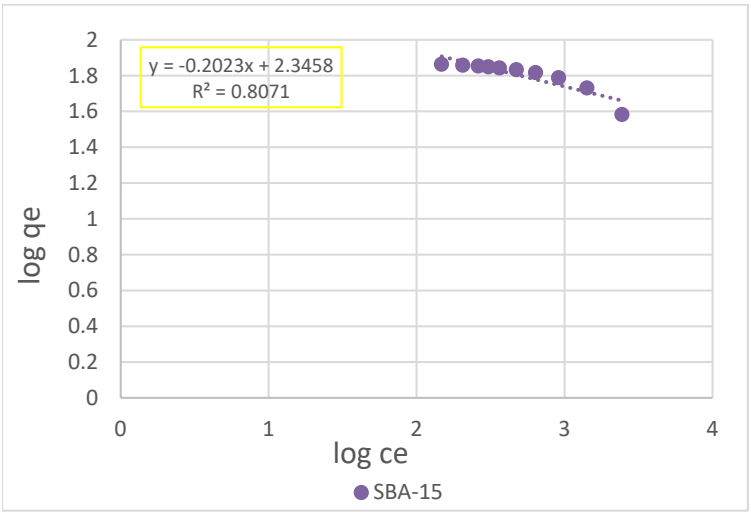


Figure 6. isotherm plot for IPM gas surface absorption with different absorbent SBA-15 at temperature 25C





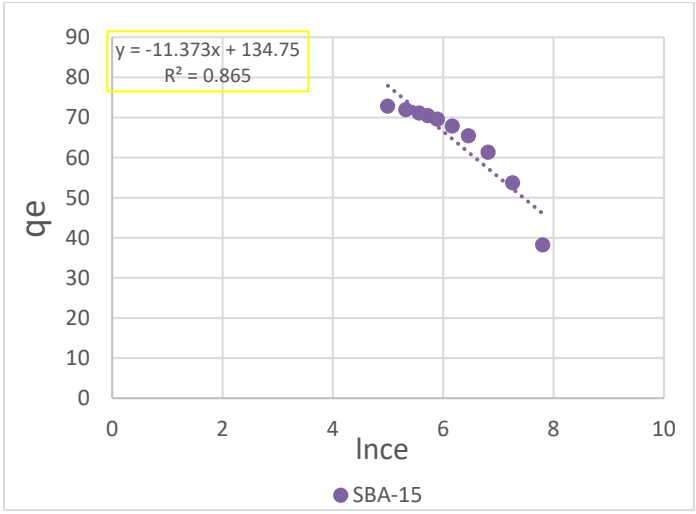


Figure 7: isotherm plot for IPM gas surface absorption with different absorbent SBA-15 at temperature 50C

Table 2. Thermodynamic Isotherm parameters of Absorbent SBA at temperature 25 and 50C

Langmuir	q_m (mg/g)	b (L/mg)	R^2
SBA-15	26.95	-0.0025	0.992
Frundlich	K_f(mg/gr)	$_n$	R^2
SBA-15	-0.3677	665.2	0.836
Temkin	A	B	R^2
SBA-15	-19.56	188.5	0.895
Langmuir	q_m (mg/g)	b (L/mg)	R^2
SBA-15	38.16	-0.0053	0.971
Frundlich	K_f(mg/gr)	$_n$	R^2
SBA-15	-0.202	221.3	0.801
Temkin	A	B	R^2
SBA-15	-11.37	134.7	0.865

Conclusion

Iso propyl Mercaptan had hasardous enviromental effect and it is corrosive for industrial equipment. In thi s project removing isopropyl mercaptan by using mezo pore with SBA- 15studied. High area of mezo pore make it suitable for absorption. In this project, SBA-15 mezo pore absorbent with co-precipitation. It was detected by XRD, BET and ICP.Absorbent and de-absorbent plot of specific area nitrogen SBA-15 show for 438 m^2g^{-1}. Studies of effect, initial concentration,time shows that increaseing of temparture decreases percentage of IPM gas removing. Since increaseing temperature motivate gas molecule moving. Therefore increasing intial concentration decreasing absorption trend. Inc. Isotherm equpation of surface absorption is important for designing an absorption system.Several equation at 25 and 50C and analysised by Langmuir, Freundlich, Temkin isotherm. For Langmuir, it was supposed that surface absorption of absorbent (Mercaptan iso propyl) occurs by absorption in single layer on uniform area without any reaction between absorbed species. According to calculation, considering R2, Kf, n for mercaptan isopropyl, it can be concluded that iso propyl surface absorption follows Langmuir isotherm model.Freundlich isotherm model occurs for chemical-physical absorptin on non-uniform area by surface absorption in multi layer.So it doesn't follow Freundlich or Temkin. Therefore removing mercaptan iso propyl using nano SBA-15 on the base of SBA-15 follows Langmuir model.

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