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Study on Removing Methanthiol with Chlorine Dioxide

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In this paper, the experimental device of chlorine dioxide (ClO_2) solution removing methanthiol (CH_3SH) gas was designed and the removal process was studied. The absorbent of residual ClO_2, the amount of ClO_2, the reaction temperature, the pH value of ClO_2 solution and the air flow effect on the removal rate of CH_3SH were studied. The optimum conditions of removing CH_3SH are as follows: the mixed lye of NaOH and Na_2S as the absorbent of residual ClO_2 and the molar ratio of NaOH and Na_2S 1:1, the molar ratio of CH_3SH and ClO_2 1:2.5, the temperature 35 °C, the pH value of ClO_2 solution 2, the compressed air flow 0.75 m^3/h. Under this conditions, the results show that the concentration of CH_3SH is reduced from the initial 1.457 g/m^3 to 0.032 mg/m^3, the removal rate of CH_3SH attains to 99.8 %, which meets level 3 national emission standards.

Keywords: ClO_2 solution, CH_3SH gas, Kraft mill.

INTRODUCTION

The malodorous pollutants generated from the kraft mill are mainly the total reduced sulfides (TRS), whose main ingredients includes four chemicals, such as hydrogen sulfide (H_2S), methanthiol (CH_3SH), dimethyl sulfide (DMS) and dimethyl disulfide (DMDS), *etc*[1]. The CH_3SH is generated in the production process of the kraft pulp mill, which is also a typical kind of atmospheric odor pollutants. The boiling point of CH_3SH is 6.8°C, which is a colourless gas with a strong smell of rotten cabbage leaves at room temperature. Its olfactory threshold is 0.15 $\mu g/m^3$ (lower than 1 ppbv) and the stink can easily be perceived. The CH_3SH is water-insoluble, but it is soluble in ethanol, benzene and other organic solvents. In addition, CH_3SH gas is a type of neurotoxin and it has a strong stimulation to human mucous membranes. A small amount of CH_3SH inhaled may damage human nervous and respiratory system, a medium amount of CH_3SH caused headache, nausea and even narcotism of differentt degree, a high concentrations of CH_3SH can cause respiratory paralysis and even death. In view of all the hazards of odor pollutants, many countries have established control standards of stink pollutions and published the Prevention Act. Many countries have brought CH_3SH into monitoring stink pollutants and in our country the publication of "Emission standards for odor pollutants" has stipulated that the CH_3SH level 3 emission limits is from 0.02 to 0.0350 mg/m^3.

In the paper, the main subjects are that in the self-designed reactor the CH_3SH gas fully mixs and reacts with the atomized ClO_2 liquid by compressed air, the unreacted ClO_2 gas is absorbed by lye and the residual CH_3SH gas is absorbed by ethanol. At last, the residual non-condensable gases are discharged into the atmosphere.

EXPERIMENTAL

1 % (mol/mol) of CH_3SH standard gas was purchased from the foshan of KODI gas chemical industry co., LTD. The ClO_2 solution was obtained from Guangxi Nanning Phoenix Pulp & Paper. Other reagents are analytical grade.

Agilent 6890N gas chromatograph (with Agilent G1888 Headspace Sampler), the self-made absorption device of CH_3SH gas.

Solution preparation and calibration: 0.1 mol/L $Na_2S_2O_3$ standard solution, 0.1mol/L iodine standard solution, 0.1 mol/L HCl solution as well as ClO_2 solution are prepared and calibrated[2]. Determination of the concentration of CH_3SH[3], the procedures are as follows: (1) Take 200 mL absolute ethanol into a 500 mL brown reagent bottle, then lead slowly the CH_3SH standard gas into the bottle for 20 min and the solution of CH_3SH absolute ethanol is obtained. The prepared solution is stored airtightly in the refrigerator at 4 °C after calibration. (2) Calibration method: Take 10 mL the prepared solution into a 250 mL conical flask, add 15 mL absolute ethanol and 15 mL 0.025 mol/L silver nitrate solution into the flask, shake for

5 min and add 3 to 5 mL iron alum indicator (dissolve 40 g iron alum with 60 mL distilled water, add 20 mL nitric acid, then make the solution volume reach 100 mL by adding the distilled water. Remove the nitrogen oxides in the solution by boiling before using the solution and dilute with water 4 times) into the same flask and then titrate the solution until the colour of light pink appearing with 0.025 mol/L ammonium thiocyanate (a mL) and then continuely titrate the solution until the colour of light pink disappearing with silver nitrate solution (b mL). At last, titrate with ammonium thiocyanate solution (c mL) until the colour of the solution becomes the micro-light pink that is the endpoint colour. The concentration of CH_3SH is calculated as follows:

$$C = \frac{48 \times 0.025 \times (15 - a + b - c)}{10} \quad (1)$$

where: C - the concentration of CH_3SH, g/L; a, c = the titrated volume of 0.025 mol/L ammonium thiocyanate solution, mL; b = the titrated volume of silver nitrate solution, mL.

Gas chromatography conditions about the detection of methanthiol content: Headspace sampling method: heating box 60 °C, quantitative tube 70 °C, transmission line 80 °C, balance time of headspace vial 3 min, injected time 1 min.

Gas conditions: Inlet temperature 150 °C, spliting ratio 1:9, chromatographic column temperature 150 °C, running time 15 min. Column: GS-Q (the U.S. J&W CO.) 30.0 m × 0.53 mm × 0.00 μm, FID detector, hydrogen flow 35 mL/min, air flow 300 mL/min, nitrogen flow 35 mL/min.

Methylmercaptan standard curve: Standard concentration of 0.41g/L CH_3SH ethanol solution was diluted to 0.0082, 0.0123, 0.0164, 0.0205, 0.0246, 0.0287, 0.0328, 0.0369 and 0.041 g/L. The different concentrations of standard solution were taken 1 mL into headspace vial, which was measured in the headspace gas chromatography in accordance with a predetermined chromatographic conditions. Every standard solution was done 3 parallel times and the average value of the peak area was obtained. Draw CH_3SH linear standard curves with the concentration of CH_3SH solution for abscissa and the peak area for ordinate. The results are showed in Fig. 1. The regression equation is Y = 1184.5X-2.6064, the correlation coefficient R^2 is 0.998.

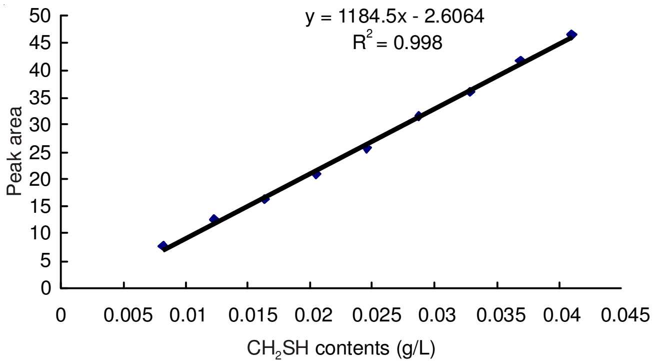

Fig. 1. Graph of CH_3SH standard curve

Technological diagram: The technological diagram of the experiment is shown in Fig. 2. The experimental devices are mainly consisted of atomizing device of ClO_2 solution, reaction apparatus of stench, alkali absorber tower and residual gas absorption apparatus.

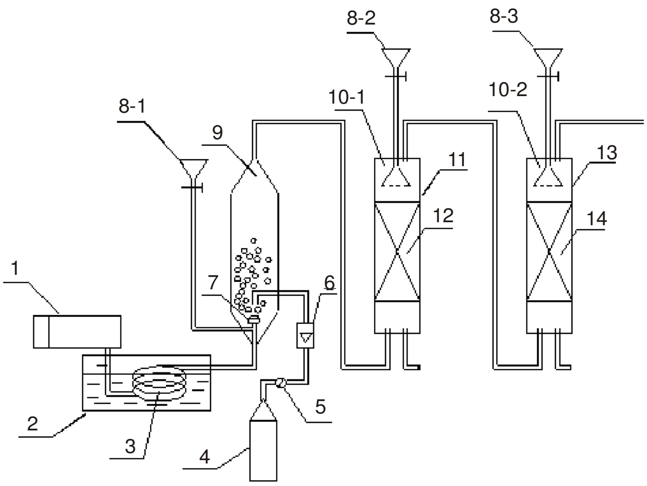

Fig. 2. Technological diagram of the experimental device. 1. Air compressor 2. Water bath 3. Plastic air pipe 4. CH_3SH standard cylinders 5. Relief valve 6. Flowmeter 7. Atomizer 8-1. Separatory funnel 9. Reactor 8-2. Separatory funnel 10-1. Liquid distributor 11. Alkali absorber tower 12. Plastic filler 8-3. Separatory funnel 10-2. Liquid distributor 13. Residual gas absorption tower 14. Wire filler

The main role of ClO_2 atomization device is to atomize ClO_2 liquid into 5-50 μm tiny droplet under the driving of compressed air. Moreover, ClO_2 has strong oxidation, which can instantly reacts with the CH_3SH gas to produce odorless sulfonate and sulfones[4]. The main effect of the stench reactor is that the CH_3SH gas and atomized ClO_2 liquid sufficiently mix and react in the apparatus. The main effect of alkali absorber tower is to absorb residual ClO_2 and CH_3SH gas and further to be removed by the lye in the alkali absorber tower. The residual gas absorption device is used to absorb the residual CH_3SH with absolute ethanol and the removal effect of CH_3SH is evaluated through analyzing the CH_3SH content in the absorption liquid.

The compressed air is produced by the air compressor 1, then the air goes through plastic compressed air pipe 3 and the air is heated by the water in electric water bath 2. The ClO_2 liquid sheding from separatory funnel 8-1 is fogged into 5-50 μm tiny droplet by the atomizer 7 under the driving of compressed air. The CH_3SH gas sheds from CH_3SH standard cylinder 4 into the reactor 9 through the pressure relief valve 5 and flowmeter 6. In the reactor 9, the CH_3SH gas sufficiently mixs and reacts with atomized ClO_2 droplets. Those mixtures of the unreacted ClO_2, Cl_2 and CH_3SH are leaded into the alkali absorber 11. After the mixtures go through the plastic filler 12, they are sbsorbed by alkali absorbents, which shed from separating funnel 8-2 and are evenly distributed by liquid distributor 10-1. The waste liquid flows from the bottom of the alkali absorber tower 11. The residual gas mixtures in the alkali absorber tower 11 are leaded into gas absorption tower 13. After the residual gases go through wire filler 14, they are sbsorbed by the absolute ethanol, which sheds from separating funnel 8-3 and is evenly distributed by the liquid distributor 10-2. The waste liquid flows from the bottom of the residual gas absorption tower 13 after the ethanol absorbent absorbs those residual gas mixtures. At last, the residual non-condensable gases are discharged into the atmosphere from the top of tower 13.

Experimental device airtightness test: The purpose is to check the airtightness of the experimental apparatus. The specific experimental steps is to put the exhaust pipe at the top of gas absorption tower 13 into a flask contained water. 250 mL distilled water is loaded into the separatory funnel 8-1 in advance, which is guided slowly into the reactor 9. Then check whether there is any bubble in the flask.

Selection of absorbent in alkali absorber tower: During the process of reaction there will be large amounts of ClO_2 and Cl_2 gas generated from ClO_2 droplets and these gases will be leaded into the residual gas absorption tower. If these gases will not be dealt with promptly, they would have effect on detecting the content of residual CH_3SH gas. Moreover, if the residual ClO_2 and Cl_2 are directly discharged into the atmosphere, they would pollute the air. Therefore, it is necessary to set the absorption device to remove the residual ClO_2 and Cl_2.

The ClO_2 and Cl_2 can dissolve into lye (for example NaOH and Na_2S) with strong oxidizability. Because the S^{2-} of Na_2S solution has reductibility, the NaOH and Na_2S must be added during cooking process in a sulfate pulp mill, which can be used to absorb these oxidizability gas. In accordance with the literature[5], the mixed lye of NaOH and Na_2S can absorb and remove ClO_2 and Cl_2. In the experiment, the NaOH solution, the Na_2S solution and the mixed liquid of NaOH and Na_2S, are used as absorbents. In the absorption solution, the content of ClO_2 and Cl_2 is titrated with 0.1 mol/L $Na_2S_2O_3$ standard solution and the content is expressed with the available chlorine content. The calculation formula is as follows:

$$M = \frac{[(250 + V) \times C - V_1C_1] \times 35.5}{1000} \qquad (2)$$

where, M = Available chlorine content of residual gas, g; V = Titrated volume of $Na_2S_2O_3$ solution, mL; C = Concentration of $Na_2S_2O_3$ solution, mol/L; V_1 = Volume of iodine standard solution, mL; C_1 = Concentration of iodine standard solution, mol/L; 35.5 = 1 mol $Na_2S_2O_3$ quality corresponding to a chlorine atom.

Blank experiments of chlorine dioxide removing CH_3SH: Because CH_3SH may be adsorbed by the experimental device and the gases may flow badly within the experimental device, which both effect the removal rate of CH_3SH. The feasibility of experiment equipment is tested by detecting the recovery rate of CH_3SH through proceeding blank experiment. The formula of CH_3SH recovery rate is as follows:

$$N = \frac{n_{CH_3SH\ recovery}}{n_{total\ CH_3SH}} \times 100\ \% \qquad (3)$$

$$n_{CH_3SH\ recovery} = \frac{V \times (Y + 2.6064)}{1184.5 \times 48} \qquad (4)$$

$$n_{total\ CH_3SH} = \frac{L \times t \times w}{22.4} \qquad (5)$$

where: N = the removal rate of CH_3SH, $n_{CH_3SH\ recovery}$ = the content of CH_3SH in ethanol absorbent, mol, $n_{total\ CH_3SH}$ = the content of standard CH_3SH gas passed into, mol, V = the volume of absolute ethanol absorbent, L, Y = the peak area of gas chromatographic, L = the flow of CH_3SH gas, L/min, t = the leaded time of CH_3SH gas, min, w = the concentration of CH_3SH gas, 1 % (mol/mol)

The recovery rate of CH_3SH is 98.87 % after the blank experiment has been proceeded. Therefore, it is possible that CH_3SH is adsorbed little by the self-designed apparatus, that the gas flowability is good in the experimental device. The absolute ethanol on absorption effect of CH_3SH is good. So it can be considered that the self-made experimental apparatus would be feasible.

Experiments of ClO_2 removing CH_3SH: In this experiment, absolute ethanol is used as the absorbent of residual CH_3SH gas according to the properties that CH_3SH can be dissolved into the organic solvent, such as alcohol, ether, ester. The experimental procedures are as follows: (1) The device is connected and the airtightness of system is inspected. The 7 g/L ClO_2 liquid is added to the separatory funnel 8-1, in addition, the alkali absorbent is added to the alkali absorber tower 11 and the separatory funnel 8-2. Then absolute ethanol is added to the separatory funnel 8-3. (2) First open inlet switch of compressed air device and the air flow is controlled at 0.75 m^3/h. Then open the switch of funnel 8-1 and the ClO_2 solution is leaded into the reactor 9 with the flow of 40 mL/min. At the same time, absolute ethanol flows into absorption tower 13 with the rate of 250 mL/min. Within 5 min, the standard methanthiol gas is leaded into the reactor 9 with the speed of 0.85 L/min, after at the end of leading into CH_3SH gas the flow of compressed air is increased to 1.25 m^3/h to purge the CH_3SH gas in devices and the time of purge is 3 min. (3) After the end of the purge, stop add absolute ethanol, then collect absolute ethanol absorbent solution and store hermetically at 4 °C refrigerator. The CH_3SH content in absolute ethanol absorbent solution is measured by headspace gas chromatography[6].

RESULTS AND DISCUSSION

Choice of absorbent: The absorbents of NaOH solution, Na_2S solution and mixed lye of NaOH and Na_2S are selected as absorbent solution to conduct the experiment of screening efficient absorbent. Under the same adding amount of chlorine and CH_3SH conditions, the content of available chlorine in each absorbent solution is detected to screen out the efficient absorbent solution.

The results are found that the colour of NaOH solution becomes yellow-green when it is used to absorb the residual ClO_2 and Cl_2, the reason may be that most of the absorbed ClO_2 has no reaction with the NaOH solution, which only dissolves into the lye with the form of ClO_2 molecular. And the ClO_2 with relatively strong volatility easily escapes from solution into the residual gas absorption tower and whose available chlorine content is higher. So it is not very satisfactory with the absorbent of NaOH solution. When Na_2S solution is used as absorbent to absorb the residual ClO_2 and Cl_2, the absorbent effect is good, but it is found that the S^{2-} is oxidized into elemental sulfur and adhered on the filler.

The cooking lye contains of NaOH and Na_2S in a kraft pulp mill. In view of the above results, the mixed lye of NaOH and Na_2S is investigated on the absorption effect of ClO_2 and Cl_2 and the proportion of the NaOH and Na_2S should also be determined. The molar ratio of NaOH and Na_2S, respectively 1:0.5, 1:1, 1:1.5 and 1:2, is investigated in order to determine the influence of absorbing ClO_2 and Cl_2. The experimental results are found that when the molar ratio of NaOH and Na_2S is 1:1, under the same adding amount of chlorine and CH_3SH condition, the content of available chlorine in the absorbent is higher and the turbidity and yellow precipitation disappear, so that the mixed alkali of NaOH and Na_2S is good absorbent and their molar ratio is 1:1.

Methanthiol gas chromatogram: The standard CH_3SH 1 % (mol/mol) is filled into headspace bottle with water displacement method and the gas is sealed in the bottle and detected by headspace gas chromatography. Fig. 3 is the gas chromatogram of the CH_3SH. From the Fig. 3, the results are obtained that the retention time of CH_3SH is from 4.45 min to 4.60 min, which can be used to carry out CH_3SH qualitative analysis. The gas chromatogram of the CH_3SH ethanol solution is shown in Fig. 4.

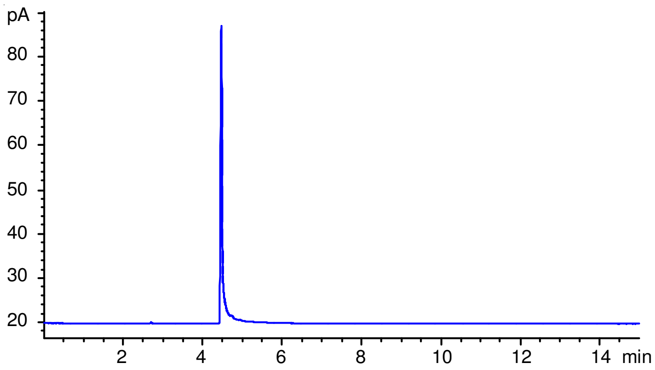

Fig. 3. Gas chromatogram of CH_3SH

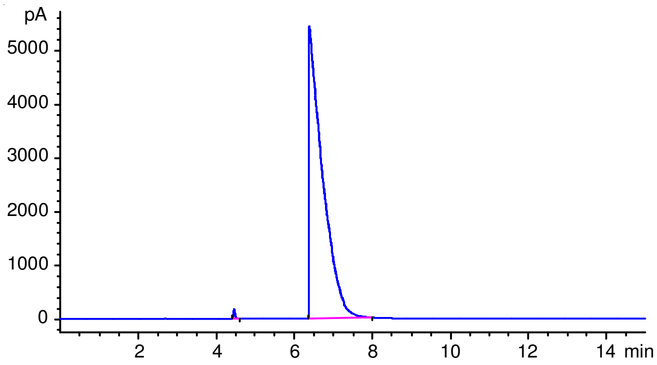

Fig. 4. Gas chromatogram of CH_3SH ethanol solution

Effects of the dosage of chlorine dioxide on the removal rate of CH_3SH: The effects of the molar ratio of CH_3SH and ClO_2 on removing CH_3SH were investigated, which molar ratio were respectively 1:1, 1:1.5, 1:2, 1:2.5, 1:3. The experimental results are shown in Table-1.

As shown in Table-1, with increasing molar ratio of CH_3SH and ClO_2 the CH_3SH content in the residual gas is gradually reduced and the removal rate of CH_3SH is gradually improved. When the molar ratio increases to 1:2.5, the increasing trend about the removal rate of CH_3SH becomes gentle, while the content of available chlorine in the absorbent has been increased substantially. The reasons may be that when the molar ratio increases to 1:2.5 the content of ClO_2 reacting with CH_3SH is in excess, which makes the concentration of available chlorine in alkali absorbent increases greatly. Therefore, the molar ratio of CH_3SH and ClO_2 1:2.5 is optimal.

TABLE-1
EFFECTS OF DIFFERENT MOLAR RATIO
ON CH_3SH REMOVAL RATE

Molar ratio	CH_3SH recovery (%)	Removal rate of CH_3SH (%)	Concentration of available chlorine in alkali absorbent(g/L)
1:1	38.90	60.41	0.04
1:1.5	34.92	64.34	0.06
1:2	29.67	69.54	0.08
1:2.5	27.95	71.24	0.13
1:3	27.47	71.71	0.18

Conditions: the molar ratio of NaOH and Na_2S 1: 1, the pH of ClO_2 solution 2, the temperature 35 °C, the air flow 0.75 m^3/h. Other experimental conditions are the same as 1.3.5

Effects of different temperature on the removal rate of CH_3SH: The reactivity of the reactants increased while enhancing appropriately the reaction temperature. The temperature in the reaction system is controlled by adjusting the temperature of the compressed air within the compressed air hose with the constant temperature water bath. Five different temperatures of 25, 30, 35, 40 and 45 °C were investigated. The results are shown in Table-2.

TABLE-2
EFFECTS OF DIFFERENT TEMPERATURE
ON CH_3SH REMOVAL RATE

Temperature (°C)	CH_3SH recovery (%)	Removal rate of CH_3SH (%)	Concentration of available chlorine in alkali absorbent (g/L)
25	28.53	70.66	0.11
30	28.29	70.90	0.12
35	27.95	71.24	0.12
40	28.73	70.46	0.08
45	28.92	70.28	0.09

Conditions: The molar ratio of NaOH and Na_2S 1:1, the molar ratio of CH_3Sh and ClO_2 1:2.5, the pH of ClO_2 solution 2, the air flow 0.75 m^3/h.

Table-2 shows that, when the temperature is increased from 25 to 35 °C the removal rate of CH_3SH and the concentration of available chlorine are increased slowly, whereas these values are reduced slightly when the temperature is increased to 35 °C. The reason is that when the temperature is elevated moderately the reactivity of ClO_2 and CH_3SH is improved and a part of the ClO_2 gas volatilizes from the small atomized liquid into alkali absorber tower, the removal rate of CH_3SH and the concentration of available chlorine are both increased. But when the temperature is raised to 35 °C the decomposition rate of ClO_2 decomposing into Cl_2 and O_2 is accelerated, so the effect of ClO_2 absorbing CH_3SH is weakened and the concentration of available chlorine is reduced. So the temperature has little influence on the CH_3SH removal rate, which are more conducive to industrialization realization. Therefore, the reaction temperature of 35 °C is determined.

Effects of the pH value of ClO_2 solution on the removal rate of CH_3SH: Since chlorine dioxide has strong oxidability under the acidic or alkaline conditions, the effects of pH value on the removal rate CH_3SH were investigated when the pH value was respectively 2, 5, 7, 10, 12. The pH value is adjusted with 6 mol/L HCl solution and 100 g/L NaOH solution. The experimental results are shown in Table-3.

TABLE-3
EFFECTS OF pH VALUE ON CH_3SH REMOVAL RATE

pH	CH_3SH recovery (%)	Removal rate of CH_3SH (%)	Concentration of available chlorine in alkali absorbent (g/L)
1	27.85	71.44	0.09
2	27.95	71.24	0.10
5	29.25	69.95	0.11
7	30.37	68.84	0.12
10	31.62	67.61	0.43
12	34.06	65.19	1.61

Conditions: The molar ratio of NaOH and Na_2S 1:1, the molar ratio of CH_3SH and ClO_2 1:2.5, the temperature 35 °C, the air flow 0.75 m^3/h.

Table-3 showed that with the raise of the pH value, the CH_3SH removal rate is reduced gradually while the concentration of available chlorine is increased gradually. Two reasons are as follows. One is that the stability of ClO_2 solution increases with the pH values increasing[7], which reduces the ClO_2 decomposition rate and the ClO_2 volatility from the solution. The other is that ClO_2 generates easily chlorate and chlorite under higher pH value conditions, which reduces the reactivity of CH_3SH. When the pH value is 1 and 2, the removal rate of CH_3SH is almost same. And the acidity is higher, the corrosion is greater. Therefore, the pH value of 2 is better.

Effects of air flow on the removal rate of CH_3SH: Although CH_3SH can be oxidized into sulfonic acid or sulfonate by ClO_2 instantly, the mixed time and effect of ClO_2 and CH_3SH gas both affect reaction. In this experiment, the residence time of ClO_2 and CH_3SH in the reactor is adjusted by controlling the flow of compressed air. When the flow of compressed air is little, ClO_2 and CH_3SH gas have a long residence time in the reactor and mix uniformly. But when the compressed air flow are big, the mixed gas of ClO_2 and CH_3SH quickly are purged into the alkali absorber tower, the residence time is short and these gases mix unevenly and the reaction is not sufficient. The compressed air flow of 0.5, 0.75, 1and 1.25 m^3/h are investigated in order to evaluate the effect on the CH_3SH removal rate. The experimental results are shown in Table-4.

TABLE-4
EFFECTS OF COMPRESSED AIR FLOW
ON CH_3SH REMOVAL RATE

Air flow (m^3/h)	CH_3SH recovery (%)	Removal rate of CH_3SH (%)	Concentration of available chlorine in alkali absorbent (g/L)
0.5	15.88	83.17	0.14
0.75	27.95	71.24	0.08
1.0	37.16	62.13	0.10
1.25	43.85	55.52	0.13

Conditions: The molar ratio of NaOH and Na_2S 1: 1, the molar ratio of CH_3SH and ClO_2 1:2.5, the temperature 35 °C, the pH of ClO_2 solution

Seen from Table-4, the CH_3SH removal rate decreases rapidly with the increase of air flow, which show that when the compressed air flow is smaller ClO_2 and CH_3SH mix more evenly, the efficiency of removing CH_3SH is higher. But the residence time of CH_3SH in the reactor is prolonged when the air flow is small, which augments the investment of the reactor and also increases the cost of pipe. And when the compressed air flow is increased more than 0.75 m^3/h, the ClO_2 gas quickly is purged into the alkali absorber tower by the compressed air, such that in the alkali absorbent the concentration of available chlorine increases. In conclusion, the flow of compressed air 0.75 m^3/h is better.

Removal of CH_3SH experiment under the optimal conditions: The optimal conditions are obtained for removing CH_3Sh with ClO_2 solution. The conditions are as follows: The absorbent of residual ClO_2 gas is the mixed lye of NaOH and Na_2S, the molar ratio of the mixed lye is 1:1, the molar ratio of CH_3SH and ClO_2 is 1:2.5, the temperature is 35 °C, the pH value of ClO_2 solution is 2, the flow of compressed air is 0.75 m^3/h. Under this optimum conditions, the experiment of removing CH_3SH is conducted and the results are shown in Table-5.

TABLE-5
RESULTS OF REMOVING CH_3SH UNDER
THE OPTIMAL CONDITIONS

CH_3SH recovery (%)	Removal rate of CH_3SH (%)	Concentration of available chlorine in alkali absorbent (g/L)
0.198	99.80	0.09

Table-5 showed that the removal rate of CH_3SH is 99.80 %, the concentration of available chlorine is 0.09 g/L and the concentration of CH_3SH gas reduces from the initial 1.457 g/m^3 to 0.032 mg/m^3. The emission concentration of 0.032 mg/m^3 reaches level 3 national emission standards.

Conclusion

The optimal conditions of removing CH_3SH with ClO_2 are obtained, they are as follows: the absorbent of residual ClO_2 gas is the mixed lye of NaOH and Na_2S, the molar ratio of the lye is 1:1, the molar ratio of CH_3SH and ClO_2 is 1:2.5, the temperature is 35 °C, the pH value of ClO_2 solution is 2, the flow of compressed air is 0.75 m^3/h. Under the conditions, the removal rate of CH_3SH is 99.80 % and the concentration of CH_3SH reduces from the initial 1.457 g/m^3 to 0.032 mg/m^3, which reaches level 3 emission standards stipulated by the state.

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