Sulphur trioxide - the sulphuric acid contact process

(Item No.: P3110400)

Curricular Relevance

Area of Expertise: Chemistry
Education Level: University
Topic: Industrial Chemistry
Subtopic: Gases
Experiment: Sulphur trioxide - the sulphuric acid contact process

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	20 Minutes	2 Students

Additional Requirements:

- ice
- Precision balance, 620 g / 0.001 g

Experiment Variations:

Keywords:

sulphur trioxide, sulphuric acid, contact process, oxidation, redox reaction

Overview

Short description

Related Topics

Principle

The contact process is currently used in the chemical industry to produce sulphuric acid in the high concentrations needed for industrial processes. In this model experiment, platinum-palladium-aluminiumoxide beads are employed as a catalyst for the reaction.

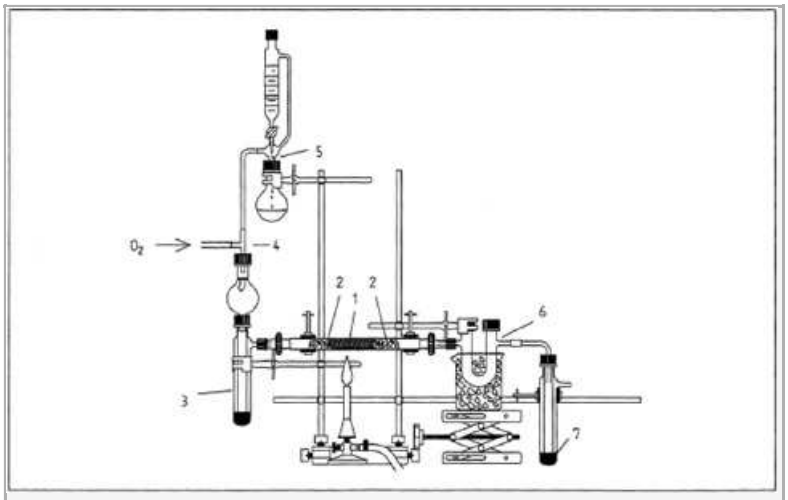

Fig. 1: Experimental setup.

Safety instructions

Concentrated acids are highly caustic. They burn the skin and destroy textile fabrics. For diluting, first add the water, then the acid (protective glasses, laboratory coat, gloves).

Sodium hydroxide solutions have a strong irritating effect on the skin, eyes, and mucous membranes. Mists irritate the respiratory organs.

Chemical burns lead to the destruction of the tissue and intense pain. Aqueous solutions of sodium pyrosulphite can lead to the development of sulphur dioxide that irritates the skin, eyes, and mucous membranes.

First aid: Rinse the affected skin areas (eyes, etc.) thoroughly with plenty of water. Go to a doctor immediately in the event of eye injuries. If inhaled (sulphur dioxide and hydrogen chloride): Fresh air. Keep the respiratory tract free. In the event of respiratory distress, bring the affected person in a semi-recumbent position to a doctor.
Disposal: Solutions must be diluted with water, neutralised pH 6-8), and flushed away .Collect any solutions hat contain heavy-metal ions in a collecting vessel for heavy-metal salt solutions. Solid residues that containheavy metals or their ions must also be collected in this vessel.

Barium hydroxide
H302: Harmful if swallowed.
H314: Causes severe skin burns and eye damage.
H318: Causes serious eye damage.
P280: Wear protective gloves/protective clothing/eye protection/face protection.

Sodium pyrosulphite
H302: Harmful if swallowed.
H318: Causes serious eye damage.
EUH031: Contact with acids liberates toxic gas.
P280: Wear protective gloves/protective clothing/eye protection/face protection.

Sodium hydroxide
H290: May be corrosive to metals.
H314: Causes severe skin burns and eye damage.
P280: Wear protective gloves/protective clothing/eye protection/face protection.

Hydrochloric acid, 37%
H290: May be corrosive to metals.
H314: Causes severe skin burns and eye damage.
H335: May cause respiratory irritation.
P280: Wear protective gloves/protective clothing/eye protection/face protection.

Sulphuric acid, 95%
H290: May be corrosive to metals.
H314: Causes severe skin burns and eye damage.
P280: Wear protective gloves/protective clothing/eye protection/face protection.

Quartz glass wool
H332: Harmful if inhaled
H335: May cause respiratory irritation

P261: Avoid breathing dust/fumes/gas/mist/vapours/spray.

Oxygen
H270: May cause or intensify fire; oxidizer.
P280: Wear protective gloves/protective clothing/eye protection/face protection.
P220: Keep/Store away from clothing/…/combustible materials.

Equipment

Position No.	Material	Order No.	Quantity
1	Support base DEMO	02007-55	1
2	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
3	Support rod, stainless steel, 750 mm	02033-00	1
4	Right angle boss-head clamp	37697-00	8
5	Universal clamp	37715-00	6
6	Lab jack, 160 x 130 mm	02074-00	1
7	Combustion tube, 300 mm, quartz, ns	33948-01	1
8	Connecting tube IGJ 19/26-GL 18/8	35678-01	2
9	Clamp f.ground joint,plastic,NS19	43614-00	2
10	Teflon sleeve IGJ 19, 10 pcs	43616-00	1
11	Round bottom flask, 100ml, GL 25/12	35841-15	1
12	Funnel for gas generator, 50 ml, GL18	35854-15	1
13	Wash tube with fritted disc	36699-00	2
14	Stutzer attachment GL25/12	35791-15	1
15	Capillary tube, T-shaped	37030-00	1
16	U tube, 2 side tubes, GL25/8	36959-15	1
17	Beaker, low, BORO 3.3, 400 ml	46055-00	1
18	Glass tube,right-angled, 10 pcs.	36701-52	1
19	Steel cylinder oxygen, 2 l, filled	41778-00	1
20	Table stand for 2 l steel cylinders	41774-00	1
21	Reducing valve f.oxygen	33482-00	1
22	Wrench for steel cylinders	40322-00	1
23	Teclu burner, DIN, natural gas	32171-05	1
24	Safety gas tubing, DVGW, sold by metre	39281-10	1
25	Lighter f.natural/liquified gases	38874-00	1
26	Hose clip f.12-20 diameter tube	40995-00	2
27	Rubber tubing, i.d. 6 mm	39282-00	2
28	Spoon, special steel	33398-00	1
29	Wash bottle, plastic, 500 ml	33931-00	1
30	Funnel, glass, top dia. 55 mm	34457-00	1
31	Beaker, high, BORO 3.3, 600 ml	46029-00	2
32	Beaker, high, BORO 3.3, 250 ml	46027-00	4
33	Glass rod,boro 3.3,l=300mm, d=7mm	40485-05	1
34	Tweezers,straight,blunt, 200 mm	40955-00	1
35	Indicator paper, pH1-11, roll	47004-01	1
36	Quartz glass wool 10 g	31773-03	1
37	Sulphuric acid, 95-98% 500 ml	30219-50	1
38	Sodium pyrosulphite 250 g	30152-25	1
39	Bead catalyst,Pt-Pd-Al-oxide 10 g	31763-03	1
40	Sodium hydroxide, pellets, 500 g	30157-50	1
41	Hydrochloric acid 37 %, 1000 ml	30214-70	1
42	Barium hydroxide 250 g	30034-25	1
43	Water, distilled 5 l	31246-81	1

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Tasks

1. Oxidise sulphur dioxide to sulphur trioxide
2. Use the sulphur trioxide to produce sulphuric acid

Setup and procedure

1. Oxidation of sulphur dioxide to sulphur trioxide

Procedure

Seal one end of a quartz glass combustion tube (1) with quartz glass wool (2), fill it with platinumpalladium- aluminium-oxide beads, and secure these beads on the other end of the tube with quartz glass wool (2) so that the beads cannot move in the gas flow.

Fasten this prepared combustion tube horizontally to two support rods as shown in Fig. 1. Connect a connecting tube and a wash tube with a fritted disc (3) to one end of the combustion tube. This wash tube is filled with approximately 30 ml of concentrated sulphuric acid for drying the gases that will be fed in. Connect an SO_2 generator (5) to this set-up via a T shaped capillary tube (4). TheSO_2 is generated by dripping concentrated sulphuric acid into a 40% sodium pyrosulphite solution (of 35 g of$Na_2S_2O_5$ and 52.5 g of water). Connect an oxygen steel cylinder to the free end of the T-shaped capillary tube (4).

Connect a dry U-tube (6) to the second opening of the combustion tube. Seal this U-tube with 2 sealing caps and place it in a beaker with ice water for cooling. Connect a wash tube (7) to the U tube.

Fill this wash tube with diluted sodium hydroxide (approx. 30 ml) for the adsorption of any unconvertedSO_2 . Heat the platinum-palladium-aluminium-oxide beads in the middle of the combustion tube with a non-luminous flame (the optimum temperature is approximately 400 °C). Then, generate a slow flow ofSO_2 by letting the concentrated sulphuric acid drip slowly into the 40% sodium pyrosulphite solution in the gas generator. Let pure oxygen from a steel cylinder (adjust only a slight flow) flow into this SO_2 flow via the connecting tube (4) so that the result is a mixture ofSO_2 and oxygen that flows through the apparatus.

2. Formation of sulphuric acid

Procedure

If the white-grey deposit in the U-tube is dissolved in pure water, filled into a beaker, acidified with hydrochloric acid, and mixed with barium hydroxide solution, the result is white precipitate. A sample of the sodium hydroxide solution that is withdrawn from the wash bottle is neutralised with hydrochloric acid in a beaker and mixed with a barium hydroxide solution. In this case, the result is also a white precipitate. (Attention: Do not generate the precipitate directly in the wash tube since, otherwise, the fritted disc may become clogged.)

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Theory and evaluation

1. Oxidation of sulphur dioxide to sulphur trioxide

Procedure

Observation

In the combustion tube behind the platinum-aluminium-oxide beads, in the U-tube, and also in the wash bottle, a white mist can be observed. This mist condenses partly in the cooled U-tube, thereby forming a fine-crystalline, white-grey film.

Interpretation

At the platinum contact, $\mathrm{SO_2}$ is oxidised to $\mathrm{SO_3}$

$$2\,\mathrm{SO_2} + \mathrm{O_2} \longrightarrow 2\,\mathrm{SO_3} \qquad \Delta\mathrm{H} = \text{-}176\,\mathrm{kJ/mol/}$$

Unlike the gaseous $\mathrm{SO_2}$, $\mathrm{SO_3}$ is a solid substance at temperatures below 16.85 °C.

2. Formation of sulphuric acid

Result

The dissolution of $\mathrm{SO_3}$ in water results in sulphuric acid based on the equation

$$\mathrm{SO_3} + 3\,\mathrm{H_2O} \longrightarrow 2\,\mathrm{H_3O^+} + \mathrm{SO_4^{2\text{-}}}$$

Since $\mathrm{SO_3}$ dissolves only moderately when it is fed into water, it is fed into concentrated sulphuric acid during the industrial production of sulphuric acid, where it dissolves well. This solution is then diluted by the addition of water so that the resulting concentration is always approximately 98%.

Notes

When producing the $\mathrm{SO_3/SO_2}$ mixture, ensure that the air or oxygen is added only at low pressure to the $\mathrm{SO_2}$ so that the $\mathrm{SO_2}$ can flow continuously out of the constant-pressure gas generator. Do not dispose of the platinum-palladium-aluminium-oxide beads after the experiment. They can be used several times.

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