Sulphur trioxide - the sulphuric acid contact process

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.

Chemistry > General Chemistry > Chemical reactions > Redoxreactions

Chemistry > Industrial Chemistry > industrial synthesis

Difficulty level	Group size	Preparation time	Execution time
hard	2	20 minutes	30 minutes

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General information

Application

The experimental setup

In industry, sulfur trioxide is required for the production of sulfuric acid and forms other important pharmaceuticals, cleaning agents and colorants in sulfonation reactions.

With so many uses, sulfur trioxide is one of the most useful and versatile oxides of sulfur.

It is mainly produced by the so-called contact process, which is examined in more detail in this experiment.

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Other information (1/2)

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Prior knowledge

The students should be familiar with the basics of oxidation reactions and the dissolution of of chemical compounds in water. Furthermore, students should be familiar working autonomously with chemical agents and be familiar with good laboratory practice.

Scientific 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.

Other information (2/2)

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Learning objective

The students learn to synthetize sulphur trioxide from sulfur dioxide and how to dissolve it in water using the contact process to receive sulfuric acid.

Tasks

1. Oxidize sulphur dioxide to sulphur trioxide

2. Use the sulphur trioxide to produce sulphuric acid

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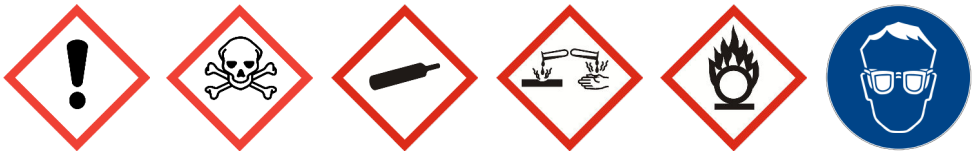
Safety instructions

For this experiment the general instructions for safe experimentation in science lessons apply.

For H- and P-phrases please consult the safety data sheet of the respective chemical.



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Equipment

Position	Material	Item 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	37715-01	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 pipe with frit, GL 25/8	MAU-27229000	2
14	Support to Stutzer, GL 25/12	MAU-27226500	1
15	Capillary tube, T-shaped	37030-00	1
16	U-tube with lateral connector, GL 25	MAU-27229500	1
17	Beaker, Borosilicate, low-form, 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. 50 mm	34457-00	1
31	Beaker, Borosilicate, tall form, 600 ml	46029-00	2
32	Beaker, Borosilicate, tall form, 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	Glass wool 10 g	31773-03	1
37	Sulphuric acid, 95-97%, 500 ml	30219-50	1
38	Sodium pyrosulphite 250 g	30152-25	1
39	Bead catalyst, 50g	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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Setup and procedure

Setup (1/3)

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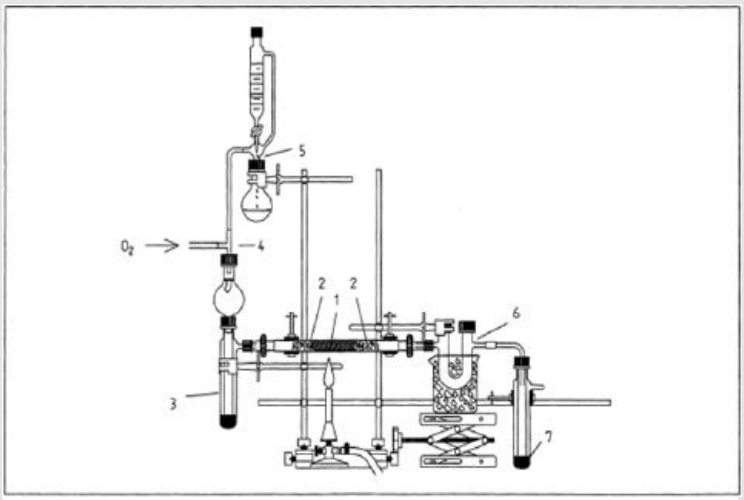

Fig. 1: Schematic illustration of the experimental setup

1. Seal one end of a quartz glass combustion tube (1) with quartz glass wool (2), fill it with platinumpalladium- aluminium-oxide beads.

2. 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.

3. Fasten this prepared combustion tube horizontally to two support rods as shown in Fig. 1.

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Setup (2/3)

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4. 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.

5. Connect an SO2 generator (5) to this set-up via a T shaped capillary tube (4). The SO_2 is generated by dripping concentrated sulphuric acid into a 40% sodium pyrosulphite solution (of 35 g of NaS_2O_5 and 52.5 g of water). Connect an oxygen steel cylinder to the free end of the T-shaped capillary tube (4).

6. 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.

Setup (3/3)

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Displayed is the final setup. Please, use the pop-up picture to gain a closer look.

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Procedure (1/2)

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1. Oxidation of sulphur dioxide to sulphur trioxide

1.1 Fill this wash tube with diluted sodium hydroxide (approx. 30 ml) for the adsorption of any unconverted SO_2.

1.2 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).

1.3 Then, generate a slow flow of SO_2 by letting the concentrated sulphuric acid drip slowly into the 40% sodium pyrosulphite solution in the gas generator.

1.4 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 of SO_2 and oxygen that flows through the apparatus.

Procedure (2/2)

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2. Formation of sulphuric acid

2.1 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.

2.2 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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Evaluation (1/3)

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1. Oxidation of sulphur dioxide to sulphur trioxide

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, SO_2 is oxidised to SO_2

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

Unlike the gaseous SO_2 , SO_3 is a solid substance at temperatures below 16.85 °C.

Evaluation (2/3)

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2. Formation of sulphuric acid

The dissolution of SO_3 in water results in sulphuric acid based on the equation

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

Since 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%.

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Evaluation (3/3)

Notes

When producing the SO_3/SO_2 mixture, ensure that the air or oxygen is added only at low pressure to the SO_2 so that the 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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