Organic chemistry

Reactions in organic chemistry

Oxidation reactions

LD Chemistry Leaflets

C2.2.2.1

Oxidation of propanol

Aims of the experiment

- To learn about redox reactions for synthesis
- To manufacture acetone
- To learn about different properties within a family of substances

Principles

Alcohols can be subdivided into primary, secondary and tertiary alcohols. They differ only in the position of the OH group. In the case of primary alcohols, this is located on the end carbon atom. In the case of secondary alcohols, it is located on a carbon atom with two neighbouring carbon atoms and in the case of tertiary alcohols on a carbon atom with three neighbouring carbon atoms (see Fig. 1).

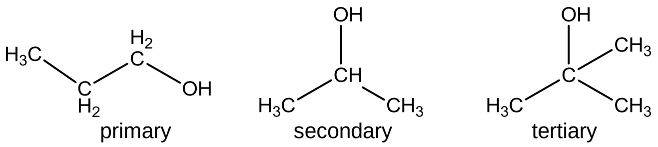

Fig. 1 Structural formulas of the various alcohols.

Because of these structural differences, the various alcohols also differ in their chemical properties. These properties also include oxidisability. In the case of alcohols, one must differentiate between partial and total oxidation. Total oxidation can be equated to flammability. The alcohol is oxidised to carbon dioxide and water. It decreases with increasing chain length and is utilised for combustion.

In the case of partial oxidation, primary, secondary and tertiary alcohols react differently. Primary alcohols can be converted to aldehydes as an intermediate product and then completely to carboxylic acids (see Fig. 2, with oxidation of 1-Propanol).

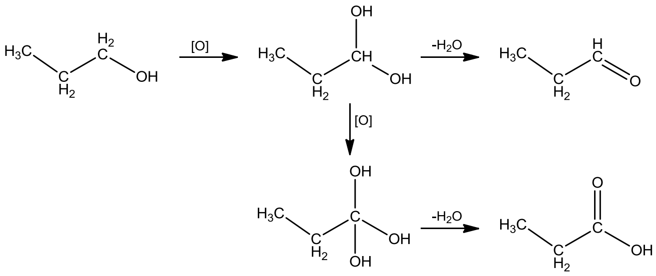

Fig. 2 Oxidation of the primary alcohol 1-propanol.

In the case of secondary alcohols, the oxidation to carboxylic acids cannot take place. They are converted to their corresponding ketones (see Fig. 3). Tertiary alcohols are unaffected by most oxidising agents or would be destroyed by oxidation.

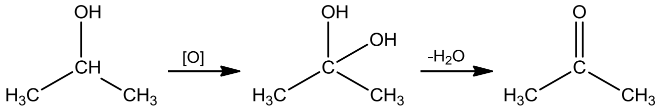

Fig. 3 Oxidation of the secondary alcohol 2-propanol.

Fig. 3: Set-up of the apparatus

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The oxygen of the oxidising agent removes hydrogen from the individual alcohol. This is a special form of oxidation that is termed dehydrogenation. The oxygen combines with the hydrogen removed to form water.

In this experiment, acetone will be produced through oxidation of 2-propanol. Copper oxide will be used as the oxidising agent, as at high temperatures it readily gives up its oxygen to reducing substances. Other possible oxidising agents would be potassium permanganate and chromium(VI) oxide. Because of the constant supply of air, the copper itself is immediately oxidised back again. In order to offer a sufficiently large copper/copper oxide surface area, a roll of copper wire gauze is used.

Acetone is an important starting material for many other chemical reactions. Furthermore it is an important solvent and extraction medium.

Risk assessment

2-propanol and the acetone produced from it are both flammable substances. The work should be performed under a fume cupboard and care must be taken not to open the apparatus when the burner flame is lit. The copper(II) sulfate used is harmful to living organisms and to the environment. It must under no circumstances be emptied into drains.

2-propanol	
  **Hazard**	**Hazard statements** H225 Highly flammable liquid and vapour. H319 Causes serious eye irritation. H336 May cause drowsiness or dizziness. **Precautionary statements** P210 Keep away from heat/sparks/open flames/hot surfaces and other sources of ignition. No smoking. P233 Keep container tightly closed. P305+351+338 If in eyes: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing.
Copper(II) sulfate (anhydrous)	
  **Caution**	**Hazard statements** H302 Harmful if swallowed. H315 Causes skin irritation. H319 Causes serious eye irritation. H410 Very toxic to aquatic life with long-lasting effects. **Precautionary statements** P273 Avoid release to the environment. P305+351+338 If in eyes: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing. P302+352 If on skin: Wash with plenty of water.

Equipment and chemicals

1 Base rail 55 cm..666 602
1 Reaction tube, quartz, GL 18 ....664 0771
1 Copper wire gauze roll 60 x 10 mm diam. ...664 078
2 Glass connector, GL 18 with glass olive......667 313
1 Woulff's bottle with manometer 665 935
1 Glass connector, 2 x GL 18........................667 312
1 Vacuum rubber tubing, 8 mm Ø, 1 m 667 186
1 Water-jet pump..375 56
2 Universal clamp 0...80 mm.........................666 555
2 Bosshead S...301 09
2 Universal bosshead...................................666 615
1 Stand tube 450 mm, 10 mm Ø, set of 2.......666 609ET2
2 Test tube with side arm, 20 x 180 mm.........664 051
2 Rubber stopper, 1 hole, 16-21 mm Ø..........667 256
2 Angled tube 90°, 250/50 mm, 8 mm Ø. 665 231
1 Cartridge burner, DIN type 666 714
1 Wide-flame attachment 666 724
2 Beaker, DURAN, 400 ml, tall......................664 114
1 Laboratory stand 16 cm x 13 cm 300 76
1 Spatula with spoon end, SS, 120 mm 666 963
1 Evaporating dish, 80 mm Ø........................664 442
1 Crucible tongs, 200 mm 667 035
1 LD tripod, 24 cm x 14 cm 608 010
1 Wire gauze 160 mm x 160 mm...................666 685
1 Wooden turnings, 200 pcs..........................661 083ET20
1 Tweezers, pointed 130 mm 667 026
1 Safety screen 667 605
1 Glass wool, 100 g......................................672 1010
1 Glycerine, 99 %, 250 ml 672 1210
1 2-Propanol, 250 ml....................................674 4400
1 Copper(II) sulfate, anhydrous, 250 g..........672 9710
Also required:
Ice cubes

Set-up and preparation of the experiment

Set-up of the apparatus

1. The apparatus is set up as can be seen in Fig. 1. For safety reasons, set up the apparatus behind a safety screen or in a fume hood.

2. Attach the two universal bossheads to the base rail at a good distance apart and fix the stand tubes to these.

3. Fix a universal clamp with a bosshead S to each stand tube.

4. Insert both angled tubes into the stoppers.

Note: To make is easier to insert the tubes, be sure to apply glycerine to the holes of the stoppers. The tubes could otherwise break if too much pressure is used.

5. Insert the stoppers into the two test tubes and fix these to the stand system using universal clamps.

6. Attach a glass connector to the side arm of the left-hand test tube so that the olive points away from the test tube.

7. Prepare the reaction tube such that the copper wire gauze is in the middle of the tube and fill both ends with some glass wool using tweezers.

8. Fix the olive of the glass connector into the reaction tube and also connect the olive of a glass connector to the right side of the reaction tube. At the same time, ensure that the reaction tube is at a suitable height, as it must be heated later using a cartridge burner.

9. Attach the right-hand glass connector to the angled tube of the right-hand test tube. If necessary, move one of the two stand tubes with the universal bosshead to the right or the left to achieve the correct separation.

10. Attach a further glass connector to the side arm of the right-hand test tube without an olive.

11. The Woulff's bottle acts as a safety bottle and must be attached to the right-hand glass connector with the short angled tube.

12. Connect the long angled tube to the vacuum tube of the water-jet pump.

Preparation of the experiment

1. Fill the left-hand test tube with 2-propanol to a level of about 4 cm and then close it again with the stopper. The angled tube should be immersed in the alcohol to a depth of about 3 cm.

2. Place about one spatula of copper(II) sulfate into the right-hand test tube and also close this again with the stopper.

Performing the experiment

1. Heat tap water in a beaker up to shortly before boiling. To do this, place the beaker on a tripod with a wire gauze and position the Bunsen burner beneath it.

2. Place a mixture of cold water and ice cubes into the second beaker.

3. Place the beaker with the ice water under the right-hand test tube so that the test tube is immersed in the ice water.

4. Heat the copper wire gauze with the Bunsen burner until it glows red.

Note: Darken the room so that the red glow is more easily recognised.

5. Heat the 2-propanol with the hot water. To do this, place the beaker with the hot water onto a laboratory stand using crucible tongs and raise it so that the test tube is immersed in the hot water.

6. Turn on the water-jet pump and regulate the air flow such that the copper wire gauze continues to glow even after the burner flame has been turned off.

7. As soon as about 3 - 4 ml of condensate has collected in the right-hand test tube, the hot water bath can be removed and the water-jet pump turned off.

Observation

When the beaker with the hot water is placed under the test tube filled with 2-propanol, a small production of vapour can be observed. At the moment when the water-jet pump is also turned on, this vapour is drawn in the direction of the second test tube. This begins to cloud over. Additionally, bubbles can be observed in the left-hand test tube. By cooling with ice and water, the resulting vapour condenses and a clear liquid begins to collect in the tube.

Evaluation

First perform a smell test of the contents of the second test tube. For this, carefully take the apparatus apart. At this point in time there must no longer be a naked flame in the fume cupboard, as the resulting condensate and the vapours are highly flammable.

Perform the smell test by careful fanning. Then place the condensate in an evaporating dish and test its flammability with wooden turnings.

Results

In this experiment, acetone was produced from 2-propanol by means of oxidation with copper oxide.

To achieve this, the copper wire gauze was first oxidised to copper oxide with oxygen from the air:

$$2\ \mathrm{Cu} + \mathrm{O_2} \rightarrow 2\ \mathrm{CuO}$$

Owing to the hot water, propanol vapours are formed in the left-hand test tube. These vapours are drawn through the apparatus with the help of the water-jet pump. When the propanol vapours are passed over the heated copper oxide, the propanol is oxidised to 2,2-propanediol.

$$2\ \mathrm{C_3H_8O} + 2\ \mathrm{CuO} \rightarrow 2\ \mathrm{C_3H_8O_2} + 2\ \mathrm{Cu}$$

With the elimination of water, this becomes propanone, also known as acetone. The oxygen from the copper oxide binds to the hydrogen to form water, which can be demonstrated through the blue colouration of the copper sulfate.

$$2\ \mathrm{C_3H_8O_2} + 2\ \mathrm{CuO} \rightarrow 2\ \mathrm{C_3H_6O} + 2\ \mathrm{H_2O} + 2\ \mathrm{Cu}$$

In the smell test, a slightly sweet odour can be smelled, similar to that of nail polish remover. The resulting acetone is also readily flammable and can form explosive mixtures with air.

Cleaning and disposal

Dispose of the copper sulfate in the collecting container for toxic inorganic residues and heavy metal salts and their solutions. Collecting containers must be clearly marked with the systematic description of their contents. Store containers in a well-ventilated place. Transfer these to the responsible authority for waste disposal.

Place the residual propanol and acetone in a collection container for organic solvents or subject them to controlled burning in the fume cupboard.