Analysis of cigarette smoke

Aims of the experiment

- Perform an exhaust gas analysis.
- Work with testing tubes for air analysis.
- Become familiar with various detection reactions for air pollutants.

Principles

The tobacco smoke from cigarettes contains a wide variety of harmful substances. More than 70 of the chemical substances that are released from a burning cigarette have been identified as toxic or carcinogenic or are suspected of being carcinogenic.

These chemical substances include irritants (e.g. ammonia or nitrogen oxides) and substances that are blood-toxic (e.g. carbon monoxide), carcinogenic (e.g. toxic heavy metals) and neuro-toxic (e.g. nicotine). All these substances have different effects on the human organism. The irritant substances damage bronchi, carbon monoxide blocks oxygen absorption, nicotine acts directly in the brain and carcinogenic substances can cause cancer.

Three individual reactions are undergone in a burning cigarette: Firstly, the cigarette burns at temperatures from 500 to 900 °C, the tobacco carbonises at temperatures from 200 to 600 °C and volatile components present in the tobacco evaporate. Both organic and inorganic substances are broken down in these processes. A mixture of substances also forms, this containing minute solid particles and liquid substances beside gases. Tobacco smoke consequently contains a large number of chemical substances in all three states of matter and thus represents an aerosol. The solids are also referred to as tar.

Three different substances or groups of substance are to be identified in this experiment using testing tubes: Carbon monoxide (CO), nitrogen oxides (NO_x) and sulphur dioxide (SO_2). CO binds to haemoglobin in the blood, thereby blocking the absorption of oxygen from the blood. The nitrogen oxides belong to the group of irritant substances. They damage the respiratory organs and, in particular, the bronchi. SO_2 also harms the respiratory organs as it represents a significant respiratory toxin. A colour reaction occurs in the testing tubes used if the respective analytes are present. This can be read off directly from the tube itself.

The reactions that occur are:

CO testing tube $5\,CO + I_2O_5 \xrightarrow{H_2SO_4} I_2 + 5CO_2$

Colour reaction: white → brown

NO_x testing tube $3\,NO + 2\,CrO_3 \xrightarrow{H_2SO_4} 3\,NO_2 + Cr_2\,O_2$

Colour reaction: white → dark blue

SO2 testing tube $SO_2 + I_2 + 2\,H_2O \quad SO_4^{2-} + I + 4H^+$

Colour reaction: violet → white

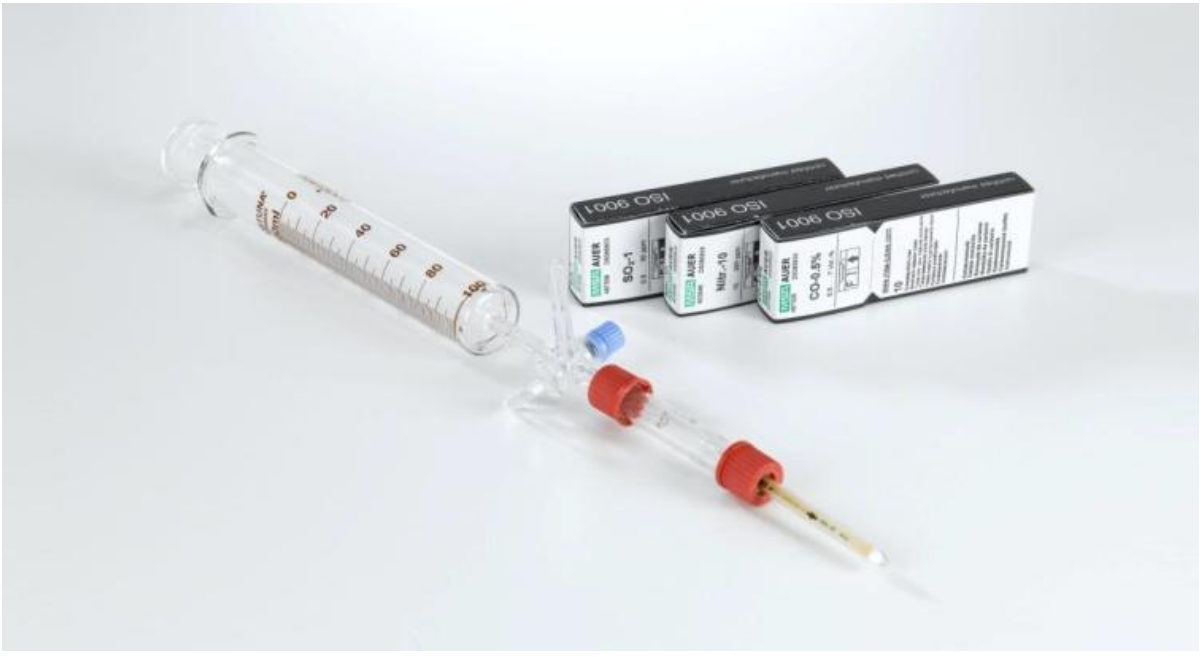

Fig. 1: Set-up of the experiment.

Risk assessment

The carbon monoxide, nitrogen oxide and sulphur dioxide substances examined in the experiment only occur in such small amounts that they do not pose any hazard. Nevertheless, the experiment should be carried out under a fume cupboard on account of the tobacco smoke

CO testing tube	
	Hazard statements Harmful if inhaled, swallowed or coming into contact with the skin. R35 Causes severe burns. R37 Irritating to respiratory system. **Safety statements** Keep out of reach of children P260 Do not breathe dust/fume/gas/mist/vapours/spray P262 Do not get in eyes, on skin, or on clothing P305+P351+ P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing. P313 Get medical advice/attention. P302+P352 IF ON SKIN: Wash with plenty of soap and water.
NOx testing tube	
	Hazard statements R21/22 Harmful in contact with skin and if swallowed. R34 Causes burns. R43 May cause sensitisation by skin contact. **Safety statements** P102 Keep out of reach of children P262 Do not get in eyes, on skin, or on clothing P305+P351+ P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing. P313 Get medical advice/attention. P302+P352 IF ON SKIN: Wash with plenty of soap and water

SO2 testing tube	
	Hazard statements Harmful if inhaled, swallowed or coming into contact with the skin. R35 Causes severe burns. **Safety statements** P102 Keep out of reach of children P260 Do not breathe dust/fume/gas/mist/vapours/spray P262 Do not get in eyes, on skin, or on clothing

Equipment and chemicals

1 Gas syringe 100 ml, with 3-way stopcock 665 9148
1 Glass connector, 2 x GL 18..... .... 667 312
1 Testing tube NOx 0.5 … 50 ppm, set of 10 ... 666 313
1 Testing tube CO 0.5 … 7.0 %, set of 10... .... 666 319
1 Testing tube SO_2 1 … 25 ppm, set of 10 .. .... 666 314
1 Glass file 667 015
1 Hand stopwatch..... .... 313 07
Also required:
cigarettes, lighter

Set-up and preparation of the experiment

Set-up of the apparatus

1. The gas syringe and glass connector are connected to each other as shown in Fig.1.

Performing the experiment

1. The cigarette is lit with a lighter, installed in the free GL screw fitting of the glass connector and then the gas syringe is slowly pulled on until about 30 ml tobacco smoke is present in the gas syringe.

2. Now close the three-way stopcock so that there is only a connection between the glass connector and the unused outlet of the gas syringe. In this way, the cigarette smoke cannot escape from the gas syringe.

3. Carefully extinguish the cigarette and shut off together with the screw cap.

4. Now place the first testing tube for CO in the screw cap. Insert the testing tube so that the tobacco smoke is routed to the side at which the measuring scale begins.

5. Using the file, break off both tips and file off the sharp break edges.

6. Screw the screw cap into the glass connector.

7. Establish a connection between the gas syringe and glass connector again for the analysis with the three-way stopcock.

8. Slowly empty the gas syringe so that the tobacco smoke finds its way into the testing tube.

9. Start stopwatch and read off the result from the testing tube after 2 minutes.

10. Repeat this experiment with the testing tubes for nitrogen oxides and SO_2. For this, first attach the cigarette on the glass connector, light and draw up the resultant smoke.

11. The cigarette and testing tube are replaced again and the analysis can begin.

Note: Testing tubes in which an analysis yields a negative result can be used again on the same day.

Observation

After the cigarette is lit and the gas syringe pulled on, it can be observed how the tobacco smoke collects in the gas syringe. By closing the gas syringe the tobacco smoke remains in the gas syringe and the cigarette can be replaced with a testing tube. If the relevant analyte is present, guiding the tobacco smoke through the testing tube results in a reaction between the analyte and the testing tube material. Colour changes occur in the testing tubes for the evaluation of the analyses. In the case of CO, a colour change from white/yellowish to brown occurs for a positive result. With the nitrogen oxides NO_x, this change is from white or pale blue to dark blue. With SO_2, a colour change from violet to white should occur.

The result of the relevant analysis can be read off directly from the testing tube. In our experiments, the tests for CO and NO_x were positive, while those for SO_2 were negative.

Evaluation

In this experiment, both the tobacco smoke in a stronger type of cigarette and in a weaker type of cigarette were tested with and without filter respectively. The content of CO, NO_x and SO_2 in the tobacco was examined.

The analyses are evaluated using the calibrated scape on the testing tubes. The values must be read off and noted, so that different cigarette brands or the effect of filters can then be compared.

Result

Table 1 shows the results from the analyses of CO, NO_x and SO_2 in the tobacco smoke of two different types of cigarette. Both types are also tested with and without filter.

Tab. 1: Results of the individual analyses.

	Cigarette 1	Cigarette 2	
CO	0.15 %	0.3 %	with filter
NO_x	0.5 ppm	0.75 ppm	
SO_2	-	-	
CO	0.3 %	0.5 %	without filter
NO_x	0.8 ppm	1.0 ppm	
SO_2	-	-	

The values indicated for CO are lower in the weaker type (cigarette 1) than in the stronger type (cigarette 2). This is also revealed from the values determined in the test. With a filter, the CO content in the tobacco smoke is lower by half at 0.15 % to 0.3 %. Without a filter, it is about a third less at 0.3 % to 05 %. The manufacturer's data can therefore be confirmed in this respect. On the other hand, the filter effect is clearly discernible as the values for CO are around double without a filter (table 2).

Tab. 2: Manufacturer data concerning harmful substances in each cigarette.

	Cigarette 1	Cigarette 2
Tar	6 mg	10 mg
Nicotine	0.5 mg	0.8 mg
CO	7 mg	10 mg

The total content of nitrogen oxides in the tobacco smoke is determined with the testing tube for NO_x. These include both nitrogen monoxide and nitrogen dioxide. In this test too, a clear difference is discernible between the weaker type of cigarette and the stronger type. As in the test for CO, the stronger type exhibits higher values for NO_x with (0.75 ppm) and without filter (1.0 ppm). These values are 0.5 ppm and 0.8 ppm for the weaker type. The filter effect also plays a role. If this effect is lost by removing the filter, this again leads to an increase in the values.

The test for SO_2 in the tobacco smoke has a negative result for both types. SO_2 can typically be found in the tobacco smoke of a water pipe, as the tobacco is burned there via a charcoal briquette and SO_2 results during the burning of fossil fuels such as coal or petroleum.

The blood-toxic CO as well as the irritant nitrogen oxides NO_x could thus be detected in this experiment.

The way the experiment is carried out can be varied by testing several types of cigarette, one type with and without filter or also several types with and without filter in succession.

Cleaning and disposal

The testing tubes must not on any account be disposed of in normal waste, as they contain small amounts of chemicals. The Waste Disposal Act (AbfG) and the Hazardous Chemicals Act (ChemG) must be observed for this.

Inorganic substances are contained in the testing tubes for CO and SO_2. They therefore have to be disposed of in the waste for inorganic solids. An organic amine is present in the testing tube for NO_x,along with chrome (VI) oxide, which is highly toxic. The testing tubes must therefore by collected and disposed of in a separate and marked container.

The cigarette residues can be disposed of in normal household waste after extinguishing and cooling down.