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Decreasing the dew-point of gases at measuring

Concentration alterations and diluting of pollutant and odour gases

Gas coolers used in measurement reduce dew-point. This is associated with condensation of surplus water, the total gas flow is reduced and the concentrations of other gas components increases. However, dilution also occurs with soluble components through absorption by the condensate. The concentration of these components decreases. Both effects are influenced by the degree of dew-point reduction and from the temperature in the cooler.
Dilution has to be watched out for especially with odour gases. According to the extent of solubility there occurs different concentration changes.
The resultant odour impression can therefore change extensively through the alterations of the relative composition.

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The water content must always be considered during gas measurements, especially when from biological sources. The substance development and its release always take place in a moist medium and there is also an increased temperature level through the biological transformation of the substance. During sampling of gases from composting processes or from biofilters, temperatures of around 60 °C can occur, the measurement gas flow is water-saturated with associated dew-points. Heated pipelines means the gas can be transported further without condensation. A problem with the concentration measuring always appears when the gas analyser – because of its design and measurement method – is applied at a temperature below dew-point. A reduction of gas moisture cannot then be avoided and must be carried out under controlled conditions. The standard method is through a gas cooler which through intensive contact of the measurement gas with cooled wall surfaces secures a controlled reduction of the dew-point [1].

Reduction of the gas dew-point

A temperature of 5 °C is common when using coolers for gases during measurement and this ensures considerable condensation of water component. At 5 °C the water component is only 0.54 %, at 70 °C on the other hand, it is 21.74 % of the total air mass (including the water). The difference of around 21 % is removed from the gas flow through condensation. The mole fraction, which is proportional to the water volume fraction, is even more substantial through the mole mass difference of 18 g/mole for water to 28.94 g/mole for dry air. At 5 °C 0.87 vol.% of the gas consists of water. At 70 °C, on the other hand, as much as 44.52 vol.%. The above-mentioned withdrawal of 21 % of total mass means, therefore, the withdrawal of around 44 % of the gas volume. Because all concentrations of pollutant or odour gases are related to total gas volumes, these concentrations therefore increase substantially by such intensive dew-point decreases.

Formula symbols used

p_{ges}	[bar]	Total pressure
$p_s(\delta)$	[bar]	Saturation pressure of water at temperature δ
p_d	[bar]	Partial pressure of water
p_{Gas}	[bar]	Partial pressure of gas
$c_{gel.Gas}$	[mol/kg]	Equilibrium concentration in water
c_{ein}	[m^3_{Gas}/m^3_{Luft}]	Concentration of gas to be measured
c_{aus}	[m^3_{Gas}/m^3_{Luft}]	Concentration after the cooler
$\lambda(\delta)$	[mol/kg bar]	Absorption coefficient
$\Lambda(\delta)$	[mol/kg]	Absorption coefficient
δ_K	[°C]	Cooler temperature
δ_{Tau}	[°C]	Measurement gas dew-point
$\delta_{Neutral}$	[°C]	Neutral temperature (no concentration alteration)

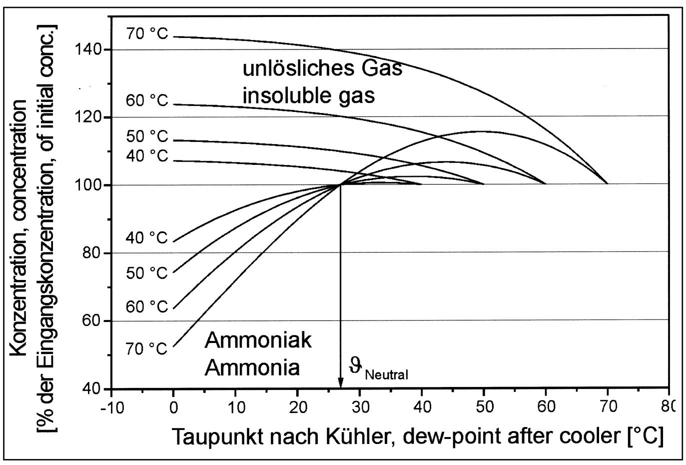

Fig. 1: Comparing changes in concentration of ammonia with insoluble gases

Dilution of gas components

Gas components can be released in the condensate produced by the decreasing of the dew-point. Physically-chemically, the dilution procedure involves absorption of the gas in the condensate [4]. The absorption of gases is described by the Henry Law which assumes a linear relationship between the concentration of a gas component over that of the absorbent and its resultant equilibrium weight concentration.

$$c_{gel.Gas} = \lambda(\delta) \cdot p_{Gas} \qquad (1)$$

The Henry Coefficient of Absorption λ is dependant on the temperature δ. An exponential concept for λ equals:

Gleichung einsetzen (2)

Often one finds coefficients A and B not tabulated but instead a reference value for $\lambda_{25°C}$ at 25°C and a coefficient C = d(ln(λ))/dn(1/T) describing the procedure of the Henry Coefficients with the temperature [5]. The calculation of $\lambda_{25°C}$ and C in the coefficients of the exponential form is thus formulated:

$$B = C \text{ and } A = \ln(\lambda_{25°C}) - C/298{,}15\,K \qquad (3)$$

The conversion of both Henry Coefficients involves [6]:

$$\Lambda = \lambda \cdot p_{ges} \qquad (4)$$

Condensation and dilution

The relationship of both condensation and dilution processes leads to alterations in concentration when a gas cooler is used.

The concentration alteration of a soluble gas after decrease of dew-point is given through the relationship (comprehensive derivation in [6]):

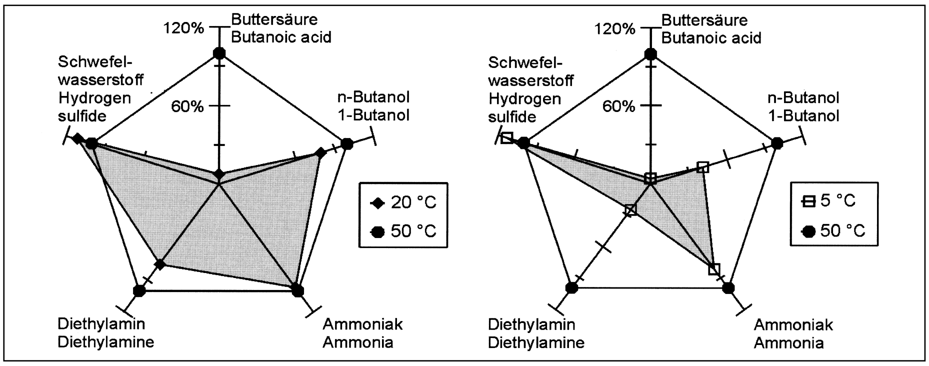

Fig. 3: Change of odour pattern by lowering the dew-point from 50 °C to 20 °C and 5 °C

((Gleichung einsetzen)) (5)

with δ_{Tau} as the gas dew-point and δ_K as the cooler temperature and the reduced dew-point temperature.

The inlet and exit concentration agrees with one another for a certain value Λ in that the effect of the condensing-out and of the dilution just compensate. The value of Λ can be calculated:

$$\Lambda(\delta_K) = 1/M_{Wasser} \qquad (6)$$

Dilution of ammonia

The solubility curve of ammonia cuts the reciprocal of the water mole mass at 26.34 °C. In *figure 1* the concentration alterations for four different starting points are represented with alterations of the gas cooler temperature. Increases in concentration appear above the neutral temperature, under this, on the other hand, there is a decrease in the concentrations. With insoluble gases there always occurs an increase in the gas concentration through the decrease in total gas amount during the condensing-out of water. The increase is greater in line with the amount of water condensed through the dew-point decrease.

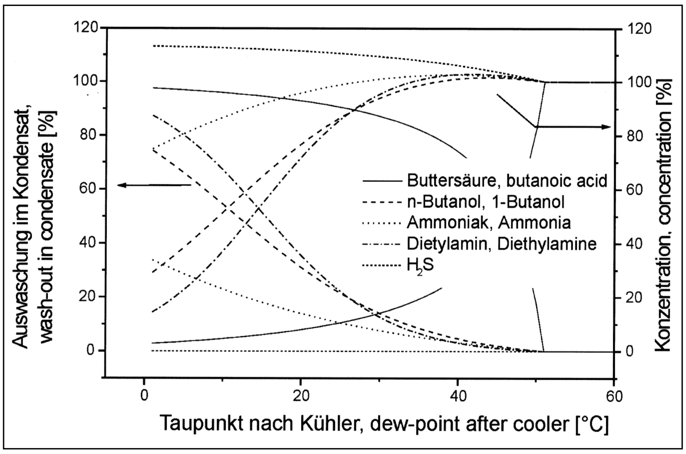

Fig. 2: Changes in concentration of odorous substances

Henry equation coefficients	Butyric acid	n-Butanol	NH_3	Diethyl-amine	H_2S
B or C	4000*	7200	4200	10000	2200
$\lambda_{25°C}$	4700	130	58	130	0,1
A	-4,96	-19,28	-10,03	-28,76	-9,68
$\delta_{Neutral}$	-	36,2	26,3	33,0	-

* no available value, estimate

Table 1: Henry equation coefficients (data from [5])

Dilution of odour gases

The application of microsensoric gas measurement technology („electronic noses“) to be expected in the future requires as a rule the conditioning of the measurement gas flow. The sensors cannot be directly applied to the gases being investigated because the moisture contents would act as interference components. However should the odour mixes have to be identified by an odour sensor system, then the changed influence of the gas conditioning, such as a dilution, must be known.

Odour gases must have a certain solubility in that reception within the smell-organ mucous membrane is the requirement for the locking action of odour cell receptors. This water-solubility can also naturally lead to dilution when the degree of solubility is large. In *table 1*, substance data is listed for some selected odour gases with calculation of the coefficients of the Henry Equation as defined in equation 2 and 3. In the last line the calculated neutral temperatures are given.

With the solubility data in table 1 concentration alterations as in *figure 2* are given with the example for a starting dew-point of 50 °C. Especially butyric acid, but also n-butanol are diluted to a very large proportion. With three of the odour gases presented here there is a neutral temperature – with the already presented ammonia, with n-butanol and with diethylamine.

The calculated condensation alterations lead to alterations in the composition of an odour gas mixture. The alterations for the selected odour gases are given in *figure 3* through a radar plot for various large dew-point decreases. The original odour gas mixture shows in each case 100 % starting concentration. The dew-point decrease acts in different ways, the very soluble gas shows very strongly decreased concentrations, the less soluble through to the largely insoluble gases, on the other hand, even indicate increases in concentration.