3 Manufacturing and Purification

Very different methods are used to manufacture a gas

- Separating a mixture of different gases. Typical examples are separating air to obtain O₂, N₂, Ar, Kr or Xe or the separation of CO₂ in the large-scale chemical industry.
- Using natural resources such as producing CO₂ from geological sources.
- Special syntheses such as C₂H₂ or AsH₃.

In most cases using one method does not achieve the desired purity so it is necessary to take further steps. The path to obtaining a very pure gas is always a combination of several manufacturing and cleaning processes.

Furthermore, the quantity flow rates vary enormously according to the requirements of the different gases. There is no terminology for the classification which is why the following table is provided for a rough guide. We give the volumetric flow rate Qᵥ as a derivative dV/dt at STP. Another possibility is the mass flow of the derivative Qₘ = dM/dt.

Table T3-1: Overview of different volumetric flow rates and the appropriate working methods.

<table>
<thead>
<tr>
<th>Qᵥ in [m³·h⁻¹]</th>
<th>Working method</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.1</td>
<td>laboratory</td>
<td>adsorptive purification of NO for calibration mixtures</td>
</tr>
<tr>
<td>0.1 – 10</td>
<td>batch</td>
<td>distillation of Kr and Xe</td>
</tr>
<tr>
<td>10 – 10⁴</td>
<td>industrial</td>
<td>carbide synthesis of C₂H₂</td>
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<tr>
<td></td>
<td></td>
<td>combustion gas synthesis of HCl-gas</td>
</tr>
<tr>
<td>&gt; 10⁴</td>
<td>large scale</td>
<td>H₂ by steam reforming air separation</td>
</tr>
</tbody>
</table>

With many of these processes there is a dependency on the physical or chemical reactions of the volumetric flow rates in relation to the dimensions of the containers or pipes. Only when the flow is below certain values it is possible to obtain reliable results of distillation, adsorption or catalysis.

Three different technical and physical concepts are commonly used to characterise the volume.

Linear velocity vₑₙ with A as the cross sectional area of the container or pipe which is assumed to be empty can be obtained from the Eq.

\[ vₑₙ = \frac{Qᵥ \cdot p_{atm}}{A \cdot p} \]  

(3-1)
One must be aware of the inversely proportional dependence on pressure $p_{\text{abs}}$. The higher the pressure, the smaller and more advantageous is $v_{\text{lin}}$, which is normally given in $\text{m} \cdot \text{s}^{-1}$.

The dwell time $t_{\text{dwell}}$ gives the period of time, in which an impurity caused by sorption can be kept in the container. We use $s$ for the internal length of the container with $V_{\text{geom}} = A \cdot s$ which is valid exactly only for the cylinder. Thus we obtain the Eq.

$$t_{\text{dwell}} = \frac{s}{v_{\text{lin}}} = \frac{A \cdot s \cdot p_{\text{abs}}}{Q_V \cdot p_{\text{1bar}}}$$

(3-2)

With the gaseous hourly space velocity (GHSV) $v_V$ we get a further specific value for the permitted gas flow in use. The unit is $\text{h}^{-1}$.

$$v_V = \frac{Q_V \cdot p_{\text{1bar}}}{V_{\text{geom}} \cdot p_{\text{abs}}} \left[ \text{h}^{-1} \right]$$

(3-3)

The information provided by manufacturers of zeolites or catalysts normally refers only to atmospheric pressure. Further details will be dealt with in the section “heterogeneous catalysis”. A comparison with Eq. (3-2) shows that $t_{\text{dwell}}$ and $v_V$ behave reciprocally to one another:

$$t_{\text{dwell}} [\text{s}] = \frac{3.6 \cdot 10^3}{v_V [\text{h}^{-1}]}$$

(3-4)

Example E3.1-1: From a cylinder bundle $25 \text{ m}^3 \cdot \text{h}^{-1}$ CO is taken, purified through an adsorption bed to remove (adsorber) iron pentacarbonyl and then recompressed. In the beginning the pressure falls in the adsorption bed from 200 bar to $p_{\text{min}}$ whereby $v_{\text{lin}} \leq 0.25 \text{ m} \cdot \text{s}^{-1}$ is still achieved. The adsorption bed is cylindrical with the internal dimensions: diameter of 12 cm and length $s$ of 90 cm ($V_{\text{geom}} \approx 10 \text{ liter}$). $p_{\text{min}}$ and the appropriate $t_{\text{dwell}}$ have to be calculated.

All sizes are adjusted to $m$ and $s$ and Eq. (3-1) is adapted

$$Q_V = 25 \left[ \text{m}^3 \cdot \text{h}^{-1} \right] = \frac{25}{60 \cdot 60} = 6.94 \cdot 10^{-3} \left[ \text{m}^3 \cdot \text{s}^{-1} \right]$$

$$A = r^2 \cdot \pi = (0.06)^2 \cdot 3.14 = 1.13 \cdot 10^{-2} \left[ \text{m}^2 \right] \quad \text{and} \quad s = 90[\text{cm}] = 0.9[\text{m}]$$

$$p_{\text{min}} = \frac{Q_V}{A \cdot v_{\text{lin}}} = \frac{6.94 \cdot 10^{-3}}{1.13 \cdot 10^{-2} \cdot 0.25} = 2.46[\text{bar (abs.)}]$$

$$t_{\text{dwell}} = \frac{s}{v_{\text{lin}}} = \frac{0.9}{0.25} = 3.6[\text{s}]$$