A Curtain-Gas Filter that Widely Protects Mass Spectrometers from Neutral Molecule Contaminations

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Principle: Ions formed in an electrospray source are pushed from the ion-source buffer gas into the flow of a purified gas that moves them into a mass spectrometer, while the ion-source buffer gas itself moves to an exhaust together with all neutral molecules. Important is here that nonvolatile molecules are barred from entering the mass spectrometer where they could block the gas flow through thin capillaries or diaphragms and cover electrodes with undesired surface layers.

Method
In a curtain-gas filter the ion-source buffer gas streaming out of an electrospray ion source is forced to flow parallel to a flow of purified clean gas for a short distance, while an electric field that is superimposed over both gas flows, moves ions from the ion source buffer gas into the purified clean gas (see Fig.1). This clean gas, that now contains ions, is then allowed to enter the mass spectrometer, while the ion-source buffer gas is passed to an exhaust together with all neutral molecules in this gas flow. Here it is important that nonvolatile molecules are barred from entering the mass spectrometer since they could stop the operation of the mass spectrometer by blocking the gas flow through the inlet capillary or inlet aperture within a few seconds or minutes. This also avoids that these molecules form insulating layers on electrodes within the mass spectrometer.

In a first test the curtain-gas filter was used to analyze neurotensin in a Shimadzu 2010 MS equipped with an electrospray ion source. The obtained mass spectrum is shown in Fig.4. Please notice the convoluted low mass region in its upper mass spectrum and also that in the lower mass spectrum the curtain-gas filter has filtered out most of the low mass high-mobility ions which were mainly solvent and solvent cluster ions, though 40% of the neurotensin ions were still recorded. In another investigation of neurotensin in an ion trap equipped with a curtain gas filter one thus could record neurotensin ions with higher intensity (see Fig.5) when most of the low mass ions were eliminated and so was much of the small ions' space-charge in the ion trap.

In another test the same Shimadzu 2010 MS equipped with an electrospray ion source and a curtain gas filter was used in a 100 hour experiment recording 1ppm papaverine in a 10mM phosphate buffer. Herein over these 100 hours no substantial loss in signal of the 1ppm papaverine sample was observed (see Fig.7) when mass spectra were taken a) at the beginning, b) after 50 hours and c) after 100 hours of the experiment. Under normal operating conditions, however, and without the curtain gas filter, the inlet capillary of the mass spectrometer had been clogged within 10 seconds.

In the experiment with the curtain gas filter phosphate deposits were formed only in the container of the electrospray ion source, while the inlet capillary stayed fully open over the duration of the experiment. Besides the experiments with phosphates we also used solutions of 1000ppm dissolved silica in flow injection studies of pharmaceuticals and found no effects that would deteriorate the recorded mass spectra.

Preliminary Data

Figure 1: Principle of a curtain-gas filter. Shown are two parallel gas flows (1) the gas flow of ion-source buffer gas and (2) the gas-flow of a purified clean gas into which ionized molecules are moved by electric fields from the ion-source buffer gas. Neutral molecules on the other hand will stay in the ion-source buffer gas which moves them to an exhaust.

Figure 2: Illustration of a curtain-gas filter in which the flows of the ion-source buffer gas and of the purified clean gas are annular gas flows formed around the inlet capillary of a mass spectrometer. Please note the black arrows that symbolize electric forces which move ions from the flow of the ion-source buffer gas into the flow of the purified clean gas. This electric field is formed by the potential difference between the extension of the MS inlet capillary and the conical repeller.

In detail the curtain gas filter is built so that the two gas streams have both an annular shape and are arranged to be concentric to the inlet capillary of a Shimadzu 2002MS (see Fig.2) and the electric field is radial and perpendicular to both gas flows. In this arrangement only molecule ions within a certain range of mobilities are passed into the mass spectrometer while ions of very high mobilities are dragged all the way through.

Figure 3: Photograph of a curtain-gas filter, demonstrating its small size of ≈50mm in length and ≈5mm in diameter. Because of this small size it is relatively easy to implement a curtain-gas filter to a capillary or diaphragm inlet of a mass spectrometer.

Figure 4: The mass spectrum of neurotensin as obtained with an electrospray ion source on a Shimadzu 2010 MS equipped without and with a curtain gas filter. Note that in the mass spectrum obtained without a curtain-gas filter (top) a large number of low mass high-mobility ions (i.e. mainly solvent and solvent cluster ions) were recorded, while these ions were eliminated to the largest extent when the curtain-gas filter was used (bottom).

Figure 5: The ion signal in an ion trap with and without a preceding curtain-gas filter:

Figure 6: A 100 hour experiment in which 1ppm papaverine in a 10mM phosphate buffer was electrosprayed into the mass spectrometer. Shown above is the total ion current (black) as well as the ion current of papaverine ions (purple).

Figure 7: Mass spectra of papaverine recorded in the 100 hour experiment shown in Fig.5, obtained at the beginning, in the middle and at the end of the 100 hour experiment, demonstrating that the spectra are all practically identical.

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references

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2. M. Ueda, private communication