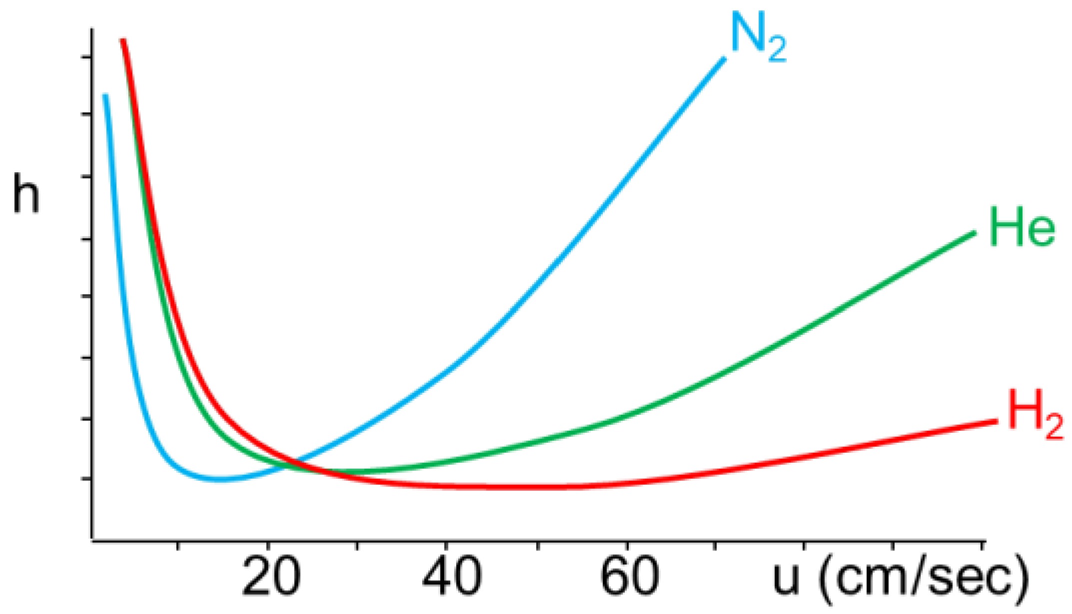
Guest Author – Zachary Woodward, Technical Specialist – Phenomenex USA

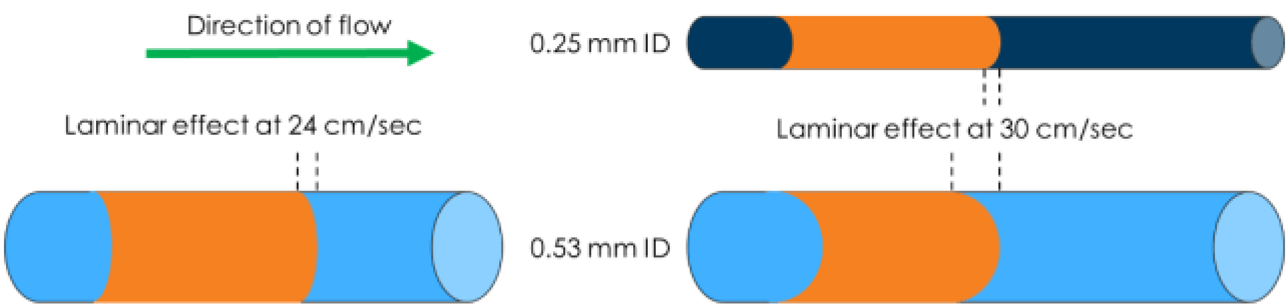
Shorter run-times, sharper peaks, improved resolution, and low costs of carrier gas…we want it all! These goals can seem at odds with each other, but can be achieved with an awareness of gas behavior as it flows through different dimensions of gas chromatography (GC) columns. Nitrogen has been used as a carrier gas with GC columns that feature a narrow internal diameter (ID) to accomplish these goals, and I would like to discuss how this is achieved with respect to the efficiency of different carrier gases and occurrence of laminar effects at different column dimensions.

Nitrogen gas has far more molecular mass than helium or molecular hydrogen. When nitrogen is used as a carrier gas, it will strike the volatilized analytes with greater force than helium. This is particularly important when the analyte is in the middle of transitioning either into or out of the stationary-phase. The collective of molecules that comprise a particular analyte will then spread across a longer length, resulting in band broadening and wider peaks. Imagine trees swaying during a strong wind with rain, and you can see how analyte bands will broaden if nitrogen is flowing through the GC column too quickly. The result is that nitrogen must flow through the column at slower speeds (linear velocity, to be specific) than helium to maintain sharp and efficient peaks.



The larger mass of nitrogen gas actually presents an advantage over helium or hydrogen. Nitrogen yields the most efficient peaks during GC when used at optimal velocity, as the high mass of nitrogen minimizes longitudinal diffusion once the analyte is in the volatilized state. The larger mass of nitrogen forcefully ushers along the volatilized analyte from behind, while also inhibiting particularly energetic molecules of the volatilized analyte from rushing forward. So, how can we use nitrogen without having long run-times? Use a narrower column.

Carrier gas is subject to "laminar" flow effects when passing through a GC column. Laminar effects describe the difference in behavior of gas-flow near the center of a column as opposed to along the interior walls of the column. The gas in the center benefits from both the majority of the force from the pressure at the head of the column, and also benefits from a lack of friction along the inner walls of the column. Conversely, the gas near the walls suffers both of these maladies, resulting in a bulge of the gas near the center. A column with a wider ID presents greater opportunity for this bulge, and the user will need to apply a slower linear velocity when using wider diameters. Laminar effects will not be as pronounced within a column that has a narrow ID, and the user can actually apply a faster linear velocity than is typical for a given carrier gas.



As a quick note, the flow-rate will certainly increase and decrease with a column's ID in the same manner as with HPLC. Typically we will adjust the flow-rate to maintain consistent linear velocity by applying fast flow-rates with wide columns and slow flow-rates with narrow columns. An HPLC column is packed with particles, while a capillary GC column is an open tube, so laminar effects become more of a consideration during GC (at least when using WCOT columns).

If we put all of this together, nitrogen requires a slower linear velocity than helium, but a narrow ID column allows us to increase the linear velocity of the intended carrier gas. Nitrogen has an idealized linear velocity of about 12 cm/sec on a 0.25 mm ID column, but has an ideal linear velocity of about 15 cm/sec on a 0.10 mm ID column. Nitrogen can be run slightly faster than these idealized values and still maintain suitable efficiency that rivals helium when helium is idealized (don’t forget about that lack of longitudinal diffusion when using nitrogen). The end result is that the you may run nitrogen at 18 – 20 cm/sec through a 0.10 mm ID GC column, which is comparable to the 24 cm/sec flow-rate of helium through a wider 0.32 mm ID column.

Nitrogen will generate the sharpest analyte peaks of the three common carrier gases. The only disadvantage of nitrogen is the slower linear velocity needed for optimal efficiency on account of nitrogen’s heavier mass. Laminar flow dynamics allow nitrogen to be run at higher linear velocities when using a GC column with a narrow ID, ultimately leading to shorter run-times while generating sharper peaks and using a safer and cost-effective carrier gas.

Thank you for your consideration, and as always, I wish you very well!

If you have any additional questions regarding the above, or other chromatographic inquires, reach out to our Technical Specialists, like Zach, through our free online chat service – Chat Now.

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