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SUPELCO® Analytical

# Application Note 184

# Hydrogen: A Superior Carrier Gas Alternative to Helium

***Hydrogen has long been considered a great carrier gas choice for temperature-programmed gas chromatography (GC) analyses. However, safety concerns coupled with an abundant supply of helium have resulted in the low usage of hydrogen. With recent disturbances in the worldwide availability of helium, many analysts may wish to reconsider whether hydrogen should be their carrier gas choice.***

## Introduction

Carrier gas for GC use should be an inert gas that does not react with the sample components. Its main role is to transport the vaporized solute molecules through the column. The selection of the carrier gas and the linear velocity being used both affect resolution and retention times.

Nitrogen, hydrogen, and helium are the most widely used gases by today's chromatographer. Each has unique benefits as well as drawbacks. Nitrogen shows the best efficiency, but over a low and narrow linear velocity range. Therefore, it is extremely slow as a carrier gas, and not a great choice for temperature-programmed use. Hydrogen provides the fastest analysis time over a broad linear velocity range. However, safety concerns must be addressed. Helium is a compromise, with efficiency and analysis times between nitrogen and hydrogen. However, it is becoming an expensive choice.

When selecting a carrier gas for temperature-programmed use, hydrogen may be the best overall choice and should be considered for the following reasons.

## Benefits of Hydrogen as a Carrier Gas: Speed 1

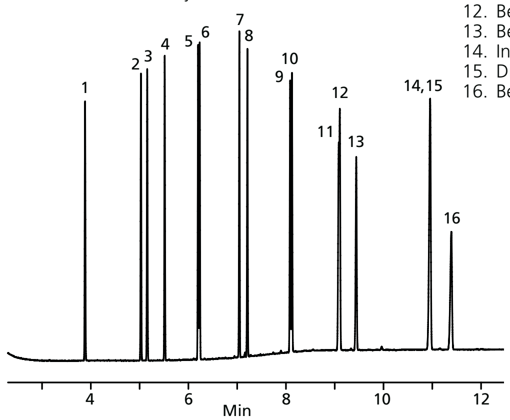
The Golay Theory for open tubular columns predicts that optimum gas velocity is proportional to diffusivity. Hydrogen has a higher diffusivity than helium, thus its optimum linear velocity is higher, and can be used at a higher flow rate without adversely affecting efficiency. Specifically, under isothermal analysis conditions, the typical linear velocity for hydrogen is 40 cm/sec., which is twice the optimum linear velocity of helium at 20 cm/sec. Therefore, simply switching to hydrogen carrier gas, even while keeping column dimensions and oven conditions constant, can be expected to decrease analysis time.

Figures 1 and 2 illustrate this benefit of hydrogen with the separation of 16 commonly analyzed polynuclear aromatic hydrocarbons. The analysis was performed on a 15 m x 0.10 mm I.D., 0.10 µm Equity®-5 column. A fast temperature-programming rate was used to decrease the run time to less than 12 minutes using helium at its optimal linear velocity. Switching to hydrogen carrier gas (at its optimal linear velocity) under the same conditions resulted in a 25% decrease in run time.

### Figure 1. Helium

column: Equity-5, 15 m x 0.10 mm I.D., 0.10 µm (28083-U)
oven: 100 °C (1 min.), 35 °C/min. to 325 °C (5 min.)
inj.: 250 °C
det.: FID, 350 °C
carrier gas: helium, 20 cm/sec., constant
injection: 1 µL, 200:1 split
liner: 4 mm I.D., split, cup design
sample: each analyte at 200 ppm in methylene chloride

1. Naphthalene
2. Acenaphthylene
3. Acenaphthene
4. Fluorene
5. Phenanthrene
6. Anthracene
7. Fluoranthene
8. Pyrene
9. Benzo(a)anthracene
10. Chrysene
11. Benzo(b)fluoranthene
12. Benzo(k)fluoranthene
13. Benzo(a)pyrene
14. Indeno(1,2,3-cd)pyrene
15. Dibenzo(a,h)anthracene
16. Benzo(g,h,i)perylene

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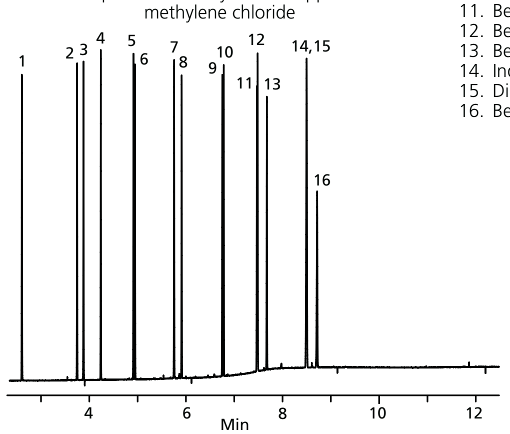
### Figure 2. Hydrogen

column: Equity-5, 15 m x 0.10 mm I.D., 0.10 µm (28083-U)
oven: 100 °C (1 min.), 35 °C/min. to 325 °C (5 min.)
inj.: 250 °C
det.: FID, 350 °C
carrier gas: hydrogen, 45 cm/sec., constant
injection: 1 µL, 200:1 split
liner: 4 mm I.D., split, cup design
sample: each analyte at 200 ppm in methylene chloride

1. Naphthalene
2. Acenaphthylene
3. Acenaphthene
4. Fluorene
5. Phenanthrene
6. Anthracene
7. Fluoranthene
8. Pyrene
9. Benzo(a)anthracene
10. Chrysene
11. Benzo(b)fluoranthene
12. Benzo(k)fluoranthene
13. Benzo(a)pyrene
14. Indeno(1,2,3-cd)pyrene
15. Dibenzo(a,h)anthracene
16. Benzo(g,h,i)perylene

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## Benefits of Hydrogen as a Carrier Gas: Speed 2

What if carrier gas is run at higher than optimal linear velocity to decrease analysis times? Hydrogen, having a flatter Golay curve, may be operated over a wide range of linear velocities while maintaining a low height equivalent to a theoretical plate (HETP). This allows the use of a linear velocity higher than optimal with little decrease in efficiency, resulting in shorter analysis times.

## Benefits of Hydrogen as a Carrier Gas: Cost 1

A shortage of helium began surfacing in 2006. Helium must be extracted from the ground and then refined. However, there are not enough refineries to keep up with the increased demand, such as for applications in the medical, scientific, and industrial fields. As a result, helium is becoming a rare commodity with rising prices. Hydrogen has not seen a drastic rise in price because its production is not dependent on the same factors.

## Benefits of Hydrogen as a Carrier Gas: Cost 2/Safety from using Gas Generators

Because helium generators are not available, it can only be obtained in expensive cylinders. Hydrogen is also available in cylinders, but can also be generated on-demand on-site using a gas generator. Over time, a gas generator will pay for itself compared to purchasing the same volume of gas in cylinders. In addition to being a much more sensible source of gas from a cost standpoint, gas generators are safer, more aesthetically pleasing, take up less space, and do not require the labor needed to move bulky cylinders around the lab.

The biggest concern with any high-pressure cylinder is that a full cylinder may be accidentally knocked over, causing the valve to break off and the cylinder to become airborne, damaging anything and everything in its path. Each time a cylinder is handled, extreme caution must be used. Also, if a high-pressure regulator fails, the full pressure of the cylinder will be released into the system. Very few plumbing systems can withstand pressure of 2000-3000 psi. Such pressures are never encountered with gas generators – as pressures in these systems rarely exceed 125 psi**.** Additional, gas generators store a minimal volume of hydrogen gas.

## Conclusion

Hydrogen has several features (higher optimal linear velocity and flatter Golay curve) that result in desirable benefits (decreased analysis times) when compared to other GC carrier gas choices. If operating exactly at optimal linear velocities, hydrogen results in a faster analysis time. Because hydrogen has the flattest Golay curve, the GC can be operated with an even higher linear velocity without a significant loss in efficiency. As long as the proper safety controls are in place, hydrogen, with its broad working range, is the superior carrier gas choice for most temperature-programmed applications.

## Ordering Information

| Description | Max. Output | Cat. No. |
|---|---|---|
| **Parker PEM and ChromGas Hydrogen Generators** | | |
| Model H2PEM-100, 110-230 volt | 100 mL/min.; 90 psi | 27773-U |
| Model H2PEM-165, 110-230 volt | 165 mL/min.; 90 psi | 27620-U |
| Model H2PEM-260, 110-230 volt | 260 mL/min.; 90 psi | 22751 |
| Model H2PEM-510, 110-230 volt | 510 mL/min.; 90 psi | 22801 |
| Model 9800, 110 volt | 1200 mL/min.; 100 psi | 22835 |
| **domnick hunter NITROX UHP Hydrogen Generators** | | |
| Model 20H, 110-230 volt | 160 mL/min.; 100 psi | 27748-U |
| Model 40H, 110-230 volt | 250 mL/min.; 100 psi | 27749-U |
| Model 60H, 110-230 volt | 500 mL/min.; 100 psi | 27750-U |
| **Premium Grade 304 Stainless Steel Tubing** | | |
| 50 ft. x 1/4 inch (6.35 mm) O.D. x 0.209 inch (5.3 mm) I.D. | | 20527 |
| 50 ft. x 1/8 inch (3.18 mm) O.D. x 0.085 inch (2.1 mm) I.D. | | 20526-U |
| 100 ft. x 1/16 inch (1.59 mm) O.D. x 0.030 inch (0.762 mm) I.D. | | 20553 |
| **Cleaned Copper Tubing** | | |
| 50 ft. x 1/4 inch (6.35 mm) O.D. x 0.190 inch (4.83 mm) I.D. | | 20489 |
| 50 ft. x 1/8 inch (3.18 mm) O.D. x 0.065 inch (1.65 mm) I.D. | | 20488 |
| **Swagelok® Tubing Fittings** | | |
| Swagelok Fittings Kit | | 22668-U |
| Nuts Plus Front and Back Ferrules, brass, 1/8 inch, 10 of each | | 22014 |
| Nuts Plus Front and Back Ferrules, SS, 1/8 inch, 5 of each | | 22040-U |
| Tee, brass, 1/8 inch | | 22020-U |
| Tee, stainless steel, 1/8 inch | | 22046 |
| On/off throttling valve, brass, 1/8 inch | | 22138-U |
| On/off throttling valve, stainless steel, 1/8 inch | | 22139-U |
| Toggle valve, brass, 1/8 inch | | 22699 |
| Toggle valve, stainless steel, 1/8 inch | | 22698 |
| Union, brass, 1/4 inch male NPT to 1/8 inch male, 2 each | | 22066 |
| Union, brass, 1/4 inch female NPT to 1/8 inch male, 2 each | | 21978-U |
| **Diaphragm Shutoff Valves** | | |
| Brass, 1/4 inch male NPT (inlet), 1/4 inch female NPT (outlet) | | 23896 |
| Brass, 1/4 inch male NPT (both ends) | | 23897 |
| **Hydrogen Flash Arrestor** | | |
| Brass, 1/4 inch female NPT (both ends) | | 23315 |
| **In-Line Regulators** | | |
| High purity, single-stage, 1/8 inch male (both ends) | | 23882 |
| Ultra-high purity, single-stage, 1/8 inch male (both ends) | | 23884 |

### Related Information

For information on the principals of Fast GC, including practical considerations, theoretical discussions, a listing of columns in Fast GC dimensions, twenty-six chromatograms, plus a list of literature for additional reading, request "Fast GC: A Practical Guide for Increasing Sample Throughput without Sacrificing Quality" (T407096 JTW).

For information on gas generators, request "Gas Generators: Generate High Purity Gas with Reliability and Safety" (T407110 JXP). Alternatively, visit our website sigma-aldrich.com/gc.

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