

GC Method Development

Simon Jones
GC Application Engineer
GC Columns and Consumables

What to Consider

The Sample

Method of injection

Inlet

Detector

Carrier Gas

Column

COMPOUND REQUIREMENTS FOR GC

Only 10-20% of all compounds are suitable for GC analysis

The compounds must have:

- ✓ Sufficient volatility
- ✓ Thermal stability

NO Inorganic Acids and Bases

Be mindful of salts!

Sample Considerations

1. Sample matrix
 - residues?
 - dirty samples?
2. Analyte Composition
 1. Isomers?
 2. Polar vs. non-Polar?
 3. Organic Acids?
 4. Light Gases?
 5. Nobel Gases?
 6. Halogens?

Sample Residues

Semi-volatile residues

Bake out

Back flush

Non-volatile residues

Guard column

Bake out

Back flush

Dirty Samples

Sample clean up?

Back flush

**We have thought about the sample
...What's next?**

Let's Get the Sample Onto the Column...

Manual Injection

Liquid Injection

Headspace

Purge & Trap

Gas Sampling Valve

SPME

Thermal Desorption

Custom

The Inlet

Volatiles Interface

Cool-On-Column

Purged Packed

PTV

Split / Splitless

Multi-Mode

Volatiles Interface

Used for 'volatile' samples

Sample is already a vapor

Headspace

Purge & Trap

Volatiles Interface

Mode	Sample Concentration	Sample to Column	Comments
Split	High	Very little, most is vented	
Splitless	Low	All	Can switch to split mode electronically
Direct	Low	All	Must physically disconnect split vent, plug the interface, and reconfigure the GC. Maximizes sample recovery and eliminates possibility of contamination to pneumatic system.

Cool-On-Column

- * Good for Labile Samples

 - Sample is deposited “ON” the column

 - Temperature of inlet follows Oven Temperature

- Good for ‘Active’ analytes

 - Minimizes inlet discrimination
 - No inlet Liner*

- Good for Trace Analysis

- Guard Column Highly Recommended

Purged Packed

Good for HIGH flow applications

Used with Packed columns

Can be used with 0.53 mm and 0.32 mm ID columns

****Has a minimal capacity for sample expansion**

****Back Flash****

PTV (Programmable Temperature Vaporization)

Good for Large Volume Injections

Trace Level Analysis

Can be cooled to -160°C with liquid Nitrogen

Can run in hot or cold, Split or Splitless mode

PTV

(Programmable Temperature Vaporization)

Good for Trace Level Analysis – Large Volume Injections

Mode	Sample Concentration	Sample to Column	Comments
Split	High	Very Little	
Pulsed Split	High	Very Little	
Splitless	Low	All	
Pulsed Splitless	Low	All	
Solvent Vent	Low	All	Multiple injections concentrate analytes and vent solvent.

Split / Splitless

Mode	Sample Concentration	Sample to Column	Comments
Split	High	Very Little	
Pulsed Split	High	Very Little	Useful with large injections
Splitless	Low	All	
Pulsed Splitless	Low	All	Useful with large injections. *better transfer of sample to column*

SPLIT INJECTOR

Split Ratio

- Too low: Poor peak shape
 - Column overload
- Too high: Poor sensitivity
 - Wastes carrier gas (gas saver)
- Usually non-linear
 - Do not use ratio as a dilution factor

MINIMUM RECOMMENDED SPLIT RATIO

	mm I.D.	Lowest ratio
Higher flow rates ↓	0.10	1:50 - 1:75
	0.18 - 0.25	1:10 - 1:20
	0.32	1:8 - 1:15
	0.53	1:2 - 1:5

Want to have 20 mL/min flow through the inlet

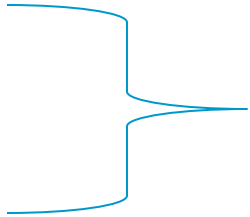
Multimode

Mode	Sample Concentration	Sample to Column	Discussion
Split	High	Low	
Pulsed Split	High	Low	
Splitless	Low	All	
Pulsed Splitless	Low	All	
Solvent Vent	Low	All	Multiple Injections concentrate sample and vent solvent
Direct	Low	All	

Sample Expansion...Liners?

Split / Splitless Inlet

Multimode Inlet



Use the same liners

Packed inlet

PTV

Inlet Liners - Purpose

Glass Inlet Liners provide an “inert” space for liquid samples to be uniformly vaporized to a gas and moved to the column.

Liquid-gas phase change involves a significant change in volume.

Gaseous sample volume depends on

- the solvent type
- column head pressure
- temperature of inlet

These aspects should be optimized for your sample volume and application.

Solvent (1 μ L, ambient)	Volume (μ L at 250°C and 20psig)
n-Hexane	140
Acetone	245
Acetonitrile	350
Methanol	450
Water	1010

See “A Practical Guide to the Care, Maintenance, and Troubleshooting of Capillary GC Systems”, Third Revised Edition, by Dean Rood, Wiley-VCH, New York, 2001.

Liners - 3 Key Aspects Govern Applications

Liner Volume

Liner Treatments or Deactivation

Special Characteristics (glass wool, cup, taper, etc.)

When choosing a liner for your application, consider all three aspects to give you the best chromatography.

You must also determine what type of inlet is in your GC

Then consider the application itself, and the types of liners and injection techniques used for it:

- Split
- Splitless



Liner Volume

Choose a liner with enough volume to accommodate the vaporized sample.

Important, especially for polar solvents with large vapor volumes.

If vapor volume of sample exceeds liner volume, samples may back up (backflash) into carrier gas supply lines, causing ghost peaks and reproducibility problems in chromatography.

Liner Volume (contd.)

Agilent liners are primarily 2mm or 4mm in inner diameter (without tapers and additional features) and 78mm long.

- Thus, 2mm liners hold approx. 0.245 mL or 245 μ L of vapor
4mm liners hold approx. 0.972 mL or 972 μ L of vapor

Recommended injection volumes are 1-2 μ L or less for organic solvents, 0.5 μ L for water.

Liner Volume

How Do we Calculate the Vapor Volume?

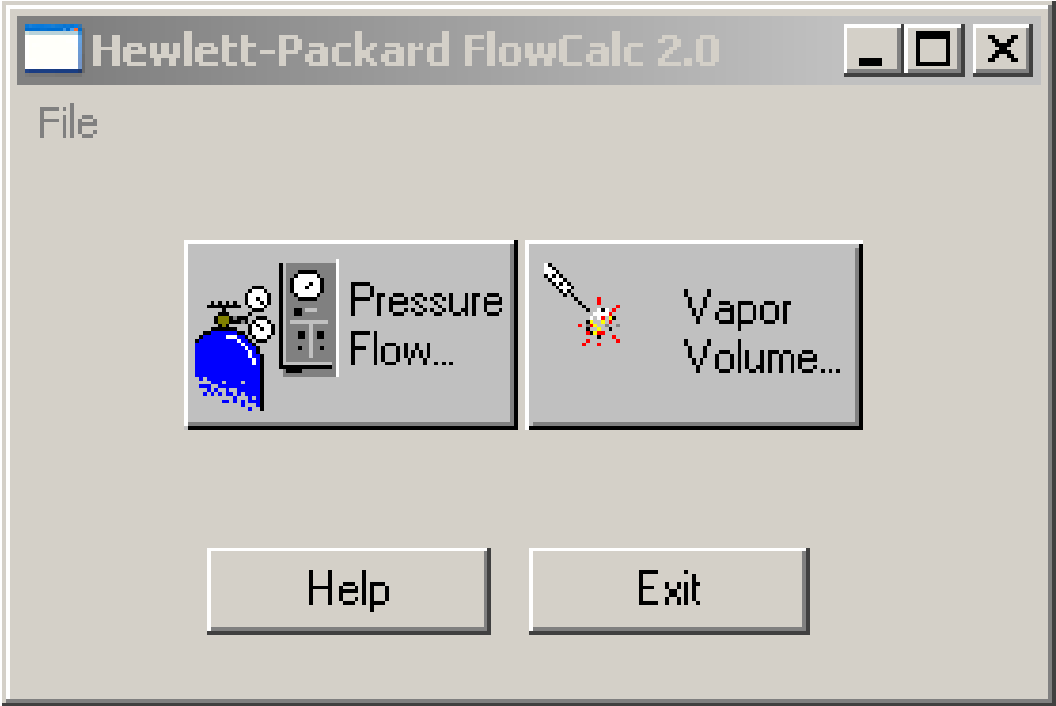
Pressure / Flow Calculator

Free download from our Website

www.chem.agilent.com

<http://www.chem.agilent.com/en-US/Technical-Support/Instruments-Systems/Gas-Chromatography/utilities/Pages/GCPressureFlowCalculatorPCRev205.aspx>

Pressure / Flow Calculator



Determine what the inlet pressure will be:

Column Pressure/Flow Calculator

Column Parameters

Length (m)

i.d. (mm)

Temp (C)

Carrier Gas Parameters

Inlet Pressure (gauge)

Outlet Flow (mL/min)

Average Velocity (cm/s)

Outlet Pressure (Absolute)

1 Atm Vacuum Other

Split Ratio

Split vent flow

Split Ratio(vent flow/col flow) :1

Holdup time

1.67 minutes

Inlet

Inlet Temperature (C)

Inlet Flow (mL/min)

Carrier gas

Helium Opt. Vel. range 20 40

Pressure Units KPa psi bar


Test Inlet Conditions For Solvent Expansion

The screenshot shows the 'Solvent Vapor Volume Calculator' window. At the top, it displays 'Approximate vapor volume(ul): 669 ul' and '79 %' next to a progress bar. Below this are three sliders for 'Injection Volume (ul)' (set to 1.0), 'Inlet Temp (C)' (set to 250), and 'Inlet Pressure' (set to 8.6). The 'Pressure Units' section has radio buttons for 'KPa', 'psi' (selected), and 'bar'. On the right, the 'Solvent Properties' section shows 'Methanol' selected in a dropdown, with 'Boiling Pt (C): 64.7', 'Denisty (g/cm3): 0.791', and 'Mol Wt. (amu): 32'. Below this is a 'Solvents' button with a syringe icon. At the bottom right, the 'Injection Liner' is set to '5183-4647 single-t' with a volume of '850' and 'Capacity limits (%)' of '75' and '100'. Buttons for 'Print', 'Help', 'OK', and 'Edit Liner list' are located at the bottom.

Water as Solvent

Solvent Vapor Volume Calculator [X]

Approximate vapor volume(ul): **1499 ul** **Overload** **176%**



Injection Volume (ul): 1.0

Inlet Temp (C): 250


Inlet Pressure: 8.6

Pressure Units: KPa psi bar

Solvent Properties

Water

Boiling Pt (C): 100
Denisty (g/cm3): 0.998
Mol Wt. (amu): 18.02

 Solvents

Injection Liner Volume (ul)

5183-4647 single-t 850

Capacity limits (%)

75 100

Print Help OK Edit Liner list

Water as Solvent

Cut Injection Volume in Half

The screenshot shows the 'Solvent Vapor Volume Calculator' window. At the top, it displays 'Approximate vapor volume (ul): 750 ul' and '88 %'. Below this is a progress bar. The main interface is divided into several sections: 'Injection Volume (ul)' with a slider set to 0.5; 'Inlet Temp (C)' with a slider set to 250; 'Inlet Pressure' with a slider set to 8.6; 'Pressure Units' with radio buttons for KPa, psi (selected), and bar; 'Solvent Properties' with a dropdown menu set to 'Water' and fields for Boiling Pt (C): 100, Density (g/cm3): 0.998, and Mol Wt. (amu): 18.02; and 'Injection Liner' with a dropdown menu set to '5183-4647 single-t' and a volume field set to 850. There are also buttons for 'Print', 'Help', 'OK', and 'Edit Liner list'. A 'Capacity limits (%)' section shows 75 and 100.

Solvent Vapor Volume Calculator

Approximate vapor volume (ul): **750 ul** **88 %**

Injection Volume (ul): **0.5**

Inlet Temp (C): **250**

Inlet Pressure: **8.6**

Pressure Units: KPa psi bar

Solvent Properties: **Water**
Boiling Pt (C): 100
Density (g/cm3): 0.998
Mol Wt. (amu): 18.02

Solvents


Injection Liner: **5183-4647 single-t** Volume (ul): **850**


Capacity limits (%): 75 100


Print Help OK Edit Liner list

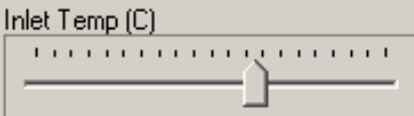
Water as Solvent Pulsed Injection

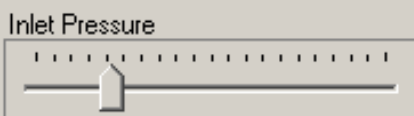
Solvent Vapor Volume Calculator

Approximate vapor volume(ul): **750 ul**  **88 %**




Injection Volume (ul) 

Inlet Temp (C) 


Inlet Pressure 


Pressure Units
 KPa psi bar

Solvent Properties



Boiling Pt (C): 100
Denisty (g/cm3): 0.998
Mol Wt. (amu): 18.02

 Solvents

Injection Liner Volume (ul)
  850

Capacity limits (%)
75 100

Liner Treatments or Deactivation

Minimizes possibility of active sample components from adsorbing on active sites on the liner or glass wool surface.

Unwanted sample adsorption leads to tailing peaks and loss of response for polar compounds.

Although not necessary for all applications, deactivated liners provide added insurance against possible sample adsorption.

Deactivation of borosilicate glass liners is often done with a silylating reagent like Dimethyldichlorosilane (DMDCS)

Special Characteristics

Some liners have special features that are necessary for different injection techniques. For example:

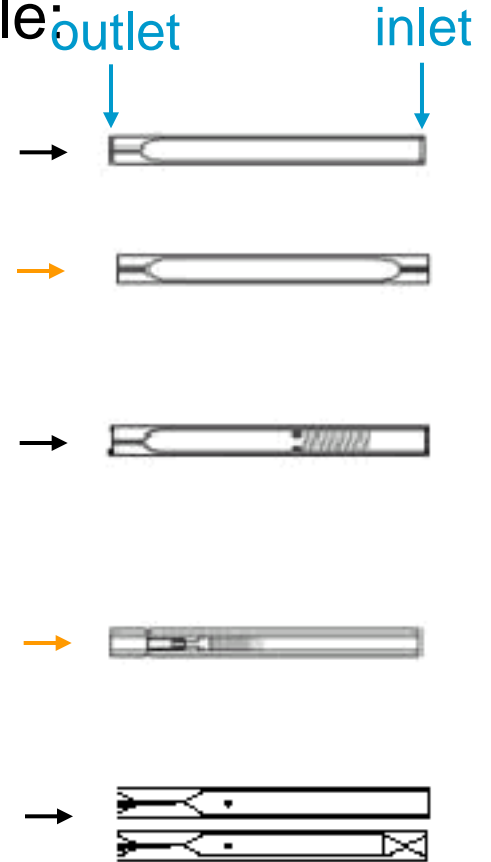
Taper (gooseneck), minimizes sample contact with gold seal.

Dual taper, also minimizes sample contact with inlet weldment and reduces potential for backflash.

Glass wool and shelf to hold it in place, prevents non-volatiles from reaching column and removes residual sample from needle. Glass wool should be deactivated.

Jennings cup, normally used for efficient sample mixing in split inlets, reduces sample discrimination and prevents non-volatiles from reaching the column. Not for very dirty samples.

Press fit (direct) connection end to hold capillary column firmly (virtually all sample goes onto the column). Side hole needed for Electronic Pressure Control with direct connect liners.



Special Characteristics (contd.)




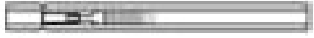
Other special characteristics include:

- Baffles
- Spiral paths
- Glass or ceramic frits or beads
- Laminar cups (elongated version of Jennings cups)
- Column packings with stationary phases





All designed to provide:

- a turbulent sample flow path for sample mixing
- protrusions, barriers, or adsorbents to collect high molecular weight sample components or particles
- surfaces for efficient vaporization of sample components.

Split Injection Liners

Liner	Part No.	Comments
	<p>19251-60540</p>	<p>Simplest split liner, glass wool, no-deactivation, large volume, 990μL volume. Use for general purpose applications for compounds with low glass adsorption activity. Also used for Splitless mode.</p>
 <p>Glass nub</p>	<p>5183-4647</p>	<p>Glass wool (held near needle entrance to remove residual sample on needle), deactivated, 870μL volume. Glass nub ensures that gap remains below liner for split injection. Efficient, for most applications, including active compounds. Fail-safe insertion into injection port. Needle length is important.</p>
	<p>18740-80190</p>	<p>Liner with Jennings cup, no glass wool, 800μL volume. For manual injection only. Use for general purpose applications, high and low MW compounds. Reduces inlet discrimination.</p>
	<p>18740-60840</p>	<p>Liner with Jennings cup, glass wool, and column packing, 800μL volume. For manual injection only. For dirty samples, traps non-volatiles and particulates well. For high and low MW compounds. Not recommended for use with EPC.</p>

Splitless Injection Liners

Liner	Part No.	Comments
	5181-3316	Single taper, deactivated, 900 μ L volume. Taper isolates sample from metal seal, reducing breakdown of compounds that are active with metals. For trace samples, general application.
	5062-3587	Single taper, deactivated, with glass wool, 900 μ L volume. Glass wool aides volatilization and protects column. For trace (dirty) samples.
	5181-3315	Double taper, deactivated, 800 μ L volume. Taper on inlet reduces chance for backflash into carrier gas lines. High efficiency liner for trace, active samples.
 <p style="color: red; margin-left: 20px;">↖ Side hole</p>	G1544-80730 G1544-80700	Direct connect liners, single and dual taper, deactivated. Capillary column press fits into liner end, eliminating sample exposure to inlet. Ultimate protection for trace, active samples. Side hole permits use with EPC.

GLASS WOOL

Liner Packing Recommendations

Amount, size and placement must be consistent for consistent results

Can be broken upon installation into the liner, exposing active sites

Liner deactivation with glass wool plug in place is ideal

GLASS WOOL

Placement in Liner

Near top of liner:

- Wipes syringe needle of sample
- Can improve injector precision
- Helps to prevent backflash

Near bottom of liner:

- Helps in volatilization of high MW components
- Increases mixing

Both positions help retain some non-volatile residues from reaching the column

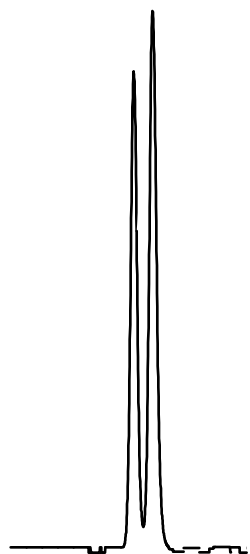
Carrier Gas Considerations

- Carries the solutes down the column
- Selection and velocity influences efficiency and retention time

RESOLUTION VS. LINEAR VELOCITY

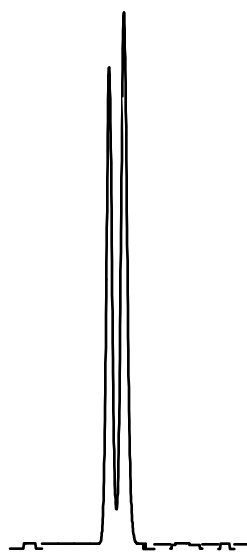
Helium

Resolution of 1.5 = baseline resolution



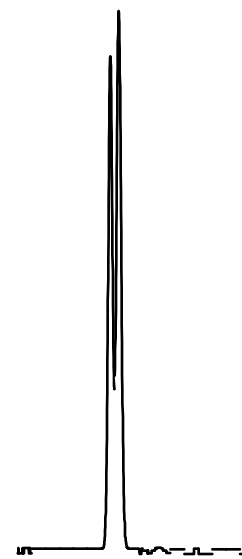
$R = 1.46$
30 cm/sec

4.4 psig



$R = 1.31$
35 cm/sec

5.1 psig

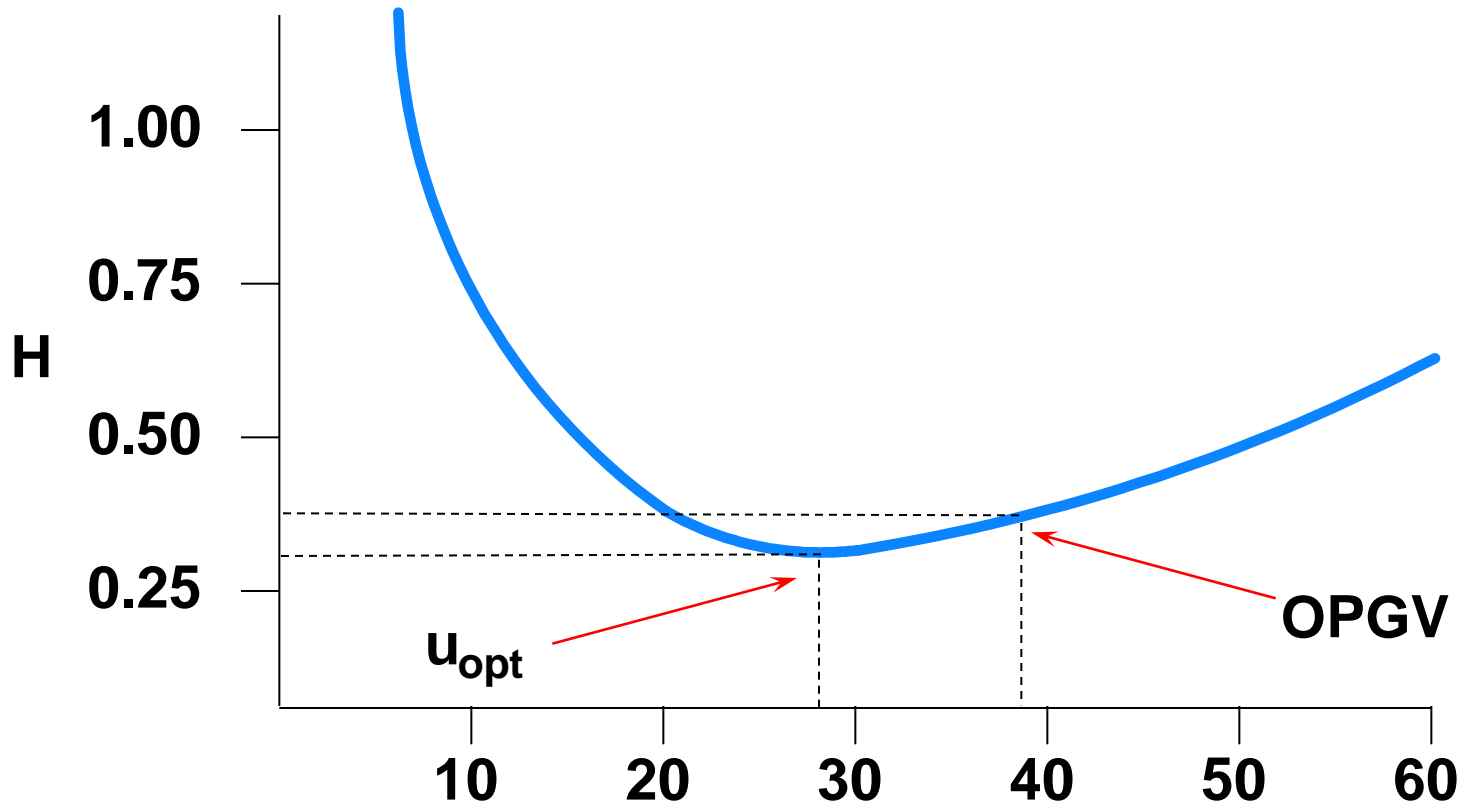


$R = 0.97$
40 cm/sec

5.8 psig

DB-1, 15 m x 0.32 mm ID, 0.25 μ m
60°C isothermal
1,3- and 1,4-Dichlorobenzene

VAN DEEMTER CURVE



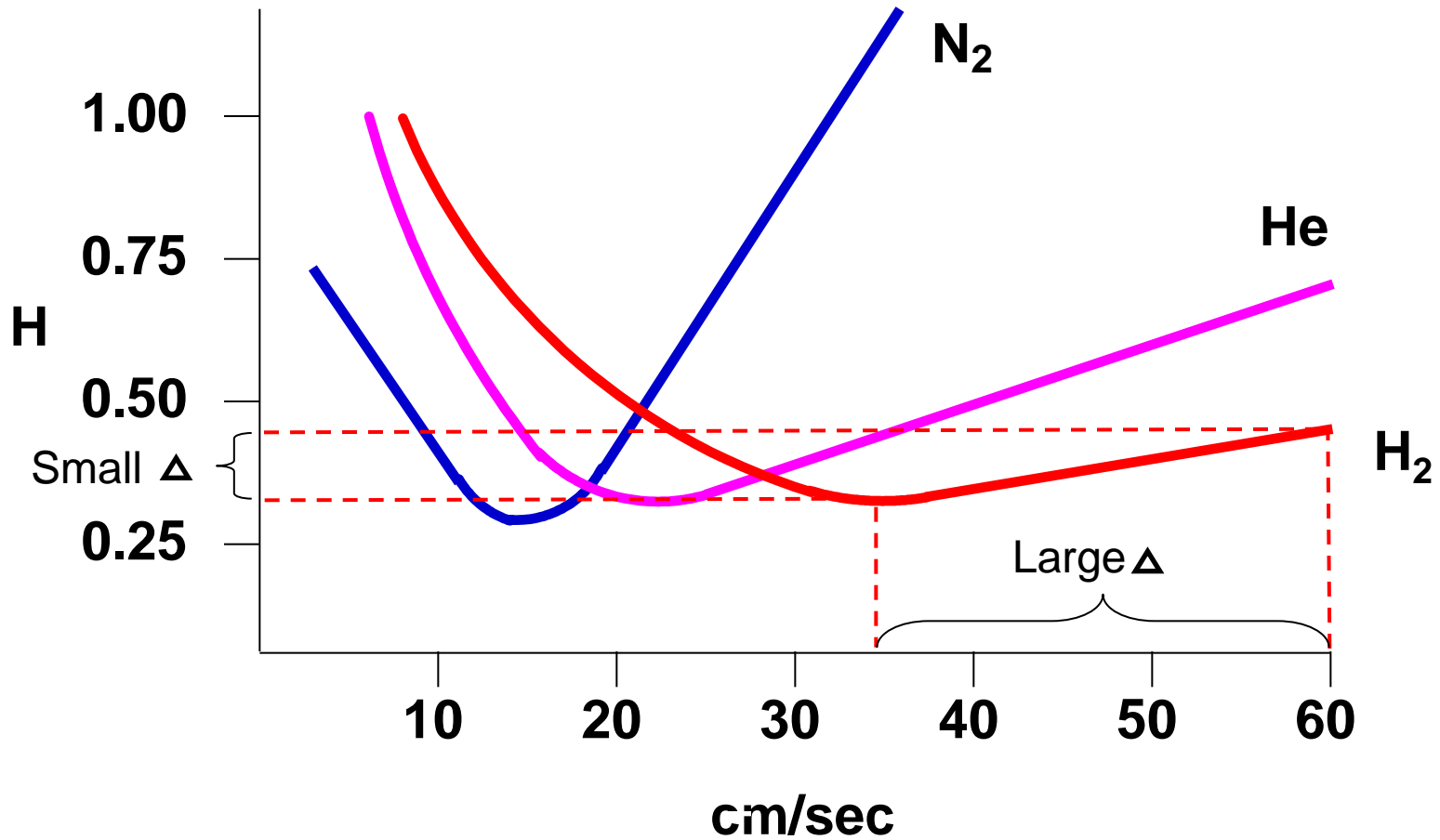
\bar{u}_{opt} and OPGV

\bar{u}_{opt} : Maximum efficiency

OPGV: Optimal practical gas velocity
Maximum efficiency per unit time

$$1.5 - 2x \bar{u}_{opt}$$

VAN DEEMTER CURVES



What Happens to the Flow as Oven Temp Increases?

The screenshot shows the 'Column Pressure/Flow Calculator' window with the following settings:

- Column Parameters:**
 - Length (m): 30.0
 - i.d. (mm): 0.320
 - Temp (C): 50
- Carrier Gas Parameters:**
 - Inlet Pressure (gauge): 8.6
 - Outlet Flow (mL/min): 1.75
 - Average Velocity (cm/s): 30.0
 - Outlet Pressure (Absolute): 14.7
- Split Ratio:**
 - Split vent flow: 0.0
 - Split Ratio (vent flow/col flow): :1
- Holdup time:** 1.67 minutes
- Inlet:**
 - Inlet Temperature (C): 175
 - Inlet Flow (mL/min): 1.81
- Carrier gas:** Helium (Opt. Vel. range: 20-40)
- Pressure Units:** psi (selected)

Buttons at the bottom include: 1 Atm, Vacuum, Other, Help, Plot..., Print, and OK.

Carrier Gas: Constant Pressure

Column Pressure/Flow Calculator

Column Parameters

Length (m)

i.d. (mm)

Temp (C)

Carrier Gas Parameters

Inlet Pressure (gauge)

Outlet Flow (mL/min)

Average Velocity (cm/s)

Outlet Pressure (Absolute)

1 Atm Vacuum Other

Split Ratio

Split vent flow

Split Ratio(vent flow/col flow) :1

Holdup time

Inlet

Inlet Temperature (C)

Inlet Flow (mL/min)

Carrier gas

Opt. Vel. range

Pressure Units

KPa psi bar

Carrier Gas: Constant Flow

Column Pressure/Flow Calculator

Column Parameters

Length (m)

i.d. (mm)

Temp (C)

Carrier Gas Parameters

Inlet Pressure (gauge)

Outlet Flow (mL/min)

Average Velocity (cm/s)

Outlet Pressure (Absolute)

1 Atm Vacuum Other

Split Ratio

Split vent flow

Split Ratio(vent flow/col flow) :1

Holdup time

Inlet

Inlet Temperature (C)

Inlet Flow (mL/min) 1.24

Carrier gas

Opt. Vel. range 20 40

Pressure Units

KPa psi bar

Detectors

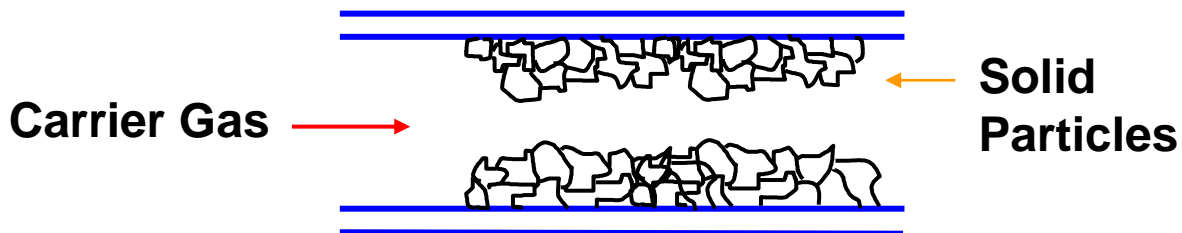
Detector	Dynamic Range		MDL
TCD	10^5	Universal	400 pg Tridecane
FID	10^7	Responds to C-H bonds	1.8 pg Tridecane
ECD	5×10^5	Responds to free electrons	6 fg/mL Lindane
NPD	10^5	Specific to N or P	0.4 pgN/s 0.06 pg P /s
FPD	10^3 S, 10^4 P	Specific to S or P	60 fg P/s 3.6 pg S/s
SCD	10^4	Specific & Selective to S	0.5 pg S/s
NCD	10^4	Specific & Selective to N	3 pg N/s
MSD		Universal	S/N 400:1 1 pg/uL OFN

Selecting the RIGHT Column

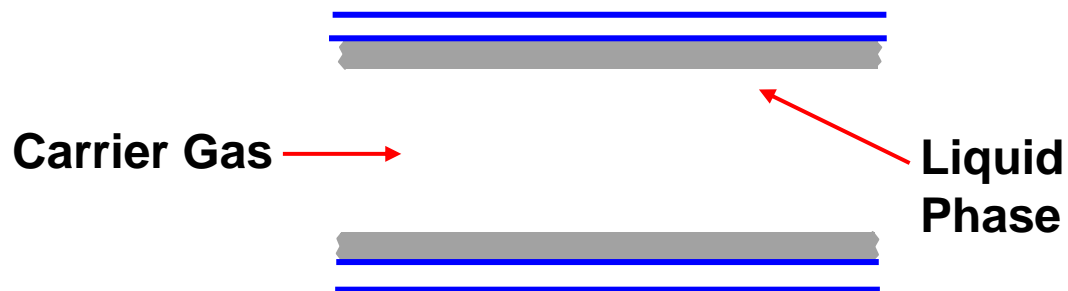
Understanding the Stationary Phase

CAPILLARY COLUMN TYPES

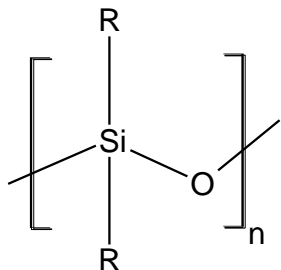
Porous Layer Open Tube (PLOT)



Wall Coated Open Tube (WCOT)

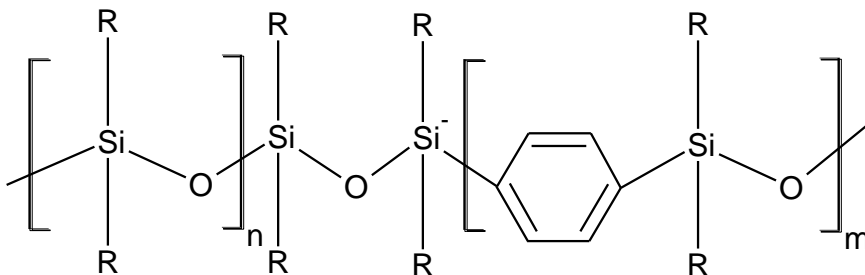


STATIONARY PHASE POLYMERS

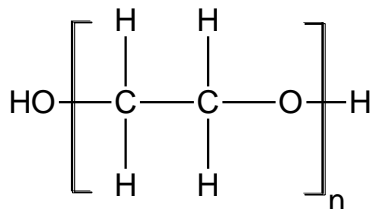


**R= methyl, cyanopropyl, cyanopropylphenyl,
trifluoropropyl**

Siloxane



Arylene



Polyethylene glycol backbone

Selectivity Interactions

- Dispersion
- Dipole
- Hydrogen bonding

Selectivity

Interaction Strengths

Phase	Dispersion	Dipole	H Bonding
Methyl	Strong	None	None
Phenyl	Strong	None	Weak
Cyanopropyl	Strong	Strong	Moderate
Trifluoropropyl	Strong	Moderate	Weak
PEG	Strong	Strong	Moderate

Selecting the Correct Column

Match analyte polarity to column polarity

‘Like dissolves like’

Look for unique interactions that analytes may have with a phase

Use preexisting information

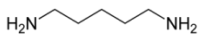
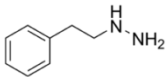
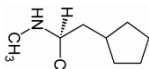
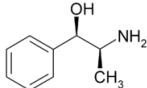
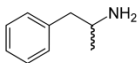
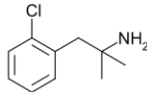
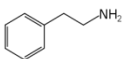
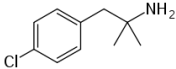
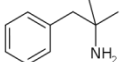
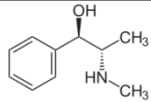
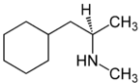
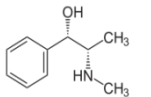
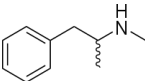
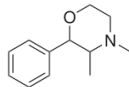

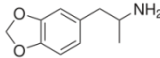

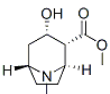
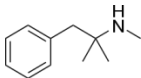
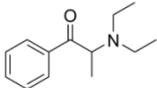
Use the column selection tool:

<http://selectgc.chem.agilent.com/>



Now Let's Apply What We learned

Sample List (drugs)

1. Cadaverine		11. Phenelzine	
2. Cyclopentamine		12. Phenylpropanolamine	
3. Amphetamine		13. Clortermine	
4. Phenethylamine		14. Chlorphentermine	
5. Pentermine		15. Ephedrine	
6. Propylhexedrine		16. Pseudoephedrine	
7. Methamphetamine		17. Phendimetrazine	
8. Methenamine		18. MDA	
9. Amantidine		19. Ecgonine methyl ester	
10. Mephentermine		20. diethylpropion	



Starting Method Parameters

Column: DB-5 30m X 0.32mm X 0.25um

S/SI Inlet: Split 50:1 Temp 250°

FID: Temp 350°

Carrier: He

Constant flow 30 cm/sec

Oven: 50°C Hold for 5 min

10°C/min to 325°C Hold for 5 min

Am I Going to Have Backflash?

Column Pressure/Flow Calculator

Column Parameters

Length (m)

i.d. (mm)

Temp (C)

Carrier Gas Parameters

Inlet Pressure (gauge)

Outlet Flow (mL/min)

Average Velocity (cm/s)

Outlet Pressure (Absolute)

1 Atm Vacuum Other

Split Ratio

Split vent flow

Split Ratio(vent flow/col flow) :1

Holdup time

1.67 minutes

Inlet

Inlet Temperature (C)

Inlet Flow (mL/min)

Carrier gas

Opt. Vel. range

Pressure Units

KPa psi bar

Injection Volume / Solvent Expansion

The screenshot shows the 'Solvent Vapor Volume Calculator' window. At the top, it displays 'Approximate vapor volume(ul): 669 ul' and '79 %'. Below this is a progress bar. The main interface is divided into several sections: 'Injection Volume (ul)' with a slider set to 1.0; 'Inlet Temp (C)' with a slider set to 250; 'Inlet Pressure' with a slider set to 8.6; 'Pressure Units' with radio buttons for KPa, psi (selected), and bar; 'Solvent Properties' for Methanol, showing Boiling Pt (C): 64.7, Density (g/cm3): 0.791, and Mol Wt. (amu): 32; and 'Injection Liner' with a dropdown set to '5183-4647 single-t' and a volume of 850 ul. A 'Capacity limits (%)' table shows 75 and 100. Buttons for 'Print', 'Help', 'OK', and 'Edit Liner list' are at the bottom.

Solvent Vapor Volume Calculator

Approximate vapor volume(ul): 669 ul 79 %

Injection Volume (ul) 1.0

Inlet Temp (C) 250

Inlet Pressure 8.6

Pressure Units
 KPa psi bar

Solvent Properties
Methanol
Boiling Pt (C): 64.7
Density (g/cm3): 0.791
Mol Wt. (amu): 32

Solvents

Injection Liner Volume (ul)
5183-4647 single-t 850

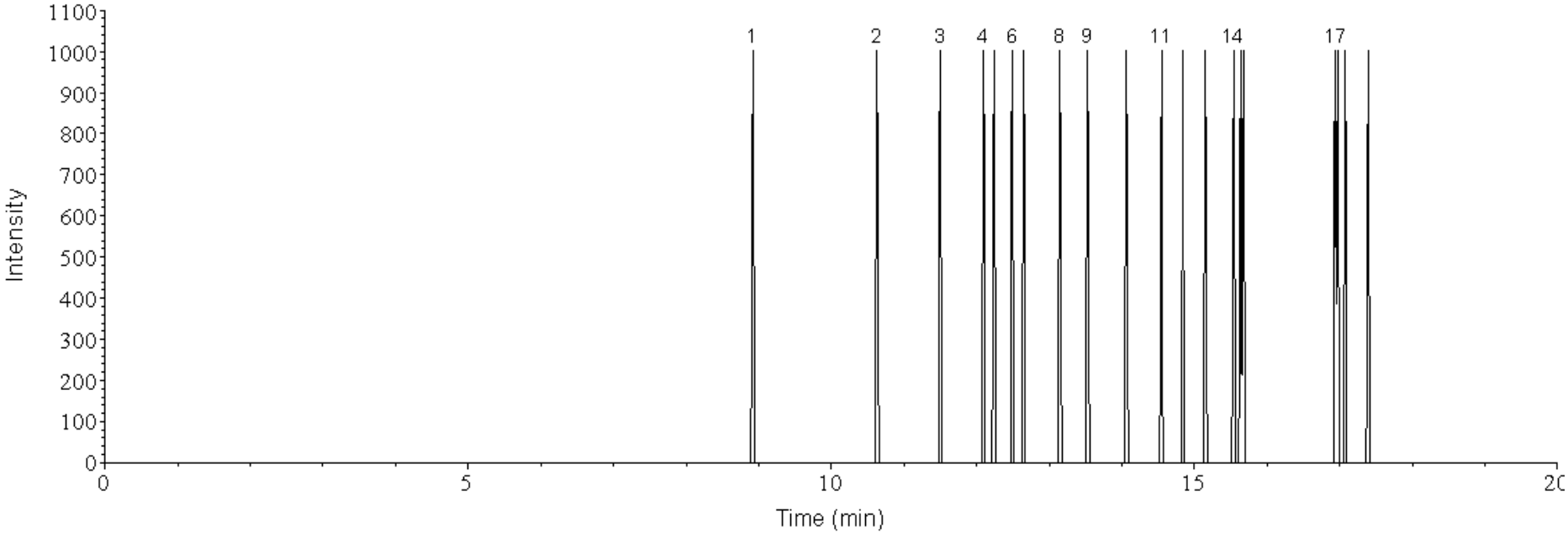
Capacity limits (%)
75 100

Print Help OK Edit Liner list

Developing Temperature Program

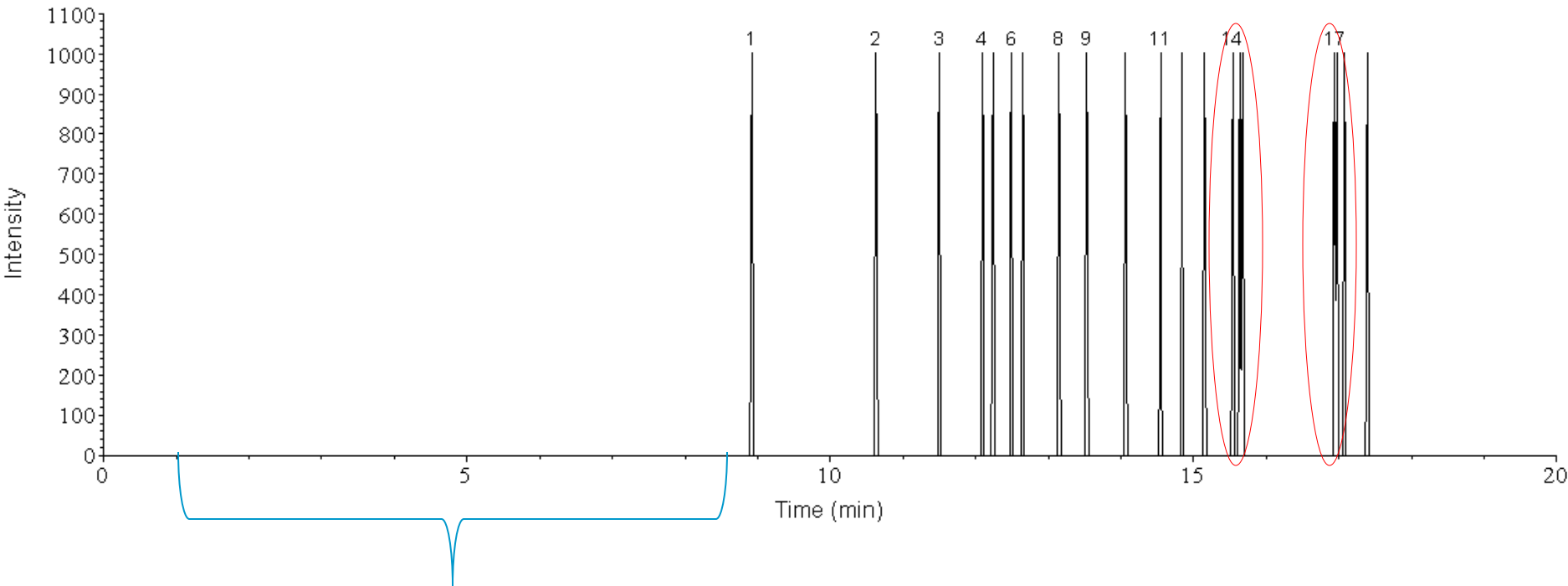
Initial Run

Initial Temp 50°C Hold for 5 min
Ramp 10°C/min to 325°C Hold for 5 min



Developing Temperature Program

Initial Run - Define Areas for Improvement



Next Step...

When does the first peak come out?

~9 minutes

What temperature does it come out at?

Temp program:

50°C for 5 minutes

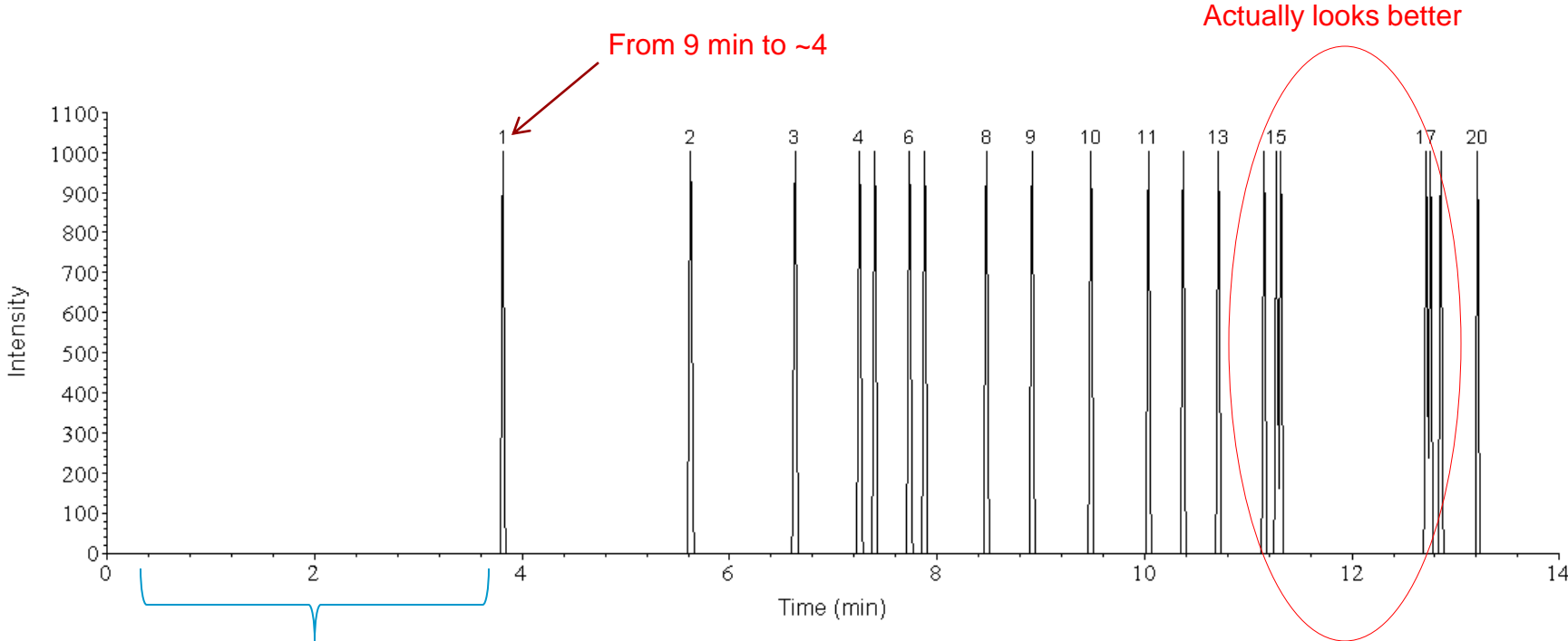
10°C to 325°C

1st Peak comes out at 90°C

Developing Temperature Program

2nd Try

Initial Temp 90°C Hold for 5 min
Ramp 10°C/min to 325°C Hold for 5 min

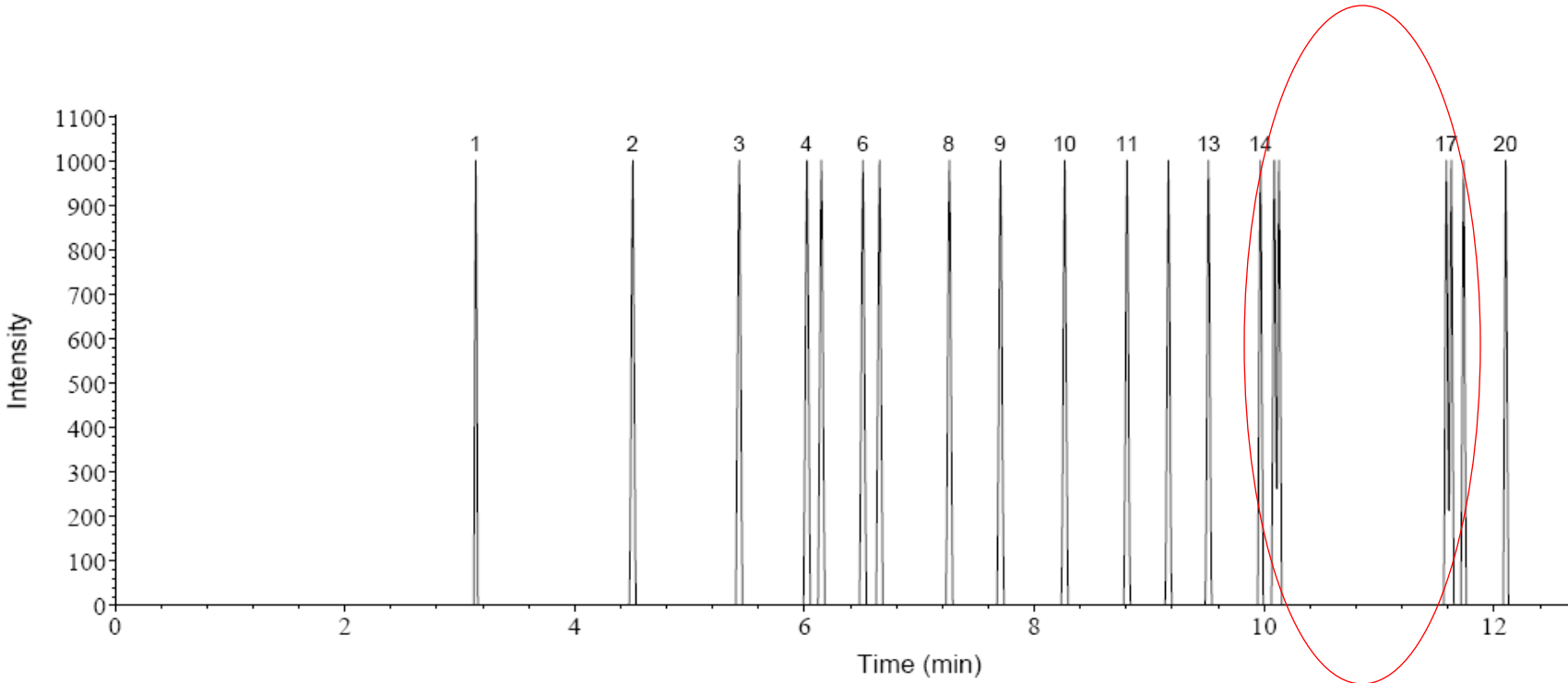


Developing Temperature Program

3rd Try

Initial Temp 100°C Hold for 5 min
Ramp 10°C/min to 325°C Hold for 5 min

Time to resolve these peaks



Resolve Co-elutions

Add a hold 20-30° below the elution temperature

Co-elutions occur at 10 minutes

100°C hold for 5 minutes

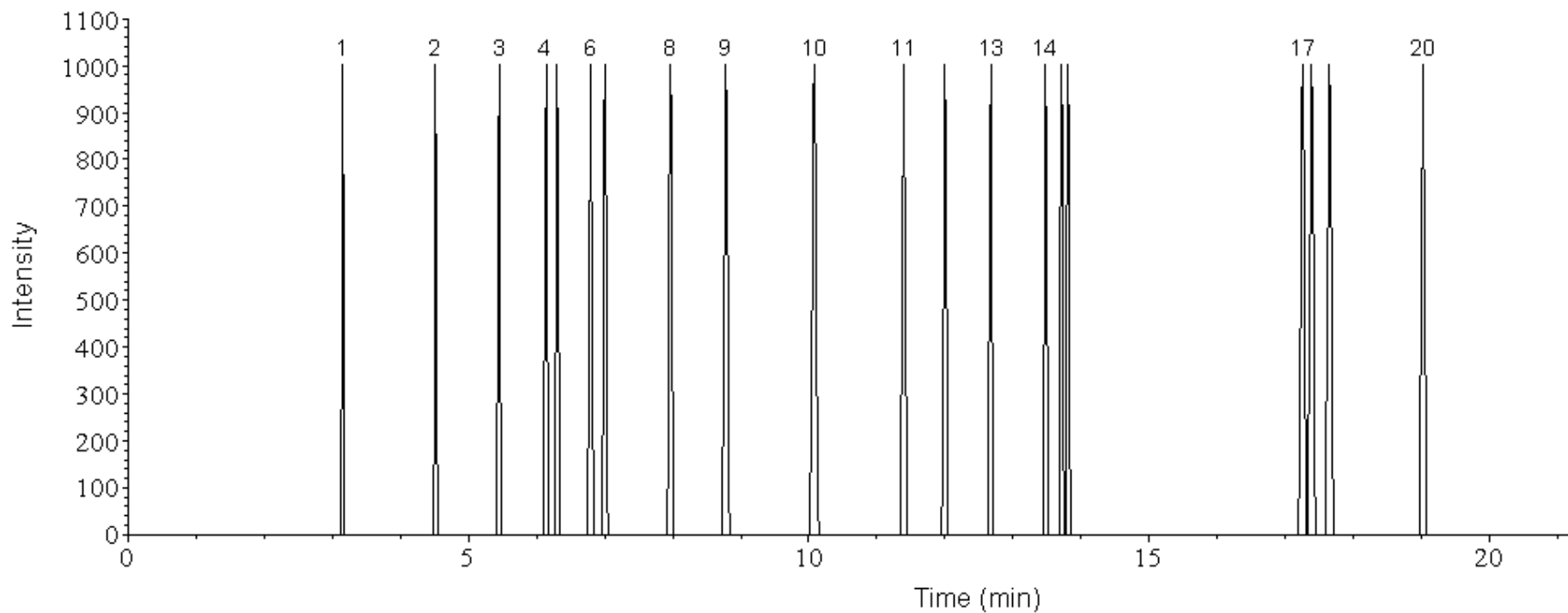
10°C/min to 325°C

Co-elutions occur at 150°C

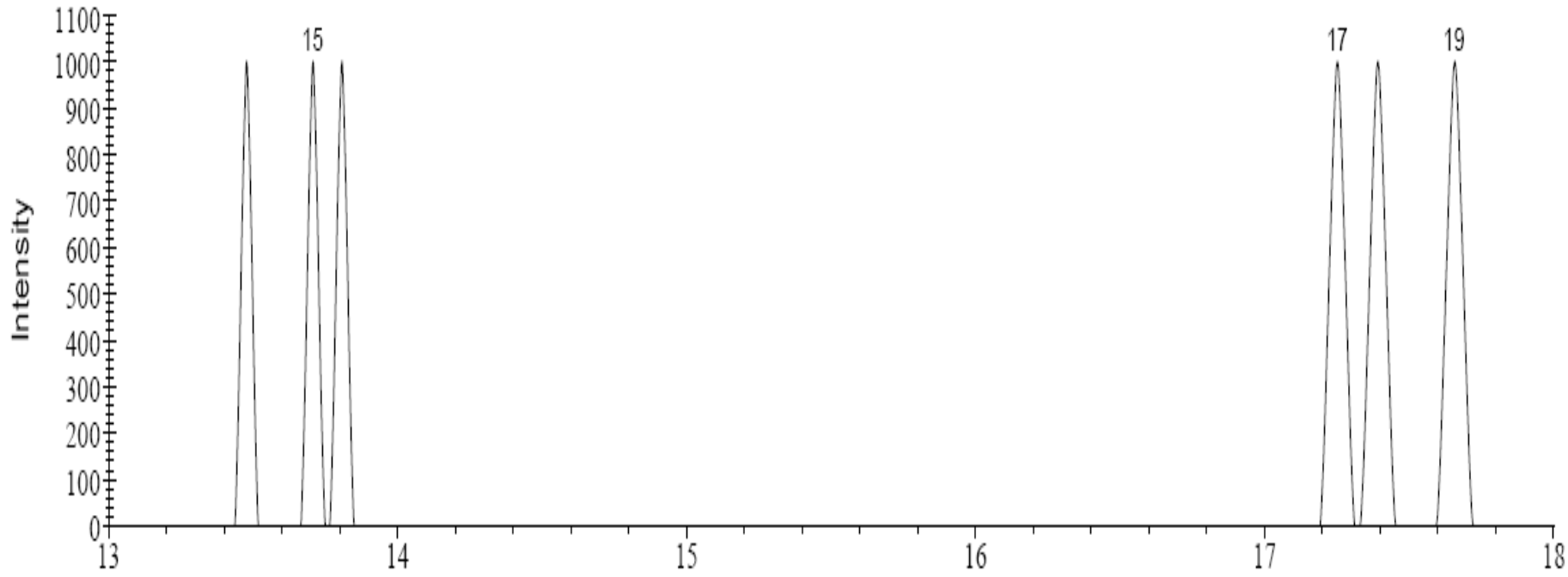
Set hold at 130°C

Developing a Temperature Program

Oven: 100°C Hold for 10 minutes
10°C/min to 130°C hold for 5 min
10°C/min to 325°C



Developing a Temperature Program



Conclusions:

Think about the sample first

****Is it chromatographable by GC?**

sample composition

sample clean up

level of detection

Use information sources first when choosing a column

Mild oven program to begin with

Utilize Technical Support

Conclusions: Starting Parameters

--Assuming S/SI – FID system

Inlet Temp: 250°C

Split 50:1

Carrier Gas: Helium ~ 30 cm/sec, Hydrogen ~45 cm/sec

Oven Temp: 40°C hold for 5 minutes

10°C/min Ramp to Isothermal Limit of column

hold for 5-10 minutes

Detector Temp: 20°C above the highest oven temp

Agilent J&W Scientific Technical Support

800-227-9770 (phone: US & Canada)*

** Select option 3, then 3, then 1.*

866-422-5571 (fax)

GC-Column-support@agilent.com



www.chem.agilent.com