When developing a method for gas chromatography, three important considerations are:

1. Instrumentation.
2. Column selection.
3. Parameter optimization for rapid, high-quality separations.

1. + 2. Considerations for Instrumentation and Column Selection

Sample Injection

To analyze a new type of sample, the first thing to consider is the volatility of your sample. The table below outlines the recommendations according to sample volatility.

	Volatile Samples	Medium Volatility Samples	High/Very High Boiling Samples
Boiling Point Range.	Gaseous or easy to vaporize samples.	Boiling point range 50 – 300 °C.	Boiling point above 250 °C.
Sample Example.	Volatiles in drinking water, Residual solvents in pharmaceuticals.	EPA Semi-volatiles, Diesel Analysis, Pesticides, FAME's, Fragrances.	Simulated Distillation, Wax Analysis, Triglyceride Analysis.
System Requirements.	Cooling may be required for the GC oven.	Proper combination of inlet liner and injector mode.	Proper combination of inlet liner and injector mode.
Injection Recommendation.	Direct injection may work for some aqueous samples. Please see further recommendations for non-liquid techniques.	1) Split Injection. This should be adjusted according to the inner diameter of the column. 2) Splitless Injection is recommended for Trace Analysis. More complicated due to high level of accuracy required when setting parameters.	On Column Injection
Liner Recommendation.	ConnecTite liner.	FocusLiner™ (containing deactivated quartz wool).	Tapered FocusLiner™.
Septa Recommendation.	Septa with temperature rating up to 200 °C.	Septa with temperature rating up to 300 °C.	High temperature septa up to 400 °C.
Further Recommendations.	Head Space or Purge and Trap unit will enable automation of the analysis – for this a narrow bore inlet liner would be recommended	Large volume injection may be considered as an injection method to enhance sample sensitivity.	PTV (Programmable Temperature Vaporizer) inlet may be used. Two basic types – split or direct inject.

Detector Selection

For your instrumentation, you need to consider which detector will be suitable to determine the compounds of your sample. Most widely used as universal detectors are the FID and the MS, but you may consider using other detectors for specific requirements like ECD, TCD, FPD, or more sophisticated detectors.

Column Dimensions

The best column dimension selection is based on:

1. Detector type – determines column ID.
2. Number of compounds to analyze will determine column length.
3. Sample volatility impacts on film thickness required.

Remember, the best result will be with the shortest column and thinnest film your sample allows.

	Atmospheric Detectors	MS Detectors
Column ID	0.18 mm – 0.53 mm	0.1 mm – 0.32 mm

Number of compounds in sample	Small number of compounds with wide range of boiling points/chemical properties	Number of compounds between 10 to 50	Number of compounds greater than 50
Column Length	10 m to 15 m	30 m	50 m or 60 m (rare cases, lengths of 100 m or 120 m can be used)

Sample Type	Volatile	Classical Volatiles (boiling points between 5 °C and 175 °C)	Wide Range of Medium Boiling Compounds	High Boiling Point Compounds
Film Thickness	Thicker films required to retain the compounds sufficiently for separation. 3 µm to 5 µm films or PLOT (Porous Layer Open Tubular)	1 µm to 2 µm films	0.25 µm	Thin film 0.1 µm

Column Phase

When selecting the column phase you need to consider the composition of the sample. Does the sample consist predominantly of non-polar, medium polar or strongly polar compounds?

Compound Polarity	Non-Polar Compounds	Medium Polar Compounds	Strongly Polar Compounds (short chain) (alcohols, aldehydes, esters, ketones and the medium boiling aromatic)
Phase Polarity Recommendation	Non-polar	Medium polar	Polar
Phase Type	100% Methyl Polysiloxane	5% Phenyl Polysiloxane	Polyethylene Glycol (wax)
Recommended Columns	BP1 and SolGel-1ms™	BP5 and BPX5	BP20 and SolGel-WAX™

There is one general column that can be used for a wide range of standard samples - this is a 30 m BPX5 column with 0.25 mm ID and 0.25 µm standard film thickness. With this column you will be able to perform up to 80% of general sample analysis. For more information on SGE GC Column phase polarity see pages 76-80.

3. Parameter Optimization for Rapid, High-quality Separations

Carrier Gas and Velocity

The first choice to be made is the selection of the carrier gas and the setting of the carrier gas velocity.

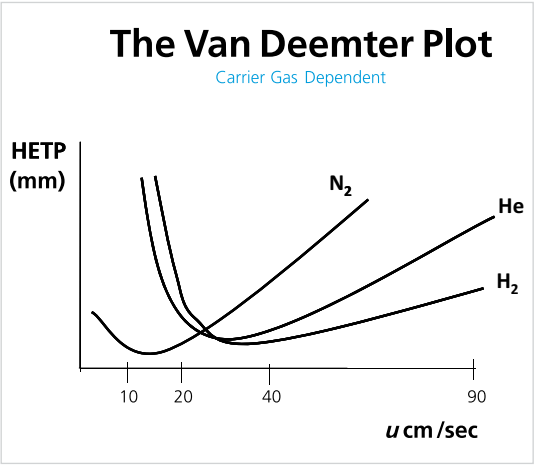
	Nitrogen	Helium	Hydrogen
Renewable Resource	Yes	No	Yes
Optimum Gas Velocity	10 to 15 cm/sec	30 to 35 cm/sec	40 to 45 cm/sec
Analysis Time Based on Optimum Gas Velocity	Long	Medium	Short
Limitations	Long analysis times	Expensive	Risk of explosion should column break, if more than 4% of Hydrogen in air
Minimization of Limitations	-	-	1) Use of Hydrogen generator which has a flow regulator and a safety "Shut Off" if too much Hydrogen is present 2) Safety system, which controls the air in the GC oven and shuts the heating and the carrier gas off, if the Hydrogen content in the oven air goes over 2 - 3% (which is below the level where an explosive mixture can be formed)
Best Suited For	Mixtures with small number of compounds that can be analyzed isothermally	GC/MS as Helium is easier for vacuum systems to pump off and has also some advantages in standard GC usage	Narrow bore columns

The optimum average gas velocity can be determined using the Van Deemter Equation:

$$HETP = A + B/u + Cu$$

HETP = Height equivalent to a theoretical plate
A = Eddy diffusion
B = Longitudinal diffusion
C = Resistance to mass transfer
u = Mobile phase velocity

Using this equation, Van Deemter Plots can be calculated (see figure to the right).



Time (seconds) needed for a non-retained compound to elute at optimum gas velocity

Column Length (m)	Helium (25 cm/sec)	Hydrogen (40 cm/sec)
12	50	30
15	60	37
25	100	60
30	120	73
50	200	120
60	240	146

Retention time in seconds (dead volume) for a non-retained compound.

Column Length (m)	He Carrier Gas (24 cm/sec)	H_2 Carrier Gas (40 cm/sec)
12	48	29
15	60	37
25	100	60
30	120	73
50	200	120
60	240	146
100	400	240

Average column flow (mL/min) for various column diameters and average linear velocities.

Column ID (mm)	Flow Velocity (cm/sec)									
	10	20	25	30	35	40	50	60	70	80
0.1	0.05	0.09	0.12	0.14	0.16	0.19	0.24	0.28	0.33	0.38
0.15	0.11	0.21	0.27	0.32	0.37	0.42	0.53	0.64	0.74	0.85
0.22	0.23	0.46	0.57	0.68	0.80	0.91	1.14	1.37	1.60	1.82
0.32	0.48	0.97	1.21	1.45	1.69	1.93	2.41	2.90	3.38	3.86
0.53	1.32	2.65	3.31	3.97	4.63	5.29	6.62	7.94	9.27	10.59

Note: Average column flows listed are calculated values from respective average column velocities and not absolute measurements.

$$F\,(mL/\text{min}) = F\,(cm/\text{sec}) \bullet 60\,\pi\left(\frac{d}{20}\right)^2$$

where d = column I.D. (mm)
Conversely, the conversion from cm/s to ml/min is given by:

$$F\,(cm/\text{sec}) = \frac{F\,(mL/\text{min})}{60\,\pi\left(\frac{d}{20}\right)^2}$$

Oven Temperature

	Isothermal Conditions	Temperature Program
Sample Type	Use for simple mixture	Use where the last eluting compound needs more time for elution and gives a broad peak, or where there is a separation problem in the area of the low boiling compounds.
Suited For	Split	Direct
Temperature Settings	Starting temperature - boiling point of the major compounds. If complete separation is occurring, the temperature can be increased. If there appears to be lack of separation then lower the temperature.	Temperature program should start as low as needed to separate the early eluting compounds. Temperature then increases at a certain rate to achieve the separation in the middle part of the chromatogram. The final temperature should be sufficiently high to ensure the last compound elutes within the temperature program. Going higher but staying below the maximum usage temperature of the phase and having an isothermal period at the end, helps to bake out high boiling compounds. An isothermal period at the beginning of the program improves the separation of low boiling compounds, but should be kept as short as possible.
Advantages	Samples can be run in series without having to accommodate a cooling cycle for the GC oven. Lifetime of the column will be extended provided it is not contaminated with high boiling point compounds.	Analysis can then be optimized by adjusting the temperature parameters as specified above. Fine tuning can include a two step temperature program, or including an isothermal plateau. If there is sufficient separation, the temperature rate can be increased to shorter retention times, giving you increased sample throughput.

Detector and Injector Temperatures and Split Ratio

Parameters to Set	Considerations
Detector Temperature	Should be set at least as high or slighter higher than the end temperature of the temperature program.
Injector Temperature	Set to approximately the same temperature as oven temperature - high enough to vaporize the whole sample in a short time, however, can be limited if some of the sample compounds are thermally labile. The lower the injector temperature to evaporate your sample the better for consistent analysis.
Split Ratio	Setting a low value (5:1 or 10:1) will result in poor sample transfer and broad peaks. Setting a high value will cause loss of sample – especially of compounds with low concentrations. For a standard column (30 m x 0.25 mm ID and 0.25 µm film) a split ratio between 50:1 and 100:1 is appropriate.

Column Performance Formulas

Capacity Ratio

$K = t_R\text{-}t_m/t_m = t'_{R(N+n)}/t_m$

Column Coating Efficiency

$N_{theoretical} = 5.54\ (t_R/W_h)^2$

$N_{effective} = 5.54\ (t_R\text{-}t_m/W_h)^2$

Kovats Retention Indices

$I_A =$ $100N+(100n(\log t'_{R(A)}\text{-}\log t'_{R(N)}/\log t'_{R(N+n)}\text{-}\log t'_{R(N)}))$

I_A is the retention index of compound A (from corrected retention times) which elutes between two n-paraffins separated by either one or two carbon numbers.