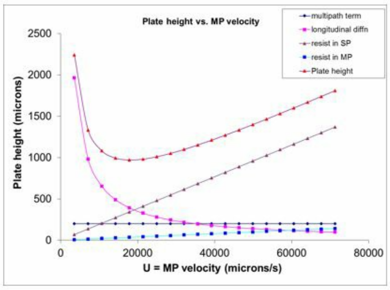
Gas Chromatography Cheat Sheet

by shaylannxd via cheatography.com/149855/cs/32547/

Basic Theory

Gas Chromatography	SP ➔ Liquid
	MP➔ Inert gas ▸ No role in separation ▸ Only directs analyte down column (carrier gas)
	D_m >>> D_s ▸ C_mU ~ 0
	Flow rate ▸ Dictate by choice of SP (thickness, properties) ▸ Modest plate height ~1mm (🡅 L = 🡅N)

Theory Equations



$$A = 2\lambda d_p \qquad \frac{B}{U} = \frac{2\gamma D_m}{U}$$

$$C_s U = \frac{f_s(k')d_f^2}{D_s} U$$

$$C_m U = \frac{f_m(k')d_p^2}{D_m} U \approx 0$$

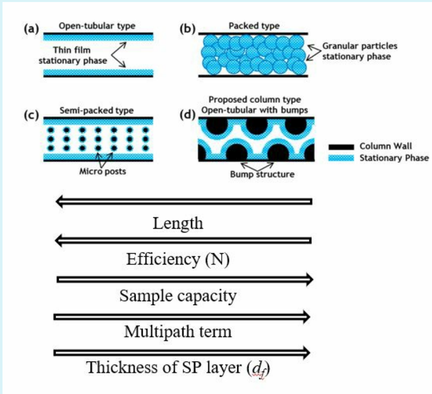
Column Type

Packed	Packed full of particles
	Put SP on particles
	MP pushes through packed bed
	Tubing ▸ Glass, stainless steel, etc. ▸ Inert = not part of separation

Column Type (cont)

Wall Coated Open Tubular (WCOT)	Inside wall of quartz/glass tube ▸ Chemically roughen ▸ 🡅 Surface area ▸ Coated with SP
Fused Silica Open Tubular (FSOT)	SP coating on wall of long thin tube ▸ Smooth wall
	Diameter ~ 75-200 um

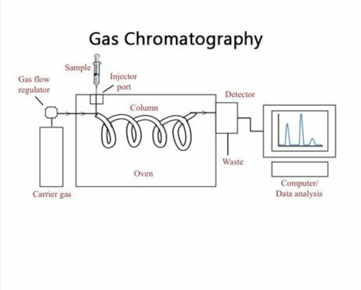
Column Diagram



GC Systems

Sample	Introduce into injector port ▸ Vaporize sample ▸ Vaporized analyte swept into column
Mobile phase	High pressure cylinders ▸ Use a gas flow regulator ▸ Regulate the pressure
Detector	Detect components of the mixture being eluted off the chromatography column ▸ Some may require a reference flow
Oven	Separation occurs ▸ Controlled temperature ▸ Fan ➔ Circulates air and controls temperature

GC System Diagram



Split Flow Injector

Sample dissolved in volatile solvent

Collect sample into syringe and inject through rubber septum
- Seals injector for analyte to go into column
- Protects from outside atmosphere
- Bad peak shapes = hole in septum

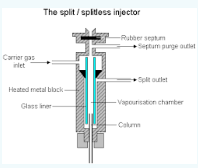
Use a heat block to "flash" sample into vapour
- ~50-100C hotter than oven
- Need to vaporize sample

GC systems design to operate with 3 main columns
- Each column has a different flow rate
- Adjust based on column used

FSOT/WCOT
- Can't handle large sample mass
- Small diameter
- Limited SP
- Limited volume capacity
- Control by valve system

Split flow outlet
- Avoid overloading the column
- Packed ➔ Set at 0 (closed)
- FSOT/WCOT ➔ Split flow ratio ➔ Depends on [analyte] in injection volume

Split Flow



Requirements of SP

Requirements of SP (cont)

	Prefer a low volatile solvent ➔ Don't want SP to vaporize in oven
Thermal Stability	SP in column
	Don't want thermal breakdown products
Inert/Reactive	Don't want analyte to react with SP
	Only want to interact

Stationary Phase

Siloxane Polymer	Low volatility
	Thermally stable bond
	Contains a silicone backbone ▸ Close to inert ▸ Can be derivatized
	Add pendant functional groups ▸ Tune selectivity/solubility/retention ▸ Adjust polarity
Non-Polar	Poly(dimethyl)siloxane (PDMS) ▸ Good quality
	Flurocarbons
Polar	Can replace dimethyl/methyl groups ▸ CN,CO,OH
Phenyl Groups (Benzene Ring)	Non-polar
	π e^- ➔ delocalized
	When approach by polar molecules ▸ e^- reorganized ➔ Induced dipole interactions ▸ Can behave polar with polar molecules (vice versa)
Chiral Moiety	Chiral-chiral interactions on SP
	Rise to selectivity of 1 enantiomer over another

Solvent	Must dissolve analyte
	Bad SP ▸ Unretained ▸ Affects R'~0 ▸ No separation
Volatility	A substance with high volatility is more likely to exist as a vapour
	A substance with low volatility is more likely to be a liquid or solid

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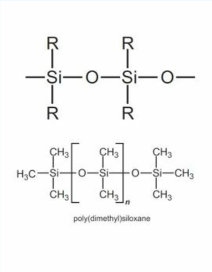
Siloxane Polymer



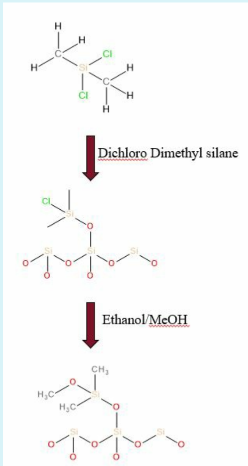
Minimize Loss of SP

Bonded Phase	Process of the SP polymer is attached to ‣ Silica support particle ‣ Wall of a capillary
	A liquid-liquid chromatography method in which a stationary phase is covalently bound to a carrier particle
Cross-- Linked Phase	Polymer attached to wall
	Polymer cross-linked with each other ‣ Critical for separation
	Produce more rigidty, hardness and ↑ Melting point ‣ Formation of covalent bonds
Issue	Most SP are non-polar and silica support surface are polar ‣ Not much intertaction
	Uses phases to prevent issue of contact
	Use silane reaction to bond/cross-link
Silane Reaction	Use to anchor/bond silicones to silica surfaces ‣ In packing materials (particles) ‣ FS capillaries
	Use to deactivate silanols
	Same chemistry for polymerization and cross-linking

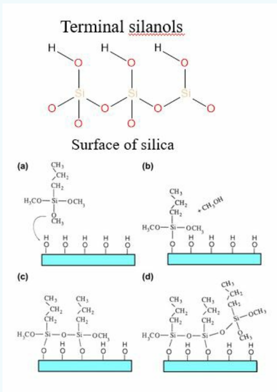
Minimize Loss of SP (cont)

	Silanol ‣ Very polar ‣ Expose on surface of silica ‣ Disagree with SP polarity ‣ Competition for polar analyte
	Deactivation chemistry ‣ Use dichloro dimethyl silane ‣ Use ethanol/MeOH ‣ Create less polar surface
Inertness of Column	Residual silanols ‣ React strongly to polar compounds ‣ Produce tailing peaks ‣ Undesirable interactions in column

Deactivation of Silanol



Silane Reaction Mechanism



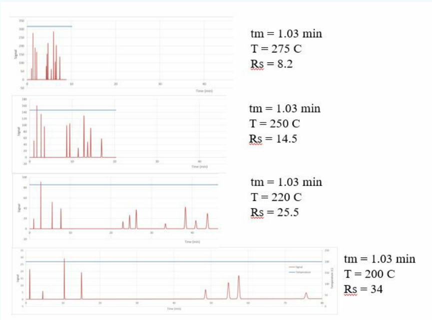
Controlling Retention

Retention	Controls resolving power (R') ▸ R' depends on K' ▸ K' depends on separation conditions
	Want all peaks to fall in "ideal range" of retention ▸ 1-10
	MP is inert ▸ Only function to control retention ▸ Equilibrium constant = thermodynamic property
	Temperature ▸ Alter overall retention
	Type of SP ▸ Alter selectivity
Impact of Different Temperature	Isothermal separation ▸ A thermodynamic process, in which the temperature of the system remains constan
	↓ Temperature = ↓ Thermal energy available ▸ Less thermal energy ▸ Analyte spends more time in SP ▸ More time in column ▸ Clearer separation
	↓ Temperature =↑ Resolution = ↑ Overall time ▸ Can become excessive ▸ Needs to adjust separation as it proceeds
	↓ Temperature → Favors SP
	↑ Temperature → Favors MP
Different Ramp Rates	Altered t_r and resolution independently

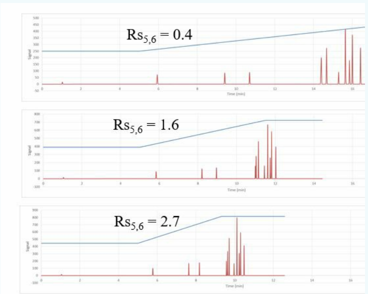
Controlling Retention (cont)

	Adjust temperature during course of separation
	Resolution imporves under better retention conditions for the analyte
	Change in gradient steep → Improves separation ▸ Shorten separation time ▸ Increase resolution ▸ As a function of temperature
Round-Up of T Programming	Powerful tool for controlling K'
	Directly affects distribution constant
	↑ Temperature = ↓ K'
	Ramped (gradient) temperature is used to adjust K'
	Make GC less intuitive ▸ ↓ R= {{fa-arrow down}} K' (general) ▸ ↑ R= ↓ K' (T programming) ▸ K'=f(T)
	Separation limited by ΔT/Δt (ramp rate)
	Column lifetime is shorter at higher temperature
Other Factors	K'=K(V_s/V_m) ▸ SP thickness ▸ Total mass of SP
	FSOT columns ▸ Calculate phase ratio (V_s/V_m)

Graphs with Different Temperature



Ramp Rate Graphs



GC Detectors

Requirements

Sensitivity

- 10^{-8}-10^{-15} g analyte/s
- Packed ➔ All sample used ➔ Decrease efficiency = broader peaks
- FSOT ➔ Split flow injector (5-10% sample used)➔ Increase efficiency = narrow peaks

Stability

- Noise on baseline ➔ Smooth {[fa-arrow-right]} Detect the smallest peaks ➔ Minimal DL
- Drift ➔ No baseline (goes up and down)

LDR

- 5-8 orders of magnitude

GC Detectors (cont)

Can accept MP over a wide temperature range

- T Programming {[fa-arrow-right]} Improves separation
- Immune to T change
- Compensate T change ➔ Require reference gas flow

Fast response and independent of T

Simple to use, maintain, repair

Selective/Universal

- Detect analyte of interest (S)
- Detect all species (U)

Non-destructive

Flame Ionization Detector (FID)

Analyte elute from column

- Mix with H2 gas
- Combusted

Reduced carbons

- Produce ions that alter conductivity of flame and alter current

Signal proportional to # of reduced carbons

- Mass sensitive

Oxidized and e^- capturing species

- No-little signal
- Cannot be oxidized further

Non-combustible gasses

- No signal
- Already oxidized

High sensitivity

- 10^-13& g/s
- use FSOT/WCOT

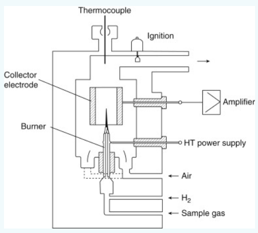
Large LDR

- 7 orders of magnitude

Destructive

No reference flow

FID Diagram



Electron Capturing Detector (ECD)

An ionization detector
- response is based upon the ability of molecules with certain functional groups to capture electrons generated by the radioactive source

Radioactive source ➔ ^{63}Ni
- Emits beta-particles

When disintegration occurs
- Large energy release
- Beta particle emission
- Impacts any filler gas and/or MP present in detector and ionize it

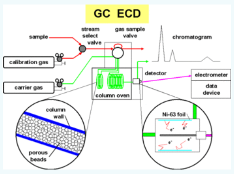
Use a N2 make-up gas
- Get ionized by high energy
- Ionized N2 gas ➔ Pass an electric current through detector cell

In absence of analyte with e^- capturing groups
- A constant current established through the detector

When analyte with e^- capturing groups enters cell
- Quench some ionization
- Reduce conductivity of gas = reduce current in cell

Selective detector
- analytes with a high electron affinity
- Sensitive for species that can disrupt ionization of N2 gas
- Pesticides ➔halides, peroxides, nitro groups

ECD Diagram



Thermal Conductivity Detector(TCD)

Properties	Signal proportional to change in heat capacity ▸ Difference between MP and MP+analyte are relatively small
	Universal detector ▸ Detect solvent as well ▸ Undersirable ➔ Solvent order of magnitude is more concentrated than analyte ▸ Result in large solvent peaks and small analyte peaks ▸ If analyte is not well retained ➔ Interfered by solvent

Thermal Conductivity Detector(TCD) (cont)

	Modest sensitivity ~ $10^{-9 \text{ to } -10}$ g/ml ▸ Less sensitive than FID
	Modest LDR ▸ Very short linearity
	Non-destructive
	Require a reference flow
Basic Theory	Based on ability of the gas exciting the column to absorb heat
	Contains thin filament ▸ electrically heated ▸ As heat capacity of gas changes (MP vs MP+analyte), so does the T of the filament
	Resistance of thin filament ▸ T changes the resistance ▸ Resistance changes the current of the circuit ➔Current is VERY sensitive to T
Reference Flow (Type 1)	To compensate for the T of MP coming from the oven ▸ T is changing with T programmed elution ▸ left section of diagram
	Equation ▸ $V_{out1} = V_{applied} * (R_{ref}/(R_{column}+R_{ref}))$
	If $R_{column} = R_{ref}$ ▸ two resistors are "balanced" ➔The signal from the column is coming from the MP ▸ $V_{out1}=(1/2)V_{app}$

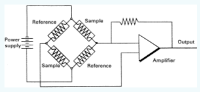
Thermal Conductivity Detector(TCD) (cont)

	If $R_{column} \neq R_{ref}$ ▸ Analyte's heat capacity changes T ➔ heating or cooling of filament ▸ V_{out1} increases as analyte elutes ➔ As R_{column} gets closer to 0, V_{out1} gets closer to V_{app}
Reference Flow (Type 2)	Opposite concept as reference flow type 1 ▸ right section of diagram
	Equation ▸ $V_{out2} = V_{applied} * (R_{column}/(R_{column}+R_{ref}))$
	If $R_{column} = R_{ref}$ ▸ two resistors are "balanced" ➔ The signal from the column is coming from the MP ▸ V_{out1}=(1/2)V_{app}
	If $R_{column} \neq R_{ref}$ ▸ Analyte's heat capacity changes T ➔ Heating or cooling of filament ▸ V_{out2} decreases as analyte elutes ➔ As R_{column} gets closer to 0, V_{out2} gets closer to 0
Reference Flow (Type 3)	Type 1 and Type 2 TCD operating together ▸ With separate power supplies
	If $R_{column} = R_{ref}$ ▸ two resistors are "balanced" ➔ The signal from the column is coming from the MP ▸ V_{out1}=(1/2)V_{app}

Thermal Conductivity Detector(TCD) (cont)

	If Rcolumn ≠ Rref ▸ As analyte elutes ➔ V_{out1} increases ➔ V_{out2} decreases ▸ V_{out1} and V_{out2} have same magnitude, opposite signs ➔ Taking the difference of the two will double the V measured ➔ Double the signal for the same effort
Reference Flow (Type 4)	Same as Type 3, but with a single power supply
	Wheatstone bridge ▸ Name of this circuit ▸ Common approach for detecting VERY small change in resistance ➔ Advantage: Doubles the signal magnitude

TCD Diagram



GC-MS

Properties	Versatile ▸ Provide identification power
	Have to run known standards (spiked)
	Electron beam ionization ▸ M^+ and fragments
	Excellent DL ▸ Depending on instrument and analyte ▸ ~ 2-20 picog injected
	Concentration DL in sample ▸ Depends on sample work-up
	Long LDR ▸ Dependent on instrument ▸ 4-6 orders of magnitude

GC-MS (cont)

	Selective ▸ Less interferences ▸ Filters out MP signal
	Destructive
	Expensive
Basic Theory	Quadruple MS ▸ Contains 2 positive and 2 negative poles
	Movement of M^+ ▸ M^+ travels in a sinusoidal path ▸ If M^+ is too light or too heavy, it is kicked out of quadrupole →b/c they are not really able to respond to polarity change ▸ How to fix this →Quickly change the frequency and voltage of the poles →Can quickly scan through all m/z ratio to obtain mass spectrum
	Spectrum generated ▸ Total ion current (TIC) →Easiest way →Sum of all ion signals that passes through →Acts as a universal detector: does not filter out MP signal →Tells you how many species are present ▸ Extracted mass spectra →Take a slice of TIC peak and see its fragments

GC-MS (cont)

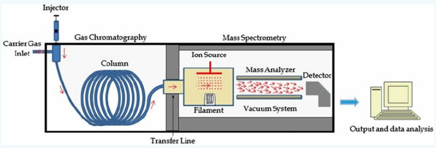
Isotopes
- ▸ Parent ion
- → Most prominent and heaviest
- ▸ Isotopes
- →Daughter peak from most prominent peaks
- →can provide more info depending on its ratio with parent peak
- ▸ Isotopically labelled analytes
- →Replacing parts of molecule with deuterium
- →Produces a known mass higher than the original mass
- →Compare spectrum with orignal

Positive identification
- ▸ Compare experimental spectrum with the “real” analyte spectrum
- ▸ 3 steps
- →Correct mass of molecule?
- →Correct set of fragments?
- →Correct fragment intensities?

Quantitation
- ▸ Usually multiple ions monitored/measured
- →Validate ratio of peaks at the correct m/z ratio

Column bleed
- ▸ SP is boiling and bleeding out
- ▸ Leads to a rise in baseline
- →Not good
- ▸ How to fix it
- ▸ Running at low T
- →Purchase column made specifically for MS ($$$)

GC-MS Diagram



Key Factors and Applications

When will GC be useful	1. Analyte ▸ Needs to be volatile ▸ Not proteins ➔ Unstable at high temperature ▸ Silation reaction ➔ Produce volatile products (Risk of contamination, loss, produce new products) ▸ Needs to be stable ➔ Stable enough to transit the column
	2. High enough concentration to detect ▸ Packed columns: great sample capacity but low resolving power and resolution ▸ FSOT: lower capacity (split flow) but high resolving power and resolution ▸ Detectors: Has a good sensitivity
	3. Does sample require high R' separation ▸ Depends on the type of detector ▸ Universal = high R ▸ Selective = low R
	4. Generally faster than LC
Applications	Anti-doping and forensics
	BAC (Crime/forensics labs)
	Pharmaceuticals ▸ Process control ▸ Quality control ▸ Research and development

Key Factors and Applications (cont)

Food and Beverages ▸ Wine/alcohol ▸ Pesticides
Environmental ▸ Pesticides ▸ PAH and industrial solvents ▸ Oil/hydrocarbon spills
R&D ▸ Organic synthesis ▸ Catalysis (monitor products)
Industrial ▸ Feedstock ▸ Off gassing