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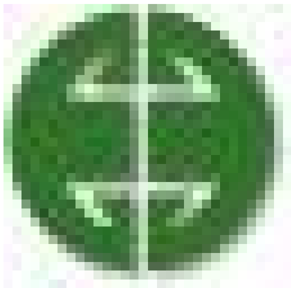

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THE ROLES OF GASES USED IN GAS CHROMATOGRAPHY

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Abstract

Gases play various roles in Gas Chromatography (GC). The most important use of gases in GC, is their utility to function as carrier gas. Besides this, they play several other roles, which are of interest to gas chromatographers. The entire information on such an important aspect lies scattered in books and literature. An attempt has been made in this manuscript to bring together most of this information in a concise form. The first section (Section A) of the article deals with information mostly related to packed column GC, while the second section (Section B) deals with information specifically related to capillary GC. The aspects covered include, (a) Carrier gas – its choice and requirements, (b) Influence of trace impurities in carrier gas, (c) Influence of carrier gas on detector response, (d) Influence of impurities in carrier gas on detector response, (e) Procedures to purify gases, (f) Trace additives, (g) Addition of sample components to the carrier gas, (h) Other gases used in GC and their functions.

In this comprehensive review, references have been chosen on a selective basis, even though every attempt has been made to cover as many aspects as possible, including the recent trends.

Introduction

Gas Chromatography (GC) is that form of the general chromatographic technique in which the moving phase is a gas(carrier gas). In the conventional GC approach (called “Packed Column GC”(PCGC)), the stationary phase may either be a liquid of low volatility, coated generally on an inactive solid support, or an active solid, packed into a long narrow column. We accordingly, speak of Gas Liquid (GL) or Gas Solid (GS) Chromatography, carried out in packed columns.

In the modern version of GC (called “Open Tubular Column Chromatography”(OTC), or “Capillary GC”(CGC)), a packed column is not used. The walls of a capillary tube are coated with a thin layer of the stationary phase. More recently, bonded or cross-linked phases are made use of. In CGC, one can obtain much better resolution, with a much smaller quantity of the sample and shorter analysis time, compared to packed column GC. The discovery of very sensitive detectors enhanced the sensitivity of the technique, and this gave additional momentum to this modern development. In view of these additional capabilities, CGC is also referred to as High Resolution GC (HRGC).

A fundamental requirement of GC is that the analyte must be present in the form of a gas or vapor, before it enters the column. Besides gases and vapors, any substance that can be volatilized without decomposition, or with reproducible decomposition, or converted into a volatile derivative (by a suitable derivatisation procedure), can also be analyzed, with proper choice of column, detector and operating conditions.

VARIOUS ROLES PLAYED BY GASES IN GAS CHROMATOGRAPHY

The most important use of gases in GC is their utility to function as carrier gases (c.g.). This aspect will be discussed in some detail in the subsequent sections of this article. There are, however, many other roles gases play in GC operations. A brief overview of these various roles played by gases will also given. In Section (A), the aspects related to the conventional PCGC will be discussed. Some of them may be relevant to CGC as well. In Section (B), some additional aspects related to CGC will be discussed.

Section (A): Packed Column GC

(a) Carrier Gas—Its choice and requirements

In GC, the carrier gas (c.g.) acts as the mobile phase, and transports the sample components through the column to the detector. It is very necessary to select the best c.g., as it affects both the column separation processes, and the detector performance. Column efficiency and detector sensitivity are important factors to be considered in the choice of the c.g. While the latter is important in trace analysis, the former deserves careful consideration, while carrying out difficult separations. It is quite possible that the c.g. that gives the optimum column performance may not be the one most suitable from the point of view of the detector employed.

Physical and chemical properties of the various gases determine diffusivities, pressure drop and reactivity, which are all of practical concern in GC column operation. Gases commonly used as c.g. include, H_2, N_2, Ar and He. The pure gases are generally employed. Occasionally, mixtures are used for specific purposes.

The c.g. has to be inert to the column materials and sample components. For example, air will tend to oxidize materials such as aldehydes or olefins, especially at elevated temperatures. Moisture is undesirable, as it may deactivate several adsorbent stationary phases, and cause various other undesirable effects.

In general, the choice of the c.g. has little effect on the retention behavior in GLC. However, retention by adsorption in GSC can significantly get altered with different c.g. This results from the different affinities of the adsorbent for gases, including the one used as c.g. An adsorbent in equilibrium with a c.g. may exhibit a greatly reduced heat of adsorption, and reduced retention for any solute (1).

When a strongly adsorbed solute vapor is introduced into a column, adsorbed c.g. is displaced by the solute, and a pressure pulse (negative, positive or zero) is observed, depending upon the quantity of the c.g. displaced (less, more or equal , compared to the volume of the solute adsorbed). Obviously, this effect is evident only with flow sensitive detectors.

When permanent gases (e.g., hydrogen, oxygen, nitrogen, rare gases), are analyzed by Gas Solid Chromatography(GSC), a different permanent gas must necessarily be used as c.g. This may also be adsorbed by the adsorbent, so that chromatography turns out to be a function of the c.g. It has been reported that the heavier the c.g., the shorter are the retention times, for a mixture of permanent gases and light hydrocarbons. For example, on charcoal, CH_4 was found to have a retention time(t_R) of 34 min. with He, 15 mins. with air and 5 mins. with C_2H_2 as c.g.(1)

It is worth mentioning here that reactive substances like carbon dioxide(2), ammonia(3), steam(4), carbon monoxide(5), carbon disulfide vapour(6), formamide vapour(6), etc., have been used as c.g., in certain studies. Nonaka(4) used steam as c.g., and carried out GSC of organic compounds with high temperature pre(detector) column. These are to be taken as interesting exceptions, rather than the general rule.

For better column performance, one must choose the c.g. with the smallest diffusion coefficient. High molecular weight gases(N_2, Ar, CO_2) give lower flow rates than H_2 or He. Viscosity essentially dictates the gas pressure required for a given flow rate. The smaller the ratio of viscosity to diffusion coefficient, the better it will be, from the point of view of rapid analysis. From these considerations H_2 and He turn out to be the best choice.

A pulse free c.g. flow(at preset pressures and constant flow rates) is a very essential requirement in isothermal GC analysis(to obtain a steady base line, and to obtain reproducibility in retention times/peak sizes). The flow rate commonly used is in the range 20-100 ml per minute. The case of programmed temperature operation is discussed elsewhere. In programmed temperature GC(PTGC) operations, one can work under constant pressure, when the flow rates change as a function of temperature. In PTGC, one can also program the pressure as a function of temperature, to maintain constant flow rate.

The influence of the c.g on the GC column performance(both in GSC and GLC) have been discussed well in the literature(7,8). Theoretical considerations indicate that higher density of c.g. or lower temperature of operation would lead to decreased longitudinal diffusion, and increased resistance to mass transfer in the gas phase. Theoretical treatments are, however, beyond the scope of this review.

Gas viscosity enters into all equations for pressure and flow, and is implicit in column constants. This is highly temperature dependent. Viscosity of gases increases with temperature. The inlet pressure needed will obviously depend on the viscosity of the c.g. used. For normal isothermal operations, the temperature dependence of viscosity is of little consequence. However, in programmed temperature operations, this factor introduces the problem of maintaining a constant flow rate, against increasing column pressure.

In certain applications, such as process analysers and controllers, as well as in pollution studies, separation speed becomes an important factor, because of the rapidly changing composition of the sample. The effect, the average c.g. velocity has, on the magnitude of HETP(Height Equivalent to a Theoretical Plate) has been considered in detail in the literature(7-12). Normally, the average c.g. velocity($\bar{u}$) is adjusted to the optimum value, $\bar{u}_{opt}$, in order to obtain the minimum value in the HETP- $\bar{u}$ plot. The higher the $\bar{u}_{opt}$, the faster will be the separation.

The choice of the c.g. is made, based on theoretical considerations and practical experience. Theory, in the form of van Deemter equation(7) and practice, show that (i) a c.g. of high molecular weight can, at the minimum of HETP- $\bar{u}$ curve, give a more efficient separation, than one of lower molecular weight and (ii) a c.g. of lower molecular weight displays the minimum of the H- $\bar{u}$ curve, at a higher c.g. velocity than one of higher molecular weight. C.g. velocity is a more easily altered parameter than column length. Hence, one who desires to speed up analysis can often use a column, which is longer than strictly necessary, at a flow rate higher than optimum. Low molecular weight gases such as He and H_2 have an advantage in this respect. This aspect is very attractive in CGC, discussed elsewhere.

Cases have been reported in which gas phase interactions occur during GC conditions such that, a change in c.g. can change the order of elution of a pair of components(13).

In gas analysis, the c.g. has physical properties which are similar to those of sample components. Sometimes, it may even be a sample component, and so cannot be treated simply as an inert vehicle. The concept of gas hold-up time, as a measure of c.g. velocity, then, becomes difficult to apply. Measurement of “air peak” becomes meaningless, when air separated into its components(14).

Column performance in GSC can be affected by the choice of the c.g., as the adsorbent surfaces become fully saturated with c.g. It can be shown that two components cannot be separated by GC, once they are both present in the c.g. Owing to the changes in the column behaviour that can result from various causes, conventional means of expressing elution order (such as adjusted relative retention times or retention indices, etc.) should be used with the required caution.

In common GC experiments, the c.g. is intended only for mass transport. A review has recently appeared on the role of c.g. on the separation process(15). It demonstrates that c.g. interactions are integral to the GC process. This may be regarded as inadvertent by some, yet others intentionally modify the c.g. to obtain specialized effects. One such gas, NH_3, was the subject of a review on interactive gases in GC(16). Examples have been presented and discussed where NH_3, blended at low levels in the c.g., has improved peak symmetry and detection limits.

Carrier Gas Purity(Influence of Trace Impurities)

The steps required to purify carrier gases used in GC have been discussed well in the literature(17, 18).

Carrier gases are available in various grades of purity. “Research grade” or “GC grade” gases are preferred, because they have been refined to contain a very low level of contaminants. Trace impurities commonly found in such gases are water, light hydrocarbons, CO_2, and other permanent gases. The significance of particular impurities varies with the application, depending upon the sample, the column and the detector.

Though gases of sufficient purity are obtainable commercially, care must still be taken to eliminate dust particles, moisture, and other volatile impurities. A filter system, devoid of leaks, is another desirable requirement.

Air/oxygen will tend to oxidize materials such as aldehydes or olefins, especially at elevated temperatures. Moisture is undesirable, as it may deactivate several adsorbent stationary phases and cause various other undesirable effects.

Oxygen and water vapour can degrade a column packing, which is being used at or near its upper temperature limit. Porous polymers may be subject to this in gas analysis. Stainless steel diaphragm regulators and flow controllers are preferred. O_2 contamination, by diffusion through neoprene diaphragm and O-rings, has been documented(18) . C.g. lines should be metal, rather than plastic. The degree to which O_2 causes column deterioration is influenced by the type of stationary phase and the temperature to which the column is exposed. For systems that are susceptible, some protection against O_2 entry through leaky fittings is desirable. Additional indicating O_2 scrubbers should be installed immediately before each inlet system, to minimize the amount of O_2 coming in contact with the column. It is necessary to point out here that many parts of the system(including septa, flow controller O-ring seals, pressure regulator diaphragms, elastomeric lines) are all permeable to O_2, and may turn out to be a source for oxygen contamination, under suitable conditions. Generally, diffusion of oxygen from outside may not be very probable, especially when positive pressure is maintained inside the GC unit.

Sample components may be prone to oxidation, which can cause them to be lost(e.g., silane) or converted(e.g., thiols to disulfides)(14). Some stationary phases(e.g., polysiloxane, poly ethylene glycol, carbowax, etc.) undergo degradation, when exposed to high temperature and/or O_2(19-24). Stationary phases such as polyesters, FFAP, Sp-1000 and carbowax depolymerise rapidly with even 100 ppm of water vapour in the c.g. Columns may go bad within a day's operation. This is generally indicated by the progressive increase in tailing of peaks or polar compounds. A molecular sieve trap will enable to prevent rapid deterioration.

Impurities in the c.g. may gradually saturate the active sites in the adsorbent, and affect retention value from run to run. This will bring about a reduction in the original activity of the adsorbent in course of time. In fact, adsorbents are commonly deactivated by the addition of controlled amounts of water, CO_2 or NH_3.

Water vapour is adsorbed by most adsorbents, particularly those with polar groups, and those which are heterogeneous. If an adsorbent, with adsorbed water is heated at a temperature higher than its normal operating temperature, the water is progressively removed, with consequent increase in retention volumes at the normal temperature of operation. Studies have been made on the separation characteristics of stationary phases(e.g., alumina) as a function of their water content(25, 26). The presence of water vapour generally reduces retention, as there is competition between the water and the analyte for the adsorption sites. Interestingly enough, a reduction of temperature may, in some cases, produce a fall in retention, rather than the usual rise, since the reduction in temperature may favour adsorption of extra water, more than the adsorption of extra vapour. Change of water content of an adsorbent may also change relative retention times by altering the proportions of –OH groups. For example, water on molecular sieves 5A can cause inversion in the usual order of elution of CH_4 and CO(27). Adsorbents like molecular sieves, silica gel, alumina, etc., can adsorb moisture from the c.g.(and also from the atmosphere and from samples), and consequently change their characteristics.

Owing to the above-mentioned reasons, conventional means of expressing elution order, (such as adjusted relative retention times or retention indices) should be used with great caution, while dealing with such systems.

It is worth stressing here that some of the trace impurities will get concentrated as a gas cylinder becomes depleted. Concentration of c.g. impurities is also observed on adsorption columns. This will obviously affect the retention behaviour of solutes during column life. This stresses the greater concern needed for the purity of the c.g., in GSC, than in GLC. In programmed temperature GC, water and other c.g. impurities may accumulate on the column at low temperatures and get eluted at higher temperatures, resulting in greater background signal. In some cases, some high retention impurities may get concentrated at the beginning of the column, and decrease the retention behaviour with time This effect is especially important in GSC(10).

The Influence of Carrier Gas on Detector Response

In several cases, the operational principles of the detector itself will demand the use of a particular c.g. For example, in the mass integral detectors(which continuously weigh the accumulation of the eluted components), the detector chamber contains an adsorbent, which will retain the components of the sample, but not the c.g. In the case of volume/pressure integral detectors, the c.g. gas used(generally CO_2) is absorbed in alkali, and the volume of the impurities collected are measured(17).

He is to be used as c.g. for Helium ionization detector, Pulsed discharge HeID, DC He plasma detector, He Photo ionization detector, Pulsed high voltage discharge ECD, etc. Ar is to be used for Ar ionization detector, Ar pulsed discharge detector, etc. Photo ionization detectors use a variety of rare gases to identify and quantify unknown compounds.

The detector needed to carry out a particular analysis may often impose certain restrictions on the c.g. to be employed. The c.g. commonly used for Flame ionization detector(FID), N-P detector(NPD) and Electron capture detector(ECD) is N_2 or Ar. H_2 or He is employed for Thermal conductivity detector(TCD).

Over and above these general considerations, the use of detectors which measure the difference in properties between c.g. and eluted component(such as TCD) influence the choice of c.g. considerably. When analyzing gases, as opposed to liquids and solids, there is the possibility that the c.g. is a component of the sample, or that it has properties, which are very similar to those of the sample components.

The difference in thermal conductivity(TC) between c.g. and component is not the only factor which determines detector response, but it is usually the most significant. The approximate sensitivities that can be obtained, while using various gases as c.g. can be deduced from the TC values available in the literature. H_2 and He give the highest sensitivity with

TCD, and allow more rapid analysis. Of the two, He is much preferred on safety grounds, and also because it is a less common component of gas mixtures. When using He as c.g., anomalous results can be obtained if H_2 is a sample component(14). When Ar is used as c.g.(with TCD) to analyse samples(e.g., flue gas), the sensitivity will obviously be low, as its TC is close to those of the analytes. While analyzing a mixture of butanes and butenes, some components will give positive peaks, and some will give negative peaks. Some will give virtually no peak at all. This is due to the fact that the TC of Ar lies within the TC values of the butanes and butenes. If Ar is replaced by He, all the components will give peaks on one side only. Hence, He will be a better choice. While analysing low level of CO_2 in N_2, the use of He will give an unusually large peak for N_2, which may overlap that of CO_2. The use of N_2 may reduce the intrinsic sensitivity, but there is no need to separate N_2 from CO_2. A large sample and short column should be effective.

In a TCD, the sensing element is placed in a flowing gas. The response actually depends on TC, only to a first approximation. This is because, the heat removed from the element is affected by other factors such as rate of flow of the gas, convection(free or forced), radiation and end losses. The form of heat loss coming under forced convection is termed the "Heat capacity effect". Theoretical and experimental studies have been carried out to understand the response of the TC cells to changes in gas composition and operating temperatures. Peak inversions have been reported while using TCD(28, 29). Continuous operation of a thermistor TCD in a current of H_2 gas has been reported to result in the deterioration of the bead, and after a short while, it becomes impossible to balance the bridge. Glass coated beads have been employed to meet certain applications(17, 30). Two TCD's connected in series were utilized by Guillot and coworkers(31) for selective determination of materials which could be hydrogenated. The effluent-H_2 mixture passed through the first detector, and then through the second one, which contained the elements coated with a Pd catalyst. The response obtained from the second detector was due to the normal thermal characteristics plus the heat of hydrogenation reaction. Castello and Anato(32) pointed out that negative peaks in vacancy chromatography were the cause of anomalous responses of TCD. As this arises due to the use of impure c.g., a purification step will eliminate such problems. Tsuda and Ishii(33) used a combination of UV and TCD. The GC effluents were initially passed through a TCD. Thereafter, the vapour was mixed with ethanol vapour, the mixture condensed, and passed through a flow through cell of a UV detector. Under certain conditions, distorted, split or negative peaks are obtained, while using TCD(i.e.,anomalous responses) (34). While H_2 gives a better sensitivity than N_2 in TCD, the hot wire filaments can initiate catalytic reactions with organic compounds. Oxidation of the filaments may occur when samples of air are run, depending upon the filament current and/or the amount of air entering the hot filament cavity. Oxidation of the tungsten filament is the most vulnerable characteristic of a TCD. Oxygen even at ppm levels in the c.g., leaks in the injector septum, column fittings and filament seals, can cause continuous unidirectional drift in the base line, as the filament oxidizes. Consequently, the practice of injection of air with the sample is not recommended. Coating the filaments with a gold layer protects them against oxidation.

Since the FID does not, in normal operation, respond to permanent gases, the choice of c.g. is much less influenced by detector characteristics. A gas of lower TC, such as N_2, allows maximum response from the detector, as a result of higher flame temperature. Unless the analysis requires that the detector be operated at maximum sensitivity, He will probably be the best choice for the advantage it offers in analysis time.

Bocek and Janak(35) discussed the mechanism of FI, and considered the various types of flames in common use. Askew(36) investigated the FID response(negative peaks) of inert gases(e.g., CO_2, SO_2, N_2, or He) by using an ionizing c.g.(e.g., tetrafluoro methane or hexa fluoro ethane). Normal positive peaks were obtained for hydrocarbons. Thombs(37) investigated the response of a FID to pulses of noble gases.

The FID has been modified for N-P selective detection(AFI/TI detectors). The use of CO, NH_3, formamide, formic acid and CS_2, as flame forming agents in the FID, has been discussed. Some detection selectivities have been reported in these cases. For example, the response to chlorinated hydrocarbons doubled when CO was used as the fuel. The response to positive ions was greater than that to negative ions(5).

FID's have been modified to respond to inorganic gases. An oxygen specific FID has been reported. In general, these have CH_4 or some other hydrocarbon as fuel, resulting in high background current. When certain inorganic gases are eluted, there is a decrease in the current, and hence, a negative response(38).

One more item of interest, perhaps, in OTC GC, is the hydrogen atmosphere FID(HAFID)(39). In this detector, the H_2 and air flows are interchanged, to provide an air diffusion flame burning in H_2. In addition, the collecting electrode is positioned several cms above the flame. When both metal atoms and silicon atoms are present, the response characteristics change markedly. Two versions are available. In the first version(HAFID), the c.g. is doped with silane, so that the detector is sensitive to metal-containing compounds getting eluted(40). In the second version(HAFID-Si), the c.g. is doped with a metal, and response is to silylated compounds(41). Depending upon the parameters chosen, the response of HAFID can be, either positive(the signal increases with analyte concentration) or negative(the signal decreases with increase in analyte concentration, resulting in an inverted peak). The controlling factor appears to be the amount of silane present in the flame.

Eventhough FID is a mass flowrate detector, if the column flow is changed more than about 25%, the H_2 flow may require adjustment to maintain constant sensitivity. In many cases, addition of a makeup gas has been recommended to optimize the detector and to sweep the detector volume. This helps to minimize band spreading. In addition, the response in OTC is sensitive to flowrate changes, as the flowrates are low. For optimization, one has to examine the following: (a) Interdependancy of c.g.(plus make up) flow and combustion gas flows, (b) Detector response as a function of makeup gas flow rate and (c) Detector response as function of flowrates of c.g., H_2 and air(42). Such investigations will reveal that there is a maximum in sensitivity at a particular ratio of c.g. plus makeup gas to H_2 flow, and that this ratio depends on the particular makeup gas. One should also plot the gas ratio(c.g./H_2) –FID response curve to arrive at optimum experimental conditions. The controlling feature appears to be that, maximum ionization comes from flames having approximately the same temperature.

In FID, a linear response is obtained to varying sample sizes, atleast at low concentrations. However, as the amount of material in the sample gets larger, the flame characteristics change from a pure H_2/air diffusion flame to a larger, more hydrocarbon-like flame. This increase in flame size would mean that ion production takes place higher in the collector, where the electric field is weaker, and the flame is cooler. These ion collections and the formation processes thus become less efficient, resulting in nonlinear response. Graiff(43) reported enhanced sensitivity in the H_2 FID to hydrocarbons when singing or "whistling" flame was used.

Water is reported to depress the FID response(44, 45). False responses have been obtained in certain cases(e.g., amines)(46). FID sensitivity is increased by hyperoxygenation(47). The efficiency of FID is reported to be strongly dependent upon pressure changes. In general, the efficiency decreased with increasing pressure. Above 10 atm., the detector became independent of pressure(48, 49). Anomalies in FID responses have been reported(50).

Schaefer(51) estimated inorganic sulfur compounds(e.g., CS_2, COS, H_2S and SO_2) using a normal FID, under certain experimental conditions. Lucero(52) found that FID, with O_2 saturated with water vapour for support of the H_2 flame, causes considerable drop in sensitivity for organic compounds.

A regular FID was made to operate in a H_2 rich condition by reversing the gas flows such that, air and O_2 were fed into the column effluent and the flame burned in a H_2 atmosphere. Several metal compounds showed strong responses with this detector(53). The signal for C was suppressed.

Parameters and pitfalls in the construction and operation of a H_2 atmosphere FID have been discussed(54). Schaefer(55) found that water gives a negative response in flames composed of more than 25% H_2 in N_2. In the presence of CH_4 in the flame, water gives a positive response. An approach to detect/estimate water in some organic compounds has been discussed.

Berezkin and Shkolina(3) described the use of NH_3 as a c.g. and flame forming agent. The disadvantages are, increased background current and formation of corrosive products in the detector. The effect of c.g. on FID sensitivity has been investigated(56). Russev and coworkers(57) found that several inorganic gases(e.g., Ar, CO, CO_2, He, H_2S, NO_x, O_2 and SO_2) can be detected by introducing minor modifications in a normal FID.

The FID is capable of constantly providing a sensitivity of between 10^{-10} and 10^{-12} g. For a given detector design, the ultimate sensitivity will depend on optimization of H_2 and air flows. For a ¼" OD column, a good general relationship is to use about 10 times the amount of air as H_2 used. The H_2 flow may be between 30 and 50 ml/min. and c.g. flow from 20 to 80 ml/min.

The response of FID was reported to increase when NH_3 was either used as the c.g. or mixed with the N_2 makeup gas at the 5% level(58).

The choice of c.g. does affect the correct operation of the ECD. Most commercial detectors work satisfactorily on N_2, which is much more convenient than the alternatives of 5% or 10% methane in Ar.

In the case of ECD, a c.g. of moderate molecular weight is required(Pure H_2 or He alone will not work).The interaction of the c.g. and the Beta rays produced by the radioactive source produces a population of positive ions and electrons, throughout the active volume of the detector. The c.g. must also be able to rapidly thermalise these secondary electrons, to participate in the electron capture process. It must also quench unwanted side reactions, particularly metastable atom formation, where possible. In pulsed mode operation, the electron mobility should also be high. For these reasons, Ar with 5-10% CH_4 or He with 5% CH_4 is generally recommended for use with pulse operated ECD. CO_2 can also be substituted for CH_4 in either case. N_2 can also be used as c.g. for pulsed ECD operation. Any c.g. can be used, provided it dos not itself have a large electron affinity. The negative ions, formed by the analytes with high electron affinity(by capturing the secondary electrons), combine more readily with the positive ions formed by the interaction of c.g. molecules with Beta rays emanated by the radioactive source. The preferred c.g. is N_2, as Ar and He produce other undesirable side effects. For maximum sensitivity, the N_2 must be free from impurities, particularly water vapour. This is because, impurities in c.g. can also enter into electron capture reactions, and thereby, interfere in quantitative estimation of the component of interest. If H_2 is used as c.g., H-3 will be lost by chemical exchange at ECD temperatures far below 300^{o}C. In the pulsed mode ECD, Ar-methane mixture(95/90-5/10%) is normally suggested. At the voltages employed, the electron velocity is 10 times greater in this mixture than in N_2. Through inelastic collisions with CH_4, the metastable species formed from Ar are eliminated, before they can cause undesirable sample ionization. A constant thermal equilibrium, essential for reproducible electron capture, is maintained by these inelastic collisions. The Ar-CH_4 mixture is added as a makeup gas, introduced into the system after the column, but prior to the ionization portion of the detector. ECD responds well to traces of O_2. Leak free systems and O_2 free c.g. are a necessity. Response to traces of water vapour can cause unstable baselines. The gases must be dried prior to use(17).

<u>Influence of Impurities in the Carrier Gas on Detector Response</u>

In the case of the Volume integral detector(17), trace impurities in the c.g., which are not absorbed by the alkali, will introduce inaccuracy in the analysis. In the titration cell type of detectors(17), the c.g. must be absolutely free from acidic/basic components.

From the practical point of view, nominal concentrations of impurities in c.g. may not normally affect retention behaviour. However, the effect of impurities on sensitivity and detector response is very important. This problem will increase with the sensitivity of the detector.(e.g., the presence of traces of hydrocarbons in the c.g. gives higher background for Argon ionization detector(ArID) and FID). The background can be significantly reduced by passing the c.g. through an appropriate low temperature purification trap. Presence of trace impurities in the ppm range is usually inconsequential in the case of TCD. The performance of the more sensitive and specific detectors can be ruined by impurities to which other types of detectors would be completely oblivious. The presence of O_2 can cause serious problems in the performance of the ECD. A trace of intensely electron capturing materials, which may be undetectable by any other method, can prevent proper operation of an ECD. The trace contamination may not always originate from the cylinder(17). Farwell et al(59) have summarized several interesting aspects of ECD response characteristics and idiosyncrasises. Te ECD response can be markedly affected by contaminants in the c.g. High purity gases must, therefore, be used and care should be taken to avoid contaminations(from O_2, moisture, etc.) Besides absorbing detector electrons, O_2 can form ions such as O_2^- and $(H_2O)_nO_2^-$, which can, in turn, undergo ion-molecule reactions with the solutes. Contamination of the c.g. by compounds desorbed from elastomeric parts or pressure and flow regulators, lubricants in metal tubing, compounds derived from unconditioned injection septa, etc, must also be eliminated. Procedures have been recommended for getting good performance from the ECD(60). Many other consequences of impurities on the response characteristics, have been described.

In cross section ionization detector (CID), the gas concentration is effectively measured by adsorption of ionization radiation. Regardless of the radioactive source employed, however, the fundamental physical basis of the method and the principles of operation of CID are essentially the same(61). Ionization detectors are all based upon the conduction of electricity by gases. Under normal conditions, gases do not conduct electricity, but if an energy source is used to promote ionisation of the gas, then, under the influence of an electric field, the gas will conduct. The sources commonly used to promote ionisation are, H_2 flame or radioactive source (such as Sr-90). The CID can be used with any c.g. and will detect all gases. The flow rate is not critical. However, it is very sensitive to trace impurities present in the c.g(17).

In 1958, Lovelock (62) reported that a normal β-ray ionisation detector, when used with Ar as c.g., at a relatively high applied potential, produced greatly magnified signals for most organics at concentration levels as low as 10^{-12} mole. The metastable Ar atoms(Ar^*) do not have sufficient energy to ionise compounds having ionisation potentials above 11.6 ev. This ionization detector (Ar ID), therefore, cannot detect permanent gases. The use of pure He as c.g. enables one to overcome this problem.(63-66). This direct approach was considered better than the indirect approach (67) of using Ar containing small amounts of ethylene or acetylene (in which case the permanent gases were being detected by their quenching effects upon the standing current of the impure Ar. When Kr and Xe are used as c.g., the response to various polyatomic gases is much higher than that obtained with Ar (68). Welti and Welkins (69) found that sensitivity of the Ar detector could be varied continuously over a wide range by use of a mixture of Ar and N_2 as c.g. Martin (70) described a simple procedure for the elimination of water effect on Ar ID. It has been observed that removal of traces of O_2 from Ar improved the sensitivity by about 20%.

High impurity levels of the c.g. will increase the lower detection limit and narrow the linear dynamic range. Eventhough addition of some impurities to the c.g. may be useful in the analysis of permanent gases, any impurity will decrease the sensitivity of the detector (71). Popp and Opperman (72) reported a Ne ID, for the analysis of several gases (N, H, O, Ar, CH_4, propane and CO).

In Helium ionisation detector (HeID), transfer of the excitation energy occurs from metastable He (He^*) to the other atoms/molecules. Because of the high excitation potential (19.8 ev), He is capable of ionising all other compounds. Ne also can be employed for this, in principle (excitation potential of 21 ev) for this purpose. It has been reported that when He ID is operated using ultra high purity He c.g., and a clean chromatographic system, the responses for H_2, Ar, N_2, O_2 and tetra fluoromethane turn out to be negative. Many other species give positive signals(73-78). The HeID, with its extreme sensitivity to permanent gases, is very much affected by trace impurities. To sum up, for He ionization detector, the c.g. must be ultrapure He. All care must be taken to see that the c.g. does not get contaminated during the course of the GC analysis(by leaks, back diffusion of air, etc.).

In principle, Ar ID and He ID differ only in the energy of the metastable species produced (11.6 eV for Ar and 19.8 ev for He). Replacement of Ar by He allows the determination of several species with higher ionisation potentials.

In the majority of the cases a H_2 – air flame is used as the source of the ionisation energy in Alkali flame ionisation detectors (AFID). Interestingly enough, a conventional FID, without any added alkali metal salt (used in AFID), has been reported to have responded selectively to metals when air and H_2 connections are reversed(53).

In the thermionic ionization detector (TID), a considerable improvement in detector performance was observed (79) when an 8% H_2 in He plasma was used, instead of pure H_2. It has been reported (80) that the optimum P selectivity was obtained for relatively high flow rates(5-7 ml/min), while the best selectivity for N_2 was obtained using low H_2 flow rates (about 2 ml/min). One must ensure that H_2 flow rate does not increase to the point where the plasma ignites into flame, as this will enhance the hydrocarbon responses by the normal hydrocarbon FID reactions. This will, obviously, reduce the selectivity of the detector.

The basic principle behind the flame photometric detector(FPD) is the measurement of emission of radiation of a hydrogen flame. In the simple arrangement, the c.g., mixed with O_2 rich air, enters a H_2 filled chamber through a burner tip. The eluted species pass into the flame, usually a H-enriched low temperature plasma, inside a shielded jet. Its sensitivity is not seriously affected by changes in c.g. flow rates (17). The presence of gaseous non-S containing organic compounds, in either the c.g. or the sample, causes a decrease in the response of single FPD's (81, 82). In FPD, the choice of c.g. is similar to that for FID. However, the oxygen level in the c.g. should be checked, as O_2 can adversely affect the measurement of oxidisable S compounds such as mercaptans.

The principle of operation of the Electrolytic/Electrical Conductivity Detector(ElCD) is described below(83). The GC effluent undergoes thermal decomposition under predetermined conditions of furnace temperature, reaction gas, reaction catalyst and chemical abstractors. The gas phase reaction products are then combined with a stream of deionised liquid in a simple gas-liquid contactor. The electrical conductivity of the liquid is continuously measured. Thermal decomposition of the GC effluent is based on the reduction(H_2 reaction gas), oxidation(O_2 or air reaction gas) or pyrolysis(inert reaction gas) of the organic species at high temperatures in a flow through reaction chamber. Selectivity and sensitivity are determined by a particular combination of furnace chemistry, cell chemistry and conductance variables(84). By creating proper furnace chemistry(especially reactor temperature and reaction gas flowrate), the Hall Electrolytic Conductivity detector can exhibit good elemental selectivity, besides showing selectivity for certain classes of compounds within that heteroatom selective mode.

In the coulometric detector, as individual components are eluted from the column, they are mixed with reactant gases(O_2 or H_2) and passed into the pyrolysis chamber. Here, they are oxidized or reduced, and eluted into the titration cell(85, 86). In 1966, Burton et al(87) introduced a detection principle based on electrochemical measurement of O_2. In this case, the component parts(the reactor, generator and the electrochemical cell) could be made very small. The coulometer cell output is maintained at a constant level by feeding to the cell, an amount of O_2 equivalent to that which is used during pyrolysis. The amount of O_2 is thus a measure of material combusted.

By combining the chemistry of ionization with ion mobility measurements, the Ion Mobility detector(IMD)(61) provides a flexibility in GC detection, which is not available from other methods. N_2 is used as the drift gas in IMD. The N_2^+ produced from N_2 undergoes a series of ion-molecule reactions with traces of H_2O, NH_3, NO, etc., to produce stable secondary ion clusters called reactant ions. Similarly, thermal electrons produced during the primary ionization process can undergo capture reactions with O_2, H_2O, CO_2, etc., to form negative reactant ion clusters. More informations on the operation of IMD are covered in Ref. 61. Baim and Hill(88) interfaced a capillary GC with a modified IMD, operated in the negative ion mode. N_2 doped with 0.5% O_2 was used as the make-up gas. An enhanced response to low molecular weight compounds was shown. They also studied the effects of contaminants(like hexane and CCl_4) and of unseparated compounds in the column effluents, on the accuracy of the results. The detector response was apparently affected by background contamination. This was comparable to those experienced in the case of FID and ECD.

Several different GC detection methods have been developed in recent times on chemical reaction that produces light(89)(chemiluminescence). Ozone reacts with a variety of organic and inorganic compounds to produce light(90,91). When these detectors are operated with excess O_3, and hydrocarbon samples, they can detect various unsaturated organic compounds(92). Many inorganic analytes(e.g., NO, H_2S, CS_2, SO_2, etc.) have been analysed. The commonly available sulfur Chemiluminescence detector(CLD) is based on the combustion of S containing compounds in a reducing flame(H_2 rich conditions) to form S monoxide, which is then sensitively detected, based on O_3 induced chemiluminescent reaction to form electronically excited SO_2, which relaxes by emission of light around the 260 nm region. A selective detector for reduced S compounds, based on the fluorine induced chemiluminescence reactions, has been used(93). The effluent from the GC is mixed post column with 5% F_2 in He to form vibrationally excited HF. Emission is monitored between 660 and 704 nm. An extensive review of chemiluminescene detectors for GC has been published(89). Detectors have been reported which utilize an atmospheric pressure active nitrogen after glow(94), He-Ne laser intracavity absorption(95), He after glow(96) and Ar after glow(96).

The c.g. used in the flame temperature detector(FTP) is a mixture of H_2 and N_2 (75:25) (97, 98). In a modified version (99), N_2 is used as c.g. The column effluent was injected into a constant H_2 stream, and at the tip of a S.S.Capillary. In a modified FTP described by Geldenhuis(100), two hydrogen jets, each with its thermocouple, have been used. The c.g. used was natural gas containing about 93% methane or an 1:3 mixture of N_2 and H_2, in a version described by Nabivach and Dal (101). A home made dual flame FTD was described by Desai and Sahgal(102).

In the Flame emissivity detector(103), coal gas was mixed with the GC effluent in constant proportions, and the mixture burnt in a wide S.S. jet. The emissivity of the flame was monitored. In subsequent investigations, changes in the H_2 flame detector's light intensity was monitored(104), as organic compounds in GC effluents entered the flame.

In the Flame IR emission detector(FIRE) (105), the GC effluent is introduced into a H_2- air flame, and the IR emission of CO_2 band at 4.3 µm monitored. A dual channel FIRE detector has been proposed(106).

The conductivity of a H_2 flame developed from 2 jets has been measured (107). The sample could be introduced through both jets or a reagent (e.g., CsBr vapour for selective detection of P) could be added to one of the jets to make it selective. Aue and Hill(108) measured conductivity under H_2-rich conditions, and for emission under both air rich and H_2- rich conditions. It has been observed (109) that the electrical conductivity of a H_2 flame, or the flame of a mixture of H_2 and an inert gas (e.g., N_2) burning in O_2, or diluted O_2 (e.g., air) is increased significantly when an organic gas or vapour is given access to the flame.

In a proportional flow counter(110) Ar was used as c.g. In modified versions of this (111, 112), pure CH_4 was used, both as c.g. and counting gas. In 1963, Gudzinowicz and Smith(113), found that some strong oxidants (e.g., Br_2, NO_2, OF_2, Cl_2, etc.) eluted from a GC column- reacted with a Kr-85 quinol clathrate, releasing radioactive Kr atoms, which could be detected by a Geiger rate meter. Ion chamber type of radioactive detection has been reported in which the sensitivity depends, among other things, on diluent gas, and c.g. and diluent gas flow rates. Ar is used as the purge gas to enhance sensitivity(114). Many other informations of practical interest on radiation counter detectors have been given by Barrie et al(115).

Several other detectors have been reported in the literature. A brief survey has been attempted (Ref. 17, p.184-201). Some interesting highlights are given below. Zlatkis and Ridgway(116) reported a CH_4 conversion detector. The GC effluents eluted by the c.g. (H_2) are converted to CH_4 and water, by passage through a tube filled with a Ni catalyst (Kept at 350-450°C). The CH_4 formed was monitored afterremoving the water vapour. Even aqueous solutions of alcohols, aldehydes and ketones could be analysed. Sternberg and Poulson(117) used air as a c.g. in their inexpensive high sensitivity detectors using a testa coil leak tester

A catalytic reaction was described by Nakajima and Sakai(118). The detector consists of a catalyst microbed and two thermocouples (one in catalyst and the other just above that) within the detector furnace. When the component eluted from the column reacts with H_2 or O_2 on the catalyst, an endo-or exothermic signal is recorded (as an e.m.f. difference between the thermocouples). Electrolytically generated H_2 or O_2 is mixed with the GC effluent before it enters the furnace.

The thermal energy analyser(TEA) (119-121) is a gas phase technique with the essential chemical sequences occurring in the gas phase and/or at the solid-gas interface. It is extremely useful for the determination of traces of N-nitroso compounds. The N-nitrosocompound dissolved in a suitable solvent is introduced into a flash catalytic heater (or pyrolyser), where the N-NO bond is ruptured with the release of the nitrosyl radical (NO). This is then oxidised with O_3 in an evacuated chamber to give electronically excited NO_2^*. The excited NO_2 decays back to its ground state with the emission of characteristic radiation (in the 0.6 and 3.0 µ regions), which is measured. Because of the unique series of reactions, TEA is very selective. The possible uses and advantages of chemical reactions have been discussed by Berezkin(122). A detector based on the thermal effect of ozonolysis has been described (123). It consisted of a thermostatically controlled steel reaction chamber containing a glass coated thermistor. The GC effluent is mixed with air containing 0.5% O_3 in the reaction chamber, and the thermal effect of ozonolysis is measured by the thermistor. The detector is selective to alkenes, and does not respond to aromatic compounds.

Bereskin(124) summarised the chemical methods used in GC. A specific detector for O_2 has been reported by Steinmuller (125). The GC effluent in the c.g.(mixture of N_2 and H_2) passes through a cracking reactor containing Pt-Rh(9:1) spiral at 1300°C, to convert oxygen containing compounds into CO. This then passes through a methaniser to reduce CO to CH_4, which is detected by conventional FID. Scolnik(126) detected organophosphorus pesticides by their gas phase ionization reaction with CsBr vapour, in an electrically heated inert gas atmosphere (Chemiionisatioin detection).

The problems caused by impurities in c.g. and detector gases in capillary GC have been discussed by Hinshaw (127). Prevot (128) presented an overview of the recent developments in, and the current state of capillary column GC. Topics covered included coupling to specific detectors. Optimisation of GC detector parameters using electronic pressure control was described (129, 130). “Detectors for chromatography” was reviewed by Brazhnikov(131).

In ultrasonic detector, the choice of c.g. will be controlled by the fact that the response is a function of the difference between the molecular weight and/or specific heat of c.g. and sample component(132, 133). When looking for trace impurities the major component of the sample can be used as the c.g., as with TCD. There is an upper limit on the molecular weight of the c.g. For example, SF_6 completely absorbs the signal. A new ultrasonic sensing method reported(134) is suited for the analysis of permanent gases. The main disadvantage is that it is extremely sensitive to the presence of O_2 and N_2. So even the slightest leak in the system cannot be tolerated.

Purification Traps

As already stated, impurities present in all the gases discussed above, may adversely affect the equipment and analysis. Gases of required purity can be purchased directly from the manufacturers. It is also possible to use appropriate purifiers in the gas line(135). Purifiers are much more essential where self-generation of gases is practised. The indicating Oxytrap(which can be regenerated) is a compact unit designed to remove O_2 (and also traces of S and Cl compounds) from c.g. streams. They are very essential for capillary column operation(to help preserve the integrity of the thin film of liquid phase), ECD set ups, and to protect special packings(such as carbosphere, from traces of O_2 in the c.g.). They can also be used as subtractive columns, for the analysis of Ar at room temperature. Oxytraps are capable of reducing the O_2 level in gases to less than 0.1 ppm. Its indicating characteristics(by a change in color) give a warning that the absorbents must be regenerated. A very important precaution, while using oxytraps, is that, care must be exercised, not to discharge the contents, without wetting the absorbent with water.

Gas purification and control panels provide color coded locations for control, conditioning and convenient observation of laboratory gases. These panels are supplied with high quality valves, gauges, regulators, purifiers and fittings. Systems normally comprise of a set of color coded panels for H_2, N_2, air, etc.

Gas purifiers are available commercially to remove moisture, oil and other trace impurities in the c.g. These units include traps of molecular sieves, silica gel, activated charcoal, drierite, etc., in various combinations. Most of the disposable purifiers cannot handle incoming contaminants of more than 10 ppm. It is necessary to avoid teflon and nylon tubings, as they are permeable to O_2 and water vapour. Metal tubes are to be used for c.g. lines. Purifiers are available which can react to CO_2, CO, most S compounds, most halogen compounds, alcohols, phenols and other trace impurities. Removal of these is extremely important when using a Hall electrolytic conductivity detector, ECD or GC/MS system.

Commercial gas generators are now available for gases like H_2, N_2, air, etc. The pure air generators produce “Zero air” in the laboratory(135).

Trace additives

The presence of small amounts of other components in the c.g. can affect column performance or detector characteristics. In the former area, mention may be made of addition of water vapour to the c.g., so as to maintain the degree of activity of alumina or porous silica columns for light hydrocarbons(14). The effect of water vapour on the retention of substances on alumina has been studied by Halasz and Heine(136). An alumina capillary column has been used with c.g. passing through a tube packed with a hydrated salt($CuSO_4.5H_2O$). This was maintained at a constant temperature, and hence provided a constant water vapour pressure(137).

The ECD has been shown to be sensitized to sample components, to which it would not normally respond, by the addition of traces of O_2 or N_2O, ethyl chloride, etc., to the c.g. These gases can be added between the column and detector, as they do not, in any way, affect the column performance(138, 139). The Helium ionization detector has been shown to behave more consistently with controlled levels of other permanent gases in the c.g. and these can be added immediately before the detector(140). New uses of the Ni-63 pulsed ECD’s have been made possible through various schemes known collectively as the “Chemically sensitized” ECD(CS-ECD). In this approach, chemical dopants are used to improve the response characteristics of the ECD for various classes of molecules. While it is easy to complement these modes of ECD operations, one must realize that they will introduce additional complexities when they are adopted in practice(17).

Addition of methane to the remote FID(RFID) and Flame thermionic ionization detector(FTID) has been reported to improve selectivities of both detectors for carbon containing compounds(141).

Addition of NH_3 to the N_2 makeup gas in ECD, in amounts as large as 20%, increased the response for various chlorinated compounds.(142)

Under the standard operating conditions of a He discharge photoionisation detector, it was found that the response of Ne could be improved 6 fold by the addition of 3.8 ppm of Ne to the He discharge gas(143).

The addition of naphthalene vapour to the effluent from a GC column provided a means for indirect fluorescence detection of nonfluorescent species(144). Reactions with ozone can produce chemiluminescence for the detection of sulfur and nitrogen compounds(145). Fluorine induced chemiluminescence has been reported for the detection of biologically methylated Te, Se and S compounds and for PH_3, alkyl phosphines and monophosphinate esters(146).

Detection limits of a Photo ionization detector were improved by reducing background current by dosing the c.g. with a small amount of a low ionization potential organic compound(147).

Addition of Sample Component to the c.g.

When a c.g. containing small quantities of another gas is used as the c.g., and a purer gas is injected as a sample, a negative peak will be observed corresponding to the retention time of the minor component (when TCD is used). This approach is called Vacancy chromatography. Castello and Amato (148) opined that these negative peaks were the cause of anomalous responses of TCD.

In the 1960's, Vacancy chromatography (with TC detection) was a popular idea(149-151), although its popularity was perhaps more in concept than in practice. If the c.g. were to contain a sample component at the anticipated or desired concentration, then injection of the sample should show, by the size and direction of the signal, the nature of the variation from the intended level. Subsequent work, however, showed that the practice is more complicated than this simple outline, since the size of the signal for the component depends, not only the difference between its concentration in the sample and in c.g., but also on the identities and concentrations of all other components.

Mixed carrier gases.

Components may be added to the c.g. at trace levels to improve column or detector performance, or sample components may be added at percentage levels. These represent different types of application.

One application in which mixed c.g. is practicable, concerns analysis of H_2, with He as c.g.(using TCD). H_2 gives a relatively small response in He, as expected from TC data. However, at low concentration, the signal is in the same direction as that for all other components with thermal conductivity lower than He. As the concentration increases, the peak inverts at its maximum, eventually becoming strongly negative (152, 153). This behaviour has been attributed to the shape of the TC vs composition curve. The minimum in this curve occurs at about 6% of H_2, and the mixture with the same TC contains about 12%. The effect on the peak shape, as the concentration at the peak maximum reaches and exceeds these levels have been studied and reported. This behaviour is to be kept in mind while using H_2-He mixture for any application. While analyzing a mixture of H_2(90%), O_2(2%) and N_2(8%).on molecular sieve 5A column, one can choose Ar or H_2/He mixture as c.g. The mixed c.g. requires a polarity change, but allows more accurate measurement of other components. An interesting side effect concerns the relative retentions of He and H_2. When the same column is used with mixed c.g., He and H_2 coelute. No adverse effect on the separation of other components is, however, observed(14)

Another important example, of a mixed c.g. is the Ar/methane mixture(95/5%), used for ECD. The methane acts as a moderator, ensuring that the electrons are in thermal equilibrium with the c.g. However, the mixture is less commonly used, compared to N_2, although it gives rather greater response. This is partly due to the inconvenience of having specialized c.g. for this application alone.

Other Gases used in GC and their Functions

In FID, H_2 is commonly used as the fuel gas. Oxygen/air is supplied to support combustion. Only very trace amounts of ions are present in an uncontaminated oxygen/hydrogen flame. However, when organic compounds are introduced into the flame for combustion, the ion concentration goes up several orders of magnitude. The detection is based on this significant effect. Any c.g. can be used with this detector. The temperature of the flame, and hence the response of the detector, depends on the H_2-air/oxygen ratio used to maintain the flame. Variations in detector designs may require different flowrates of H_2 and air. In capillary GC, the addition of a makeup gas is often recommended to optimize the detector and to sweep the detector volume, thus minimizing band spreading. Moreover, at the low flowrates used in OTC, the response is sensitive to flowrate changes. Adequate informations are available in the literature concerning the dependency of FID response on variables such as c.g./makeup gas flow, combustion gas flow/ratios, etc(17) .

The use of makeup gas allows both chromatography and the detector response, to be optimized independently. In some cases(e.g., ECD), a moderating gas is used. This assures an equilibrium concentration of thermal electrons inside the detector. Sevcik(154) evaluated N_2-n-pentane mixture as purging gas for ECD. The sensitivity increases considerably in this case.

Many detectors use flame. Hydrogen is the fuel used and air/oxygen is used to aid combustion. Air is used in many cases for pneumatic control applications. A gas can also be used as a reactant in typical applications. For example, in the Argon or He ionization detector, metastable argon or He atoms, formed in the presence of the radioactive source, facilitate ionization of the analyte gas/vapour molecules inside the detector. In trace level analysis of CO and CO_2, H_2 is used as a reactant in the methanator to obtain methane, so that the final determination can be carried out using FID. In some cases, components may be added to the c.g. at trace levels to improve column or detector performance, or sample components may be added at percentage levels. These represent applications of mixed carrier gas.

In Chemical Ionisation Mass Spectrometry(CIMS), which is a soft ionization process, gases like CH_4, NH_3, acetonitrile vapour, etc. are used as reagent gases.

Gases are often employed for purge and trap analysis, thermal desorption processes, etc. of volatile components(from effluents, liquids and environmental samples)..

Finally, it is worth pointing out that standard gases and gas mixtures of known purity are required in GC for calibration purposes.

Section (B): Capillary GC(CGC)

Introduction (Special Features of CGC)

CGC or Open Tubular Column GC(OTC GC) or High Resolution GC(HRGC) is the modern form of GC.

In the conventional packed column GC(PCGC), the chromatographic process is limited by the slowness of diffusion of the sample molecules around the support particles, and within their pores. The capillary GC provides an open and unrestricted path for the c.g. and the sample molecules along the column tube.

Soon after its introduction by Golay(155, 156), CGC demonstrated its higher separation power and smaller analysis time compared to packed column GC. Both these aspects revolutionised GC. The discovery of very sensitive detectors around the same time give additional momentum to this development. With the advent of fused silica capillary columns in 1979, the acceptance of CGC became very wide spread. Many other developments have followed during the last 25 years. Many chemically bonded phases have been developed which could be bonded, not only to fused silica but also to many metal surfaces. Recently aluminium clad fused capillaries have also become available. MXT capillary columns are made from depositing a uniform micron layer of flexible fused silica on the inner surface of stainless steel tubing. To sum up, the availability of a wide range of fused silica and other capillary columns with different dimensional characteristics and coated with a variety of stationary phases (or with bonded phases) has catalysed changes in every aspect of the GC analytical process, from preparation and introduction of the sample to chromatographic separation of the solutes to their detection. CGC is capable of separations that are vastly superior to those obtained on PCGC. The shorter analysis times and higher sensitivities are other attractive features. They also make it possible to construct much more inert analytical systems. The tremendous gains in column technology have placed increasing demands on detectors to achieve matching levels of performance. For example, small bore FSOT columns have relatively small sample capacities. This, in turn, demands improved detector sensitivity and detectability. To sum up, the evolution of high resolution GC has brought with it stringent requirements for rapid, low volume, sensitive and selective methods of detection. The reduced sample capacities of OTC limit the quantities of sample that can be introduced into the GC, and thus increase the need for higher detector sensitivity. Many other relevant informations have been reported(157).

The average linear gas velocity ($\bar{u}$) turns out to be important in deciding HETP. The higher the $\bar{u}_{opt}$ the faster can one analyse a sample and still obtain the best performance. In general, for a given column, $\bar{u}_{opt}$ will be higher with a low density c.g. (e.g. He or H_2) than with a high density gas(e.g., N_2). Hence He or H_2 are the preferred c.g. in CGC, compared to N_2, which is commonly employed for PCGC. The slope of this ascending region of the Van Deemter curve(after the minimum is reached) represents the resistance to mass transfer contributions in the column related to the diffusion of the analyte in the gaseous and liquid phases. This slope is smaller for CGC than for a packed column(156, 157). The choice of the c.g. velocity is very important as it profoundly affects separation efficiency, analysis time, sensitivity and even to the extent to which thermally labile solutes survive the GC process.

The gas flows through CGC are very low when expressed in normal volumetric terms. However, in general, CGC uses a higher $\bar{u}$ than packed columns, (e.g., ~8 cm/sec. for a typical packed column, and ~18 cm- 20 cm/sec. for CGC). A much longer CGC can be used with the same inlet pressure used in the case of a much shorter packed column (e.g., a 96 m long Wall Coated Open Tubular(WCOT) column or a 125 m long Support Coated Open Tubular(SCOT) column would need the same pressure drop as a 2.5 m long packed column). Since overall column efficiency (expressed as N) is proportional to L, CGC shows higher overall efficiency than a packed column. Higher efficiency means better resolution. To sum up, CGC will always give a better performance than a packed column. The resolution obtained in a given time will be significantly higher. Similarly if resolution is fixed, the retention time in CGC will be much smaller(157).

The sample capacity of CGC is much smaller than PCGC. This is further combined with a much lower volumetric c.g. flow rate. Hence, it is necessary to reduce the sample size reaching the column using appropriate devices/procedures.

Regardless of the injection mode, H_2 or He is the preferred c.g. for CGC, because they yield better overall separations and shorter analysis times. While using the splitless mode, these gases provide another advantage. Because of the higher average linear c.g. velocity, the flow through the inlet is higher and solutes are transferred from the inlet to the column more rapidly and more completely.

The larger diameter OTC that (0.53 and 0.75 mm i.d.) can be directly substituted for packed columns can tolerate normal size injections. The c.g. flow rate through these can be the same as that uses in packed columns. As a result, the standard injector is rapidly cleaned. With the smaller diameter OTC gas flow volumes are much more restricted and specialised injectors are required.

Each solute in a sample has different $\bar{u}_{opt}$ and column efficiency. $\bar{u}_{opt}$ also changes with temperature. Theoretical considerations(which are outside the scope of this paper) underline the importance of selecting c.g., velocity values for the earlier rather than later peaks, and higher than the optimum value.

Selection of c.g. velocity is an important aspect in Temperature programming operations.
The viscosity of a gas increases with temperature. The linear c.g. velocity and the flow rate will, therefore, decrease with increase in temperature, if a constant inlet pressure is maintained. In a pressure regulated system, the c.g. velocity will continuously decrease as the temperature program proceeds to higher temperatures.

An overview of modern high speed capillary GC has been provided in several publications(158, 159, 160, 161)

The Roles of Gases used in CGC

Many aspects relevant to CGC have already been included under Section (A). Some recent trends are indicated below, which relate exclusively to CGC.

One of the most promising uses of thermal desorption is as an injection method for fast capillary GC(162, 163, 164). The effects of the sniffing-port air make up in GC-olfactometry was discussed. The necessity for admitting make-up air to improve the removal efficiency of aroma molecules from the column(and thereby to increase the odour detection frequency and intensity rating) is confirmed(165). A comprehensive two dimensional GC via differential flow modulation has been described. This method was used for analysis of mixtures of alkanes, alkenes, aldehydes, alcohols, aromatics, esters and ketones with high speed and high resolution. In this approach, the flow in the secondary column is kept 20 times larger than the flow in the primary column(166). Peene et al, has discussed the use of reduced pressure GC with high optimal gas velocity, which allows for shorter column lengths and, therefore, faster separations(167). An enantioselective stopped flow multidimensional GC for the determination of the inversion behaviour of 1-chloro-2,2-dimethyl aziridine has been reported(168, 169). Pulsed flow modulation for high speed GC using pressure-tunable column ensemble has been described. In this case, a pressure pulse is used to selectively increase the separation of a component pair that is separated by the first column but coelutes from the series coupled ensemble(170). Ammonia has been suggested as a c.g. for acidic-basic GC(171). The importance of pure air for maximum FID performance has been stressed(172). Maximisation of column life time using c.g. purifiers has been explained. The correct sequence for installation of GC c.g. purifiers is H_2 trap, high capacity moisture and oxygen purifier and lastly an oxygen-moisture indicator. The symptoms of contaminated GC columns are described and resolution of the problem by installation of c.g. purifiers is outlined(173). Ettre(174) has outlined the contributions made by Zhukhovitski in GC procedures (a) without c.g. and (b) chromarheography(c.g. flow gradient). Low pressure continuous flow systems for automated sample preparation(based on solid phase extraction(SPE)) has been described(175). Neat water at temperature above its boiling point was used as mobile phase for packed capillary column chromatography. Mixtures of alcohols and phenols were analysed(176). Gastiger and Jurcik(177) discussed the effects of impurities in gases used for GC on column and detector performance. A method to calculate the gas purity required for use with different detectors has been presented. The suitability of commercially available GC gases for various detectors is discussed, along with methods of preventing gas contamination. The separation of stereoisomers using recycle capillary GC has been reported(178). Berezkin et al(179) described the use of equations for the des cription of experimental dependence of HETP on c.g. velocity in capillary GLC. David and Sandra(180) demonstrated the superiority of H_2 as c.g. in capillary GC by comparing it with He(in the separation of fatty acid methyl esters). Ewender and Strigl(181) described an automated purge and trap analytical system. Effect of various binary gas mixtures as mobile phases in capillary GC has been reported. Two mixtures of N_2/H_2 and He/H_2 and 3 pure gases were used as mobile phases(182). The advantages of H_2 and He as c.g. in capillary GC, compared to N_2 has been demonstrated(183). Capillary GC of trichlorophenols using NH_3 as c.g. has been reported. He and NH_3 have been compared. NH_3 gave improved peak symmetry and an increased FID response for these(184). The practical, analytical and financial advantages of a fully glass/metal gas purifying system for GC gases have been discussed(185). A historical review of fast GC temperature programming has been presented(186). Cahill and Tracy(187) have discussed the effect of permeation of He through the walls of FSOT columns. Abdel-Rehim(188) has provided an overview of interactive c.g., including NH_3, in GLC. Irvin(189) demonstrated that increased column life can be obtained by using a column operated with purified c.g. Berezkin et al(190) examained the effect of He. N_2 or CO_2 as c.g., at pressures ranging from 1.6-4.5 atm. Gavril et al(191) described reversed flow GC systems for measuring conversion of CO to CO_2 in the presence of excess oxygen(under steady state and nonsteady state conditions) at various temperatures over Pt-Rh alloy catalysts. Evaluation of column performance in constant pressure and constant flow capillary GC(in temperature programming operations) has been carried out(192). The active and fundamental role of c.g. in GC separations have been demonstrated by Berezkin and coworkers(193), while describing the approach “Acidic-basic GC”. He alone(or containing 1-3% CO_2 or 1.7% water) or CO_2 alone (or containing 1.7% water) were examined for the separation of amines. NH_3 containing 0.8% water was tried for carboxylic acids. The study of the sorption of CO, O_2 and CO_2 on Pt-Rh alloy catalysts was carried out using a new GC technique. He was used as c.g. At times the c.g. flow was reversed, during which the sample was analysed on a column(194). Andronikashvili et al(195) studied the effect of the nature of the c.g. on the nature of the GC separation of isomeric mixtures of benzene derivatives(Benzene, halogen substituted benzenes, cresols and xylenes). Separations were carried out using combined columns. He, Ar, N_2 and CO_2 were used as c.g. Under suitable conditions separation of a 16 component mixture of o/m/p-benzene derivatives was achieved. Results showed that as the molecular weight of the c.g. increased, the retention time decreased and peak symmetry increased. Robson et al(196) described the results of their investigations on high pressure microcolumn GC(250 micron i.d. fused silica column packed with 5 micron particle diameter bonded silica stationary phases. 10-40 cm long columns were used.).

Rood(197) has explained why changing the c.g. from helium to hydrogen causes shorter retention times and decrease the resolution. Etrre(198) has made some comments about the errors and discrepancies in the paper published by Vassilaros et al(Reference No.182). A reply to this was given, acknowledging the serious errors, but however, maintaining that the basic findings and conclusions are essentially unchanged(1991). Berezkin(200) has emphasized that c.g. is a new factor influencing the selectivity in GLC. Theoretical and experimental study of recycle capillary GC, with c.g. propelled by a peristaltic pump, has been carried out by Kubinec et al(201). An overview covering the c.g leak and its effects on base line, has been provided by Hinshaw(202). Zhang and coworkers(203) used different temperature programs and the isothermal conditions on DB-5 and DB-1701 columns for the correct identification of PCB in temperature programming GC, with EC detection. This was achieved by means of accurate calibration of the retention time, based on the concept of the relative retention index, P_i and retention time of the selected PCB internal standards.

Korytar(204) carried out high resolution separation of PCB by comprehensive to dimensional GC. The effect of water injection on column performance was investigated by Kuhn(205).

Liquid Gas Chromatography

A review has been presented(206)on the principles of a form of GC, where the stationary phase is a gas trapped in the pores of a solid support, and the mobile phase is a liquid. This permutation of GC, known as Liquid/Gas Chromatography(LGC) is in the early stages of development and results suggest a genuine phenomenon in separations.

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Concepts In Chemistry:
Using Computer Programming to Teach Organic Nomenclature

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Abstract

Although chemistry is extremely complex, the subject is built upon powerful ideas that are elegantly simple. Students can understand these ideas, in a deep and abstract way, by writing computer programs to draw and name molecules. The key idea is a microworld, a computer model in which certain important properties are emphasized to enhance learning. By beginning very simply, and then developing progressively more sophisticated microworlds, students can understand powerful ideas in chemistry. The broader implications are ways to teach chemistry to students who are not interested in becoming chemists, but who desire to be informed citizens.

Introduction

The accomplishments of chemists have been so stunning that they made world news. In April of 2003, the 50th anniversary of the discovery of the DNA double helix, scientists announced the completion of the sequencing of the human genome. This is an enormous discovery – three billion chemical base pairs have been analyzed!

It is obvious that expert chemists must possess an enormous amount of detailed information. It is also essential that future chemists must learn to manage an even larger body of knowledge. However, all experienced chemistry educators realize that most students have no interest in learning much chemistry. Since this silent majority will vote on issues of policy, it is essential that methods be available to help them learn at least something of the scope and power of modern chemistry.

Although chemistry has developed the tools to examine extremely complex structures, the field began by exploring very simple problems. One of those problems was to explain why two substances could be made up of the same components and yet behave very differently. In the 1850's, Friedrich August Kekule solved the problem: atoms are connected in a very definite manner, and there is a simple elegant way to represent those connections (Brock, 1993; pp. 245-253; see also Asimov, 1972, for an account that is accessible to non-chemists).

In the history of chemistry, chemists began with very simple problems. They made mistakes, learned from their errors, and gradually made enormous progress. Although it is tempting to begin to give students this enormous information, another approach is possible. Let students explore very simple examples, make mistakes, and learn.

As students gain understanding, they can begin to learn the ways that chemists name molecules. There is an organization that referees the process: the International Union of Pure and Applied Chemists (IUPAC). IUPAC had released the standard Nomenclature of Organic Chemistry. In that work, expert chemists can see the elegances of the systems. For many students, however, that elegance is obscured by the mass of details (see Traynham, 1991, for a tutorial appropriate for students).

Of course, we are not going to ask students to re-invent chemistry without any hints! But it is possible to look at the powerful ideas without overwhelming students with details. Young children have reasoning skills which, if carefully developed through sound instruction, can result in lead to a deep understanding of powerful ideas in chemistry.

Microworlds

In this paper, I will describe a way to teach organic nomenclature, an important area of chemistry. The topic is treated as a microworld, a term made prominent by Seymour Papert (1980). A microworld is an area of knowledge that highlights certain essential features, while deliberately making the situation simpler.

Papert created Logo, a powerful computer language for education. Logo allows young children to write programs to draw simple shapes, and college students to explore differential geometry. Logo permits students to organize complex procedures into well-structured pieces.

Uri Leron (1985) noted that although it is possible to organize a procedure by using subprocedures, children often write complex programs with few subprocedures.

Children may structure their programs if the teacher requests it, but soon return to non-structured style as soon as they are left alone.

In creating computer microworlds for chemistry education, my colleagues and I (Ploger and Lay, 1992, Ploger and Carlock, 1996) have aimed to provide the instructional support for students to write programs. One student wrote a program that can draw, name, and describe over 200 organic molecules (Ploger and Lay, 1992). In order to write such a program, the student had to see the value of organizing his program.

Exactly as Leron had predicted, Dan originally had no interest in organizing his programs. He wrote a procedure to draw the structure of glucose, a molecule with 24 atoms. His program had forty-two commands. Essentially, his program would draw an atom; then move to the next place.

A Computer Toolkit

When the investigator asked Dan if he wanted to use a set of tools, he expressed no interest. A new approach was needed. Instead, the investigator showed the structure for galactose, a molecule with the same number of atoms (a stereo-isomer). The student realized that it would be reasonable for him to modify his program to draw galactose. When he could not do it, he became interested in getting a set of programming tools which could easily be assembled to make a large program easier to understand and modified.

With the tools, the program had a clear structure that corresponded to the structure of the molecule. He realized that it would be useful to draw any kind of hexose, not just glucose. Consequently he developed a code for the placement of the hydroxyl groups. In this way, the procedures for glucose and galactose indicated that they differed only in placement of one hydroxyl group. The difference in the structure of the procedures reflected the difference in the structure of the molecules.

Once Dan recognized the power of subprocedures, he was able to create truly remarkable work. In the Molecular Toolkit, students can create any of a wide range of molecules by specifying the skeleton. A skeleton consists of the carbon and oxygen atoms as well as the nature of the bonds. The program knows the valences of the atoms involved. The Molecular Toolkit can classify examples from eight classes of organic compounds: alkanes, alkenes, alcohols, aldehydes, ketones, ethers, esters, and carboxylic acids.

Let us consider another example. For the skeleton: C-C-O, the Toolkit will select two carbon atoms and one oxygen atom, assign the appropriate bonds, and add the required 6 hydrogen atoms. The program can determine the molecular weight, and then print the following message: “The molecular weight is 46 - each of its 2 carbon atoms has a weight of 12, each of its 1 oxygen atoms has a weight of 16, and each of its 6 hydrogen atoms has a weight of 1.”

In order to name the molecule, the Toolkit first determines the total number of oxygen atoms. In this case, there is one oxygen atom, which eliminates alkanes and alkenes (which have no oxygen atoms), as well as esters, and carboxylic acids (which have two). In order to select among alcohols, aldehydes, ketones, and ethers, the program considers the relationship between the oxygen atom and the carbon atoms. Because the oxygen atom is attached to exactly one carbon atom by a single bond, it can eliminate aldehydes, ketones, and ethers. The Toolkit correctly concludes that the molecule is an alcohol. Because there are exactly 2 carbons, it must be ethanol.

After the first student created the Molecular Toolkit is a computer program, two other high school students explored it. They wrote a sequence of simpler programs to draw molecules (Ploger and Carlock, 1996). Although this simpler version narrowed the scope, it made it easier for students to understand the underlying mathematical ideas.

A Simple Mathematical Problem

Let us start with a simple mathematical problem. Suppose you have an ordinary table. You can place four chairs around it. If you have two tables placed together, you can place 6 chairs. If you have three tables, you can place 8 chairs. How many chairs can be placed around 10 tables arranged in a row?

There are several ways to solve this problem. One way is to extend the pattern, showing the number of chairs for each of the first ten tables. For the tenth table, there will be 22 chairs

There are other problem-solving strategies. Notice that each time a table is added to the arrangement, the number of chairs increases by two. For each table, there will be two chairs associated with it. In addition, there are two chairs at the end of the arrangement. So with 10 tables, there will be $2 \times 10 + 2 = 22$ chairs. The answer is the same in each case: two very different mathematical methods give the exact same result. While this connection may seem obvious to an adult, it is an interesting discovery for a child.

Third grade children can learn to solve this problem in about an hour, using visual models for the tables and chairs. Many fifth graders can learn to solve general case: if there are n tables, there will be $2n + 2$ chairs.

The chemistry teacher will, no doubt, recognize the relationship between the tables-and-chairs problem and the structure of alkane molecules. If there are n carbon atoms in an alkane, there are $2n + 2$ hydrogen atoms. Of course, the structure of molecules is much more complex than the arrangement of tables and chairs. So we are clearly not advocating teaching organic chemistry to elementary school students! But children are ready to begin learning powerful ideas that can be applied to a wide range of topics in science and mathematics.

There several benefits in having educators from a range of perspectives discuss the issues of chemistry education. In particular, if there are connections to education in mathematics or technology. Furthermore, it is useful to look at a broader range of age development. It can be helpful for a chemistry educator to take a step back and look at the subject matter from the point of view of its mathematical potential, how students could write programs to show the features. It is also useful to consider the question: how would young children begin to understand some of the ideas? This does not mean we will teach organic chemistry to 10 year olds, but it does mean we would like to inspire them to learn powerful ideas.

Writing Programs

In writing a computer program, we want students to think of a complex problem as being composed of pieces. We want to solve each of the smaller problems, and then assemble these components. The goal is to get something that works, of course. But there is a much deeper goal. It needs to be easy to modify and extend.

In the Boxer computer system, the programmer has a choice. You can see as much detail as you want in order to understand the process. Once understood, however, you can organize the screen to conceal details and focus on the important principles. In this case, you can look at the jump procedures (and even examine them, if you wish), or you can simply look at the one-table procedure, to get a more global view of the program. Finally, you can simply call the procedure, knowing that it makes a table with four chairs – without any concern for how it does this.

Extending the Program to Draw Molecular Structures

The tables and chairs program could be adapted to draw representations of alkane structure. This new program was able to build upon the tables and chairs program. Let us start at the beginning.

The first program we wrote with tables and chairs was one-table which had a shape to represent a table and four chairs arranged around it. We are going to do the same idea to draw methane, a molecule with one carbon atom and four hydrogen atoms.

The draw-alkane procedure is a direct analog to the tables and chairs procedure. It looks for the number of carbons. If there is only one carbon, it will draw methane.

It will also show the connection to the tables and chairs. For example if you select 3 carbons, it will a molecule with 3 carbons and 8 hydrogens. (see Figure 1) It is also possible to show the analogy to the tables and chairs: $2n + 2$.

This program was extended to serve as a simple tutorial. A student could select the number of carbons and the type, and the program will draw the molecular structure. For example, if the student selected from the number of carbons as 3 and the type as alkane. The program would select prefix 3 (which is prop-) and suffix for alkanes (-ane) and put the two together to form “propane”.

Applications for the Classroom

This paper has described a set of learning activities that can introduce organic chemistry nomenclature to students. There is a simple, elegant mathematical relationship between the number of carbons and hydrogens in an alkane. Students can understand this mathematical idea by exploring the arrangement of tables and chairs.

Students can then learn about the problems that chemists puzzled over in the 1850’s. Without insight, the problem is truly confusing. After Kekule’s discovery, the solution makes perfect sense. As students gain understanding, they can begin to learn the standard Nomenclature of Organic Chemistry (IUPAC). This paper follows the rules that are standard, but simplifies the situations considerably. Everyone is familiar with the process of making a decision. This paper has shown that this process can be applied to naming molecules.

If students are taught too many facts with seeing the purpose, they will forget more information than a teacher likes to admit. If, however, students are allowed to explore very simple problems, it is possible for them to learn general principles that will help them learn more chemistry and more science.

This approach can be expanded to make the concepts of chemistry more available to a wider range of educators. One example is the work of Andrea diSessa (1999, 2000).

Although the major subject matter focus of that work is on physics and computer programming, it can be applied to any area of science. In describing an earlier version (Ploger and Lay, 1992) of this work, diSessa (2000, p. 180-185) notes that the student has created a way to represent the knowledge of organic chemistry that is not in any textbook. It had clear data structure that could be followed by persons outside chemistry. (Trained as a physicist, diSessa is an expert computer designer. He does not have formal training in chemistry.) DiSessa notes that the student's program was so well organized, that a non-chemist could not only understand, but could see the power of the organization of knowledge.

This paper has aimed to organize the knowledge of organic nomenclature so that it appeals to a wider range of students. It is especially important to reach students who do not intend to become chemists. It is hoped that expert chemistry educators will find value in this approach. Toward that end the computer materials are available to those who are interested.

Note: The programs for drawing molecules are freely available by contacting the author (ploger@fau.edu). These programs require the Boxer programming language. For information, please contact http://pyxisystems.com/.

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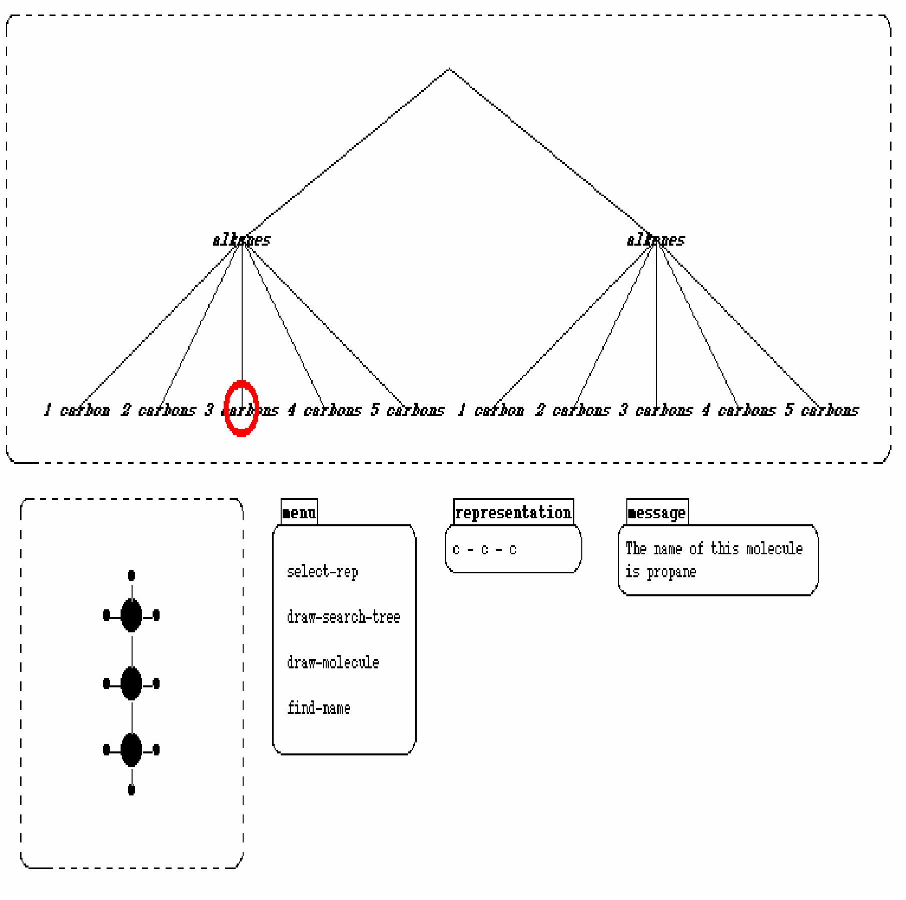

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c - c - c
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The name of this molecule
is propane
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Figure 1. The results of a student's program to determine the name of a 3 carbon alkane.

Report on the Seminar entitled "Accidents in Chemical Laboratories and Industries—Causes and Guidelines for their Prevention"

The broad range of hazards encountered in today's chemical laboratories include simple corrosive reagents to the complexities of radioactive materials, cryogenics and lasers. Hazards unique to industries include corrosive/flammable/toxic/radioactive chemicals, process hazards like runaway reactions, detonations or rapid decompositions, etc.

Continuing safety requires a genuine interest in safety from the top management to the lowest worker. Further, this interest must be continually demonstrated and transmitted. Laboratory and industrial workers must be trained to work safely.

The ground rules for accident free operation is the same for most of the organizations. In all these cases, important ingredients are "people, preparation and prevention". Most accidents are the result of employees deviating from accepted, correct working methods. Safeguards for prevention should become a normal part of the operation processes. Prevention is better than cure.

Case histories of accidents in the chemical laboratories and industries indicate that flammable liquids, exothermic reactions, unstable materials and toxic and corrosive materials play a large part in causing severe injuries. Severity of injury and damage can vary from minor to extreme, depending upon the physical situation of the personnel and the design features of the laboratory and equipment.

A good set of safety practices must incorporate Safety policy, Accident prevention programs, Organisation of a reliable safety program, Proper design of the working environments and areas, Proper disposal of wastes, Appropriate sampling techniques, Work permit systems, Periodic safety audits, Emergency management systems, Safety drills, etc.

In order to give a comprehensive exposure to the various aspects concerning chemical laboratory and industrial safety, the Asian and Mideast Institute of Chemists(AMIC), which is a Division of the American Institute of Chemists(USA), in collaboration with C.K.T. Arts, Commerce & Science College, New Panvel, is organizing a two day seminar entitled " Accidents in Chemical Laboratories and Industries—Causes and Guidelines for their Prevention", at the College premises at New Panvel, during June 26-27, 2004. This seminar was very useful for those working in academic/research institutions, as well as those working in industries. A brief coverage of the proceedings of the seminar is given below.

A special feature of the seminar was that AMIC decided to charge only Rs.300/- from college teachers/students to enable them to benefit by the seminar. Thirty college teachers attended the seminar, taking advantage of this concessional rate. AMIC also charged this reduced rate only, for its members, who have been in good standing for more than one year. This is a special concession and encouragement announced by AMIC, for those who continue to maintain their membership in AMIC. Similar concessional rates will be offered in the future also. Of course, in the future seminars, only a restricted number of AMIC members will be admitted under this concessional rate, for obvious reasons. The industrial delegates were charged a fee of Rs.3,500/-. Thirty three delegates from industry attended the seminar.

The seminar started on 26th June, by 9 A.M., with a devotional song by the students of the college. In a brief speech, Dr. P.S.Ramanathan, President—AMIC, explained that AMIC, which is a Division of the American Institute of Chemists, USA, has several aims and objectives to promote the advancement and spread of chemical sciences in India and the neighbouring countries, including the middle east. Conducting, periodically, seminars, on subjects of interest and relevance to chemists/chemical engineers/technologists fulfils these objectives to a great extent. Since its inception in the year 2000, and registration as a scientific society in 2001, AMIC has conducted 8 national seminars on various subjects, and at various locations. It proposes to continue such efforts in the future also.

The theme of the seminar was chosen in such a way that it would be beneficial, not only to participants from industries, but also for those from academic/research institutions. Experienced faculty members from several organizations of repute were chosen to deliver the lectures on the various topics chosen.

Dr. Ramanathan, thereafter, dealt with the various subjects chosen for discussion in the seminar. Eventhough a sincere attempt has been made to cover various subjects of interest, it was, obviously, not possible to cover all items coming under “safety”, in a two day seminar. Because of this constraint, certain topics could not be included. A Resource Material has been prepared and distributed to all delegates, in which, notes on the lectures delivered have been included. This may function as a source of reference to all delegates in the future. Many organisations came forward to help AMIC financially by releasing advertisements and liberal donations. On behalf of AMIC he conveyed gratitude to all such well wishers.

He hoped that the deliberations conducted on both the days of the seminar may prove useful, not only to the delegates, but also to the faculty members and other dignitaries who participated in the seminar.

Dr. M.C.Badarinarayana, Adviser, SHE, Bombay Chamber of Commerce and Industry, Mumbai, who was the Chief Guest of the function then delivered his Keynote address on the theme of the seminar. He emphasized that accidents are unplanned, unexpected, usually undesired outcome of carefree actions, overlooked conditions, under ill organized set up. They can occur at any place, any time, and to any one. Therefore, their prevention calls for perpetual vigilance and commitment.

Avoiding accidents is the cherished wish of every one of us. Yet this concern is not translated into deliberate and sustained program of action. There are periodic rituals of Target setting and Celebrations, like Road safety, Railway safety week, Mines safety , 4th March, etc. He questioned whether these have delivered what we desire, and whether there are any lessons to be learnt out of these?

He pointed out that the seminar focuses attention on two specific areas, that, over the years, have been identified to be relatively more prone to accidents in Chemical laboratories and industries. Here, both the inventory and the processes are classified as Hazardous materials and Hazardous processes, respectively. To deal with the topics of the seminar, the organizers have arranged subject experts of proven credentials. Also, the structure of the program is in line with the continual improvement model of Plan, Do, Check and Act.

He, thereafter, cited an accident which occurred in Mumbai, in the very presence of personnel charged with the responsibility of protecting people and property in a controlled area. Persons falls from train, run over by train, knocked down by speeding vehicles, collision of vehicles on roads, head injury to two wheeler riders, etc. are reported, as if it is an event, wherein there is no involvement of the victim. Careless and irresponsible driving habits have resulted in innumerable avoidable accidents.

The common thread in all these familiar happenings is that rules and regulations have no meaning to the violator and the regulator fails to enforce the rules. The importance of Rules and Regulations in Loss prevention needs no further emphasis. Safety is a more positive and proactive concept than loss prevention. Safety is the management of risks at acceptable level. In order that social, environmental and economical aspects are tackled in a balanced manner and the reality of hazard being inherent to certain material and operations, focus must be on managing the risks and not eliminating them. We are not looking for a risk free society, but one in which risks are better understood.

Every one should get well informed about the tasks he has to do and the associated hazards. We have to do our jobs with care, competence and control. Besides skill, competence, confidence and knowledge, one needs the right attitude and behaviour(backed by values and wisdom) to meet the challenges of working in organisations involving hazardous material and hazardous processes.

We know many cases in which knowledgeable and experienced employees turn out to be the center of accidents, whereas an apprentice with the right attitude works accident free. Safety is a twenty four hour affair, and it also extends from cradle to grave. Wise men learn from others' mistakes. Accident investigations find great use in preventing its recurrence.

He, thereafter, briefly touched upon the predictor developed by H.W.Heinrich for disabling accident, with his 1:29:300 rule. For every 300 near misses(unsafe act), there would be 29 minor injury causing accidents, and 1 disability causing or even fatal accidents. The revised quantification of Frank E. Bird Jr. gives the figure as 1:10:30:600. That is, for every 6 00 near misses, there would be 30nproperty damage, 10 minor injuries and only 1 disabling injury. This insight needs to be exploited in full to avoid/prevent harm to personnel and property. A prompt and accurate documentation followed by detailed analysis of each and every near miss is a cheap and practically free lesson to avoid extensive harm. One should not at any time ignore the near misses. One has to go the tiniest detail of all incidents. If one can cut the number of unsafe acts, then one can reduce near misses, minor injuries and fatalities. Even failures can be turned into opportunities for improvement.

In summary, he conveyed the essence of accident prevention, substantially covering the topics planned to be covered in the seminar. He formally inaugurated the seminar by lighting the sacred lamp along with other dignitaries on the dais expressing the hope that all participants would immensely benefit from the deliberations of the two day seminar.

The inaugural function ended with an appropriate vote of thanks proposed by Dr. B.K.Desai, Hon. Secretary, AMIC.

The technical sessions started after a brief tea break. In Technical Session I two lectures were delivered. Mr. A.K.Dongre, Dy. Director, Industrial Safety and Health, Govt. of Maharashtra, spoke on "Statutory regulations related to safety. He covered the entire gamut of laws, rules and regulations, emphasizing all important points of relevance to industrial safety. His session was a very interactive one, and very much appreciated by the participants. His lecture gave the right momentum for others which followed.

The second lecture was delivered by Dr. A.K.Majumder, Director(Industrial Hygiene), Central Labour Institute, Mumbai. Starting from the definition of Industrial hygiene, he stressed that the four major categories of environmental agents and factors which can cause adverse health effects to workers(who are exposed to elevated levels and/or unacceptable conditions) are physical, chemical, biological and ergonomic. An industrial hygienist should have the knowledge of several disciplines namely, engineering, physics, chemistry and biology. He lamented that in India, the industrial hygiene discipline has not been given its due recognition and importance, as compared to industrial safety. There is hardly any institution/university in India, which offers degree or diploma course on industrial hygiene. He amplified and discussed in detail all the four environmental factors with adequate illustrations. He also covered aspects such as Evaluation of external exposure through industrial hygiene monitoring and analysis, Evaluation of internal or effective exposure through medical monitoring and analysis, Evaluation of ergonomic factors, exposure limits, concept of TLVs, etc.

Technical Session II started after the lunch break. Three lectures were delivered in this session. In the first lecture, Dr. P.S.Ramanathan, President, AMIC, stressed that the greatest challenge in the field of safety is keeping legislation and public awareness in step, with the rapid development of technology, and the new hazards that constantly arise. All accidents are caused and, therefore, can be prevented. Supervisors or instructors at all levels are responsible for preventing injuries to those working under their direction. The environment, including equipment, must be safeguarded to prevent injuries, and finally, laboratory personnel must be trained to work safely. The ground rules for accident free operation is the same for most of the organizations. In all these cases, the important ingredients are "people, preparation and prevention". Most accidents are the result of persons deviating from accepted, correct working methods. Safeguards for prevention should become a normal part of the operation process. Prevention is better than cure. He then covered aspects such as nature of accidents/hazards in a chemical laboratory, accident prevention program, disposal of wastes, sampling techniques and concepts of safety in industries. He finally summarized the general safety rules for laboratories.

The second lecture in this session was delivered by Mr. Jaspal Singh of Venus(Safety and Health), Navi Mumbai. He covered the topic "Respiratory Protection Equipments".

He began his lecture by stressing that there are four steps for selection of respiratory protection devices(RPD). They are: identification of the hazard, assessment of the hazard, selection of the appropriate RPD and finally training for the use of RPD. He amplified each of these with adequate illustrations. He pointed out that respiratory hazards include those caused by particulates, gas, odour and vapour. He dealt with in detail the physical properties of particulate matter of various dimensions and emphasized the care needed to take care of particulate matter below 5 micron size. He demonstrated the utility of various devices available for protecting those working in such hazardous environments. He concluded his talk by pointing out that right RPD assures protection, comfort and economy as well.

The last lecture of Technical Session II was delivered by Mr. K.V.Balasubramanian, Safety Consultant, Navi Mumbai, on “Emergency Preparedness”. He pointed out that the prime function of the Onsite Emergency Plan is to get together the key personnel from the necessary disciplines, who have the knowledge and experience to assess the situation and give direction, as per objectives. Initiation of the procedure for Onsite Emergency Plan is done by Works Main Controller or Emergency Controller, in consultation with the Site Controller of the concerned unit. Key personnel identified for Onsite Emergency plan are responsible for providing the necessary assistance expected from their disciplines. The senior most employee present in the manufacturing unit, arriving on the scene first, is automatically in-charge of the site. He then amplified, with adequate illustrations, the three control centers: Emergency control center, The site incident, controlled by the Site Controller and the Occupational Health Centre. He elaborated many other aspects such as Responding to an emergency and Duties of security-in-charge.

The deliberations of the first day of the seminar came to an end with the completion of this lecture. On 27th June, three technical sessions were conducted. In Technical Session III, Dr. R.C.Naik, United Phsophorus Ltd., Vapi, dealt the topic “Toxic gas/vapour monitoring equipments”. He started his talk by referring to the innumerable gaseous air pollutants which contaminate the air we breathe. They affect the air quality near their sources and affect the health and safety of workers and other personnel working in plants and factories. Pollution control begins with the identification and quantitative estimation of pollutants. Pollution control depends heavily on reliable analytical techniques, which can identify, and quantitatively determine the concentration of the pollutants in air. For the identification and determination of gaseous pollutants, many advanced analytical techniques using sophisticated instruments are available. Most of them are laboratory methods, for which the air samples are to be collected from the site, and taken to the laboratory for analysis. The ideal approach for industries would be to use cost effective instruments and devices which can detect and determine the gas concentration on the site, where it occurs, and give instantaneous results of measurement. He described in detail the devices and instruments and sensors available for this purpose. He grouped the measuring devices into two categories: (1) Chemical detectors and (2) Electronic instruments. Under Chemical detectors he covered detector strips/badges, short-term detector tubes and long-term detector tubes(dosimeter tubes and charcoal tubes). Under Electronic instruments he covered in detail the principles of their operation and the sensors used in such instruments.

Dr. G.W.Joshi of Taxan Laboratory, Thane, gave the second lecture in Session III. He spoke on “Material Safety Data Sheets”(MSDS). He started his talk by saying that MSDS give an insight to the degree of hazard of various substances used in the laboratory. MSDS is nothing but a compilation of safety related information of the material presented in a particular format. Its use is self-explanatory. In most of the countries it is required by law. The type and the amount of information required to be give, as well as style of presentation(format) varies from country to country. The material may be a pure substance or a mixture, including formulations/finished products, etc. MSDS can be as small as two pages, or can spread over to ten to fifteen pages. Extensive data are available on MSDS in the form of books, journals and product-booklets. He stressed that MSDS is a legal requirement in India for all Major Accident Hazard Units(MAH) under various statues. He presented the MSDS schedule(format) as per the Maharashtra Factories Rules, 1963(Rule 73-M). There are nine sections in MSDS and the tenth one is a disclaimer, that is optional. They are material identification and use, hazardous ingredients of material, physical data for material, fire and explosion hazard of material, reactivity data, toxicological properties of material, preventive measures, first aid measures and date of preparation of MSDS. He illustrated the concept by presenting the MSDS of methanol.

The first lecture in Technical Session IV commenced after the tea break. Dr. B. Saha, Director(QA), Gharda Chemicals Ltd., Dombivli, delivered the lecture on “ Safe working procedures. Personal protective equipments”. He pointed out that it is the responsibility of the management of any organization to provide a safe working place. Ideally, the working environment should be free from hazardous conditions, which pose a risk to the workers or anybody present in that area. Engineering control and safe system of work must be implemented first, to eliminate risk altogether. This is called the first line of defence. However, in certain job situations, or in emergencies, these controls are either not adequate or impractical to implement. In such cases, personal protection equipments(PPE) are the only practical protection available to workers. PPE are considered as the second line of defence. PPE do not eliminate hazards in the work place. They act as barriers between the hazards and the worker, preventing injury or reducing the intensity. Since other methods of risk control are preferred, PPE are to be used only when (a) other alternative controls are not available or ineffective, (b) close contact is necessary to carry out work, such as in manual handling of chemicals or welding operation, (c) there is possibility of heavy objects falling and (d) in emergency situations such as rescue work. He, thereafter, covered in detail the PPE available for Eye and Face protection, Head protection, Respiratory protection, Hand and arm protection, Body protection and Foot and leg protection. He concluded by saying that PPE should be selected such that the equipment will provide adequate control of risk and minimum discomfort to the wearer.

The second lecture in Technical Session IV was delivered by Mr. Vipin B. Doshi, General Manager(EHS), Excel Industries Ltd., Mumbai. He discussed in detail the various aspects related to “Handling, Storage, Transportation and Disposal of Hazardous Wastes”. He commenced his lecture by defining hazard as the potential to cause harm, whereas risk is the probability that this potential will manifest into actual harm. He presented a list of hazardous materials and stressed the need to know the hazardous properties of the materials that we handle. He cited several sources of information. The knowledge gathered over the years has been converted into Codes of

Practice by the concerned persons. He illustrated this point by providing examples of some Indian Standards pertaining to code of handling chemicals. The other aspects he covered include, Laws, Rules and Regulations, Safe Handling and Storage of various kinds of chemicals, Safe Transportation of Hazardous Chemicals, Safe disposal of Waste generated in industry, including the safe disposal of hazardous wastes.

Technical Session V, the last one in the seminar, started after lunch break. Mr. A.A.Raichur, Hindustan Petroleum Refineries, Mumbai, delivered the speech on “Fire Fighting”. He opened his presentation by emphasizing that for an effective fire fighting, it is essential to first understand the chemistry of fire, and basic principles of extinguishing fires with various media. Once the detailed knowledge of fire is known the preventive measures can be taken appropriately. Fire may be defined as a chemical reaction, accompanied by evolution of heat and light. Oxygen, fuel vapour and heat are essential ingredients of the fire triangle. When any one of the sides is removed, the fire triangle will collapse, and fire will cease to exist. Propagation of chain reaction is a fourth ingredient of fire. Hence, in a more precise way, fire should be represented by a trapezoid, rather than by a triangle. Fire extinction, in principle, consists of the limitation of one or more of these factors. Fire extinction approaches may be classified under starvation, smothering, cooling and inhibition of chain reaction. He amplified all these aspects in detail. Fire may spread from the place of origin by conduction, of heat, by convection currents and by radiation of heat or by direct burning. The various extinguishing media are water, foam, dry chemical powder(DCP), carbon dioxide and halons. He illustrated the various Classifications of fire. The other points which he dealt with include basic definitions regarding fire safety, fire fighting in special scenarios, fires involving pesticides, fire detection and protection systems and statutory requirements regarding fire safety.

The last lecture of the seminar was delivered by Dr. M.C.Badarinarayana, Adviser, Bombay Chamber of Commerce and Industry, Mumbai. He provided an excellent presentation on the various intricate aspects of “Safety Audits”. Safety audit is an important tool in Risk Management. Regular, meticulously planned and executed safety audit, with prompt implementation of the recommendations arising from it, is very effective in loss prevention. Structured safety improvement cycle arising out of vision, values and beliefs of an organisation includes this element. Central to the structure is management commitment and employee involvement. The position of safety audit in the chain link is the ultimate one. Auditing is to be carried out on systems, facilities, to assess the performance and identify strengths and weaknesses. The audit findings are utilized to begin the next cycle of structured improvement. Major hazardous chemical units are required statutorily to get Safety Audits done annually by independent professionals and submit the audit report and action taken/compliance on observations and recommendations to concerned authorities(State Pollution Board/Central Pollution Board, Directorate of Industrial Safety and Health). In his extensive presentation, he covered the definition of safety audit, audit objectives, audit team and methodology(including pre-audit information exchange, kick-off meeting). Safety audit examines and assesses, in detail, the standards of all facets of a particular activity-- Technical operations under normal conditions, start up and shut down, abnormal/emergency conditions and the adequacy and enforcement of Standard Operating Procedures for all these situations. The competence and confidence of personnel manning the area are assessed by going through the qualifications, induction program, training and refresher training records and interviews. The audit covers management system and specific technical features. The five main features of safety audit are: identification of possible loss producing situations, assessment of potential losses associated with these risks, selection of measures to minimize losses, implementation of these measures within the organization and monitoring the changes. Every component of the total sys tem is critically examined. The final report incorporates recommendations. The auditee is expected to respond with action plan. The follow up involves monitoring of compliance. Apart from this, elaborate audit should be conducted by external agencies. Audits by internal assigned audit teams and informal, on-going audits by each member of management team, would strengthen safety system. He concluded by stressing that if audit turns out to be a ritual, aimed at compliance, rather than a value based genuine exercise, the effectiveness of the safety management system would not be ensured, and the safety performance cannot be sustained.

At the conclusion of the seminar, Mr. P.P.Tarde, EHS Adviser, Johson Mathey Ltd., Taloja, spoke for a few minutes and shared his views on aspects related to safety. He pointed out that we have hazardous as well as nonhazardous chemicals. Our skill and knowledge in handling them or taming them, proves our competence in the chemical profession, as chemists. Basically, all the hazardous chemicals have two types of degree of hazards. One is, the First degree hazards(those which do not cause damage either to person or property, but they can set the stage for accident/incident, e.g., presence of flammable materials, presence of toxic materials, etc.) and the other the second degree hazards(those which are capable of directly inflicting damage to life, material and property). The right method of combating these hazards is to deal with First degree hazards in a way, to prevent the occurrence of the second degree hazards. This can be achieved by incorporating safety in process and design, followed by prevention measures. He concluded by saying that the wisdom of a person is reflected by the attitude of the person. Attitude is built up by a self-analysis. The things improve, if we learn the technique of Human relations and behavioural science.

Judged from any point of view, the two day seminar was outstanding success. This added one more feather to the scintillating cap of AMIC. The delegates were given a feedback form to fill up. Most of them expressed the opinion that the seminar was conducted in a good manner, in spite of some of the unforeseen hardships AMIC had to face during the two days. The delegates were given Certificates of Participation.

(Report compiled by Dr. P.S. Ramanathan, President, AMIC)

BOOK REVIEWS

Circulating Tumor Markers of the New Millennium

Author:	James T. Wu
Publisher:	AACC Press
ISBN#:	1-890883-73-5
Price:	$35.00

This is an excellent book for the person who wants more in depth information (than one would get in a clinical chemistry textbook) about tumor markers in a very readable and concise format. It has 173 pages which are divided into 10 chapters plus a list of abbreviations, an index, and a preface. Each chapter has a list of associated references and these date from 1990-2004. The first chapter describes normal growth related biological processes and the characteristics of cancer, including target therapy and circulating markers of the new millennium. The second chapter addresses the growth of normal cells and the survival of tumor cells including sections on: the cell cycle, apoptosis, signal transduction pathway, tumorigenesis, angiogenesis, and adhesion. Chapters 3-5 detail the properties of individual tumor markers associated with the cell cycle, signal transduction pathway, apoptosis, angiogenesis, adhesion, and specific properties of tumor cells such as association with inflammation, tumor cell necrosis etc. Chapter 6 discusses individual tumor markers as they relate to clinical utility (i.e. target therapy, early detection, therapeutic monitoring, and other miscellaneous clinical applications). Chapter 7 gives numerous tables listing specific cancers (e.g. breast cancer) with the associated tumor markers which have been demonstrated to have clinical utility for each cancer. This chapter should prove useful to numerous people in the fields of oncology and clinical chemistry because it lists the sensitivity and specificity of each marker for the indicated type of cancer. Chapter 8 is an extension of Chapter 7 and lists panels of multiple markers which have been useful in determining the subtype of tumors and the improvement of test sensitivity and specificity for specific cancers. Chapters 9-10 discuss ELISA assays, luminex and antibody microarray assays. Whenever possible the authors list commercially available assays for the specific tumor markers under discussion. This has proved to be very useful for the clinical chemistry laboratory. Overall, this is a jewel of a little book with a great deal of useful information in a highly readable and concise presentation.

Reviewed by *Margot Hall, Ph.D., FAIC, CPC, FACB, CChem MRSC*

Tumor Markers, Physiology, Pathobiology, Technology, and Clinical Applications

Editors:	Eleftherios P. Diamandis, Herbert A. Fritsche, Hans Lilja, Daniel W. Chan, and Morton K. Schwartz
Publisher:	AACC Press
ISBN#:	1-890883-71-9
Price:	$99.00

This is a comprehensive textbook on tumor markers which details in one place the vast amount of new information that has been published in an important area of clinical chemistry. This superb text has 5 editors, 146 contributing authors, 541 pages, numerous charts and diagrams, 12 color plates, and stands as the most complete work of its type in the area of clinical laboratory tumor markers. Each of the 57 chapters has its own list of references (~50-500 per chapter). The book is divided into four parts: 1) general principles, 2) organ specific tumor markers, 3) genomic and proteomic approaches for biomarker discovery, and 4) some emerging tumor markers. Part one includes 13 chapters detailing basic principles and practice of tumor marker analysis and evaluation. It includes practice guidelines and recommendations for the use of markers in the clinical setting, clinical evaluation criteria, assay quality control and limitations, and an in depth look at topics such as auto-antibodies, circulating cancer cells, cell-free nucleic acids, proteases, oncogenes and tumor suppressor genes as markers of cancer. Part two includes 18 chapters on organ specific (cancer specific) tumor markers. Part three includes 4 chapters on modern approaches for biomarker discovery. These give a very thoughtful description of important genomic, proteomic, and bioinformatic approaches to the discovery of new tumor markers. Part four includes 22 chapters each of which describes current knowledge about a newly emerging set of biomarkers for specific cancers. Examples of these range from teleomerase and kallikreins to the measurement of hue and chroma in assessment of biomarkers of colon and lung cancer. Overall this book is an authoritative work that will prove exceptionally useful to clinicians and clinical biochemists as well as those involved in cancer research. It is a must have for any chemistry laboratory involved in tumor marker testing or research.

Reviewed by *Margot Hall, Ph.D., FAIC, CPC, FACB, CChem MRSC*

The Clinical Toxicology Laboratory: Contemporary Practice of Poisoning Evaluation

Editors:	Shaw, Leslie M., and Tai C. Kwong. Associate Editors: Thomas G. Rosano, Paul J. Orsulak, Bryan A. Wolf, Barbarajean Magnani.
Publisher:	AACC Press
ISBN#:	1-890883-53-0
Price:	$95.00

This excellent new textbook is based on a clinical toxicology review course which has been offered in the past by the American Association for Clinical Chemistry (AACC) and which has been extremely well received by the participants. The text focuses on the delivery of real time answers to the clinician dealing with the poisoned patient seen in the hospital emergency room setting. The book targets chemists/toxicologists and physicians involved in the delivery of clinical care to the acutely poisoned and chronically poisoned patient. Forensic toxicology with its attendant crime scene investigation is not a subject of the book. The text has 537 pages, 41 contributing authors, 29 chapters, 7 appendices, and 1 index.

Individual chapters address: 1) the epidemiology of poisoning, 2) toxicokinetics, 3) pharmacokinetics, 4) the clinical presentations and approaches to the diagnosis of the poisoned patient, 5) pharmacogenetics, 6) point-of-care testing methods, 7) samples including urine, blood, plasma, serum and alternative samples (saliva, sweat, hair, meconium), 8) urine adulteration prior to drug and alcohol testing, 9) traditional and advanced analytical techniques, 10) biological monitoring of chemical exposure, 11) a description of the successful toxicology laboratory for different size hospitals, and 12) eighteen chapters on specific toxins. All of the chapters include learning objectives and a set of self assessment questions with answers at the back of the book. In addition to these, each chapter on a specific toxin or class of toxins presents the following: a) case studies, b) epidemiology of the toxin, c) chemistry of the toxin, d) nomenclature, e) mechanism of action, f) therapeutic and toxic effects of the toxin, g) pharmacokinetics, h) toxicokinetics, i) methods of analysis with a comparison of their analytical and diagnostic parameters, j) clinical interpretations of concentration data, k) a discussion of current questions and issues relating to the toxin, and l) a list of pertinent references.

There are 7 appendices designed to tabulate in a user friendly fashion the most important data required in the clinical toxicology setting. Appendix A offers the answers with explanations to the chapter self assessment questions. Appendix B includes lists of toxins commonly associated with abnormalities of the vital signs (temperature, heart rate, blood pressure, respiratory rate, and papillary responses). Appendix C lists the five most common toxidromes (opioid, sympathomimetic, anticholinergic, cholinergic, sedative hypnotic) and the chemical agents and clinical manifestations associated with them. Appendix D lists the concentrations of drugs and other chemicals that will produce positive results in blood and urine samples for each of the currently commercially available assay methods. Appendix E offers a comparison of test methods for salicylate (aspirin) and acetaminophen (tylenol) analysis. Appendix F gives book reviews for 25 selected reference books in the field of toxicology. And Appendix G lists abbreviations used in the book.

This is a superb textbook for both the beginning and advanced student. It should prove useful to clinical chemists, toxicologists, pharmacologists, and clinicians. The learning objectives, case studies, and self assessment questions add an important dimension to the reader. Of particular note were the efforts to present algorithms by which the physician and the laboratory can use patient history, communication, and clinical presentation to develop a preliminary diagnosis and thus focus the laboratory investigation so as to obtain answers in a timely fashion. Overall, this textbook is a marvelous teaching tool for those involved in teaching clinical chemistry, toxicology, and/or clinical medicine. It is highly recommended as the primary text for courses in clinical toxicology.

Reviewed by *Margot Hall, Ph.D., FAIC, CPC, FACB, CChem MRSC*

Intellectual Properties
American Institute of Chemists

Report on the ACS Conference
Boston, MA

David W. Riley, Chairman AIC

General Overview

Although the main elements of the Symposium were presented on Tuesday, basic elements of the discussion were eluded to during the entire three days of presentations. The discussion was initiated, arranged and presented by the relatively new division of the American Chemical Society under the name of Chemistry and The Law. This does not mean that it was totally a legal prospective but often lawyers were brought in to augment the program. In most cases these lawyers also had a good background in chemistry, many having PhDs as well as JDs.

The depth of the study was quite profound. There were presentations by representatives from the elite National Science Foundation. Caroline A Whitbeck, Chair, Practical Ethics, Philosophy Department, Case Western U., indicated that NSF and ACS had created ground breaking rules on Publications that can be found on the ACS website. These rules define Professional Ethics in the role of publications.

Michael Dennis, Esq. of Chemical Abstracts (CA) cited that as of August 2002, their registry in CA had exceeded 41,000,000 entries. To review and update all this data, CA employs 400 scientist most of whom have PhDs. In 1991 the US Supreme Court decreed that all that data in CA files is protected as belonging to ACS and CA.

Linking to CA is by mutual agreement from all the parties involved. CA is now linked to 128 primary publishers.

The trend in publishing is currently to further the Intellectual Properties by

A. More Publications
B. Faster Access
C. Increased Cost
D. Greater care about avoiding unauthorized copying and distribution

Where the money comes from to do this is constantly a point of discussion.

Basic Premise

Intellectual Properties are looked at differently in different parts of the world and by different cultures. Often the perception is more important than the facts.

Copyright Laws

According to federal law copyright establishes the license as a contract. Once this has been established, the states take over to regulate the law. The freedom to make a contract is limited by:

A. anti-trust laws
B. legislative strategy
C. entertainment industry (strangely enough)

D. commercial development of proprietary technology

The Problems in this area of electronic publishing is that the publisher is threatened because the cost of publishing and distribution tends to become essentially zero and the authors are increasingly powerful as the controlling elements. The professional societies need to shift their emphasis away from the hard copy to a freedom of contract.

In electronic publishing the legal protection must be viewed in the following order:

A. Copyright law—this does not cover facts, research, data, etc.
B. Contract Law—requires contractual relationships, contractual validization, costly enforcement, and is not adequate for third party disputes.
   Both of these have been established over years of trial.
C. Digital Millennium Copyright Act, enacted in 1998, supports the control of access and copying and establishes a liability for circumventing technology protection. This does give the publisher more control, reduces enforcement costs and gives him a fairer use right.
D. Currently congress is attempting to write a Database Protection Law. Laws like this have been enacted in Europe, but not here. It attempts to cover collections of information control through substantial investment of resources, bars extraction of parts or all of collections of technology data from files that are published and tries to establish a fair use technique. Whether it is necessary at this time is not know.

Intellectual Creativity

To maintain a secure level of creativity and prevent unscrupulous people from stealing data, adequate licensing agreements must be established. This applies mainly to academia, not industry. The Supreme Court has upheld the right of authors to have the final say on the distribution of their data and works. As a result Chemical Abstracts has lost five billion dollars in record access use in recent years. To counter this they have established contractual agreements with 128 primary publishers as of 2002.

Chemical Research in Toxicology

Ninety percent of all submission of papers to this journal has been electronic—this is expected to rise rapidly toward 100%. The main concerns about electronic submission are by survey:

A. High quality peer review
B. Long term preservation of the data
C. Worldwide distribution of information
D. Reading electronically is free
E. Back volume reading and searching is free

The NIH has established a Public Library of Science referred to as the "Pub Med Center" Thirty thousand scientists have unanimously stated in an open letter that this is what they want. This is under the arm of the National Health Institute, the source of much discussion of the quality of peer reviewing.

Publishers are uniformly against this because there is no longer any return on the investment after 6 to 12 months. ACS is currently allowing free access to data after 4 years. Most editors are urging ACS to reduce that figure to one year. To pay for this ACS is striking up an agreement with most users for $1000 to $4500/year for accessing ACS journals.

Scientific Misconduct

In a report from the Office of Research Integrity, Chris B Pascal, JD, announced that the definition for scientific misconduct has been revised slightly to include the word "reckless". This is added to the other categories of plagiarism, fabrication and the like. This does not imply a problem with honest error or honest differences in interpretation or judgment of data. Three phases are amplified on:

A. All allegations of scientific misconduct are confidential.
B. Any accused person must have a fair hearing
C. Whistleblowers need to be protected unless proven to be illegal.

Ranges of Intellectual Properties

A. Acceptance of a Code of Ethics
B. Publications of all sorts.
    a. Technical journals
    b. Relevance of scientific misconduct
    c. Depth of technical paper
    d. Importance of science around the world
    e. Impact of written vs. electronic publishing

Depth of the Need for a Code of Ethics

An adequate Code defines the moral and legal responsibilities as well as spelling out the risks, uncertainties, and the problem with ignorance. One approach is the cost benefit assessment, frequently expressed as a ratio of

$$\frac{\text{Benefit}}{\text{Cost}} =$$

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Another aspect is the inspection of the Codes of Ethics assembled with the support of the National Science Foundation. This can be accessed by the web site

http://onlineethics.org

This is not an exhaustive list; for example it did not included the Codes of The American Institute of Chemists, The Association of Consulting Chemists and Chemical Engineers, or the Society of Management Consultants—these societies all critically need to demonstrate Code functions for these groups even though they are not primarily publishers.

The fundamental factor involved with publishing has to be the quality and depth of the peer reviewing process. This is why a Code of Ethics is always first on everyone's list. The more the process is buried in a shield of electronic functions, the less able are editors and their peers to adequately assess the relevance of the reviews.

The editors of many of these journals have begun to use a method of "tracking" to control some of the elements of peer review. The details of this method will be looked into at a later date. It needs to be defined and illustrated.

Gold Medal Award

The Gold Medal is The Institute's highest award. It is given annually to a person who has stimulated activities of service to the science of chemistry or the profession of chemist or chemical engineer in the United States of America. In recognition of their achievements, Gold Medalists are given Life Fellowship in The Institute. The winner for 2004 was Dr. Carl Djerassi. Nominations are now being accepted for the 2005 Gold Medal Award.

Books Available for Review

The following books are available for review at the AIC National Office. Should you be interested in preparing a book review for inclusion in a subsequent issue of The Chemist, please contact the office. There is no guarantee that the books in this list will be available. As is the custom, you are welcome to keep the book that you select as thanks for performing this service,

Advances in Chemical Physics
Adsorbents: Fundamentals and Applications
Catalytic Membranes and Membrane Reactors
Chemometrics
Computational Geometry in C
Data Acquisition and Signal Processing for Smart Sensors
Enzyme Kinetics
Fundamentals of Classical and Statistical Thermodynamics
Genomes
Mass Spectrometry and Hyphenated Techniques in Neuropeptide Research
Hydrazine and It's Derivatives
Organic Chemistry
In-Situ Spectroscopy in heterogeneous Catalysis
Interfacial Enzyme Kinetics
Magnetism: Molecules to Materials
Measuring Mass
Modern Arene Chemistry
Molecular Modeling
Glycosciences
Principles and Modern Applications of Mass Transfer Operations
Process Dynamics
Propagators in Quantum Chemistry
Quantum Mechanics
Reactive Intermediate Chemistry
Relativistic Effects in Heavy Element Chemistry and Physics
Reviews in Computational Chemistry; Vol 9
The Raman Effect
Sediment Flux Modeling
Thermodynamics of Biochemical Reactions
On the Practice of Safety
Modern Practice of Gas Chromatography
General Chemistry
Chemical Principles