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Articles

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FLAWED BLOOD TESTS: THE DUI EXCEPTION TO ADMISSIBLE EVIDENCE

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***212 I. The California Legal Requirements for Blood Alcohol Testing:**

The State of California sets forth the following requirements that it developed in the early 1970s for blood alcohol testing for Driving Under the Influence (DUI) prosecutions.¹ The archaic nature of these regulations make them unreliable and replete with confounding flaws.² These flaws are apparent by a cursory glance.

II. Blood Alcohol Testing

A. The Law Governing Laboratories

17 CCR 1220.1. Standards of Performance:³

(a) Methods for forensic alcohol analysis shall meet the following standards of performance:

(1) The method shall be capable of the analysis of a reference sample of known alcohol concentration within accuracy and precision limits of plus or minus 5 percent of the value; these limits shall be applied to alcohol concentrations which are 0.10 grams per 100 milliliters or higher;

(2) The method shall be capable of the analysis of ethyl alcohol with a specificity which is adequate and appropriate for traffic law enforcement.

(3) The method should be free from interference from *213 anticoagulants and preservatives added to the sample;

(4) Blood alcohol results on post-mortem samples shall not be reported unless the oxidizable substance is identified as ethyl alcohol by qualitative test;

(5) The method shall give a test result which is always less than 0.01 grams of alcohol per 100 milliliters of blood when living subjects free of alcohol are tested.

(b) The ability of methods to meet the standards of performance set forth in this Section shall be evaluated by the Department using a laboratory's proficiency test results and such ability must meet the requirements of these regulations.

B. The Law Governing Admissible Evidence: "Relevance" Requires "Reliability"

1. The California Rule (Kelly or Kelly-Frye)

The California Supreme Court has formulated "generally accepted rules by which the reliability and thus the relevance of scientific evidence is determined[;]"⁴ a guide to determination of reliability, and therefore relevance and subsequent admissibility.⁵ Furthermore, the party offering evidence "must demonstrate that correct scientific procedures were used in a

particular case.”⁶

The California Supreme Court in *Williams*, noted that foundational facts “will insure that the tests retain their reliability, and thus their relevance and admissibility. . . .”⁷ The *Williams*’ court reasoned that “admissibility depends on the reliability and consequent relevance of the evidence”⁸ Therefore, evidence must be reliable, or it is not relevant.⁹

*214 2. The U.S. Supreme Court Rule (Daubert)

Similarly, the U.S. Supreme Court held:

The inquiry envisioned by Rule 702 [which governs the admissibility of evidence] is, we emphasize, a flexible one. Its overarching subject is the scientific validity--and thus the evidentiary relevance and reliability--of the principles that underlie a proposed submission. The focus, of course, must be solely on principles and methodology, not on the conclusions that they generate.¹⁰

The U.S. Supreme Court also held that “the trial judge must ensure that any and all scientific testimony or evidence admitted is not only relevant, but reliable.”¹¹ There is no dispute that the evidence must be “reliable” to be “relevant,” and must be “relevant” to be admissible.¹²

3. Expert Testimony Requires “Reliable Methodology”

The trial judge has a duty to insure that expert testimony based on the interpretation of scientific data “is the product of reliable principles and methods.”¹³ Further, the judge must “make certain that an expert, whether basing testimony upon professional studies or personal experience, employs in the courtroom the same level of intellectual rigor that characterizes the practice of an expert in the relevant field.”¹⁴

4. Single Column Gas Chromatography Has Been Held to Be Unreliable

“Dual column confirmation” is a process by which samples to be *215 confirmed are run through a second GC in which the elution times of the compounds have been reordered . . . (a dual column is necessary in order to confirm which of a number of . . . compounds with similar retention times you have identified.)¹⁵

III. The Fundamentals of Gas Chromatography for Blood Alcohol Analysis

Gas chromatography,¹⁶ or “GC,” is the method used by California crime laboratories to test for alcohol (ethanol) in the blood of DUI suspects.¹⁷ The results are admitted into evidence at trial¹⁸ or presented to the defense to induce a plea bargain.¹⁹ GC is a form of chromatography (or separation) of a mixture of organic and inorganic compounds.²⁰ For the purpose of DUI prosecution, GC is used to separate the blood into the various individual volatile organic compounds (VOCs) that it contains.²¹ “Volatility” refers to the ease with which a chemical changes from the liquid state to the gaseous state.²² This is from where the “gas” in gas chromatography is derived.²³ For example, the smell of alcohol on the breath is from the gaseous ethanol that has evaporated from the ingested liquid phase, and exited through the lungs.²⁴ After the compounds in blood have been separated, it is possible, with varying accuracy depending upon the method employed,²⁵ to *216 identify and quantify the amounts of the individual VOCs, including ethanol, present in a given sample.²⁶

In GC testing, blood is warmed to vaporize the VOCs into a mixture of gasses.²⁷ The VOCs in this vapor phase are then swept into, and through a separation column using a stream of an inert gas (often helium).²⁸ The column is a long, thin, heated, coiled tube (q30 meters in length and =0.5 mm internal diameter is common for blood ethanol testing), with an inner lining composed of silica or various polymers that interact with VOCs to differing extents, depending on the VOC physical properties.²⁹ Some VOCs bind very tightly to the column lining and take longer to pass through the column,³⁰ while other VOCs bind very loosely and pass through quickly.³¹ Thus, the separated compounds in theory exit the column at different times, called “retention times” or “elution times.”³² Differing retention times are the result of the interaction of the blood VOC mixture with the column lining, column temperature, and selected carrier gas type and flow rate.³³ The physical reactivity of the column lining to VOCs varies from column-to-column, because of the use of different lining materials in different column types, and within a single column type, because of non-uniformity in applying the lining during column production.³⁴ Thus, each individual column requires

rigorous standardization and calibration to ensure accurate functioning.³⁵

*217 As the compounds exit the column, they are typically detected using a Flame Ionization Detector (FID).³⁶ The FID heats the eluted VOCs to their ignition temperature³⁷ (i.e., they are burned) with a hydrogen/air flame. When organic compounds burn, their carbon molecules release cations³⁸ (i.e., positively-charged ions), and electrons that form an electrical current that can be quantified when these particles pass between two electrodes in the detector.³⁹ The current thus generated reflects the amount of a given compound and provides the results as the current produced (i.e., amount of chemical) at each retention time.⁴⁰ This is analyzed by a computer and the results are presented as a graph of various peaks that correspond to different compounds.⁴¹ A typical GC instrument schematic, and photographs of a GC unit, and an opened GC unit showing the separating coil are provided in Figure 1 A-C, respectively.⁴²

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The identification of each individual compound is achieved by the time it takes to exit the column.⁴³ For example, an analytical chemist may run pure ethanol on the gas chromatograph with a new column and find that detection occurs at 1.5 minutes (i.e., the retention or elution time for ethanol on that column is 1.5 minutes).⁴⁴ The instrument is then programmed to identify any compounds that reach the detector at 1.5 minutes from time of *218 sample insertion into the gas chromatograph as ethanol.⁴⁵ Representative graphic results from a GC assay are presented in Figure 2.⁴⁶ Detailed GC methodology can be explored in the textbook *Basic Gas Chromatography*.⁴⁷

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The separation process is not perfect, and the problem with this testing using a single column is that blood or any organic mixture often has many individual compounds,⁴⁸ all unknown to the analyst, and several of these chemicals can have the same retention time (or “travel time” in lay terms) in any given column.⁴⁹ In the example described above, there can be another compound that exits the column at 1.5 minutes. For example, diabetics often generate acetone as a result of pathophysiological processes inherent to their disease.⁵⁰ Importantly, the popular low-carbohydrate Atkins diet⁵¹ results in a condition known as ketosis, in which blood acetone levels have been demonstrated to *219 be elevated by 6 to 8-fold above normal levels.⁵² Indeed, recent studies show that acetone production is highly variable in “ostensibly healthy individuals,”⁵³ and is increased up to 9-fold after eating a low-carbohydrate diet, which persists for several days after discontinuing the diet.⁵⁴ Additionally, acetone is consistently and highly increased in the blood of heavy drinkers, particularly during periods of abstinence (i.e., sobriety),⁵⁵ and is also elevated in diverse instances of malnutrition.⁵⁶ Thus, blood samples tested for blood ethanol levels can contain high levels of endogenous acetone in the absence of intoxication,⁵⁷ which can easily be confused with ethanol using single-column GC.⁵⁸ Another potential confounder is acetaldehyde,⁵⁹ which is a non-intoxicating breakdown product of ethanol that often has a similar elution time as ethanol, depending upon the GC column used.⁶⁰ If acetone or any of the other organic compounds found in blood do not sufficiently separate from ethanol, or have a similar retention time as ethanol, the instrument will read that compound as ethanol, as well.⁶¹ This will produce a false positive *220 result⁶² or can also cause in a drastically higher blood ethanol content result than the true value.⁶³ The FID, generally used for sample evaluation, is not specific for any particular compound,⁶⁴ and has no safeguards that ensure that a resulting peak reflects only a single chemical.⁶⁵

It is widely understood that two or more organic compounds in any mixture, including blood, often have similar elution times.⁶⁶ It is possible for many organic compounds to have the same retention times as ethanol,⁶⁷ thus rendering a high ethanol result even if none is present.⁶⁸ Analytical chemists concerned with accurate results have adopted more reliable testing methods.⁶⁹ Law enforcement in Sweden identified the high likelihood for errant results when using single-column GC for blood alcohol determination, and instituted a policy of conducting triplicate measurements on each blood specimen using three different but identical machines, which are operated by three different technicians.⁷⁰ This was an effort to minimize column-to-column and operator-induced errors.⁷¹ Although they reported improved *221 reliability in their overall results accuracy,⁷² they noted problems with ethanol cross-detection with other compounds present in some intoxicating beverages when using certain columns.⁷³ They also noted that statistical deviation among the triplicate results increased in “the summer months when more experienced laboratory staff take vacation . . .” highlighting the potentially critical role of laboratory technician-introduced error in blood alcohol determination.⁷⁴

According to McNair and Miller, “[e]rrors that occur in any step can invalidate the best chromatographic analysis, so attention must be paid to all steps.”⁷⁵ This was recently highlighted by the discovery that a forensic technician in the Colorado Springs Metro Crime Lab, which served both the city and the county, erred on 206 blood alcohol determinations between 2007 and

2009.⁷⁶ Review and retesting of these samples resulted in seven DUI dismissals, and two instances of reduced penalties.⁷⁷ Five of these defendants had spent time in jail.⁷⁸ By December 2009, 82 DUI case blood samples that had been retested showed lower blood alcohol levels than originally reported, and used for prosecution.⁷⁹

More recently, the Colorado Department of Public Health and Environment suspended all blood-alcohol and blood-drug testing at the state toxicology lab indefinitely because of potential errors in analyses.⁸⁰ The state lab processes DUI blood work for 225 law enforcement agencies in Colorado, completing approximately 8,000 tests each year.⁸¹ The suspension resulted from a *222 Department of Public Health and Environment report exposed by Colorado defense attorneys.⁸²

“Poor lab supervision, [issues] with security measures used to protect blood samples, and training [discrepancies] were [noted] in the report . . . a second internal investigation has already identified issues such as problems with lab training, understaffing, training around court testimony and supervision.”⁸³ Over 800 randomly selected blood-alcohol and blood-drug samples gathered in the preceding twelve months will be retested by an independent laboratory.⁸⁴ This is yet one more of many examples in the literature in which DUI defendants’ cases were potentially tainted by inaccurate and unreliable crime lab blood-alcohol testing.

More recent technological developments such as the synchronized use of three columns with different VOC elution times (commonly called three-dimensional gas chromatography, or GC),⁸⁵ and the use of gas chromatography with confirmatory mass spectrometry,⁸⁶ have improved specific detection of ethanol and any other compound in question.⁸⁷ These methods have significantly enhanced the reliability of blood alcohol determinations versus single-column chromatography, by eliminating false positives or falsely high results.⁸⁸ Unfortunately, these newer, more accurate and reliable methods have not been widely adopted by law enforcement due to perceived equipment and technician retraining costs,⁸⁹ and (grossly unwarranted) *223 satisfaction with their outdated single-column GC systems that often produce spurious results.⁹⁰ Law enforcement complacency with obsolete laboratory technology⁹¹ continues to result in DUI convictions of innocent individuals, as the author has personally witnessed while acting as an expert witness in DUI cases in twenty different California counties.

IV. Single-column Gas Chromatography Used in Courts

The state of California has more than twice as many annual DUI arrests than any other state in the nation, based on the latest Justice Department statistics from 2009.⁹² That year, California had over 200,000 DUI arrests, followed by Texas at a distant second with less than 100,000 DUI arrests.⁹³ California also has the second highest DUI arrest rate (behind Wyoming), at 86/10,000 persons.⁹⁴ For the purposes of this paper, the author examined the California counties with some of the highest numbers of DUI arrests, which were Los Angeles, San Diego, and San Bernardino Counties,⁹⁵ and their relevant crime laboratory data. All three counties still only perform a single-column GC analysis on blood samples, based on the records produced in pending DUI cases.⁹⁶

*224 Unfathomably, these counties are not an exception. Many laboratories in the State of California are operated by law enforcement agencies or are contracted by law enforcement.⁹⁷ The vast majority of these labs that conduct blood ethanol analyses for alleged drunk drivers use methods that are outdated, at best.⁹⁸ Prosecution laboratory materials introduced into evidence, and in the possession of the author, as well as written methods and transcripts, indicate that most California crime laboratories generally fall well below the performance standards⁹⁹ that are deemed acceptable in the scientific community for chemical detection and quantification.¹⁰⁰

It has been well known since the 1964 publication by Machata¹⁰¹ that in scientific forensic and analytical circles, the dual-column GC was the only quasi-reliable method of blood alcohol analysis.¹⁰² However, the California counties with the *225 most DUI convictions still only use single-column GC for blood alcohol testing. This method is inherently outdated and absolutely harms innocent drivers. Single-column GC is employed by the crime laboratories in San Francisco County, San Diego County, Kern County, Napa County, San Mateo County, Santa Barbara County, Ventura County, Fresno County, Humboldt County, the California Department of Justice Laboratory for Riverside County, Santa Clara County, and San Bernardino County, to name a few. The author has first-hand knowledge of the common blood alcohol testing procedures in these counties, and routinely acts as an expert witness in DUI prosecutions.

The necessity of two-column GC has been repeatedly established in studies of the number of VOCs in human blood. In one study, fifteen different individuals that were not under the influence of alcohol had their blood analyzed for VOCs and the

blood tests yielded forty-six VOCs amongst this group.¹⁰³ Almost all subjects tested had six of the same VOCs in their blood. Other authors have found over forty VOCs in blood.¹⁰⁴ Some of these VOCs had identical elution times and could not be separated or individually quantified, even with a dual-column GC.¹⁰⁵ However, it is well-accepted that using a dual-column as opposed to a single-column is more reliable for blood ethanol quantitative and qualitative determinations by GC.¹⁰⁶

A. Dual-column Gas Chromatography for Blood Ethanol Quantification Has Been Adopted by Several National Forensic Scientist Organizations

The “U.S. Department of Health and Human Services in 1987, *226 the Society of Forensic Toxicologists (SOFT) and the Toxicology Section of the American Academy of Forensic Sciences (AAFS) appointed a joint committee of members to recommend a supplementary set of guidelines for the practice of forensic toxicology,” which were published in 2006.¹⁰⁷ These nationally-adopted standards require that quantification should involve:

[A] confirmatory (second) test . . . more specific than the first test for the target analyte. The use of mass spectrometry is recommended as the confirmatory technique, [wherever] possible and practical. For example, detection of an analyte by immunoassay and ‘confirmation’ by GC/NPD [(nitrogen-phosphorous detector)] or GC/FID does not generally provide sufficient specificity for prosecution of a criminal case. However, the rigorousness required of a confirmation depends to some extent on the importance of the analytical finding and circumstances of the case. . . . [A] second analytical system is encouraged[,] . . . [such as] using a second GC column . . . IF the second [test] results in significant changes in analyte retention time AND change in elution order of at least some of the common volatiles (e.g. ethanol, isopropanol, and acetone). The second analysis should be performed on a separate aliquot of the specimen, or an alternate specimen from the same case.¹⁰⁸

B. Manufacturers Have Also Indicated That Their Gas Chromatographs Used for Blood Ethanol Analysis Must Be Performed Using a Dual-column Method

Two of the largest manufacturers of GC systems and columns have professed the benefits of using dual-column GC for accurately analyzing VOCs:

1. Perkin Elmer, Inc., with Restek® Columns Recommendation:

By sampling this vapor (the headspace) and delivering it to a gas chromatograph, the volatile compounds may be qualitatively identified and quantitatively measured. A single headspace injection is normally split into two capillary columns, each exiting to a flame ionization detector (FID). The columns have different polarity for unique separations of the volatiles of interest.¹⁰⁹

*227 2. Agilent Technologies Recommendations:

“Dual-column systems offer an advantage in that elution order of ethanol and some other common metabolites differ on the DB-ALC1 and DB-ALC2 [GC column] stationary phases.¹¹⁰ This provides added confirmation and a potential reduction in possible inferences or co-elutions with ethanol.”¹¹¹ Furthermore, the dual-column system “has an advantage since the order of elution is different on each column and therefore it adds confirmation of the peak identification.”¹¹² In their experiments, the authors equipped the system with two different columns designed specifically for BAC analysis. Each column in this dual-column system produces a different elution order for ethanol and other metabolites, thereby increasing assay reliability.¹¹³

C. Widespread Requirement of Dual-column GC, As Minimum Instrumentation in the Scientific Community for Blood Ethanol Testing

The requirement of at least having a dual-column GC for assessing blood alcohol concentration is widely known and accepted in the scientific community.¹¹⁴ Although law enforcement agencies are becoming increasingly appreciative of the need to employ more modernized equipment and approaches for blood alcohol assessment, the sluggish adoption of these techniques is disturbing. The eminent toxicologists, Tagliaro et al., indicated that dual-columns are the correct method,¹¹⁵ and the work of

McNair et al.,¹¹⁶ concluded that “the gas chromatograph by itself cannot be used to identify a single compound from among this large group[,]” and that “[r]etention times are characteristic of a GC system, but they are not unique, *228 so GC retention times cannot be used for qualitative confirmation.”¹¹⁷ Many other authorities have repeatedly made the same assertions against the reliability of single-column GC for blood alcohol analysis in textbooks and peer-reviewed scientific publications, consistently since 1964.¹¹⁸

V. Gas Chromatography With Mass Spectroscopy Confirmation is the Ideal Method for Accurate Blood Alcohol Level Determinations in Crime Laboratories.

Mass spectrometry (MS) is a well-validated analytical technique that is used to assess the sizes and structures of chemicals present in mixtures, including blood.¹¹⁹ Although many equipment variations exist, typical MS works by bombarding a sample (e.g., blood, or the blood vapor emissions from a GC column) with a beam of high-energy electrons.¹²⁰ This breaks apart the molecules in a sample and gives the resulting molecular fragments an electrical charge (known as ionization).¹²¹ A sophisticated electrical detection system analyzes these ionized fragments on the basis of their mass-to-charge-ratios and produces a highly accurate readout of the specific chemicals present, and their individual concentrations, within the original *229 sample.¹²² Although two-column GC is by far better than single-column GC for assessing blood alcohol levels in DUI cases, they both rely on the same principles of chemical separation and identification, and are therefore subject to the same technical errors.¹²³ By confirming “initial” GC results with mass spectroscopy (i.e., GC-MS), a significantly increased confidence level is achieved in accurately quantifying blood alcohol levels.¹²⁴ Mass spectrometry is widely used for analyzing complex chemical mixtures, and has become a routine, affordable, basic instrument in laboratories worldwide.¹²⁵ The following Figure 3¹²⁶ details sample ionization (A), analysis and data output (B), and shows a representative combination GC-MS instrument (C). In the data output example in Panel B, each spike corresponds to a precisely identified chemical, whose relative concentration is determined by the height of the spike; the “m/z” label on the X-axis refers to the mass-to-charge ratio, which defines the identified chemical.¹²⁷ Detailed computer analysis provides precise concentrations of each chemical present.¹²⁸

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*230 A. Mandatory Adoption of Modern Validated Methods for Accurate Blood Alcohol Determination by Law Enforcement is Urgently Required

Uniform adoption of accurate, reliable, user-friendly, and cost-effective newer technologies for assessing blood alcohol levels by law enforcement laboratories is absolutely necessary, and without delay.¹²⁹ To date, however, many different law enforcement agencies continue to rely on outdated single-column GC technology, or inconsistently apply technology for blood chemical analysis.¹³⁰ It is a clear violation of good laboratory practices for many of the California law enforcement, and forensic laboratories to continue to apply single-column GC for blood alcohol assessment in DUI prosecutions.¹³¹ Within many other law enforcement agencies, for example, the Florida Department of Law Enforcement, standard operating procedures now consistently assesses blood alcohol levels using either dual-column GC or GC-MS.¹³² Inconsistencies do exist, however, in *231 technology application for assessing intoxicants in blood samples. The Tulsa, OK Police Department, for example, uses a GC-FID (they do not specify single-or dual-column GC) for blood alcohol analysis, but uses GC-MS to test blood samples for other intoxicating drugs.¹³³

Barriers to continued inappropriate use of single-column GC for law enforcement blood alcohol analysis include perceived costs in updating equipment, technician training, and standard operating procedures.¹³⁴ Single-column GCs have limited use and reliability, and their use in biomedical research studies is often a point of reviewer criticism.¹³⁵ They are essentially dinosaurs, with no place in a modern forensic laboratory. The equipment costs to upgrade to dual-column GC or, ideally, to GC-MS are not exorbitant, and will pay for themselves within a few years of implementation in terms of reduced prosecution costs (increased “true” guilty pleas or plea bargains in the face of definitively accurate blood alcohol data),¹³⁶ decreased litigation costs (exemplified previously in the discussion of the Colorado Department of Public Health and Environment laboratory’s need to re-test 800 blood samples, and the inevitable lawsuits that will be filed by DUI defendants),¹³⁷ declining operation costs (MS instruments require minimal maintenance, and will typically *232 outlive their operator),¹³⁸ with a minimal additional investment required for re-training competent laboratory personnel.¹³⁹ Obviously, with any instrumentation, operator error will remain the largest source of error in blood alcohol determinations.¹⁴⁰ Sound standard operating procedures, which include all facets of DUI case blood analysis from blood collection and storage parameters, to establishing universally accepted

good scientific practices for assay conduction, to developing and administering appropriate technician training (and periodically re-testing performance), will give law enforcement and the prosecutor's office increased confidence in the accuracy of blood alcohol determinations in DUI cases.¹⁴¹ Nationwide law enforcement adoption of modern, accurate, and reliable blood alcohol measurement technologies will simultaneously reduce the number of DUI defendants that are wrongly convicted of a crime.

Footnotes

- ^{a1} **Okorie Okorochoa** is an intoxication test evidence expert witness and has qualified as an expert in 29 California Counties. He is also the only State Bar of California recognized Dual Nationally Board Certified Trial Lawyer.
- ¹ See Cal. Code Regs. tit. 17, §1220.1 (2013) (listing the regulations California adopted to control the methods of forensic alcohol analysis).
- ² See *infra* text accompanying notes 98-115.
- ³ Cal. Code Regs. tit. 17, §1220.1 (2013).
- ⁴ *People v. Williams*, 49 P.3d 203, 206 (Cal. 2002) (quoting *People v. Harris*, 767 P.2d 619, 649 (1989)).
- ⁵ See *id.* at 207 (“Essential to Adams, was the principle that admissibility depends on the reliability and consequent relevance of the evidence, not the precise manner in which it was collected.”) (citing *People v. Adams*, 131 Cal. Rptr. 190 (Cal. Ct. App. 1976)).
- ⁶ *Id.* at 206 (quoting *People v. Kelly*, 549 P.2d 1240, 1244 (Cal. 1976)).
- ⁷ *Id.* at 209.
- ⁸ *Id.* at 206 (citing *People v. Adams*, 131 Cal. Rptr. 190, 195 (Cal. Ct. App. 1976)).
- ⁹ See *id.* (“[A]dmissibility depends on the reliability and consequent relevance of the evidence....”).
- ¹⁰ *Daubert v. Merrell Dow Pharm., Inc.*, 509 U.S. 579, 594-95 (1993).
- ¹¹ *Id.* at 589.
- ¹² See *id.* at 597 (stating that under the Federal Rules of Evidence, pertinent scientific evidence must “rest[] on a reliable foundation and [be] relevant....”).
- ¹³ *Fed. R. Evid. 702(c)2*. Uenceote.eech. of speech.il. speech that advocates overthrow of government? ct.sufficient alternative of hen spouse or child28. See also *Kumho Tire Co. v. Carmichael*, 526 U.S. 137, 149 (1999) (describing that to ensure expert testimony is a product of reliable principles and methods, judges must examine the “factual basis, data, principles, methods, or the [] application” of their testimony (citing *Daubert v. Merrell Dow Pharm.*, 509 U.S. 579, 592 (1993)); *Guidroz-Brault v. Mo. Pac. R.R. Co.*, 254 F.3d 825, 829 (9th Cir. 2001) (“Rule 702 requires that expert testimony relate to scientific, technical, or other specialized knowledge, which does not include unsupported speculation and subjective beliefs.”).
- ¹⁴ *Kumho Tire Co.*, 526 U.S. at 152.

- ¹⁵ [United States v. Atchison, Topeka & Santa Fe Ry. Co., Nos. CV-F-92-5068 OWW, CV-F-96-6226 OWW, CV-F-96-6228 OWW, 2003 WL 25518047, at *15 \(E.D. Cal. July 15, 2003\).](#)
- ¹⁶ Harold M. McNair & James M. Miller, *Basic Gas Chromatography 1* (2d ed. 2009).
- ¹⁷ See, e.g., [People v. Lopez, 286 P.3d 469, 478 \(Cal. 2012\)](#) (stating that the defendant’s blood alcohol concentration was measured by gas chromatography to determine if she was driving under the influence, and that the California Supreme Court upheld the use of this data in court).
- ¹⁸ See 3 David L. Faigman et al., *Modern Scientific Evidence: The Law and Science of Expert Testimony* at 201 (1999) (discussing the admissibility of gas chromatography tests and the various challenges raised).
- ¹⁹ Cal. Veh. Code §23103.5(a)-(c) (West 2009).
- ²⁰ McNair & Miller, *supra* note 16, at 1.
- ²¹ *Id.* at 11, 156.
- ²² See Faigman et al., *supra* note 18, at 226, 229, 234 (discussing the GC process for alcohol).
- ²³ *Id.* at 229.
- ²⁴ See *id.* at 234 (discussing how alcohol is “sufficiently volatile” as measured by deep lung breath and how “[e]nd-expiratory breath is the proper specimen for alcohol analysis, because [it] reflects the alcohol concentration in arterial blood.”).
- ²⁵ See Faigman et al., *supra* note 18, at 200 (identifying methods to measure an individual’s BAC, including chemical, biochemical, and varying forms of gas chromatographic tests).
- ²⁶ *Id.* at 214.
- ²⁷ *Id.* at 14.
- ²⁸ *Id.*
- ²⁹ *Id.* at 24-25, 84.
- ³⁰ See *id.* at 58 (discussing how the separation of two solutes is easier if the value of α is larger).
- ³¹ See *id.* at 52 (interpreting a chart depicting the separation of solutes to show that the longer the column the easier the separation).
- ³² See Paul C. Gianelli et al., *Scientific Evidence* 637 (5th ed. 2012)
- ³³ See McNair & Miller, *supra* note 16, at 129 (explaining that retention time can be used to identify a solute so long as length, temperature, carrier gas flow rate, thickness and stationary phase are kept constant).

- ³⁴ Tom Kupiec, Quality-Control Analytical Methods: Gas Chromatography, 8 Int'l J. Pharmaceutical Compounding 305, 306 (2004).
- ³⁵ See id. at 306-08 (noting that there is "[a] multitude" of different packing materials for columns, and three different calibration methods, each with their own pros and cons that could affect the end results).
- ³⁶ McNair & Miller, *supra* note 16, at 27.
- ³⁷ Id. at 106, 115.
- ³⁸ See id. at 115.
- ³⁹ Edward J. Zachowski & Stan Paleologos, Flame Ionization Detectors: Applications and Operations, Specialty Gas Rep., 30, 30 (2d Quarter 2009), available at <http://www.aoti.net/fid.pdf>.
- ⁴⁰ McNair & Miller, *supra* note 16, at 14-15.
- ⁴¹ Id.
- ⁴² See *infra* p. 217.
- ⁴³ McNair & Miller, *supra* note 16, at 129.
- ⁴⁴ Id. at 129; see generally Gianelli et al., *supra* note 32 (describing how a chromatograph determines the components of a sample based on the time elapsed after the sample is injected).
- ⁴⁵ Id.
- ⁴⁶ See *infra* Figure 2 at p. 218; Justin McShane, The Carryover Effect: Lack of Blanks Between Tests Leads to False Positive or Inflated BAC Results, PA DUI Blog (Mar. 3, 2010), <http://www.paduiblog.com/pa-dui/the-carryover-effect-lack-of-blanks-between-tests-leads-to-false-positive-or-inflated-bac-results>.
- ⁴⁷ McNair & Miller, *supra* note 16.
- ⁴⁸ Max M. Houck & Jay A. Siegel, Fundamentals of Forensic Science 137 (Elsevier 2d ed. 2010).
- ⁴⁹ Gianelli, *supra* note 32, at 639.
- ⁵⁰ See e.g., Lori Laffel, Ketone Bodies: A Review of Physiology: Pathophysiology and Application of Monitoring to Diabetes, 15 Diabetes Metabolism Res. Revs. 412, 412, 418 (2000) (discussing the metabolism of ketone bodies, which includes acetone, in diabetics).
- ⁵¹ See generally Diet FAQ, Atkins, <http://www.atkins.com/Library/FAQ.aspx> (last visited Aug. 25, 2013) (describing the Atkins Diet).

- ⁵² Benjamin G. K. Beisswenger et al., Ketosis Leads to Increased Methylglyoxal Production on the Atkins Diet, 1043 *Annals N.Y. Acad. Sci.* 201, 201 (2005).
- ⁵³ Patrik Spanel et al., Breath Acetone Concentration: Biological Variability and the Influence of Diet, 32 *Physiological Measurement* N23, N23 (2011).
- ⁵⁴ Beisswenger et al., *supra* note 52, at N29.
- ⁵⁵ See Karen M. Holm et al., Determination of Ketone Bodies in Blood by Headspace Gas Chromatography-Mass Spectrometry, 34 *J. Analytical Toxicology* 549, 549 (2010) (noting that alcoholic ketoacidosis is “a consequence of alcohol-induced hypoglycemia typically during abstinence periods....”).
- ⁵⁶ *Id.*
- ⁵⁷ See *id.* (discussing that acetone levels can be in alcoholics, even during periods of abstinence).
- ⁵⁸ See Houck & Siegel, *supra* note 48, at 138 (explaining how inaccuracies can result from chromatography tests if two substances share the same retention time); see generally Dean Rood, Agilent Technologies, Solvent Retention Data 1, 3 (2002), <http://www.chem.agilent.com/cag/cabu/pdf/b-0292.pdf> (showing similar retention times between acetone (4.05) and ethanol (3.47)).
- ⁵⁹ See generally Rood, *supra* note 58, at 1 (showing similar retention times between acetaldehyde (2.46) and ethanol (3.47)).
- ⁶⁰ See *id.* at 1 (showing the similar retention times between acetaldehyde and ethanol).
- ⁶¹ Cf. Houck & Siegel, *supra* note 48 at 138 (explaining how an unknown substance and heroin can have the same retention time and the instrument will read them as the substance, however “the same retention time is [only] indicative of their being the same substance, [] it does not prove this....”).
- ⁶² See generally *id.* (hypothesizing that if two substances have the same retention time, one substance can be read as positive for the other substance).
- ⁶³ See generally EPA, Method 8000C: Determinative Chromatographic Separations, 8000C-5 (2003) available at http://www.epa.gov/osw/hazard/testmethods/pdfs/8000c_v3.pdf (explaining that with some selective and non-selective chromatographic methods there can be errors in quantitation due to substances co-eluting).
- ⁶⁴ See generally McNair & Miller, *supra* note 16, at 117 (noting that compounds not containing organic carbon do not burn and are not detected by the FID).
- ⁶⁵ See generally EPA, *supra* note 63 (listing the co-elution of substances as a difficulty when using FIDs).
- ⁶⁶ See McNair & Miller, *supra* note 16 at 130 (stating that there are over 30,000 organic compounds and “gas chromatograph by itself cannot be used to identify a single compound”).
- ⁶⁷ See Nancy Standler & Mohammed A. Virji, Case 83--Insecticide Poisoning, Gas Chromatography-Mass Spectroscopy, Univ. of Pittsburg: Dep’t of Pathology (last visited Oct. 6, 2013), <http://path.upmc.edu/cases/case83/gas.html> (stating that it is possible for more than one substance to have the same retention time).

- ⁶⁸ See generally EPA, *supra* note 63, at 8000C-5 (noting quantity errors are a difficulty in using certain gas chromatography methods).
- ⁶⁹ See Standler & Virji, *supra* note 67 (submitting that the coupling of gas chromatography techniques with mass spectroscopy is the “more definitive answer” to obtaining the identification of a compound).
- ⁷⁰ A. Wayne Jones & Jan Shuberth, Computer-Aided Headspace Gas Chromatography Applied to Blood-Alcohol Analysis: Importance of Online Process Control, 34(4) *J. Forensic Sci.* 1116, 1125 (1989).
- ⁷¹ See *id.* (stating that the process is used to “eliminate the risk of mix-up of specimens and to ensure a high degree of quality control of the day-to-day analytical results.”).
- ⁷² See *id.* at 1126 (noting the method used for legal purposes in Sweden had a high statistical confidence, up to 99.9% in one case).
- ⁷³ *Id.*
- ⁷⁴ *Id.*
- ⁷⁵ McNair & Miller, *supra* note 16, at 137.
- ⁷⁶ John C. Ensslin, Final Tally on Flawed DUI: 206 Errors, 9 Tossed or Reduced, *Gazette* (Apr.19, 2010, 12:00 AM), <http://gazette.com/final-tally-on-%20flawed-dui-206-errors-9-tossed-or-reduced/article/97354.%20Accessed%C20July%202016>.
- ⁷⁷ *Id.*
- ⁷⁸ *Id.*
- ⁷⁹ *Id.*
- ⁸⁰ Jordan Steffen, Colorado Toxicology Lab Halts Blood-alcohol Testing, Will Retest Samples, *Denv. Post.* (June 28, 2013, 11:45 AM), http://www.denverpost.com/ci_23561052/state-toxicology-lab-halts-blood-alcohol-testing-will.
- ⁸¹ *Id.*
- ⁸² *Id.*
- ⁸³ *Id.*
- ⁸⁴ *Id.*
- ⁸⁵ Franco Tagliaro et al., Chromatographic Methods for Blood Alcohol Determination, 580 *J. Chromatography* 161, 186 (1992).
- ⁸⁶ *Id.* at 177; see generally Michael L. Smith et al., Modern Instrumental Methods in Forensic Toxicology, 31 *J. Analytical Toxicology* 237, 237-38 (2007) (explaining the procedure associated with using GC-mass selective detectors).

- ⁸⁷ See Tagliaro et al., *supra* note 85, at 186 (“Recent promising results on the molecular mass determination of intact proteins have been achieved by mass spectrometry.... [The] endogenous formation of alcohol and other volatile compounds is, in our opinion, a subject susceptible par excellence to the application of GC-MS.”).
- ⁸⁸ Cf. Smith et al., *supra* note 86, at 241 (“[L]arge volume laboratories could replace immunoassays with LC-MS screening to reduce false-positive test results.”).
- ⁸⁹ See Tagliario et al., *supra* note 85, at 167 (“GC has encountered only limited favour [sic] in clinical chemough this view has gained widew continue to enshrine concept which support intimate partnerships?vidual right to determine intistry and emergency toxicology. The reasons are mainly related to the need for specific expertise of the personnel [] and the assumption that the purchase and maintenance of sophisticated instrumentation dedicated only to a single class of analytes is not cost effective.”).
- ⁹⁰ Cf. Cal. Office of Att’y Gen., California Task Force on Forensic Services Force Report 1 (2003) available at <http://oag.ca.gov/sites/all/files/pdfs/publications/bfsbookmarks.pdf> [hereinafter California Task Force Report] (recognizing potential errors in laboratory results, but stating the mission of the task force was to “identify the changes necessary to ensure the system has the capacity and expertise to deliver timely and accurate forensic services into the future”).
- ⁹¹ See *id.* at 47 (evidence of old and obsolete laboratory equipment).
- ⁹² U.S. Dep’t of Justice, Fed. Bureau of Investigation, Crime in the U.S., 2009-Table 69 (Sept. 2010), http://www2.fbi.gov/ucr/cius2009/data/table_69.
- ⁹³ *Id.*
- ⁹⁴ Drunk Driving Statistics and Prevention Techniques, Drinkinganddriving.org, <http://www.drinkinganddriving.org> (last visited Aug. 26, 2013).
- ⁹⁵ Sladjana Oulad Daoud & Helen N. Tashima, Cal. Dep’t. of Motor Vehicles, 2012 Annual Report of the California DUI Management Information System 9 (Jan. 2012), available at http://apps.dmv.ca.gov/about/profile/rd/r_d_report/Section_5/S5-236.pdf.
- ⁹⁶ To view pending cases please see, e.g., Superior Court of California, County of San Diego Court Index, available at <http://courtindex.sdcourt.ca.gov/CISPublic/enter> (last visited Sept. 6, 2013 at 3:40PM); Superior Court of California, County of San Bernardino, Court Case Information Online, available at <http://www.sb-court.org/Divisions/Criminal/CaseInformationOnline.aspx> (last visited Sept. 6, 2013 at 3:40PM); Superior Court of California, County of Los Angeles, Index of Defendants in Criminal Cases available at <https://www.lasuperiorcourt.org/onlineservices/criminalindex> (last visited Sept. 6, 2013).
- ⁹⁷ See California Task Force Report, *supra* note 90, at 27 (explaining that California has “establish[ed] a statewide system of regional forensic laboratories...funded initially by the LEAA [Law Enforcement Assistance Administration]. [I]n 1972, the DOJ Bureau of Forensic Services (BFS) was established and continues to serve 46 of California’s 58 counties.”).
- ⁹⁸ See *id.* at 47 (indicating that as of June 2001, 46 out of 75 GC pieces of California state laboratory equipment were characterized as either “old” or “obsolete” by Laboratory Directors).
- ⁹⁹ See generally *id.* at 10-13 (discussing the scientific and technologic advancements in instrumental chemical analyses that laboratories must upgrade to in order to “meet increasingly rigorous scientific standards and court expectations.”).
- ¹⁰⁰ “The development of forensic science standards at the national level goes hand in hand with laboratory accreditation.” *Id.* at 22. See generally Laboratory Accreditation in Forensic Toxicology, Am. Board of Forensic Toxicology,

http://www.abft.org/index.php?option=com_content&view=article&id=53&Itemid=62 (last viewed Aug. 20, 2013) (detailing eligibility requirements a laboratory must meet before receiving accreditation in Forensic Toxicology).

- ¹⁰¹ Mary-Ellen E. Sharp, A Comprehensive Screen for Volatile Organic Compounds in Biological Fluids, 25 J. Analytical Toxicology 631, 631, 636 n.5 (2001); Vanessa R. Kinton et al., AppNote, Blood Alcohol Analysis Using an Automated Static Headspace Method AN/2005/01-2, AN/2005/01-2 (2005), available at <http://www.gerstel.com/pdf/p-gc-an-2005-01.pdf>.
- ¹⁰² Sharp, supra note 101, at 631 (discussing how current work in GC was undertaken to improve some of the limitations experienced when using the original screen, using dual-column elution).
- ¹⁰³ For a full discussion of the study see Michelle M. Bushey & James W. Jorgenson, Automated Instrumentation for Comprehensive Two-Dimensional High-Performance Liquid Chromatography of Proteins, 62 Analytical Chemistry 161, 161-67 (1990).
- ¹⁰⁴ Id.
- ¹⁰⁵ Society of Forensic Toxicologists, Forensic Toxicology Laboratory Guidelines 9-10 (2006), available at http://www.soft-tox.org/files/Guidelines_2006_Final.pdf [hereinafter SOFT Guidelines].
- ¹⁰⁶ See Tagliaro et al., supra note 85, at 176-77 (discussing the advantages to using dual column GC's for the separation and analyses of volatiles); cf. SOFT Guidelines, supra note 105, at 10 (stating that confirmation of ethanol "using a second GC column is acceptable IF the the second results in significant changes in retention time AND change in elution order of at least some of the common volatiles (e.g., ethanol, isopropanol, acetone)...and that [t]he second analysis should be performed on a separate aliquot of the specimen, or an alternate specimen from the same case").
- ¹⁰⁷ SOFT Guidelines, supra note 105, at 1.
- ¹⁰⁸ Id.
- ¹⁰⁹ John Musselman, et al., PerkinElmer, Increasing Accuracy of Blood-Alcohol Analysis Using Automated Headspace-Gas Chromatography 2 (2006), available at http://www.perkinelmer.com/CMSResources/Images/44-74508CST_GasChromaIncrAccuracyBloodAlchlAnaly.pdf.
- ¹¹⁰ Roger L. Firor et al., Agilent Technologies, Static Headspace Blood Alcohol Analysis with the G1888 Network Headspace Sampler 1 (2004) available at <http://cp.chem.agilent.com/Library/applications/5989-0959EN.pdf>
- ¹¹¹ Id.
- ¹¹² Kinton et al., supra note 101, at AN/2005/01-4.
- ¹¹³ See id. at AN/2005/01-1-4.
- ¹¹⁴ See McNair & Miller, supra note 16, at 129; Tagliaro et al., supra note 85, at 176-77; Smith et al., supra note 86, at 238; Bushey & Jorgenson, supra note 103, at 161.
- ¹¹⁵ Tagliaro et al., supra note 85, at 167-77.

¹¹⁶ McNair & Miller, *supra* note 16.

¹¹⁷ *Id.* at 130.

¹¹⁸ See e.g., Darrin L. Smith, Mass Spectrometry Applications in Forensic Science, in *Encyclopedia of Analytical Chemistry* 3 (2010); Nicholas H. Snow, Multidimensional Gas Chromatography, in *Basic Gas Chromatography* 170, 170-72 (Harold M. McNair & James M. Miller eds., 2d ed. 2009); Gottfried Machata, The Advantages of Automated Blood Alcohol Determination by Head Space Analysis, 75 *Zeitschrift für Rechtsmedizin* 229, 229 (1975), available at <http://link.springer.com/article/10.1007/BF00201176#page-2>; Smith et al., *supra* note 86, at 238.

¹¹⁹ J. Throck Watson & O. David Sparkman, *Introduction to Mass Spectrometry: Instrumentation, Applications and Strategies for Data Interpretation* 3 (4th ed. 2007); see also Letter from Laura D. Barfield, Alcohol Testing Program Manager, Alcohol Testing Program, Fla. Dep't Law Enforcement, to Dustin Tate Yeatman, Chemistry/Toxicology Manager, Palm Beach County Sheriff's Office (Aug. 24, 2012), available at <http://www.fdle.state.fl.us/Content/getdoc/e03bb3b1-4fb4-49e0-bb3d-dbd6cb33f9a8/Yeatman-Correspondence.aspx>.

¹²⁰ See Watson & Sparkman, *supra* note 119, at 4; Section 4.4: Mass Spectrometry, U.C. Davis, http://chemwiki.ucdavis.edu/Organic_Chemistry/Organic_Chemistry_With_a_Biological_Emphasis/Chapter_4%3A_Structure_Determination_I/Section_4.4%3A_Mass_Spectrometry (last updated Nov. 11, 2011) [[hereinafter U.C. Davis].

¹²¹ See *id.*

¹²² See *id.*

¹²³ Justin McShane, Why Single Column Gas Chromatography-Flame Ionization Detector Analysis Is Not Forensically or Scientifically Acceptable, *The Truth About Forensic Sci.* (Sept. 1, 2011), <http://www.thetruthaboutforensicscience.com/why-single-column-gas-chromatography-flame-ionization-detector-analysis-is> (“Without any scientific doubt, a single column method of analysis is not forensically or scientifically defensible or acceptable...[and i]f there is co-elution that was ‘discovered’ by the dual column approach, then we would expect to see imprecision between these numbers [[too].”).

¹²⁴ See, e.g., *id.* (“Gas Chromatography with Mass Spectrometry (GC-MS) for example...is much more selective and borders on specific when it comes to EtOH analysis.”)

¹²⁵ See Mohamed Attya et al., Highlights of Mass Spectrometric Methodologies in Environmental Pollution, in *Pesticides in the Modern World-Trends in Pesticides Analysis* 425, 425 (Margarita Stoytcheva ed., 2011), available at http://cdn.intechopen.com/pdfs/20999/InTechHighlights_of_mass_spectrometric_methodologies_in_environmental_pollution.pdf. (“Mass spectrometry is an affordable chemical method suitable, for its specificity and sensitivity, to deal with identification and assay of molecules in complex mixtures.”).

¹²⁶ See U.C. Davis, *supra* note 120; Jared Snider, Overview of Mass Spectrometry, Thermo Scientific, <http://www.piercenet.com/browse.cfm?fldID=33C6C4ED-4B0D-49FA-ABD2-23BCB0FADEC0> (last visited Aug. 20, 2013); Jannel Reyes, Proteomics: Addressing the Challenges of Multiple Myeloma, AG Scientific (Dec. 15, 2011, 11:30 AM), <http://info.agscientific.com/blog/bid/108123/Proteomics-addressing-the-challenges-of-multiple-myeloma>.

¹²⁷ See Snider, *supra* note 126.

¹²⁸ See *id.* (“Mass spectrometers are connected to computers with software that analyzes the ion detector data and produces graphs that organize the detected ions by their individual m/z and relative abundance.”).

- ¹²⁹ See McShane, *supra* note 46 (noting that lack of standardization within laboratories and nationwide is the “single largest and most basis systemic problem” with GC).
- ¹³⁰ See, e.g., Forensic Laboratory List of Services, Tulsa Police Dep’t, <https://www.tulsapolice.org/content/forensic-laboratory/list-of-services.aspx> (last visited Aug. 15, 2013).
- ¹³¹ See McShane, *supra* note 46 (discussing the downfalls of using GC in DUI cases).
- ¹³² See Dustin Yeatman, Blood Alcohol Analytical Procedures Information Sheets, Fla. Dep’t of Law Enforcement (Aug. 21, 2012), <http://www.fdle.state.fl.us/Content/getdoc/c7c7c5a3-6ac3-4a72-8696-aa6efd3c5726/Yeatman-Procedures.aspx> (stating that updates to alcohol testing include headspace sampling with GC and simultaneous flame ionization and mass spectrometry detection); see also Toxicology, Mo. State Highway Patrol, <http://www.mshp.dps.missouri.gov/MSHPWeb/PatrolDivisions/CLD/Toxicology/toxicology.html> (last visited Aug. 17, 2013).
- ¹³³ Tulsa Police Dep’t, *supra* note 130.
- ¹³⁴ See generally Mass Spectrometry GCMS, Analytical Instruments, L.L.C., <http://www.analyticalinstrument.com/products/Hewlett-Packard-6890%7B47%7D5973-GCMS.html> (last visited Aug. 20, 2013) (cost of Hewlett Packard GCMS is \$39,995.00); 5975 Transportable GC/MS Techniques & Operation, Agilent Technologies, <http://www.chem.agilent.com/en-US/Training-Events/en-US/R1727A/Pages/default.aspx> (last visited Aug. 20, 2013) (showing that a four-day training course for Agilent Technologies GCMS costs \$3,200).
- ¹³⁵ See e.g., Phillip J. Marriot et al., Multidimensional Gas Chromatography--A Technology for Today’s Analytical Challenges, *Separation Sci.*, <http://www.sepscience.com/Techniques/GC/Articles/1077-/Multidimensional-Gas-Chromatography--A-Technology-For-Todays-Analytical-Challenges> (last visited Aug. 20, 2013) (discussing how the limitations of single-column GC’s to separate out different compounds requires analysts to pre-separate complex samples, and that the increased need to report a variety of components in samples requires more than a single column analytical separation).
- ¹³⁶ See, e.g., Cameron Steele, Police: New breath-test process leads to more DWI guilty pleas, *Charlotte Observer* (Jan. 05, 2013), <http://www.charlotteobserver.com/2013/01/05/3767451/police-new-breath-test-process.html>.
- ¹³⁷ See Steffen, *supra* note 80.
- ¹³⁸ Process Mass Spectrometry in Biotechnology, Thermo Scientific (2010), http://www.svanholm.com/Download/Thermo%20Scientific/PrimaPRO_Biotech%20Brochure.pdf.
- ¹³⁹ See, e.g., Agilent Technologies, *supra* note 134 (listing the cost and time to train analysts on GC/MS techniques).
- ¹⁴⁰ See, e.g., Don Sapatkin, Operator error in breath tests?, *Philly.com* (Apr. 4, 2011), http://articles.philly.com/2011-04-04/news/29380441_1_evidence-in-drunken-driving-cases-breath-testing-instruments-toaster-oven (discussing various lab technician errors); see also Colorado Department of Public Health and Environment Lab suspends blood-alcohol testing, *Denv. Channel* (June 28, 2013), <http://www.thedenverchannel.com/news/local-news/colorado-department-of-public-health-and-environment-lab-suspends-blood-alcohol-testing> (referring to the issues with the current lack of technician training).
- ¹⁴¹ See Sidney Kaye, The Collection and Handling of the Blood Alcohol Specimen, 74 *Am. J. Clinical Pathology* 743, 743-46 (1980), available at http://www.md.rcm.upr.edu/publications/sidney_kaye/the-collection-and-handling-of-blood.htm (listing standard operating procedures that should be in place, and the practical effects of following these procedures).

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