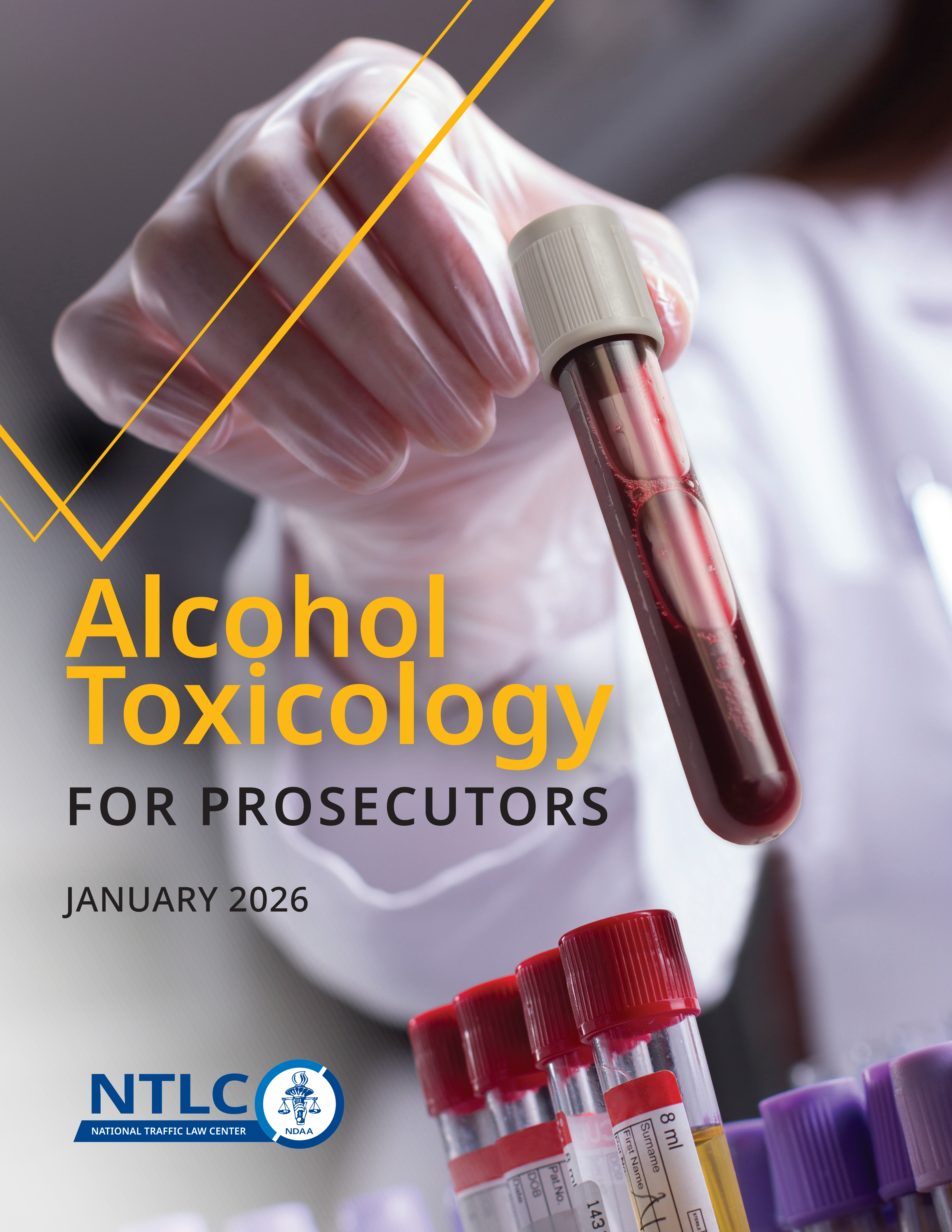

Alcohol Toxicology

FOR PROSECUTORS

JANUARY 2026

NTLC
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Alcohol Toxicology

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JANUARY 2026

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NATIONAL DISTRICT ATTORNEYS ASSOCIATION

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National Traffic Law Center

The National District Attorneys Association's National Traffic Law Center (NTLC) is a resource designed to benefit prosecutors, law enforcement, judges, and criminal justice professionals. The mission of the NTLC is to improve the quality of justice in traffic safety adjudications by increasing the awareness of highway safety issues through the compilation, creation and dissemination of legal and technical information and by providing training and reference services.

When prosecutors deal with challenges to the use of breath test instruments, blood tests, horizontal gaze nystagmus, crash reconstruction, and other evidence, the NTLC can assist with technical and case law research. Likewise, when faced with inquiries from traffic safety professionals about getting impaired drivers off the road, the NTLC can provide research concerning the effectiveness of administrative license revocation, ignition interlock systems, sobriety checkpoints and much more.

The NTLC has a clearinghouse of resources including case law, research studies, training materials, trial documents, and a directory of expert professionals who work in the fields of crash reconstruction, toxicology, drug recognition, and many others. The information catalogued by the NTLC covers a wide range of topics with emphasis on impaired driving and vehicular homicide issues.

NTLC is a program of the National District Attorneys Association (NDAA). NDAA's mission is to be the voice of America's prosecutors and to support their efforts to protect the rights and safety of the people.

For additional information, contact NDAA or NTLC, 1400 Crystal Drive, Suite 330, Arlington, Virginia 22202, (phone) 703-549-9222, (fax) 703-836-3195, or visit www.ndaa.org.

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Regional Toxicology Liaison Program

In September 2021, the National Highway Traffic Safety Administration (NHTSA) awarded the Society of Forensic Toxicologists (SOFT) with the Regional Toxicology Liaison (RTL) Demonstration Project grant. This cooperative agreement aimed to benefit state toxicology programs through increased support, communications, resources, criminal justice system coordination, decreased processing time of toxicology samples, and better data reporting.

During the first three years, the project entailed the establishment of Toxicology Liaisons that supported states in NHTSA regions 5, 7, and 9, to assist with training, collaboration, and the standardization of testing across state labs and the reporting of data to better understand the scope of the drug-impaired driving problem.[1] During this time, Project Manager Amy Miles oversaw the RTL program and had three Liaisons: Sabra Jones, Chris Heartsill, and Kristen Burke.

Since 2021, the RTLs have established key partnerships with the forensic toxicology laboratories in the regions, working to create alignment in testing, funding, and training. In addition to their work with the laboratories, the RTLs have developed and strengthened partnerships with law enforcement, prosecutors, judges, SHSOs, and public health.

Due to the program's success, NHTSA extended the cooperative agreement with SOFT for another two years. During this period, the RTL program will expand to cover more areas of the country. Sabra is the RTL for the Northeastern portion of the country, which includes NHTSA regions 1, 2, and 3. Chris remains in NHTSA Region 7 but now also covers Oklahoma, Texas, and Colorado to create the "Mid-South" region. Kristen continues to be the RTL for NHTSA Region 9, and New Mexico for the "West" region. Finally, Amy is the RTL for NHTSA Region 5, including North Dakota and South Dakota, creating the "Midwest" region, and continues to manage the program.

1 *See* www.nhtsa.gov/about-nhtsa.

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Acknowledgements

This second edition of *Alcohol Toxicology for Prosecutors* would not have been possible without the support and funding from the U.S. Department of Transportation, National Highway Traffic Safety Administration and the encouragement of **Linda Fisher** and **Devin Burke**, Highway Safety Specialists in the Impaired Driving Division, as well as the dedicated efforts of the following professionals at the National Traffic Law Center:

Erin Inman, Director

M. Kimberly Brown, Senior Attorney

Stacy Graczyk, Staff Attorney

The second edition built upon the foundation of the version of this monograph originally published in July 2003. It was the result of the dedicated work of **Patrick Harding**, then Supervisor of the Toxicology Section of the Wisconsin State Laboratory of Hygiene. This updated edition is the product of a deeply collaborative effort, shaped by the knowledge, expertise, and unwavering commitment of the following dedicated toxicologists working in traffic safety:

Kristen Burke, NHTSA Regional Toxicology Liaison, Western Region

Chris Heartsill, NHTSA Regional Toxicology Liaison, Mid-South Region

Sabra Jones, NHTSA Regional Toxicology Liaison, Northeast Region

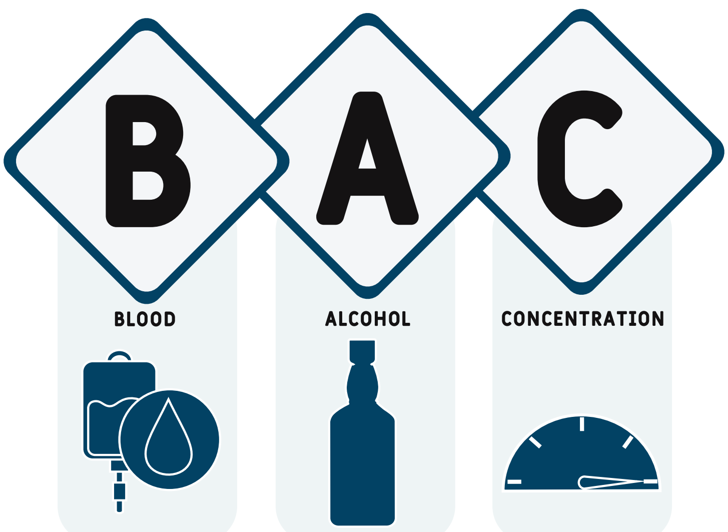
Amy Miles, NHTSA Toxicology Liaison, Midwest Region

Preface

Alcohol Toxicology for Prosecutors provides prosecutors with a comprehensive guide to alcohol toxicology, focusing on how alcohol is absorbed, distributed, and eliminated in the body, and how these processes affect blood alcohol concentration (BAC).

It explains scientific methods like retrograde extrapolation to estimate BAC at the time of driving, counter common defenses such as post-incident drinking or rising BAC claims and interpret various types of test results.

The guide emphasizes using expert testimony and scientific principles to strengthen DUI cases, especially against repeat offenders.



Introduction: Alcohol and Forensic Toxicology

Alcohol represents one of the most commonly used intoxicating substances in American society. The Substance Abuse and Mental Health Services Administration (SAMHSA) and the National Center for Drug Abuse Statistics (NCDAS) report the following:

- 82% of individuals age 12 and older report lifetime alcohol use.[2]
- 84.1% of people ages 18 or older report lifetime alcohol consumption.[3]
- Approximately (47.5%) of Americans aged 12 and older (134.7 million people) reported alcohol consumption within the past month.[4]

According to the National Highway Transportation Safety Administration (NHTSA), in 2023, 12,429 people died in alcohol-impaired driving traffic deaths.[5] In forensic toxicology laboratories, alcohol remains one of the most commonly detected drugs in impaired driving investigations, including postmortem analysis.[6]

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[2] Substance Abuse and Mental Health Services Administration. (2025). *2024 Companion Infographic Report: Results from the 2021 to 2024 National Surveys on Drug Use and Health* (SAMHSA Publication No. PEP25-07-006). Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration. Available at www.samhsa.gov/data/data-we-collect/nsduh-national-survey-drug-use-and-health/national-releases, accessed August 20, 2025.

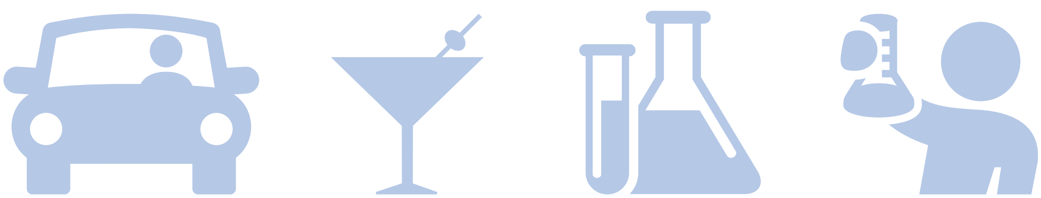
[3] National Center for Drug Abuse Statistics. 2025 Drug Abuse Statistics. Available at drugabusestatistics.org, accessed August 14, 2025. The front page of DrugAbuseStatistics.org features the most noteworthy drug abuse data, including overdose deaths, demographics, mental health, drug abuse treatment programs, and the cost of the War on Drugs.

[4] SAMHSA, 2023 Dated NSDUS Tables, *supra*.

[5] National Highway Traffic Safety Administration. Drunk Driving | Statistics and Resources. U.S. Department of Transportation, www.nhtsa.gov/risky-driving/drunk-driving, accessed August 20, 2025.

[6] Kelly AT, Mozayani A. An overview of alcohol testing and interpretation in the 21st century. *J Pharm Pract.* 2012 Feb;25(1):30-6.

In the context of impaired driving, forensic toxicology focuses on detecting and measuring substances like alcohol, drugs, or medications in a driver's system. It helps determine whether a person was under the influence at the time of driving, using biological samples such as blood, urine, or saliva to assess impairment and support legal proceedings. Toxicology plays a critical role by providing scientific analysis of blood alcohol concentration (BAC) and interpreting how alcohol was absorbed, distributed, and eliminated in the body. An expert toxicological evaluation helps determine whether a defendant was legally impaired at the time of driving, supports or refutes defense claims, and ensures that BAC results are accurately understood within the context of timing, physiology, and behavior.



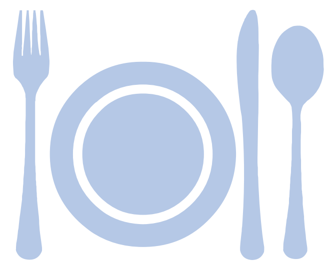
Alcohol and Human Physiology

Alcohol affects the human body through a complex process involving absorption, distribution, and elimination. Understanding how alcohol moves through and interacts with the body is essential for interpreting blood alcohol concentration (BAC) and assessing impairment, especially in legal and forensic contexts.

Understanding Alcohol's Physiological Impact

Defense attorneys in impaired driving cases often rely on a foundational understanding of how alcohol affects the human body. A common defense narrative might include statements such as:

> "I had a large meal that evening—ribs, chicken, shrimp, salad, potatoes, and apple pie. Just before leaving the restaurant, about 10 minutes prior to the traffic stop, I consumed two mixed drinks with rum and cola over ice."



This type of testimony typically supports three defense theories: (1) food consumption mitigates alcohol's physiological effects on the body; (2) insufficient time elapsed for alcohol absorption before arrest; and (3) post-arrest blood alcohol concentration (BAC) was higher than BAC during vehicle operation.[7]

These arguments reflect a widely held belief that the timing of food and alcohol intake significantly influences intoxication levels. To effectively counter such claims, a prosecutor must be well-prepared and should consider utilizing an expert witness—such as a forensic toxicologist—to address misconceptions about alcohol pharmacology.

Toxicological principles concerning alcohol absorption, distribution, metabolism, and elimination equip prosecutors with the tools to challenge these defenses. Through retrograde extrapolation and other analytical methods, experts can estimate a defendant's BAC at the time of driving. This is particularly useful when a defendant claims post-incident alcohol consumption or disputes the timing of intoxication.

Such calculations not only help determine whether legal limits were likely exceeded during vehicle operation but also assist in evaluating the plausibility of the defendant's account in the context of other case facts.

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[7] *Substance Abuse in Brief*, April 2003, Vol. 2, Issue 1, National Clearinghouse for Alcohol & Drug Information, Substance Abuse & Mental Health Services Administration, U.S. Department of Health & Human Services.

Alcohol Chemistry and Metabolism

To accurately interpret alcohol test results, prosecutors must first understand how alcohol is quantified—both in beverages and within the human body.

Ethanol, the type of alcohol found in alcoholic drinks, is a small, water-soluble molecule. Once consumed, it is rapidly absorbed into the bloodstream and distributed throughout the body's water-containing tissues. Its elimination occurs primarily through liver metabolism, with minor contributions from excretion (via urine and sweat) and evaporation (through breath).

Importantly, alcohol metabolism begins almost simultaneously with absorption and continues until all ethanol is cleared from the body. The concentration of alcohol measured at any given time reflects the dynamic interplay between absorption, distribution, metabolism, and elimination. Understanding these processes is essential for evaluating blood alcohol concentration (BAC) and its implications in impaired driving cases.

To accurately interpret alcohol test results, prosecutors must first understand how alcohol is quantified—both in beverages and within the human body.

Alcohol Content in Beverages

Alcoholic beverages are commonly categorized into three types: beer, wine, and distilled spirits. The alcohol content in these beverages is typically expressed as percent alcohol by volume (ABV) or proof, depending on the type.

- Beer and malt beverages: Generally contain 3–6% ABV, though some varieties—such as India Pale Ales (IPAs) and craft brews—can range from 3–14% ABV.
- Wine: Typically ranges from 9–14% ABV, depending on the style and fermentation process.
- Distilled spirits: Measured using the proof system, where ABV is half the proof value (e.g., 80 proof distilled spirits are 40% alcohol by volume).

To standardize alcohol intake across beverage types, the concept of a "standard drink" is used. A standard drink contains approximately 14 grams (0.6 ounces) of pure alcohol, and is defined as:

- Beer: 12 oz at 5% ABV
- Wine: 5 oz at 12% ABV
- Distilled spirits: 1.5 oz at 80 proof (40% ABV)

Pharmacokinetics of Alcohol

In an impaired driving case, prosecutors may need to establish a defendant's blood alcohol concentration (BAC) at the time of vehicle operation, rather than at the time of sample collection.[8] Delays between the incident and sample collection—sometimes extending several hours—can complicate interpretation and often require expert testimony to correlate the measured alcohol concentration to the time of driving.

Understanding the pharmacokinetics of alcohol—including absorption, distribution, metabolism, and elimination—is essential for evaluating these claims. While a single BAC measurement cannot definitively determine the concentration at an earlier time, it can serve as a foundation for estimation when combined with the timing and nature of alcohol consumption, observational evidence (e.g., law enforcement reports), and known rates of alcohol metabolism and elimination.

It is important to emphasize that a measured BAC is a snapshot of the individual's alcohol level at the time of testing. Without additional context, it cannot reveal whether the person was still absorbing alcohol, had reached peak concentration, or was in the elimination phase. Expert analysis is required to interpret BAC in relation to the time of driving.

It is important to emphasize that a measured BAC is a snapshot of the individual's alcohol level at the time of testing.

Alcohol Absorption

Absorption is the process by which alcohol moves from the site of ingestion into the bloodstream, where it can be distributed throughout the body. Ethanol, a small and fully water-soluble molecule, is readily absorbed through the mucosal lining of the gastrointestinal (GI) tract via simple diffusion and then into the blood. The amount absorbed at any given site depends upon the surface area, the thickness of the lining, and the blood supply.

Approximately 20–25% of ingested alcohol is absorbed through the stomach lining. However, due to the stomach's relatively small surface area and limited blood supply, absorption here is slower and less efficient.[9] The remaining 75–80% of the alcohol is absorbed in the small intestine, which has a large surface area and rich blood supply, allowing for rapid and efficient absorption.[10]

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8 The statutes of some states require a prosecutor prove the illegal blood alcohol concentration (BAC) at the time of driving while other states, like Montana for example, require proof of the BAC at the time of the chemical test. See MCA §61-8-1002(b) (2025), and the two 2006 cases of *State v. Weitzel*, 2006 MT 167, and *State v. McGowan*, 2006 MT 163.

9 *Garriott's Medicolegal Aspects of Alcohol.* Edited by Yale H. Caplan and Bruce A. Goldberger; contributors, including Erik H. Aguayo et al., 6th ed., Lawyers & Judges Publishing Company, 2014.

10 *Id.*

Unlike most ingested substances, alcohol does not require digestion and can be absorbed unchanged directly through the stomach lining. It enters the bloodstream unchanged, and the rate of absorption is influenced by several factors, including:

- Presence of food in the stomach (which slows gastric emptying)
- Alcohol concentration in the beverage
- Carbonation, which can accelerate gastric emptying
- Individual physiology, such as body weight and sex

Unlike most ingested substances, alcohol does not require digestion and can be absorbed unchanged directly through the stomach lining.

Understanding the absorption process is critical in forensic contexts, particularly when evaluating claims related to the "rising BAC" defense or estimating BAC at the time of driving.

Alcohol absorption can be influenced by several physiological and beverage-related factors. Alcohol absorption accelerates significantly once it reaches the small intestine, due to its large surface area and rich blood supply. However, any factor that delays gastric emptying—the process by which the stomach passes its contents into the small intestine—will also slow the rate of alcohol absorption. The fastest absorption occurs when a person consumes a 20% alcohol solution on an empty stomach, allowing alcohol to move quickly into the small intestine without interference from food or dilution.[11] Diluted drinks require somewhat longer absorption time.

In contrast, diluted alcoholic beverages or those consumed with food require more time to be absorbed, as they slow gastric emptying and reduce the immediate availability of alcohol for absorption.

Concentrated alcoholic beverages—those containing more than 40% alcohol by volume—act as gastric irritants. These drinks are often retained in the stomach until they are sufficiently diluted, delaying their passage into the small intestine where absorption is most efficient.[12] Additionally, alcoholic beverages containing digestible ingredients (e.g., sugar, cream, or other food components) may also slow absorption by delaying gastric emptying.

Other factors that can influence absorption include:

- Emotional state (e.g., stress or anxiety)
- Physiological shock
- Medications that affect stomach motility and gastrointestinal function
- Underlying gastrointestinal conditions

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[11] Mitchell Jr., M. C. "Absorption and Peak Blood Alcohol Concentration After Drinking Beer, Wine, or Spirits." *Alcoholism: Clinical and Experimental Research*, 2014 May; 38(5):1200-4.

[12] *Garriott's Medicolegal Aspects of Alcohol*, *supra*.

These variables can alter the rate at which alcohol enters the bloodstream, impacting both the timing and magnitude of peak blood alcohol concentration.

The presence of food in the stomach is the most significant factor influencing the rate of alcohol absorption. When alcohol is consumed with food, the pyloric valve—located at the base of the stomach—closes to prioritize digestion. This closure delays the passage of alcohol into the small intestine, where most of the absorption occurs.[13] The extent of this delay depends on both the amount and type of food consumed. High-fat or high-protein meals tend to slow absorption more than lighter meals. The result is a lower peak blood alcohol concentration (BAC) that is sustained over a longer period, compared to alcohol consumed on an empty stomach. Figure 1[14] illustrates this effect, showing how food alters the shape of the alcohol concentration curve by extending the absorptive phase and flattening the peak.

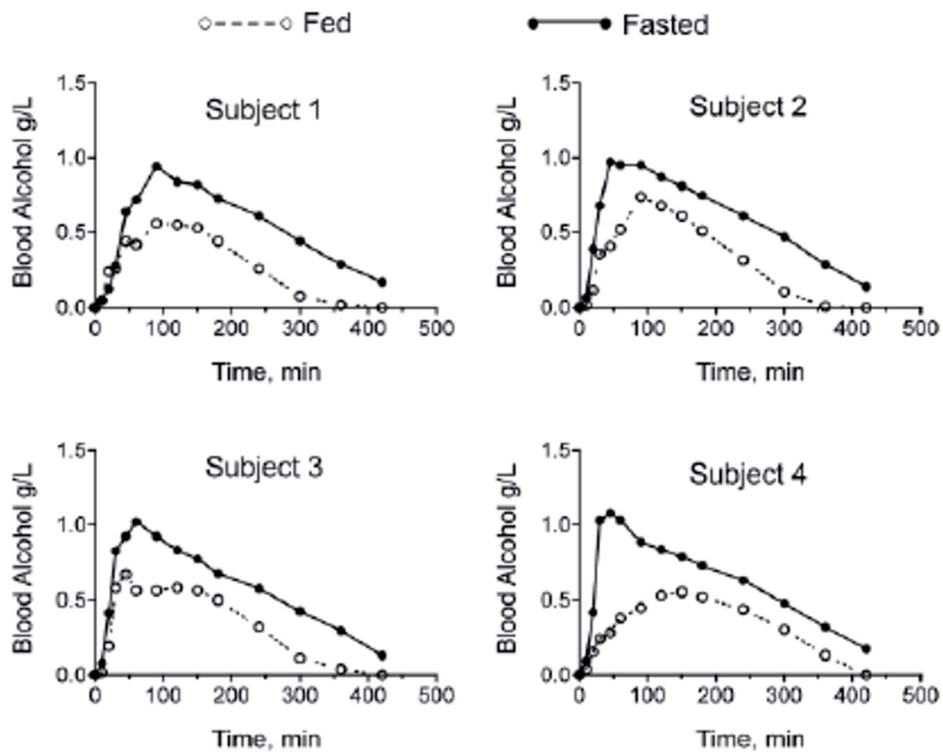

FIGURE 1.

Another essential factor in alcohol concentration analysis is determining when an individual enters the post-absorptive phase—the point at which alcohol absorption has ceased, and only elimination is occurring. This phase is critical for accurate retrograde extrapolation and forensic interpretation.

Research indicates that it may take up to two hours after alcohol consumption for a person to reach the post-absorptive phase. Importantly, this is not the same as reaching peak alcohol concentration. While peak BAC reflects the highest concentration achieved, the post-absorptive phase marks the transition to a state of pure elimination, with no remaining alcohol being absorbed from the gastrointestinal tract.

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13 *Id.*

14 Jones, AW. (2011) Pharmacokinetics of ethanol—Issues of forensic importance; *Forensic Sci Rev* 23:91.

Experts must carefully consider whether a subject was in the post-absorptive phase at the time of testing. If not, unabsorbed alcohol may still be entering the bloodstream, complicating BAC estimations. In such cases, forensic toxicologists may apply specialized models or assumptions to account for ongoing absorption and its impact on BAC calculations.[15]

Alcohol Distribution in the Body

Once absorbed, alcohol is transported via the bloodstream and distributed throughout the body.

Once absorbed, alcohol is transported via the bloodstream and distributed throughout the body. As blood circulates to various organs and tissues, alcohol diffuses across cell membranes into all areas containing water. Because ethanol is a small, water-soluble molecule, it moves freely by simple diffusion, always traveling from areas of higher concentration to lower concentration.

This process ensures that alcohol reaches equilibrium across the body's water compartments, including the brain, where its impairing effects are most evident. Figure 2 depicts a visual representation of the alcohol distribution pathway.[16]

Alcohol is fully water-soluble, meaning its concentration in the is directly proportional to an individual's total body water content. Since water content varies significantly between individuals, alcohol distribution is not uniform across the population. Obese individuals tend to have less water per pound of body weight, as fat tissue contains minimal water. Females, on average, have a higher proportion of body fat than males, resulting in lower total body water and, consequently, a smaller volume of distribution for alcohol.

According to ANSI/ASB Best Practice Recommendation 122: *Best Practice Recommendation for Performing Alcohol Calculations in Forensic Toxicology*, due to the high variability within the population, the use of a single fixed volume of distribution (Vd), is inappropriate. Instead, research supports a range of Vd values:

General population: 0.45–0.81 L/kg

Males: 0.58–0.83 L/kg

Females: 0.43–0.73 L/kg

These ranges represent the 95% confidence interval for each group, reflecting the diversity in body composition and water content across individuals.[17]

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[15] ANSI/ASB Best Practice Recommendation 122: *Best Practice Recommendation for Performing Alcohol Calculations in Forensic Toxicology*. 1st ed., Academy Standards Board, 2024. OSAC Registry, National Institute of Standards and Technology.

[16] *Alcohol Toxicology for Prosecutors, Targeting Hardcore Impaired Drivers*. American Prosecutor's Research Institute. July 2003, page 14.

[17] ANSI/ASB 122, *supra*.

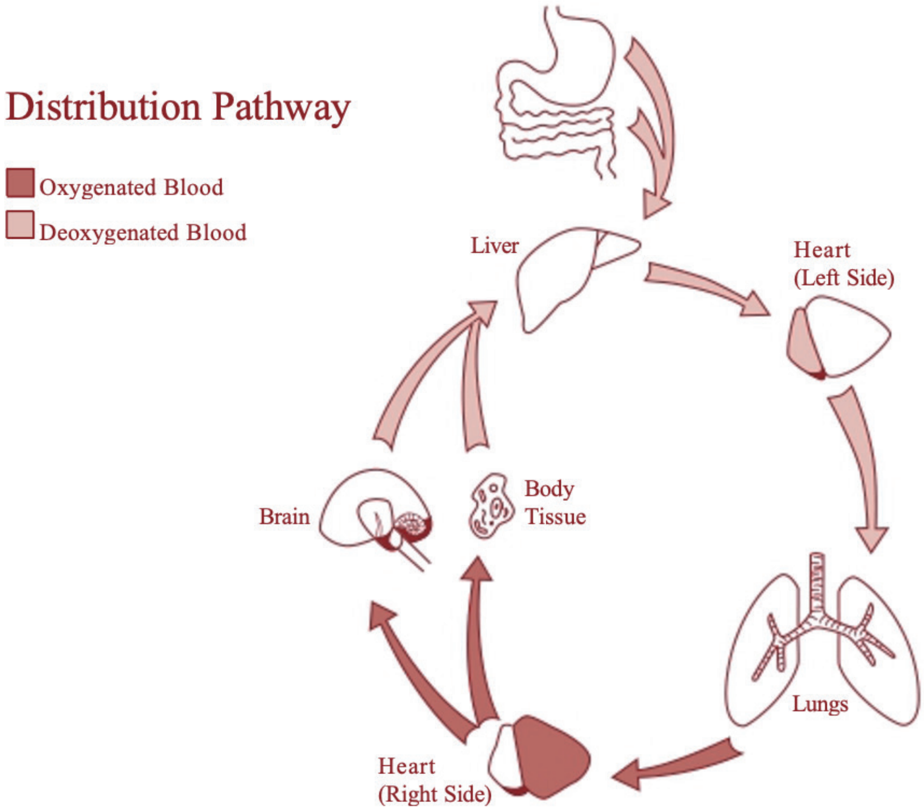


FIGURE 2.

In general, heavier individuals must consume larger amounts of alcohol to reach the same blood alcohol concentration (BAC) as lighter individuals. This is because alcohol distributes primarily into body water, and the relative alcohol concentration in any fluid or tissue is directly related to its water content. The higher the water content, the higher the relative alcohol concentration.

However, alcohol does not distribute uniformly across all tissues and fluids. Distribution is influenced by water content of the tissue, tissue perfusion (blood flow), and metabolic activity. For example, fat tissue, which contains very little water, retains less alcohol than muscle or organ tissue. This variability becomes especially important when interpreting alcohol concentrations from non-standard specimens such as sweat, breath, or tissue samples.

In forensic and clinical contexts, caution is essential when using these alternative matrices, as they may not accurately reflect the true BAC or the timing of alcohol consumption. Misinterpretation can occur if the differences in distribution and elimination are not properly considered.

Elimination Mechanisms

Alcohol is removed from the body through three primary mechanisms: metabolism, excretion, and evaporation. Of these, metabolism accounts for approximately 95% of total alcohol elimination.

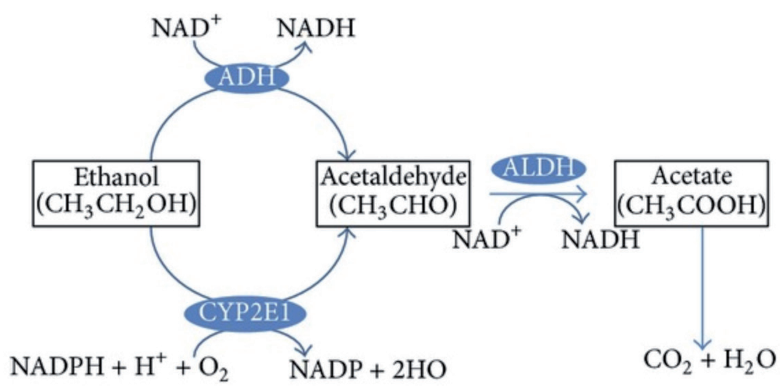
METABOLISM

The primary site of alcohol metabolism is the liver, where enzymes break down alcohol molecules to change them into simpler compounds, which undergo further metabolism. The primary enzyme in the liver responsible for alcohol metabolism is alcohol dehydrogenase (ADH). ADH converts ethanol into acetaldehyde, a toxic intermediate. Acetaldehyde is then further metabolized into acetic acid and eventually into carbon dioxide and water.

ADH is also located in the stomach lining, allowing a small amount of alcohol to be metabolized before it has a chance to be absorbed. At higher alcohol concentrations, additional enzyme systems may become active, contributing to alcohol breakdown.

Alcohol Metabolism: Step-by-Step Process

Primary Pathway: ADH/ALDH System[18]



Step 1. Ethanol → Acetaldehyde

- Location: Primarily in the liver
- Enzyme: Alcohol dehydrogenase (ADH)
- Process: ADH converts ethanol into acetaldehyde
- Important: Acetaldehyde is toxic

[18] Kawaratani, Hideto, Tsujimoto, Tatsuhiro, Douhara, Akitoshi, Takaya, Hiroaki, Moriya, Kei, Namisaki, Tadashi, Noguchi, Ryuichi, Yoshiji, Hitoshi, Fujimoto, Masao, Fukui, Hiroshi, The Effect of Inflammatory Cytokines in Alcoholic Liver Disease, *Mediators of Inflammation*, 2013, 495156, 10 pages, 2013.

Step 2. Acetaldehyde → Acetate

- Location: Liver
- Enzyme: Acetaldehyde dehydrogenase (ALDH)
- Process: ALDH converts toxic acetaldehyde into acetate
- Final breakdown: Acetate becomes CO_2 and H_2O for elimination

Secondary Pathway: MEOS (Microsomal Ethanol-Oxidizing System)

Step 3. Alternative Processing

- Location: Liver microsomes
- Key enzyme: CYP2E1 (cytochrome P450 2E1)
- Active at higher alcohol concentrations
- Process: Also converts ethanol to acetaldehyde
- Important: MEOS becomes more significant with chronic alcohol use

Genetic Factors Affecting Metabolism—ADH Gene Variants

- Fast metabolizers: Produce more active ADH enzyme
- Slow metabolizers: Produce less active ADH enzyme
- Result: Affects how quickly ethanol is converted to acetaldehyde

ALDH Gene Variants

- Normal ALDH: Efficiently processes acetaldehyde
- Deficient ALDH: Cannot effectively break down acetaldehyde
- Result: Acetaldehyde accumulation causes flushing, nausea (common in East Asian populations)

EXCRETION AND EVAPORATION

A small percentage of alcohol is eliminated unchanged through breath, urine, tears, sweat, semen, and saliva. While these routes contribute minimally to overall alcohol elimination, they are important in forensic testing, particularly breath and urine analysis.

The bladder functions as a reservoir, collecting urine that contains alcohol. However, urine alcohol concentration does not directly correlate to blood alcohol concentration (BAC) at a given moment. Each drop of urine reflects the BAC at the time it was produced, not the time it was collected. As urine accumulates and remains in the bladder, its alcohol concentration becomes a composite of multiple time points, making interpretation more complex. For this reason, it is essential to void the bladder before collecting a urine sample for alcohol testing. A fresh sample provides a more accurate reflection of the current BAC, reducing the risk of misinterpretation due to residual or pooled urine.

Alcohol is also excreted through breath. Once alcohol enters the bloodstream, it is transported to the lungs, where it diffuses into the alveoli, the tiny air sacs responsible for gas exchange. Because alcohol has a high vapor pressure at body temperature, it readily evaporates into the alveolar air and is subsequently exhaled. This property allows alcohol to be measured using breath testing devices, which estimate blood alcohol concentration (BAC) based on the amount of alcohol present in the breath. The principle behind this method is the equilibrium between blood and alveolar air, making breath alcohol testing a reliable and legally accepted tool in impaired driving investigations.

Alcohol is eliminated from the body through a combination of metabolism, excretion, and evaporation.

RATE OF ALCOHOL ELIMINATION

Alcohol is eliminated from the body through a combination of metabolism, excretion, and evaporation, with metabolism accounting for approximately 95% of the total elimination process. The average elimination rate for most individuals ranges from 0.010–0.025 g/dL per hour, encompassing variations due to age, sex, ethnicity, and drinking history.[19] Inexperienced drinkers tend to eliminate alcohol at the lower end of the range; moderate drinkers typically fall within the middle range. Chronic drinkers and individuals with alcohol use disorders often exhibit higher elimination rates due to enzyme adaptation. While elimination rates are generally consistent within the same individual, they may increase slightly during periods of heavy drinking. However, at low alcohol concentrations (e.g., below 0.02 g/dL), the elimination rate may slow significantly. This is because the enzymes responsible for alcohol metabolism are no longer saturated, and thus operate less efficiently, resulting in a non-linear elimination pattern.

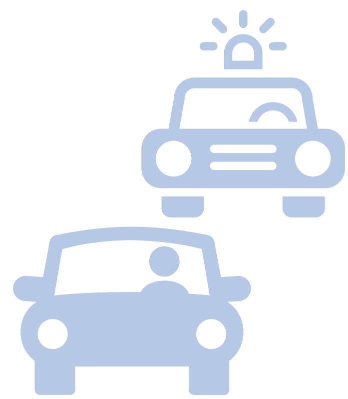
Because metabolism is the primary mechanism of alcohol elimination, there is no practical way to accelerate it. If blood continues to flow to the liver, alcohol will be metabolized at a relatively steady rate. External interventions, such as cold showers, caffeine, or exercise, do not speed up the metabolic process.

[19] ANSI/ASB 122, *supra*.

Effects of Alcohol on Behavior and Driving

Effects of Alcohol: Overview of Pharmacodynamic Properties and Driving Impairment

Alcohol significantly alters brain function and behavior, impairing judgment, reaction time, coordination, and decision-making—critical faculties for safe driving. These effects stem from alcohol's pharmacodynamic properties, which describe how it interacts with the central nervous system. As blood alcohol concentration (BAC) rises, so does the degree of impairment, often in predictable ways. Understanding these physiological and behavioral changes is essential for evaluating driving performance and determining legal responsibility in alcohol-related incidents.



Pharmacodynamic Properties

Alcohol acts as a central nervous system depressant, producing dose-dependent effects. As consumption increases, so does the degree of impairment. Alcohol affects both:

- Cognitive functions: Including judgment, reasoning, learning, and decision-making, which are critical for safe driving and situational awareness.
- Psychomotor skills: Such as voluntary movement, coordination, and reaction time, all of which are essential for operating a vehicle safely.

These pharmacodynamic effects begin shortly after alcohol enters the bloodstream and intensify as blood alcohol concentration (BAC) rises. Even at relatively low BAC levels, measurable impairment can occur, making the understanding of alcohol's impact on brain and motor function vital in evaluating alcohol-impaired driving cases.

Progressive Impairment Pattern

Alcohol produces a progressive and predictable pattern of impairment as blood alcohol concentration (BAC) rises, meaning its effects intensify as BAC rises. Initially, it affects the brain regions responsible for judgment, inhibition, personality, and emotional regulation, leading to mild euphoria, lowered inhibitions, and poor decision-making. As BAC continues to increase, cognitive and motor functions deteriorate in a predictable sequence, leading to impaired judgment, slowed reaction time, poor coordination, and increasingly compromised psychomotor functions such as coordination, balance, and eye movement. At high concentrations, alcohol can cause severe motor disruption and can depress vital involuntary functions, including respiration, potentially resulting in unconsciousness, coma, or even death. This stepwise progression of effects underscores the importance of understanding alcohol's pharmacodynamic properties when evaluating impairment in legal and forensic contexts.

Driving-Related Research

Extensive research has examined alcohol's impacts on driving through individual driving-related task analysis, driving simulator operations, and closed-course driving crash studies. Findings consistently show that alcohol increases reaction time, reduces information processing speed, impairs visual perception and judgment, compromises risk assessment and decision-making, and disrupts divided attention tasks critical to safe driving.

Importantly, impairment can occur at any measurable alcohol concentration.[20] As BAC rises above zero, the relative risk of a traffic crash increases (see Figure 3).[21] According to the National Safety Council's Alcohol, Drugs, and Impairment Division (ADID), all individuals are impaired at a BAC level of 0.08 and above and some individuals may be impaired at concentrations below 0.08.[22]

Alcohol produces a progressive and predictable pattern of impairment as blood alcohol concentration (BAC) rises, meaning its effects intensify as BAC rises.

[20] National Safety Council. *Impairment Begins with the First Drink.* Alcohol, Drugs and Impairment Division, National Safety Council, published 2020, available at www.nsc.org/getmedia/9f523dba-b7ec-4c66-9f7c-f360e4ea45dd/low-alcohol-risk.pdf.aspx?srsltid=AfmBOoprj8xt0P4P0tGeB5yoWEDNjLT6lVgMbMS8TmoNG59sdGtwStBz, accessed August 20, 2025.

[21] *Id.*

[22] National Safety Council. *Low Alcohol Concentration National Culture Change* (Position/Policy Statement No. 130). Adopted July 2016, National Safety Council, available at www.nsc.org/getattachment/ea31dcdb-360b-4035-b95e-59e24cb3fd6a/t-low-alcohol-concentration-national-culture-change-130?srsltid=AfmBOoqdSvPIVD-Xb97N-QD0A1BEZdcrai2UY6iOK3P5fk0axXtK-By6, accessed August 20, 2025. In all 50 U.S. states, it is illegal to operate a vehicle with a BAC of 0.08 g/dL. Additionally, in some instances, it is illegal to operate with an even lower BAC. For example, it is illegal to operate a commercial motor vehicle with a BAC of 0.04 g/dL or greater and, in many instances, it is illegal for an individual aged 21 years or younger to operate with any measurable BAC.

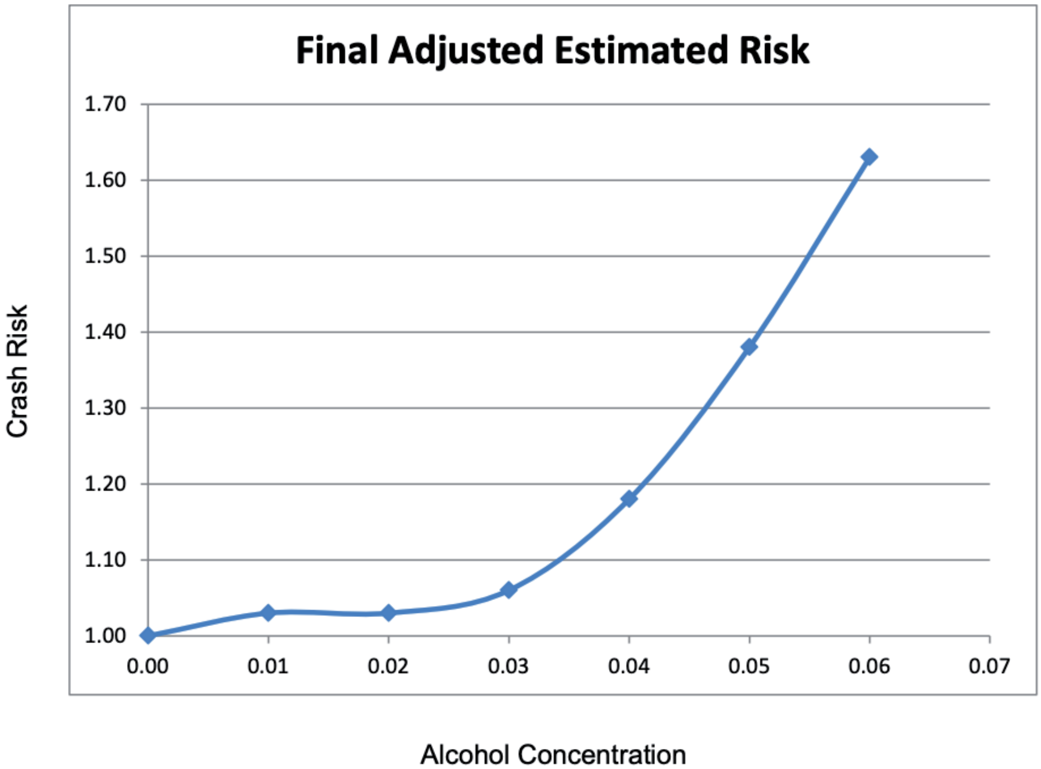


FIGURE 3.

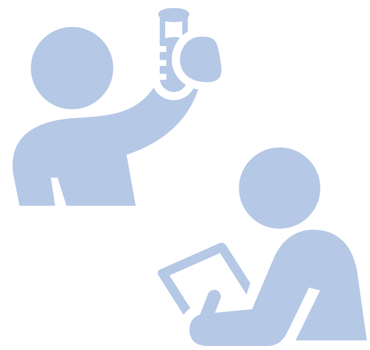
Limitations of Individual Impairment Assessment

While impairment studies typically compare an individual's performance before and after alcohol administration, they cannot definitively determine with certainty whether one person is more impaired than another at a given blood alcohol concentration (BAC). This is because impairment varies based on individual tolerance, physiology, and situational factors. However, using observational evidence—such as field sobriety tests, behavioral indicators, and officer testimony—experts can assess whether a person is impaired relative to their normal, alcohol-free state. Additionally, tools like retrograde extrapolation and BAC estimation formulas (e.g., Widmark's equation) allow forensic toxicologists to contextualize measured BAC levels and evaluate whether observed behavior aligns with expected impairment at that concentration.

Alcohol Testing and Interpretation

The Critical Role of a Toxicologist

Ethanol—commonly referred to as alcohol—is the only type of alcohol suitable for human consumption. Although legal and widely available, it is frequently misused and poses a significant risk for traffic-related incidents.[23] Due to its prevalence, many individuals develop personal beliefs or assumptions about alcohol based on experience or observation. However, these lead to misunderstandings about two critical scientific concepts:



- Pharmacokinetics: How the body absorbs, distributes, metabolizes, and eliminates alcohol.
- Pharmacodynamics: How alcohol affects the body and behavior.

While laypeople may recognize outward signs of intoxication, they may not understand that driver impairment can occur even in the absence of obvious symptoms. This gap in understanding can influence judicial outcomes, making it essential for legal professionals to proactively address common misconceptions during trial.

One of the most important decisions a prosecutor may face is determining whether expert testimony is needed to interpret alcohol test results in the context of case facts. A forensic toxicologist, or an expert trained in forensic toxicology, can provide critical insight into how alcohol levels relate to the defendant's behavior and impairment.

Qualified experts typically possess the training and experience necessary to apply ANSI/ASB Best Practice Recommendation 122 for performing alcohol calculations in forensic toxicology.[24] These calculations help contextualize test results, support retrograde extrapolation, and clarify whether the defendant's BAC at the time of driving likely exceeded legal limits.

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[23] National Highway Traffic Safety Administration. Drunk Driving | Statistics and Resources, *supra*.

[24] ANSI/ASB 122, *supra*.

Alcohol Detection in Biological Samples

Alcohol is detectable in any water-containing bodily fluid or exhaled breath. For law enforcement purposes, the most commonly collected specimens are breath, blood, and urine. In clinical settings, serum and plasma samples are often used and may occasionally be introduced in forensic investigations. For impaired driving cases, however, whole blood is considered the most reliable specimen due to its direct correlation with physiological impairment.

Forensic Sample Analysis: Laboratory Procedures

In impaired driving investigations, biological sample(s) are submitted to forensic toxicology laboratories by law enforcement or medical examiners. In fatal crash cases, additional specimens such as vitreous fluid may be analyzed alongside blood or urine. Once received, samples are tested for ethanol and other volatile substances, including acetone, isopropanol, and methanol.

Alcohol is detectable in any water-containing bodily fluid or exhaled breath.

Laboratories operate under strict operating procedures (SOPs) that govern:

- Evidence handling and chain of custody
- Sample storage and integrity
- Analytical methods and instrumentation
- Reporting and documentation results.

These procedures are often referenced during expert testimony to establish the reliability and validity of the analytical findings. Many laboratories adhere to ANSI/ASB standards and guidelines for alcohol analysis (see the section on Standards and Quality in Forensic Toxicology beginning on page 32).

Analytical Methods in Alcohol Testing

Forensic laboratories analyze blood and urine samples using headspace gas chromatography coupled with a flame ionization detector (HS GC-FID). In some cases, mass spectrometry may also be employed to enhance specificity and sensitivity. These methods are considered gold standards for quantifying ethanol concentrations in biological samples.

Forensic samples usually consist of *whole blood* collected in gray top tubes, which contain both an anticoagulant and a preservative to maintain sample integrity. Laboratory personnel—such as chemists, toxicologists, criminalists, medical technologists—should hold relevant scientific degrees and are often qualified to provide expert testimony interpreting analytical results (see the section on Standards and Quality in Forensic Toxicology beginning on page 32).

In contrast, breath alcohol testing is administered by law enforcement using calibrated instruments designed to produce legally admissible alcohol results. These operators may have limited scientific training and are generally restricted to testifying about the operation and principles of the device, rather than the underlying pharmacological or analytical science.

Clinical Sample Considerations

Biological samples analyzed in hospital laboratories may or may not be processed using the same instrumentation and standards as those employed in forensic toxicology labs. Interpreting clinical alcohol test results, therefore, requires careful attention to both the specimen type and the analytical methodology used.

SAMPLE TYPES

Specimen Type	Definition	Forensic/Clinical
Serum	The liquid that remains when blood is collected without an anticoagulant and allowed to clot.	Clinical—Not ideal for forensic testing.
Plasma	The liquid separated from whole blood, treated with an anticoagulant when the blood cells are removed.	Clinical—Can be used by forensic testing but caveats apply.
Whole blood	Blood drawn directly from the body from which none of the components, such as plasma or platelets, has been removed.	Forensic—Preferred specimen (collected in gray top tubes).
Urine	Fluid stored in the bladder excreted through the urethra.	Clinical and Forensic—Not preferred for forensic impaired driving but is often used. Caveats apply.

Hospital testing may involve analysis of whole blood, serum, or plasma—each of which can yield different alcohol concentration values due to variations in water content and distribution. Clinical laboratories often use automated analyzers operated by medical technologists, and results are frequently reported as “blood alcohol” even when the specimen analyzed is serum or plasma. This can lead to confusion or misinterpretation in legal contexts.

It is also important to note that hospital laboratories are not generally held to the same accreditation standards—such as ISO/IEC, which governs forensic toxicology laboratories. As a result, clinical results may lack the rigorous validation and chain-of-custody protocols required for forensic admissibility.

Hospital laboratory technicians are generally limited to providing basic testimony regarding the procedures used in sample analysis. They may not be qualified to interpret results beyond the scope of their operational duties. Therefore, pre-trial verification of an analyst’s qualifications and expertise is strongly recommended to ensure the reliability and admissibility of testimony.

In some jurisdictions, an expert witness may be legally required to convert alcohol concentrations measured in serum or plasma to their whole blood equivalents, as forensic standards typically rely on whole blood values for legal interpretation. This conversion is essential for accurate comparison with statutory per se limits and for ensuring consistency in courtroom presentations.

Unit Conversion and Standardization

Legal statutes define alcohol concentration using standardized units based on the type of biological specimen:

- Blood: Grams of alcohol per 100 milliliters (g/100 mL), which is equivalent to grams per deciliter (g/dL).
- Urine: Grams of alcohol per 67 milliliters (g/67mL).
- Breath: Grams of alcohol per 210 liters (g/210 L).

In clinical settings, alcohol concentrations—especially in serum or plasma—are typically reported in milligrams per deciliter (mg/dL). To convert these values to grams, divide by 1,000 (since 1 gram = 1,000 milligrams). (See example of conversion in Step 1 below.)

It is essential to recognize these differences when interpreting results, particularly in legal proceedings, as the specimen type and reporting units can significantly affect the perceived alcohol concentration.

> When interpreting alcohol test results, especially in legal contexts, it is essential to convert serum and plasma alcohol concentrations to whole blood equivalents.

Serum and Plasma Conversion to Whole Blood Equivalents

When interpreting alcohol test results, especially in legal contexts, it is essential to convert serum and plasma alcohol concentrations to whole blood equivalents. Serum and plasma represent the liquid portion of blood and contain a higher percentage of water than whole blood. Because alcohol is water-soluble, concentrations in serum and plasma are typically higher than in whole blood.

To ensure accurate interpretation, a conversion factor must be applied. The ratio of serum/plasma alcohol concentration to whole blood alcohol concentration generally ranges from 1.13–1.19.[25] This means:

Whole Blood Equivalent = Serum or Plasma Concentration ÷ Conversion Factor

(e.g., 150 mg/dL serum ÷ 1.15 ≈ 130 mg/dL whole blood)

Using this conversion helps align clinical results with legal standards, which typically define alcohol concentration based on whole blood values.

[25] ANSI/ASB 122, *supra.*

CONVERSION PROCESS

To convert a serum alcohol concentration to a whole blood equivalent:

Step 1. If necessary, convert the units to g/100 mL.

mg/dL = mg/100 mL

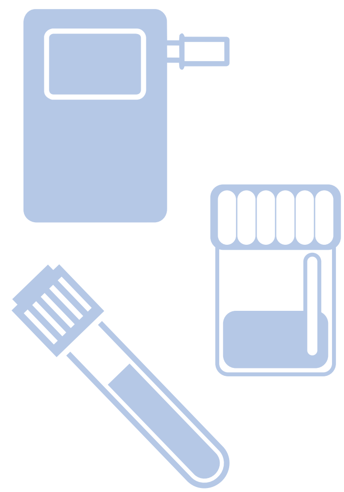
mg/100 mL = g/100 mL 1000

120 mg/*dL* = 0.120 g/100 *mL*

Step 2. Convert serum alcohol concentration (SAC) of 0.120 to an equivalent whole blood concentration—1.13–1.19:1 (SAC: Whole Blood Alcohol Concentration)

0.120 = 0.106 g/100 mL = using 1.13 SAC conversion (0.120/1.13)

0.120 = 0.101 g/100 mL = using 1.19 SAC conversion (0.120/1.19)



Interpreting Multiple Alcohol Test Results

In most cases, more than one alcohol test is performed—either through laboratory analysis or breath testing—resulting in multiple analytical values. How these results are reported typically depends on laboratory or program policies, which are designed to ensure consistency and reliability.

To maintain scientific integrity, quality control and quality assurance procedures are applied to confirm that the test results fall within an acceptable range of agreement. The officially reported result—as determined by these procedures—is the one that should be relied upon in legal proceedings.

Minor differences between test results are expected due to measurement uncertainty, and no interpretation should be made based on these small variations. Specifically:

- No inference should be drawn about the individual's position on the alcohol absorption or elimination curve based on slight differences between test results.
- The practice of estimating elimination rates from two test results—whether from blood or breath—is scientifically invalid and not acceptable.
- Any attempt by an expert to derive an elimination rate from such comparisons should be excluded from testimony.

Using and Evaluating Clinical Alcohol Results

Clinical alcohol tests are typically performed on serum or plasma samples, whereas forensic standards are based on whole blood alcohol concentrations. To accurately compare clinical results to legal per se limits, a conversion to whole blood equivalent is necessary.

Given conversion variability, due to biological differences and potential inter-laboratory variability, caution must be exercised when interpreting converted results. A forensic toxicologist should perform the conversion and be prepared to explain the differences between clinical and forensic testing methods.

Experts generally use a standard serum/plasma to whole blood conversion ratio of 1.13 to 1.19. For example:

100 mg/100 mL serum ÷ 1.13 = 88.5 mg/100 mL whole blood

100 mg/100 mL serum ÷ 1.19 = 84.0 mg/100 mL whole blood

Clinical results are often reported in mg/100mL, while forensic reports use g/100 mL. To convert, move the decimal point three places to the left:

84 g/100 mL = 0.084 g/100 mL

88.5 mg/100mL = 0.088 g/100 mL

A clinical result of 100 mg/100 mL would correspond to a whole blood equivalent of 0.084–0.088 g/100 mL, or 0.084–0.088% BAC.

> Breath and blood alcohol tests do not yield equivalent results and should not be used interchangeably for precise forensic calculations.

Breath and Blood Specimens

Breath and blood alcohol tests do not yield equivalent results and should not be used interchangeably for precise forensic calculations. In the United States, breath testing instruments typically underestimate the corresponding blood alcohol concentration (BAC) by 10–15%, and sometimes even more.

Due to the variability of an individual's blood-to-breath ratio, which can fluctuate based on physiology and timing, neither breath nor blood samples should be used to infer a subject's position on the alcohol absorption/ elimination curve. If both breath and blood test results are available for retrograde extrapolation, it is recommended to use only one type of measurement at a time, recognizing that each may yield slightly different estimates. This approach helps maintain consistency and avoids compounding uncertainties.

Estimating Alcohol Concentrations

Alcohol Concentration Estimates

The progression of alcohol concentration in the body over time can be illustrated using a generalized blood alcohol concentration (BAC) curve, which is typically divided into three distinct phases (and depicted in Figure 4):[26]

- Absorptive phase: Alcohol is actively being absorbed from the gastrointestinal tract into the bloodstream. During this phase, BAC rises as absorption outpaces elimination.
- Peak phase: Absorption and elimination occur at approximately equal rates, resulting in a plateau or peak in BAC.
- Post-absorptive phase: Absorption is complete, and BAC begins to decline as the body metabolizes and eliminates alcohol.

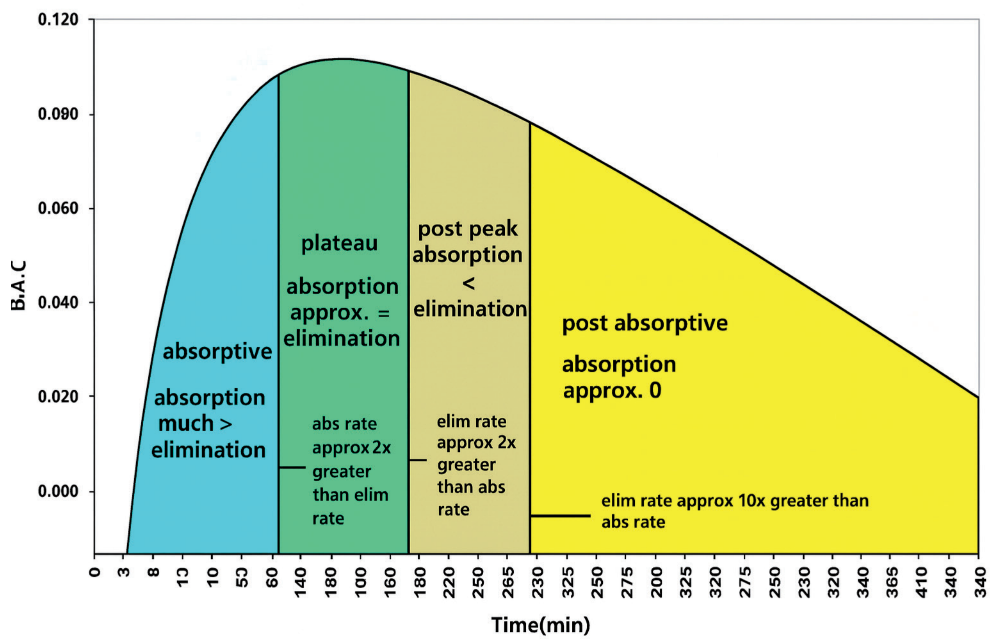


FIGURE 4.

[26] This graph was originally produced by Alanna de Korompay, Forensic Toxicology Advisor, International Criminal Investigative Training Assistance Program. It appears here with her permission.

The shape and duration of each phase vary based on individual factors such as body composition, drinking speed, food intake, and metabolic rate. Because absorption and elimination processes overlap, BAC can rise, plateau, or fall depending on the timing of sample collection.

It is critical to understand that any given BAC value—except the peak—can occur twice during a drinking episode: once during the rising phase and again during the falling phase. Therefore, a single BAC measurement provides only a snapshot of the individual's status at the time of testing. It does not reveal whether the person is still absorbing alcohol, has reached peak concentration, or is in the elimination phase.

This concept is foundational in forensic toxicology and is supported by extensive research, including the work of A.W. Jones, who outlines the pharmacokinetics of ethanal in forensic contexts.[27]

Estimating Alcohol Concentrations

Alcohol concentration in an individual may be estimated using a combination of factors, including height, weight, sex, and the amount of alcohol consumed. Accurate estimation also requires knowledge of the timing, such as when the blood sample was drawn, or the breath test was administered, and the time of interest, such as the moment of a traffic stop or crash. The specific information needed depends on the type of calculation being performed and the question being asked.

Alcohol concentration in an individual may be estimated using a combination of factors, including height, weight, sex, and the amount of alcohol consumed.

Most alcohol estimation calculations are based on the Widmark formula, developed by Swedish scientist Erik M. P. Widmark in the 1930s. This formula, and its various modifications, can be used to answer questions such as

- What is the maximum alcohol concentration a person could reach given a specific dose?
- What is the minimum amount of alcohol required to reach a specific concentration?
- What was the likely BAC at a previous point in time, such as during driving?

ANSI/ASB Best Practice Recommendation 122: *Best Practice Recommendation for Performing Alcohol Calculations in Forensic Toxicology* provides detailed guidance on performing alcohol calculations in forensic toxicology. It includes examples of different calculation types and outlines the assumptions and limitations associated with each method.[28]

[27] *See* Jones, A.W. (2019). Alcohol, its absorption, distribution, metabolism, and excretion in the body and pharmacokinetic calculations. Wiley Interdisciplinary Reviews: *Forensic Science*. 1. e1340. 10.1002/wfs2.1340.

[28] ANSI/ASB 122, *supra*.

Retrograde Extrapolation

Retrograde extrapolation is one of the most requested forensic alcohol calculations. It involves estimating an individual's blood alcohol concentration (BAC) at an earlier time—typically the time of a traffic stop or crash—based on a measured BAC obtained later through a blood, breath, or urine test.

This method is particularly useful in impaired driving cases where there is a delay between the incident and the collection of a biological sample. The goal is to provide a scientifically supported estimate of the BAC at the time of the alleged offense, not just at the time of testing.

To perform retrograde extrapolation accurately, the expert must be provided with comprehensive case information, including:

- The exact time of the incident (e.g., stop, crash)
- The time of the sample collection
- Details about the individual's drinking history
- Relevant physiological factors (e.g., weight, sex, drinking experience)
- Whether the individual was in the absorptive or post-absorptive phase at the time of testing

Without this context, the extrapolation may be unreliable or misleading. Experts may also need to account for ongoing alcohol absorption, which can significantly affect the accuracy of the estimate.

The information in the table below is useful:

Offense-Related Information	Drinking History
Time of blood draw or breath test	Time of the incident (stop, crash, etc.)
Test result (breath or blood)	Number of drinks consumed
Subject's gender	Size or volume of drinks
Subject's weight	Concentration of alcohol in the drinks (proof)
Subject's height	Timing of the drinks
Subject's age	Food consumption

An expert's estimation and testimony are only as reliable as the information upon which they are based. When there is a delay between the time of the crash and administration of a chemical test, a thorough police investigation becomes critical. For retrograde extrapolation, the most crucial elements of the drinking history are alcohol consumption within the two hours preceding the offense and any consumption after the offense but before testing. Identifying where the defendant last consumed alcohol—and its distance from that location to the site of arrest—can help establish a minimum time since the last drink. Additionally, constructing a detailed timeline and evaluating the availability of alcohol between the time of a crash and the moment police contacted the defendant are essential steps in assessing the likelihood of post-crash alcohol consumption.

The process of alcohol absorption, distribution, and elimination is dynamic and begins immediately upon consumption. Once alcohol enters the bloodstream, the body starts eliminating it—meaning elimination occurs concurrently with absorption and distribution. In retrograde extrapolation, the goal is to estimate the blood alcohol concentration (BAC) at the time of an incident (e.g., driving) based on a later test result. The first step is to calculate how much alcohol was eliminated between the time of the incident and the time of testing.

The process of alcohol absorption, distribution, and elimination is dynamic and begins immediately upon consumption.

To do this, a forensic expert multiplies the number of hours elapsed by a scientifically accepted range of alcohol elimination rates, typically between 0.010 and 0.025 grams per deciliter per hour. Importantly, an average rate should not be used, as individual metabolism varies.

The estimated amount of eliminated alcohol is then added to the measured BAC, since it represents alcohol that was present at the time of the incident but no longer detectable at the time of testing.

Depending on when the last drink was consumed, this may be sufficient. However, if alcohol was consumed within two hours of the incident, the presence of unabsorbed alcohol must also be considered, as it could affect the accuracy of the extrapolation.

If only elimination is being considered, the formula is:

> Estimated BAC at time of incident = Measured BAC +
> [(Time of test – Time of incident) x Elimination rate range]

This approach provides a range of possible BAC values at the time of the offense, reflecting the uncertainty inherent in biological variability and timing of alcohol consumption.

Example: A defendant is stopped by police at midnight, but the blood is not drawn until 3 a.m. Results from the laboratory show the defendant's alcohol concentration to be 0.070 g/100 mL. In this case, the last drink was at 9 p.m. What would the defendant's estimated alcohol concentrations be at the time of driving?

0.070 + (3 hours x 0.010) = 0.100; and

0.070 + (3 hours x 0.025) = 0.145

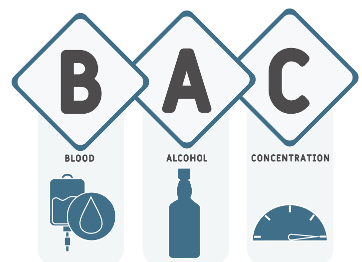
Answer: The estimated alcohol concentration at the time of driving was between 0.100 and 0.145 g/100 mL.

The estimated alcohol concentration derived through retrograde extrapolation is considered reliable only under specific conditions:

No alcohol was consumed within two hours prior to the incident, ensuring that all alcohol had been fully absorbed.

No alcohol was consumed after the incident but before the test was administered.

When these conditions are met, the calculated value reasonably reflects the blood alcohol concentration at the time of driving. Any deviation from these assumptions, such as recent drinking or post-incident consumption, can significantly affect the accuracy of the estimate.



Accounting for Unabsorbed Alcohol in Retrograde Extrapolation

If alcohol consumption occurred more than two hours prior to the incident, it is generally safe to assume the individual is in the post-absorptive phase, meaning all alcohol has been absorbed into the bloodstream. In such cases, standard retrograde extrapolation methods can be applied with reasonable confidence.

However, if alcohol was consumed within two hours of the incident, the presence of unabsorbed alcohol must be considered. This requires a more detailed analysis. The expert may estimate the quantity of alcohol consumed and assess its potential impact based on the individual's age, weight, gender, body composition, and other relevant physiological factors.

This evaluation typically results in a lower estimated BAC range, as it accounts for alcohol that had not yet entered the bloodstream at the time of the incident. The degree of adjustment depends on the timing of consumption and the expert's assessment of the individual's absorption profile.

A significant portion of an alcohol dose is typically absorbed within the first 30 minutes of consumption. However, the exact extent of absorption at any given moment cannot be precisely determined. As a result, experts must account for the possibility of unabsorbed alcohol when estimating BAC.

One conservative approach is to exclude the full contribution of the most recent drink from the BAC calculation. Alternatively, the expert may choose to remove only a portion of the drink's effect, based on the timing of consumption relative to the incident.

To ensure clarity and preparedness, prosecutors should consult with the expert before trial to discuss the details of the case and determine exactly what the witness will be able to testify to in court.

Research indicates that, under various dosing conditions—including the presence of food in the stomach—the maximum rise in BAC following a single drink is generally no more than 0.02 g/dL. Therefore, the time elapsed between the last drink, and the incident plays a critical role in determining how the expert adjusts the BAC estimate.

Alcohol consumed within 30 to 60 minutes prior to an incident holds the greatest forensic significance, as it may not have been fully absorbed at the time of the offense. The method an expert uses to estimate blood alcohol concentration—and the data they rely on—can vary depending on the specific questions being addressed in the case.

To ensure clarity and preparedness, prosecutors should consult with the expert before trial to discuss the details of the case and determine exactly what the witness will be able to testify to in court. This proactive approach helps avoid surprises and verifies that the expert's analysis aligns with the evidentiary needs of the prosecution.

> **Example:** A 5'10", 180-pound male is arrested for DUI at 1:30 a.m. His measured BAC at 2:30 a.m. is 0.130 g/100 mL. His last drink, 2 oz. of 80-proof (40%) liquor, was consumed rapidly at 1:25 a.m., just minutes before the traffic stop. What was his alcohol concentration at 1:30 a.m.?

Step 1. Consider Absorption

Because the drink was consumed so close to the time of the stop, it is unlikely that the alcohol was fully absorbed. Therefore, a forensic expert would exclude the contribution of this drink from the BAC at the time of driving, as it would not yet have entered the bloodstream.

Step 2. Account for Elimination

Next, the expert estimates how much alcohol was eliminated between the time of the stop and the time of testing (1 hour). Using the accepted range of elimination rates:

- Low rate (0.010 g/100 mL/hr): 0.130 + (1 hour x 0.010) = 0.140
- High rate (0.025 g/100 mL/hr): 0.130 + (1 hour x 0.025) = 0.155

This gives an initial estimated BAC range at the time of driving:
0.140 to 0.155 g/100 mL.

Step 3. Subtract Unabsorbed Alcohol

The contribution of the unabsorbed drink must now be subtracted. For a male of this size, 2 oz. of 80-proof liquor would contribute approximately:

- Low estimate: 0.027 g/100 mL
- High estimate: 0.039 g/100 mL

Subtracting this from the initial BAC range:

- 0.140–0.039 = 0.101 g/100 mL
- 0.155–0.027 = 0.128 g/100 mL

Final Estimated BAC at Time of Driving: Between 0.101 and 0.128 g/100 mL

For further guidance and standardized methodology, refer to ANSI/ASB Best Practice Recommendation 122: *Best Practice Recommendation for Performing Alcohol Calculations in Forensic Toxicology*, specifically Section 5.3.3, which provides detailed examples and recommendations for these types of calculations.

Post-Incident Alcohol Consumption and Its Forensic Impact

One common complication arises when the defense alleges post-incident alcohol consumption, which can affect BAC levels measured later. Defendants may claim to have consumed alcohol after a crash or incident, and prosecutors often learn of this allegation shortly before or even during trial. The forensic impact of post-incident alcohol consumption can be evaluated using similar techniques applied to unabsorbed alcohol, but with a key difference: in this case, the entire amount of alcohol allegedly consumed is subtracted from the preliminary estimated BAC. Additionally, defense strategies frequently include claims that the alcohol concentration at the time of the offense was lower than at the time of the testing due to alcohol consumption immediately before the offense (rising curve defense). The defense may utilize alcohol concentration estimates based on a drinking history to challenge test results (e.g., “I only had two beers”). Conversely, prosecutors may use the measured BAC to challenge the credibility of the defendant’s drinking history, especially when the reported consumption is inconsistent with toxicological expectations.

The extent of this impact depends on several factors, including:

- Amount of alcohol consumed
- Timing of consumption
- Body weight and gender
- Rate of absorption and elimination

It is also essential to consider any unabsorbed alcohol consumed prior to the incident, as this can further influence the BAC estimation.

To properly assess the claim, the expert must be provided with detailed and accurate information before testimony. This allows for a thorough pre-trial evaluation of the alleged post-incident consumption.

In some cases, the amount of alcohol claimed may be insufficient to lower the defendant's BAC below the legal per se limit at the time of driving. In other cases, even if the claimed consumption could theoretically reduce the BAC below the threshold, the credibility of the claim may be challenged based on inconsistencies with other known facts of the case.

Considerations with Calculation of Alcohol Concentration Estimates

When preparing for trial, prosecutors should be mindful of several practical considerations related to alcohol concentration calculations. Early pre-trial discussions with the expert are essential, especially when it is anticipated that a calculation will be necessary. These conversations allow the expert to prepare thoroughly and ensure they can confidently address key questions during testimony.

Biological factors such as gender and obesity must be considered when using the Widmark equation or other calculation tools. If gender is uncertain, a broad range of distribution volumes can be applied, as outlined in ANSI/ASB 122. However, the most accurate approach is anthropometric modeling, which incorporates sex, weight, age, and height to provide a more individualized estimate.

A useful strategy in some cases is to determine how much unabsorbed alcohol would be required to bring a defendant's BAC below the legal limit (e.g., 0.08 g/100 mL). Often, the amount needed is unrealistic, making it easier to argue that the defendant was over the per se limit at the time of driving. An expert can assist in framing this argument effectively.

Using ranges rather than averages is critical in these calculations. While averages may simplify the math, they fail to represent the variability in the population. In fact, statistical analysis shows that average elimination rates apply to less than 1% of individuals, whereas using a range can account for over 95% of the population. Including a range provides a more accurate and defensible estimate.

These calculations should not be treated as simple mental math exercises. They often involve multiple steps and require careful consideration. Performing them live on the stand is discouraged. Instead, the expert should be given all relevant information in advance to allow for thoughtful analysis. If new information arises during testimony, the expert can discuss its implications but should not be expected to perform complex calculations in real time. In such cases, requesting a recess or break is appropriate to allow for proper evaluation.

Finally, it is important to remember that any estimate—whether retrograde or forward—is inherently less precise than a directly measured result. These estimates are valuable tools, but they must be presented with appropriate context and caution.

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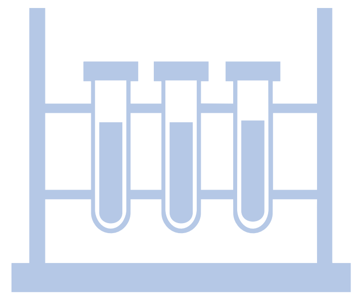
Standards and Quality in Forensic Toxicology

Quality standards in forensic toxicology are essential to ensure the accuracy, reliability, and integrity of test results used in legal proceedings. Consistent adherence to validated methods, proper chain of custody, and rigorous laboratory protocols helps prevent errors, supports expert testimony, and upholds the credibility of the evidence in alcohol-impaired driving cases.



Quality Management, Quality Control and Quality Assurance

The terms *Quality Control (QC)* and *Quality Assurance (QA)* are often used interchangeably, but they serve distinct roles within a broader framework known as the Quality Management System (QMS). A QMS is the overarching structure that encompasses all activities related to maintaining and improving quality within a laboratory, program, or testing process. It includes both QA and QC components. QA defines the systematic processes and requirements that ensure quality standards are met. It focuses on preventing errors by establishing protocols, training, documentation, and oversight. QC is a subset of QA and refers to the operational techniques and activities used to verify that a product, service, or method meets defined specifications. It involves routine checks, testing, and validation to detect and correct deviations. Together, QA and QC are interrelated and essential to ensuring the reliability and integrity of laboratory results, program performance, and individual test outcomes. Understanding their distinctions and how they fit within a QMS is critical for maintaining high standards in forensic and scientific environments.

According to ISO 9000:2015, the terms are defined as follows:

> *Quality Assurance (QA):* A part of quality management focused on providing confidence that quality requirements will be fulfilled.
>
> *Quality Control (QC):* A part of quality management focused on fulfilling quality requirements.[29]

[29] International Organization for Standardization. ISO 9000:2015, *Quality management systems—Fundamentals and vocabulary*. 4th ed., ISO, Sept. 2015, www.iso.org/standard/45481.html, accessed August 20, 2025.

QA and QC form the foundation of a robust QMS, which governs all activities related to maintaining and improving quality across programs, laboratories, and individual test results.

While QA and QC are closely related, they serve distinct purposes within a broader QMS:

- Quality Assurance involves the design and implementation of processes that define quality standards, validate methodologies, and establish performance criteria for instruments and procedures. Its goal is to prevent errors by ensuring systems are properly structured and maintained.
- Quality Control, on the other hand, is the evaluation of those systems and processes to verify that they meet the defined criteria. It involves routine testing, monitoring, and corrective actions to ensure consistent performance and reliability.

Together, QA and QC form the foundation of a robust QMS, which governs all activities related to maintaining and improving quality across programs, laboratories, and individual test results.

When evaluating specific components of a laboratory's program, it is helpful to consider which aspects fall under QA and which are part of QC, or both.

The process begins with instrument selection, where decisions are made about which instruments will be purchased and validated for use. This is typically guided by predefined performance criteria and often occurs at the state or local level. This step is firmly rooted in QA, as it sets the foundation for quality expectations.

Once instruments are acquired, they undergo validation to ensure they meet the established criteria. This step involves both QA and QC: QA defines the validation requirements, while QC confirms that the instrument performs within those parameters. A valuable resource for validation standards is ANSI/ASB Standard 036: *Standard Practices for Method Validation in Forensic Toxicology*.[30]

Before instruments can be used for testing, they must be calibrated. Calibration ensures the instrument can accurately measure alcohol concentrations in biological specimens, typically blood. This process is considered QC because it evaluates performance, but it also involves QA since it follows a defined procedure and uses predetermined criteria. Calibration typically involves analyzing a range of known alcohol concentrations and may be performed daily, after repairs, or when a quality control sample fails.

Once calibrated, the instrument is ready for testing. Most laboratories perform duplicate tests on each specimen. QA defines how close the results of these tests must be, while QC involves evaluating whether the results meet those criteria—either automatically by the instrument or manually by the analyst.

[30] American Academy of Forensic Sciences Standards Board. ANSI/ASB Standard 036: *Standard Practices for Method Validation in Forensic Toxicology*. 1st ed., 2019, American Academy of Forensic Sciences, www.aafs.org/asb-standard/standard-practices-method-validation-forensic-toxicology, accessed August 20, 2025.

During testing, quality control samples are also run. These include negative and positive controls, with positive controls containing a known amount of alcohol. The instrument quantifies these samples, and their accuracy is assessed as part of QC. For guidance on control sample requirements, refer to ANSI/ASB Standard 054: *Standard for a Quality Control Program in Forensic Toxicology Laboratories*.[31]

Routine instrument maintenance is another critical QA activity. Scheduled checks—daily, weekly, or monthly—ensure continued performance and may involve replacing consumable materials, reagents, or performing minor repairs. These procedures vary by instrument and laboratory but are essential for maintaining reliability.

Finally, the laboratory must maintain records of all validations, calibrations, tests, control samples, and maintenance activities. These records, which may be stored digitally or in hard copy, are part of QA and are retained for a defined period to support transparency and traceability.

Together, these examples illustrate how QA and QC interact throughout the testing process, helping to clarify their distinct but complementary roles. The following additional elements of a quality assurance program may further support consistency, reliability, and defensibility in forensic testing.

Accreditation

Accreditation is a formal recognition by an independent third party that a laboratory is qualified, competent, and operates in compliance with international standards. The most widely recognized standard for testing and calibration laboratories is ISO/IEC 17025:2017—General Requirements for the Competence of Testing and Calibration Laboratories. Accreditation of a laboratory may be voluntary or mandated by state legislation, depending on jurisdiction. Regardless of its origin, accreditation serves as a powerful tool for ensuring integrity, reliability, and consistency of laboratory operations. A key principle of accreditation is continual improvement. ISO/IEC 17025:2017 provides a structured framework for laboratories to define and implement a Quality Management System (QMS), identify and evaluate risks within the program, and conduct internal and external audits and reviews to assess performance and compliance. An organizational chart illustrates how various roles, such as the Laboratory Director, Quality Manager, Technical Manager, Analysts, and Auditors contribute to maintaining accreditation. Each role plays a part in upholding the QMS, ensuring that procedures are followed, risks are managed, and improvements are continuously pursued. This structure supports a culture of accountability and excellence, helping laboratories not only meet but exceed the expectations set forth by ISO/IEC 17025:2017.

Accreditation is a formal recognition by an independent third party that a laboratory is qualified, competent, and operates in compliance with international standards.

[31] American Academy of Forensic Sciences Standards Board. ANSI/ASB Standard 054: *Standard for a Quality Control Program in Forensic Toxicology Laboratories*. 1st ed., 2021, American Academy of Forensic Sciences, www.aafs.org/asb-standard/standard-quality-control-program-forensic-toxicology-laboratories, accessed August 20, 2025.

While ISO/IEC 17025:2017[32] is the most widely recognized international standard for testing and calibration laboratories, other types of accreditations may also be referenced depending on the context and scope of laboratory operations.

- ISO/IEC 17025 sets the benchmark for laboratory competence, focusing on the ability to produce valid results through rigorous quality management and technical procedures.[33]
- ISO/IEC 17034 applies specifically to the production of reference materials, which are essential for calibration and quality control processes. Laboratories involved in creating these materials must meet distinct criteria to ensure consistency and reliability.[34]
- ISO 9000 and ISO 9001 are broader standards used across various industries to assess the overall quality management systems of organizations. While they promote strong quality practices, they do not address the specific technical and procedural needs of testing or calibration laboratories.

In specialized fields such as forensic toxicology, additional supplemental requirements may be imposed by the accrediting body. These requirements are tailored to the unique demands of forensic work and are used in conjunction with ISO/IEC 17025 during the accreditation assessment process. They provide more detailed guidance on procedures, documentation, and performance expectations relevant to forensic settings.

Accreditation serves as a formal signal to the community that a laboratory meets—or exceeds—established standards of quality and competence.

Understanding the distinctions between these standards helps clarify the scope and purpose of each accreditation type and ensures that laboratories meet the appropriate criteria for their specific functions.

Accreditation serves as a formal signal to the community that a laboratory meets—or exceeds—established standards of quality and competence. Beyond this recognition, accreditation provides a structured framework for evaluating operational issues, maintaining ongoing analyst training and competence, promoting continuous improvement of the quality management system, and ensuring external oversight of laboratory practices.

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32 International Organization for Standardization, and International Electrotechnical Commission. ISO/IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories*. ISO, 2017, www.iso.org/standard/66912.html, accessed August 20, 2025.

33 *Id.*

34 International Organization for Standardization. ISO 17034:2016, *General requirements for the competence of reference material producers*. 1st ed., ISO, Nov. 2016. ISO, www.iso.org/standard/29357.html, accessed August 20, 2025.

Key elements of an accreditation program typically include:

- Impartiality and confidentiality
- Adequate resources and infrastructure
- Personnel qualifications, training, and competence
- Suitable facilities and environmental conditions
- Method selection, verification, and validation
- Proper handling of test and calibration items
- Evaluation of measurement uncertainty
- Clear and accurate reporting procedures
- Management of non-conforming work and corrective actions
- Regular reviews of the quality management system and internal audits

Accreditation may be mandatory by statute or voluntary, depending on jurisdiction and context. Importantly, the absence of accreditation does not automatically invalidate the quality of a laboratory's work or the competence of its personnel. In such cases, the laboratory must still demonstrate that it has robust systems in place to ensure the accuracy and reliability of its testing.

This includes validated instrumentation, a maintained quality management system, documented procedures, competent personnel, and mechanisms for identifying and correcting issues. When these elements are present and well-managed, a laboratory can operate with high standards—even in the absence of formal accreditation.

Accreditation may be mandatory by statute or voluntary, depending on jurisdiction and context. Importantly, the absence of accreditation does not automatically invalidate the quality of a laboratory's work or the competence of its personnel.

Uncertainty of Measurement (UM)

In any measurement process, both accuracy and precision are desired, but they represent different concepts. Accuracy refers to how close a measured value is to the true or accepted value. Precision refers to how close repeated measurements (two or more) are to each other, regardless of whether they are close to the true value. It is possible to have one without the other. For example, a measurement can be accurate but not precise, or precise but not accurate. A helpful analogy is to imagine a baseball pitcher. If the pitcher is accurate, they consistently throw the ball into the strike zone. If the pitcher is precise, they consistently throw the ball to the same spot, even if that spot is outside the strike zone. Ideally, the pitcher wants to be both accurate and precise, throwing the ball to the same location each time, and that location being the strike zone. Similarly, in laboratory testing, the goal is to produce results that are both reliable (precise) and correct (accurate).

Every measurement process inherently involves some degree of variability. Even when the same procedure is repeated under identical conditions, the results may differ slightly each time. Whether these differences are noticeable depends on the sensitivity of the measurement method. This variability is captured through the concept of measurement uncertainty—an estimate of how much a measured value might deviate from the true value. Measurement uncertainty reflects the confidence in the result and is based on a comprehensive evaluation of both the measurand (the item being measured) and the measurement process itself. Several factors contribute to this evaluation, including:

- The individuals performing the measurement, as human technique and interpretation can introduce variation.
- The equipment used, such as instruments, balances, pipettes, and other tools, each with their own tolerances and limitations.
- The reference materials or standards used in calibration and testing, including how they are prepared and the equipment involved in their preparation.
- The results of repeated measurements, such as quality control samples, which help quantify the consistency and reliability of the process.

UM quantifies the expected variability within a measurement process and provides a statistical estimate of confidence in the result.

By systematically assessing these factors, laboratories can estimate the uncertainty associated with a given measurement and ensure that results are both scientifically sound and legally defensible.

Once the contributing factors to variability are evaluated, measurement uncertainty (UM) can be calculated using accepted scientific practices. UM quantifies the expected variability within a measurement process and provides a statistical estimate of confidence in the result. It is important to understand that UM is not an indication of error or mistake—rather, it reinforces the reliability of the measurement by acknowledging and accounting for natural variation.

During the initial evaluation, identifying the parameters that contribute to UM allows the laboratory to take corrective steps. If any contributors are larger than expected or desired, adjustments can be made to reduce their impact. This not only improves the consistency of the measurement process but also leads to a more refined and lower UM value.

Once calculated, UM serves several important functions. It can be used to monitor the stability of testing processes over time through periodic re-evaluation. During actual testing, UM provides a range of expected variance around a measured value and is typically reported alongside the result as a +/- value. For example, if a blood alcohol test result is 0.100 g/dL with a UM of +/- 0.005 g/dL, then any result between 0.095 and 0.105 g/dL is considered statistically equivalent. This means that small differences between repeated tests—such as 0.095, 0.100, or 0.105 g/dL—do not necessarily indicate rising or falling BAC but rather reflect normal variability within the measurement process.

A highly recommended resource for guidance on calculating and applying UM is ANSI/ASB Standard 056: *Standard for Evaluation of Measurement Uncertainty in Forensic Toxicology*.[35]

Metrological Traceability

Metrological traceability, also known as measurement traceability, refers to the ability to demonstrate an unbroken chain of comparisons from a measurement result back to a recognized primary standard. In the United States, this chain leads to the National Institute of Standards and Technology (NIST), which connects to the International System of Units (SI). In practice, this means that every step in a measurement process—from the equipment used to the material involved—must be calibrated or manufactured in a way that ensures traceability to the SI. Importantly, each calibration step must include a reported uncertainty of measurement (UM), which quantifies the confidence in the measurement result.

Metrological traceability, also known as measurement traceability, refers to the ability to demonstrate an unbroken chain of comparisons from a measurement result back to a recognized primary standard.

For example, when calibrating an alcohol testing instrument, every component involved—such as pipettes, glassware, and reference materials—must be traceably calibrated. A pipette used to measure sample volume should be calibrated by an accredited vendor, with documentation showing traceability through NIST to the SI. Similarly, reference materials (calibrators) must be produced by a competent manufacturer, ideally accredited to ISO 17034, which ensures the reliability and traceability of the standards used. It is important to note that traceability applies to the measurement result or value, not the physical equipment itself. By ensuring that each element in the calibration process is traceable to the SI, the final calibration result of the instrument is also traceable—establishing metrological traceability.

This traceability is critical for validating the accuracy of an instrument's measurement capability. It provides confidence that the calibration process meets the required specifications and supports the reliability of the testing results. Moreover, traceability and uncertainty of measurement are interrelated—together, they define the accuracy and precision of the measurement process.

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[35] American Academy of Forensic Sciences Standards Board. ANSI/ASB Standard 056: *Standard for Evaluation of Measurement Uncertainty in Forensic Toxicology*. 1st ed., 2025, American Academy of Forensic Sciences, www.aafs.org/asb-standard/standard-evaluation-measurement-uncertainty-forensic-toxicology, accessed August 20, 2025.

For detailed guidance, refer to ANSI/ASB Standard 017: *Standard for Metrological Traceability in Forensic Toxicology*, which outlines best practices for establishing traceability in forensic alcohol testing.[36]

Currently, the implementation of such standards and best practices is voluntary. Laboratories may choose to adopt them fully, partially, or not at all, depending on factors such as legislation, legal frameworks, or budget constraints. However, implementing these standards promotes consistency, quality, efficiency, and ultimately greater confidence in laboratory results. They provide a structured framework aligned with industry expectations and help harmonize calibration and testing practices across programs.

A laboratory can still maintain high quality through validated instruments, a robust quality management system, competent personnel, and documented corrective actions.

As with accreditation, the absence of formal standards implementation does not automatically invalidate a laboratory's results. A laboratory can still maintain high quality through validated instruments, a robust quality management system, competent personnel, and documented corrective actions. These elements contribute to a reliable and defensible testing program, even without formal accreditation or full standards adoption.

A comprehensive quality management system encompasses every aspect of laboratory operations—from ordering supplies to producing final test results. It includes analyst training and competence, instrument selection and validation, consistent testing practices, and thorough documentation of any issues encountered. When issues are identified and addressed appropriately, they reflect the strength of the quality system—not a failure. Moreover, unless directly related to a specific test, timeframe, or personnel, such issues should not be interpreted as compromising the validity of an alcohol result.

Standardization in Forensic Toxicology

The Organization of Scientific Area Committees (OSAC) for Forensic Science, specifically the Toxicology Subcommittee, plays a key role in developing standards, best practice recommendations, and guidelines related to the analysis of biological samples for alcohol and other drugs, as well as the interpretation of these results. Working in partnership with OSAC is the Academy Standards Board (ASB), a Standards Development Organization (SDO). ASB is responsible for advancing documents, whether developed internally or externally, through a formal process defined by the American National Standards Institute (ANSI). The development process typically begins with the OSAC Toxicology Subcommittee drafting a proposed document. This draft is then handed off to the ASB Toxicology Consensus Body, which oversees its progression through the SDO process. This includes public review and comment, adjudication of feedback, document revision, and final publication as an American National Standard. (Figure 5.)

[36] American Academy of Forensic Sciences Standards Board. ANSI/ASB Standard 017: *Standard Practices for Measurement Traceability in Forensic Toxicology*. 1st ed., 2018, American Academy of Forensic Sciences, www.aafs.org/asb-standard/standard-practices-measurement-traceability-forensic-toxicology, accessed August 20, 2025.

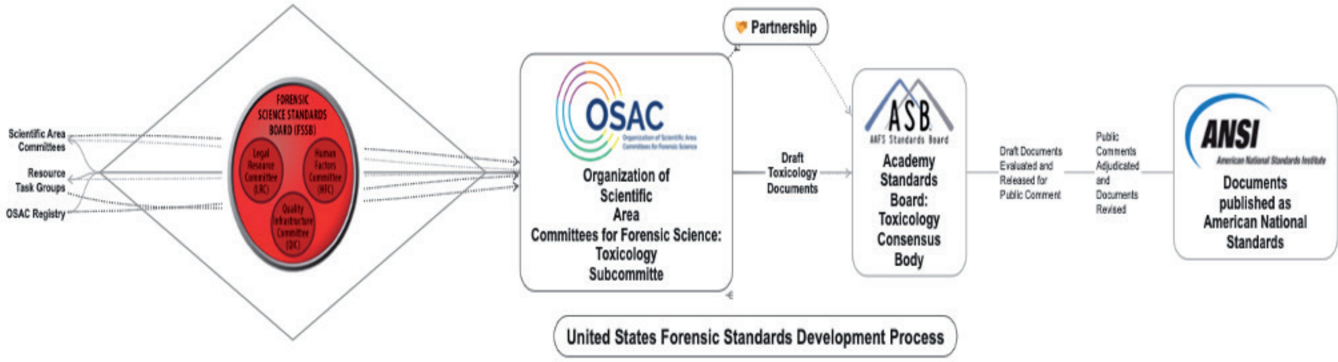

FIGURE 5. United States Standards Development Process for Forensic Toxicology

This collaborative process ensures that forensic toxicology standards are developed with scientific rigor, transparency, and broad stakeholder input, ultimately enhancing consistency and reliability across forensic laboratories.

Standards and Alcohol Testing

In addition to the previously discussed standards and best practices, several other published documents specifically support impaired driving investigations. These resources are voluntarily adopted by forensic service providers who conduct biological sample testing, offer expert opinions, and provide courtroom testimony in alcohol-related cases.

SCOPE AND SENSITIVITY IN FORENSIC TOXICOLOGY

Impaired driving remains a serious threat to public health and safety, and toxicology testing plays a vital role in investigating drug-impaired driving cases. ANSI/ASB Standard 120: *Standard for the Analytical Scope and Sensitivity of Forensic Toxicological Testing of Blood in Impaired Driving Investigations* establishes minimum requirements for both the target analytes and the analytical sensitivity of blood testing in these investigations.[37] The standard emphasizes the detection of ethanol and other drugs in blood specimens, as blood concentrations are often more directly correlated with impairment. By defining essential parameters for scope and sensitivity, the standard helps ensure that forensic laboratories produce reliable, defensible results that support public safety and legal proceedings.

[37] American Academy of Forensic Sciences Standards Board. ANSI/ASB Standard 120: *Standard for the Analytical Scope and Sensitivity of Forensic Toxicological Testing of Blood in Impaired Driving Investigations*. 1st ed., 2021, American Academy of Forensic Sciences Standards Board, www.asbstandardsboard.org, accessed August 20, 2025.

ALCOHOL CALCULATIONS IN FORENSIC TOXICOLOGY

ANSI/ASB Best Practice Recommendation 122: *Best Practice Recommendation for Performing Alcohol Calculations in Forensic Toxicology* provides comprehensive guidance for conducting ethanol-related calculations in forensic contexts.[38] These include retrograde extrapolation, forward estimations, minimum drink estimations, and other analytical scenarios commonly encountered in impaired driving investigations. This document also offers recommendations for evaluating the post-absorptive phase, handling various specimen types, accounting for population variability, and properly reporting calculation results. Given the complexity and variability in how alcohol calculations are performed, this best practice recommendation helps standardize methodologies, reduce cognitive bias, and improve the quality and consistency of forensic interpretations. Importantly, ANSI/ASB 122 is grounded in current scientific principles and provides a reliable foundation for forensic toxicologists and other experts tasked with interpreting alcohol-related data.

OPINIONS AND TESTIMONY IN FORENSIC TOXICOLOGY

ANSI/ASB Best Practice Recommendation 037: *Guidelines for Opinions and Testimony in Forensic Toxicology* outlines best practices for formulating and presenting expert toxicological opinions.[39] These opinions must be scientifically sound, coherent, and based on a comprehensive synthesis of analytical data, case history, pre-analytical factors, and other relevant information. Expert opinions may be delivered through written reports or oral testimony. According to ANSI/ASB 037, a well-founded toxicological opinion should:

- Be communicated clearly and coherently
- Be grounded in established scientific principles
- Reflect the totality of available information (including case history, observations, circumstances, and other relevant information) and not just analytical results
- Reference case-specific documents and records reviewed
- Include supporting literature or references
- Clearly state any assumptions made
- Acknowledge known limitations of the opinion.

Toxicological opinions must be scientifically sound, coherent, and based on a comprehensive synthesis of analytical data, case history, pre-analytical factors, and other relevant information.

[38] ANSI/ASB 122, *supra*.

[39] American Academy of Forensic Sciences Standards Board. ANSI/ASB Best Practice Recommendation 037: *Guidelines for Opinions and Testimony in Forensic Toxicology*. 1st ed., 2019, American Academy of Forensic Sciences, www.aafs.org/asb-standard/guidelines-opinions-and-testimony-forensic-toxicology, accessed August 20, 2025.

This document also distinguishes between types of opinions and testimony that are supported by the scientific community and those that are generally not accepted. By adhering to these guidelines, forensic toxicologists can ensure their testimony is both credible and scientifically defensible.

REPORTING IN FORENSIC TOXICOLOGY

ANSI/ASB Standard 053: *Standard for Report Content in Forensic Toxicology* outlines the essential requirements for reporting results from forensic toxicology analyses.[40] This standard ensures that laboratory reports are clear, complete, and scientifically sound. It specifies the required elements of a forensic toxicology report, including how results must be presented, how to clearly identify supplemental or amended reports, and how to document when testing is performed by an external laboratory. Additionally, it provides guidance on the inclusion of interpretive information, helping to ensure that any expert opinions or contextual explanations are appropriately framed and supported. By adhering to this standard, laboratories enhance the transparency, reliability, and defensibility of their reporting practices in impaired driving and other forensic investigations.

ADDITIONAL STANDARDS AND GUIDELINES RELATED TO ALCOHOL TESTING

Beyond the previously discussed standards and best practices, several other published documents support forensic toxicology practices in alcohol-related investigations. These standards are voluntarily adopted by forensic service providers who conduct biological sample testing, offer expert opinions, and provide courtroom testimony in impaired driving cases. Relevant documents include:

- ANSI/ASB Standard 054: *Standard for a Quality Control Program in Forensic Toxicology Laboratories*[41]
- ANSI/ASB Standard 055: *Standard for Breath Alcohol Measuring Instrument Calibration*[42]
- ANSI/ASB Standard 152: *Standard for the Minimum Content Requirements of Forensic Toxicology Procedures*[43]

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[40] American Academy of Forensic Sciences Standards Board. ANSI/ASB Standard 053: *Standard for Report Content in Forensic Toxicology*. 1st ed., 2020, American Academy of Forensic Sciences, www.aafs.org/asb-standard/standard-report-content-forensic-toxicology, accessed August 20, 2025.

[41] American Academy of Forensic Sciences Standards Board. ANSI/ASB Standard 054: *Standard for a Quality Control Program in Forensic Toxicology Laboratories*. 1st ed., 2021, American Academy of Forensic Sciences, www.aafs.org/asb-standard/standard-quality-control-program-forensic-toxicology-laboratories, accessed August 20, 2025.

[42] American Academy of Forensic Sciences Standards Board. ANSI/ASB Standard 055: *Standard for Breath Alcohol Measuring Instrument Calibration*. 1st ed., 2024, American Academy of Forensic Sciences, www.aafs.org/asb-standard/standard-breath-alcohol-measuring-instrument-calibration, accessed August 20, 2025.

- ANSI/ASB Standard 153: *Standard Practices for Proficiency Testing for Forensic Toxicology and Breath Alcohol Programs*[44]
- ANSI/ASB Best Practice Recommendation 156: *Guidelines for Specimen Collection and Preservation for Forensic Toxicology*[45]

These documents help ensure consistency, reliability, and scientific integrity in forensic alcohol testing and support the broader goals of public safety and legal defensibility.

ACCESSIBILITY OF STANDARDS AND GUIDELINES

Standards, best practice recommendations, and guidelines relevant to forensic toxicology and alcohol testing are publicly accessible through the OSAC Registry (OSAC Registry | NIST). This registry serves as a centralized repository of selected published and proposed standards for forensic science. To meet the evolving needs of the scientific and traffic safety communities, new documents are continually developed. During the standards development process, draft versions are made available for public comment, allowing stakeholders to provide input and help shape final publications. These drafts and related updates can be accessed through the Academy Standards Board (Academy Standards Board). This open and collaborative approach ensures transparency, promotes community engagement, and supports the development of high-quality, scientifically sound standards.

Standards, best practice recommendations, and guidelines relevant to forensic toxicology and alcohol testing are publicly accessible through the OSAC Registry.

[43] American Academy of Forensic Sciences Standards Board. ANSI/ASB Standard 152: *Standard for the Minimum Content Requirements of Forensic Toxicology Procedures*. 1st ed., 2021, American Academy of Forensic Sciences, www.aafs.org/asb-standard/standard-minimum-content-requirements-forensic-toxicology-procedures, accessed August 20, 2025.

[44] American Academy of Forensic Sciences Standards Board. ANSI/ASB Standard 153: *Standard Practices for Proficiency Testing for Forensic Toxicology Laboratories and Breath Alcohol Programs*. 1st ed., 2023, American Academy of Forensic Sciences, www.aafs.org/asb-standard/standard-practices-proficiency-testing-forensic-toxicology-laboratories-and-breath, accessed August 20, 2025.

[45] American Academy of Forensic Sciences Standards Board. ANSI/ASB Best Practice Recommendation 156: *Best Practices for Specimen Collection and Preservation for Forensic Toxicology*. 1st ed., 2023, American Academy of Forensic Sciences, www.aafs.org/asb-standard/best-practices-specimen-collection-and-preservation-forensic-toxicology, accessed August 20, 2025.

Legal Considerations: Common Defenses

As discussed in this monograph, forensic toxicology plays a critical role in interpreting biological evidence and determining alcohol or drug influence in an impaired driving case. Defense strategies, however, often challenge the reliability, timing, or interpretation of toxicological findings. Understanding these common defenses—and the scientific principles that support or refute them—is essential for accurately evaluating the strength of the evidence and preparing for courtroom testimony.

CLAIM: The defendant did not consume enough alcohol to achieve the measured result.

RESPONSE: Estimates of blood alcohol concentration based on self-reported drinking histories are often highly unreliable, even under scientifically controlled conditions. In contrast, forensically validated measurements—such as those obtained through blood or breath testing—have established levels accuracy and precision, making them far more dependable indicators of alcohol concentration than retrospective calculations or personal accounts.

CLAIM: The defendant consumed alcohol shortly before the alleged traffic offense. Therefore, at the time of driving, their blood alcohol concentration (BAC) was lower than the BAC measured later—the Rising Alcohol Curve Defense.

RESPONSE: In typical social drinking scenarios, BAC rarely increases more than 0.02% after the final drink. For the Rising Alcohol Curve Defense to be valid, the amount of alcohol consumed must be sufficient to offset the alcohol eliminated between the time of the offense and the time of testing. This is rarely the case.

Alcohol absorption occurs rapidly, especially within the first few minutes after consumption. Any remaining unabsorbed alcohol can be accounted for through retrograde extrapolation, a method used by experts to estimate BAC at an earlier time.

While this defense is generally ineffective in cases involving high BAC levels, it may warrant consideration if the measured BAC is close to the legal limit. In such borderline cases, expert analysis could potentially influence the interpretation of the results.

CLAIM: The test result is invalid because the defendant consumed alcohol after the crash—the Post-Incident Consumption Defense.

RESPONSE: The test result remains valid but must be interpreted considering the alleged post-crash alcohol consumption. Consult a qualified expert to assess how the claimed drinking may have affected the measured blood alcohol concentration (BAC).

Before trial, ask your expert to calculate the amount of alcohol the defendant would have needed to consume after the crash to appear over the legal limit at the time of testing, yet be under the limit at the time of the crash. This analysis helps determine whether the defense has any scientific merit and how it may affect your case strategy.

In most cases, it is highly improbable that the defendant consumed enough alcohol between the crash and the test to significantly alter the BAC reading. The timing and quantity of the alleged consumption can be challenged through:

- Cross-examination
- Officer testimony
- Receipts or surveillance footage
- Witness statements

Develop a detailed timeline from the moment of the crash to the time the defendant was taken into custody. Key questions to address include:

- When exactly did the crash occur?
- Did the defendant leave the scene?
- Where and how did they obtain alcohol afterward?
- How far did they travel, and by what means?
- How much time elapsed between the crash and the alleged drinking?
- Are there any witnesses or evidence to support or refute the claim?

This structured approach allows you to assess the credibility of the defense and prepare a strong rebuttal.

CLAIM: The blood test is unreliable because the defense's independent analysis of the same sample yielded a lower blood alcohol concentration (BAC) than the prosecution's result. This discrepancy raises reasonable doubt about the accuracy of the prosecution's test.

RESPONSE: While BAC in preserved blood samples is generally stable, it can decrease over time due to several factors:

- Evaporation: Each time a blood vial is opened, a small amount of alcohol may escape, lowering the concentration.
- Non-enzymatic oxidation: Alcohol can degrade even in the presence of preservatives, further reducing BAC.
- Time between tests: The longer the delay between the prosecution and defense analyses, the greater the potential for alcohol loss.

Additionally, minor differences between laboratory results are expected due to variations in equipment, procedures, and calibration standards. These differences do not automatically indicate an error or unreliability.

The prosecution should scrutinize the defense's test result with the same rigor applied to its own. Key considerations include:

- Chain of custody of the sample
- Storage conditions
- Time elapsed between tests
- Lab accreditation and methodology

Understanding these factors helps determine whether the discrepancy is scientifically significant or within expected margins of variation.

CLAIM: The elevated blood alcohol concentration is the result of contamination by *Candida albican*s, which produced ethanol through fermentation.

RESPONSE: This claim is not scientifically supported when dealing with properly collected blood specimens from living individuals. While *Candida albicans* can produce ethanol under certain laboratory conditions, those scenarios involve deliberate manipulation and do not reflect real-world conditions in impaired driving cases.

In living subjects:

- *Candida albicans* does **not** colonize the bloodstream under normal physiological conditions.
- It does **not** produce ethanol in vivo in any meaningful quantity.
- Proper forensic collection and preservation protocols are specifically designed to prevent microbial contamination and fermentation.

Any suggestion of ethanol production due to microbial activity is only relevant in putrefied postmortem samples, where decomposition can lead to endogenous alcohol formation. In contrast, your case involves a living subject and a properly handled sample, making microbial fermentation an implausible explanation.

Therefore, the elevated BAC should be interpreted as a valid indicator of alcohol consumption.

Conclusion

In alcohol-impaired driving cases, a solid understanding of alcohol toxicology is essential for evaluating evidence, challenging defense claims, and presenting scientifically sound arguments in court. By grasping how alcohol is absorbed, distributed, and eliminated—and by relying on expert interpretation within a framework of quality standards—prosecutors can more confidently assess blood alcohol results and strengthen the integrity of their case.

Appendix—
Sample Predicate Questions for a Toxicologist (Blood or Urine)

The best use of any list of questions is preparation. Hopefully the questions included here will assist the prosecutor and toxicologist to prepare for trial. The prosecutor should remain flexible and listen to the toxicologist's responses. When reviewing these questions, it may be helpful for the toxicologist to strike through those questions that do not apply to his or her experience.

Training/Experience

- Please introduce yourself to the members of the jury.
- What is your occupation? (Forensic toxicologist)
- What is a forensic toxicologist?
- What does a forensic toxicologist do?
- What is your educational background?
- What training and experience do you have in the field of forensic toxicology?
- What training and experience do you have that enables you to test blood/urine specimens for the presence of drugs?
- How are you currently employed?
- How long have you worked at the lab?
- What are your duties?
- How long have you been a forensic toxicologist?
- Other than blood/urine, what other substances can be tested for drugs?
- How many cases does your laboratory test annually?
- How many blood/urine tests have you run in your career?
- Have you taught in the field of forensic toxicology?
- Have you published any articles in that field?
- Are you the member of any professional organizations? Please name them.
- Why do you belong to the organization(s)?

- Do you attend seminars or conferences related to your field on a regular basis?
- Why do you attend seminars and conferences?
- Have you ever been qualified as an expert in the field of forensic toxicology?
- How many times?
- In what courts have you been qualified as an expert?
- Were they civil or criminal proceedings?
- In what areas of expertise have you been previously qualified?
- Have you been qualified concerning _____ [blood, urine, breath, oral fluids]?
- How many times? (for the relevant evidence in this trial)

"At this time, the State would like to tender [name] as an expert in the field of forensic toxicology."

- Showing you what has previously been marked as State's Exhibit Number ___ [urine/blood report] for identification purposes, do you recognize it?
- How do you recognize it? (Bears signature)
- Whose toxicology result does this contain?
- Why did you test the sample of this defendant?
- Showing you what has been marked as State's Exhibit Number ___ [blood/urine kit, defendant's blood/urine samples] for identification, do you recognize it?
- How?
- Whose sample is this?
- How do you know?
- How did that exhibit come into your possession?
- How was it packaged and marked?
- Was it in a sealed container?
- Was the seal intact?
- Can you describe its condition when you received it?
- Was there any evidence of tampering?
- When the sealed sample was received, was it identified in any way by the lab?
- How was it identified?
- Where do you store the kits prior to testing?
- Was this sample stored in that area?

- How do you know?
- Is the lab a secured environment?
- What security features does the lab maintain?
- Does the lab have limited access?
- Without discussing the results of the testing, what if anything was done with the blood/urine sample when you received it at the lab?
- Was the sample continuously in the care, custody and control of your lab?
- How do you know that?
- What do you do with the blood/urine kit after you test it?
- Was there a leftover sample for the defendant to do his own testing? (Only ask if known)
- What is the next step in the testing procedure? (A lab report is prepared)
- Was a lab report generated for the sample of the defendant, [name]?

Testing

- What is the testing procedure used to analyze this sample?
- Can you describe how it works?
- What procedure do you follow when you test a blood sample?
- Is the testing procedure accurate and reliable?
- Do you use any controls during your analysis?
- What controls do you use?
- Why do you use controls?
- How do the controls work?
- Is this testing procedure generally accepted in the scientific community?
- What is considered the best testing method in forensic urine drug testing? Why is this so?
- Is this the same method used in toxicology labs throughout the nation?
- Was the instrument reading accurately and reliably during the analysis of this sample?
- How do you know?
- Blood: Was the defendant's blood clotted or congealed when you ran the sample?
- Blood: How could you tell?
- Blood: Why does it matter whether the defendant's blood was clotted or congealed?

- What did you do with the sample when you were finished?
- From the time you opened the blood kit until the time you tested the samples were the defendant's blood samples in your care custody and control?
- Is State's Exhibit Number ___ for identification in substantially the same condition as when you finished sealing it after performing the tests?

Move blood/urine kit into evidence

Business Record Predicate

- Turning your attention back to State's Exhibit Number ___ for identification, was this document made at or near the time of the test?
- Was it made in the ordinary course of the lab's business?
- Are these reports usually kept in the ordinary course of your business?
- Is it a copy or the original?
- Is it a true and accurate copy?

Move lab report into evidence

- Showing you what has been marked as State's Exhibit Number ___ [lab report] for identification, did you review all aspects of the testing of this sample before signing the report?
- What were the results of the laboratory analysis of the defendant's blood/urine sample?

ALCOHOL

- What does _____ [blood test result] mean?
- What is the legal limit for blood alcohol level?
- What signs and symptoms does alcohol produce in the body?
- At what levels does alcohol begin to produce these effects?
- Have you participated in drinking experiments, sometimes referred to as wet labs?
- Have you read studies from organizations like the American Medical Association concerning the effects of alcohol?
- Is the per se limit established by state law consistent with the study of alcohol in the field of medicine?
- Is it higher or lower?
- If "normal faculties" are defined as the ability to see, hear, walk, talk, make judgments, drive an automobile, etc. and do the many mental and physical acts of daily life, can alcohol at ______ [blood test result] impair a person's normal faculties?