chapter 10

Forensic Toxicology

Key Terms

absorption

acid

alveoli

anticoagulant

artery

base

capillary

catalyst

excretion

fuel cell detector

metabolize

oxidation

pH scale

preservative

vein

Learning Objectives

After studying this chapter you should be able to:

- Explain how alcohol is absorbed into the bloodstream, transported throughout the body, and eliminated by oxidation and excretion
- Understand the process by which alcohol is excreted in the breath via the lungs
- Understand the concepts of infrared and fuel cell breath-testing devices for alcohol testing
- Describe commonly employed field sobriety tests to assess alcohol impairment
- List and contrast laboratory procedures for measuring the concentration of alcohol in the blood
- Relate the precautions to be taken to properly preserve blood in order to analyze its alcohol content
- Understand the significance of implied-consent laws and the *Schmerber* v. *California* case to traffic enforcement
- Describe techniques that forensic toxicologists use to isolate and identify drugs and poisons
- Appreciate the significance of finding of a drug in human tissues and organs to assessing impairment
- Understand the Drug Recognition Expert program and how to coordinate it with a forensic toxicology result

Harold Shipman, Dr. Death

Kathleen Grundy's sudden death in 1998 was shocking news to her daughter, Angela Woodruff. Mrs. Grundy, an 81-year-old widow, was believed to be in good health when her physician, Dr. Harold Shipman, visited her a few hours before her demise. Some hours later, when friends came to her home to check on her whereabouts they found Mrs. Grundy lying on a sofa fully dressed and dead.

Dr. Shipman pronounced her dead and informed her daughter that an autopsy was not necessary. A few days later, Mrs. Woodruff was surprised to learn that a will had surfaced leaving all of Mrs. Grundy's money to Dr. Shipman. The will was immediately recognized as a forgery and led to the exhumation of Mrs. Grundy's body. A toxicological analysis of the remains revealed a lethal quantity of morphine.

In retrospect, there was good reason to suspect that Dr. Shipman was capable of foul play. In the 1970s, he was asked to leave a medical practice because of a drug abuse problem and charges that he obtained drugs by forgery and deception. However, Dr. Shipman was quickly back to practicing medicine. By 1998, local undertakers became suspicious at the number of his patients who were dying. What is more, they all seemed to be elderly women who were found sitting in a chair or lying fully clothed on a bed. As police investigated, the horror of Dr. Shipman's deeds became apparent. One clinical audit estimated that Dr. Shipman killed at least 236 of his patients over a twenty-four-year period. Most of the deaths were attributed to fatal doses of heroin or morphine. Toxicological analysis on seven exhumed bodies clearly showed significant quantities of morphine. Convicted of murder, Dr. Shipman hanged himself in his jail cell in 2004.

It is no secret that in spite of the concerted efforts of law enforcement agencies to prevent distribution and sale of illicit drugs, thousands die every year from intentional or unintentional administration of drugs, and many more innocent lives are lost as a result of the erratic and frequently uncontrollable behavior of individuals under the influence of drugs. But one should not automatically attribute these occurrences to the wide proliferation of illicit-drug markets. For example, in the United States alone, drug manufacturers produce enough barbiturates and tranquilizers each year to provide every man, woman, and child with about forty pills. All of the statistical and medical evidence shows ethyl alcohol, a legal over-the-counter drug, to be the most heavily abused drug in Western countries. In the United States, nearly 17,500 automobile deaths, 40 percent of all traffic deaths, are alcohol related, with a rate of injury requiring hospital treatment exceeding two million people per year. This highway death toll, as well as the untold damage to life, limb, and property, is testimony in itself to the dangerous consequences of alcohol abuse.

Because the uncontrolled use of drugs has become a worldwide problem affecting all segments of society, the role of the toxicologist has taken on new and added significance. Toxicologists detect and identify drugs and poisons in body fluids, tissues, and organs. Their services are required not only in such legal institutions as crime laboratories and medical examiners' offices; they also reach into hospital laboratories—where the possibility of identifying a drug overdose may represent the difference between life and death—and into various health facilities responsible for monitoring the intake of drugs and other toxic substances. Primary examples include performing blood tests on children exposed to leaded paints or analyzing the urine of addicts enrolled in methadone maintenance programs.

The role of the forensic toxicologist is limited to matters that pertain to violations of criminal law. However, the responsibility for performing toxicological services in a criminal justice system varies considerably throughout the United States. In systems with a crime laboratory independent of the medical examiner, this responsibility may reside with one or the other or may be shared by both. Some systems, however, take advantage of the expertise residing in governmental health department laboratories and assign this role to them. Nevertheless, whatever facility handles this work, its caseload will reflect the prevailing popularity of the drugs that are abused in the community. In most cases, this means that the forensic toxicologist handles numerous requests relating to the determination of the presence of alcohol in the body.

TOXICOLOGY OF ALCOHOL

The Fate of Alcohol in the Body

The subject of the analysis of alcohol immediately confronts us with the primary objective of forensic toxicology—the detection and isolation of drugs in the body to determine their influence on human behavior. In the case of alcohol, however, the problem is further complicated by practical considerations. The predominant role of the automobile in our society has mandated the imposition of laws to protect the public from the drinking driver. This has meant that toxicologists have had to devise rapid and specific procedures for measuring the degree of alcohol intoxication. The methods used must be suitably designed to test hundreds of thousands of motorists annually without causing them undue physical harm or unreasonable inconvenience, while at the same time providing a reliable diagnosis that can be supported and defended within the framework of the legal system.

Alcohol, or ethyl alcohol, is a colorless liquid normally diluted with water and consumed as a beverage. Logically, the most obvious measure of intoxication would be the amount of liquor a person has consumed. Unfortunately, most arrests are made after the fact, when such information is not available to legal authorities; furthermore, even if these data could be collected, numerous related factors, such as body weight and the rate of alcohol's **absorption** into the body, are so variable that it would be impossible to prescribe uniform standards that would yield reliable alcohol intoxication levels.

Like any other depressant, alcohol primarily affects the central nervous system, particularly the brain. The extent of the depression is proportional to the concentration of alcohol within the nerve cells. The nerve functions most susceptible to alcohol are found in the surface areas of the forebrain. Later, as the person absorbs alcohol to a greater extent, the functions of the central and rear portions of the brain are affected. The nerve functions that are most resistant, and the last to fail, are centered in the brain's medulla, which regulates such vital functions as respiration and heart activity.

Theoretically, for a true determination of the quantity of alcohol impairing an individual's normal body functions, it would be best to remove a portion of brain tissue and analyze it for alcohol content. For obvious reasons, this cannot be done on living subjects. Consequently toxicologists concentrate on the blood, which provides the medium for circulating alcohol throughout the body, carrying it to all tissues, including the brain. Fortunately, experimental evidence supports this approach and shows blood-alcohol concentration to be directly proportional to the concentration of alcohol in the brain. From the medicolegal point of view, blood-alcohol levels have become the accepted standard for relating alcohol intake to its effect on the body.

Alcohol appears in the blood within minutes after it has been consumed and slowly increases in concentration while it is being absorbed from the stomach and the small intestine into the bloodstream. When all the alcohol has been absorbed, a maximum alcohol level is reached in the blood, and the postabsorption period begins. Then the alcohol concentration slowly decreases until a zero level is again reached.

Many factors determine the rate at which alcohol is absorbed into the bloodstream, including the total time taken to consume the drink, the alcohol content of the beverage, the amount consumed, and the quantity and type of food present in the stomach at the time of drinking. With so many variables, it is difficult to predict just how long the absorption process will require. For example, beer is absorbed more slowly than an equivalent concentration of alcohol in water, apparently because of the carbohydrates present in beer. Also, alcohol consumed on an empty stomach is absorbed faster than an equivalent amount of alcohol taken when there is food in the stomach. The longer the total time required for complete absorption to occur, the lower the peak alcohol concentration in the blood (see Figure 10–1). Depending on a combination of factors, maximum blood-alcohol concentration may not be reached until two or three hours have elapsed from the time of consumption. However, under normal social drinking conditions, it takes anywhere from thirty to ninety minutes from the time of the final drink until the absorption process is completed.

During the absorption phase, alcohol slowly enters the body's bloodstream and is carried to all parts of the body. When the absorption period is completed, the alcohol becomes distributed uniformly throughout the watery portions of the body—that is, throughout about two-thirds of the body volume. Fat, bones, and hair are low in water content and therefore contain little alcohol, whereas alcohol concentration in the rest of the body is fairly uniform. Hence, if blood is not

available, as in some postmortem situations, a medical examiner can select a water-rich organ or fluid—for example, the brain, cerebrospinal fluid, or vitreous humor—for determining the body's alcohol content to a reasonable degree of accuracy.

As the alcohol is circulated by the bloodstream, the body begins to eliminate it. Alcohol is eliminated through two mechanisms—**oxidation** and **excretion**. Nearly all of the alcohol (95–98 percent) consumed is eventually oxidized to carbon dioxide and water. Oxidation takes place almost entirely in the liver. Here, in the presence of the enzyme alcohol dehydrogenase, the alcohol is converted into acetaldehyde and then to acetic acid. The acetic acid is subsequently oxidized in practically all parts of the body to carbon dioxide and water.

The remaining alcohol is excreted unchanged in the breath, urine, and perspiration. Most significantly, the amount of alcohol exhaled in the breath is in direct proportion to the concentration of alcohol in the blood. This observation has had a tremendous impact on the technology and procedures used for blood-alcohol testing. The development of instruments to reliably measure breath for its alcohol content has made possible the testing of millions of people in a rapid, safe, and convenient manner.

The fate of alcohol in the body is therefore relatively simple—namely, absorption into the bloodstream, distribution throughout the body's water, and finally, elimination by oxidation and excretion. The elimination or "burn-off" rate of alcohol varies in different individuals; 0.015 percent w/v (weight per volume) per hour seems to be average once the absorption process is complete.[1] However, this figure is an average that varies by as much as 30 percent among individuals.

Alcohol in the Circulatory System

The extent to which an individual may be under the influence of alcohol is usually determined by measuring the quantity of alcohol present in the blood system. Normally, this is accomplished in one of two ways: (1) by direct chemical analysis of the blood for its alcohol content and (2) by measurement of the alcohol content of the breath. In either case, the significance and meaning of the results can better be understood when the movement of alcohol through the circulatory system is studied.

Humans, like all vertebrates, have a closed circulatory system, which consists basically of a heart and numerous arteries, capillaries, and veins. An **artery** is a blood vessel carrying blood away from the heart, and a **vein** is a vessel carrying blood back toward the heart. **Capillaries** are tiny blood vessels that interconnect the arteries with the veins. The exchange of materials between the blood and the other tissues takes place across the thin walls of the capillaries. A schematic diagram of the circulatory system is shown in Figure 10–2.

Let us now trace the movement of alcohol through the human circulatory system. After alcohol is ingested, it moves down the esophagus into the stomach. About 20 percent of the alcohol is absorbed through the stomach walls into the portal vein of the blood system. The remaining alcohol passes into the blood through the walls of the small intestine. Once in the blood, the alcohol is carried to the liver, where its destruction starts as the blood (carrying the alcohol) moves up to the heart. The blood enters the upper right chamber of the heart, called the right atrium (or auricle), and is forced into the lower right chamber of the heart, known as the right ventricle. Having returned to the heart from its circulation through the tissues, the blood at this time contains very little oxygen and much carbon dioxide. Consequently, the blood must be pumped up to the lungs, through the pulmonary artery, to be replenished with oxygen.

The respiratory system bridges with the circulatory system in the lungs, so that oxygen can enter the blood and carbon dioxide can leave it. As shown in Figure 10–3(a), the pulmonary artery branches into capillaries lying close to tiny pear-shaped sacs called **alveoli**. There are about 250 million alveoli in the lungs, all located at the ends of the bronchial tubes. The bronchial tubes connect to the windpipe (trachea), which leads up to the mouth and nose [see Figure 10–3(b)]. At the surface of the alveolar sacs, blood flowing through the capillaries comes in contact with fresh oxygenated air in the sacs. A rapid exchange now proceeds to take place between the fresh air in the sacs and the spent air in the blood. Oxygen passes through the walls of the alveoli into the blood while carbon dioxide is discharged from the blood into the air [see Figure 10–3(a)]. If, during this exchange, alcohol or any other volatile substance is in the blood, it too will pass into the alveoli. During breathing, the carbon dioxide and alcohol are expelled through the nose and mouth, and the alveoli sacs are replenished with fresh oxygenated air breathed into the lungs, allowing the process to begin all over again.

The distribution of alcohol between the blood and alveolar air is similar to the example of a gas dissolved in an enclosed beaker of water, as described on pp. 133–134. Here again, one can use Henry's law to explain how the alcohol divides itself between the air and blood. Henry's law may now be restated as follows: **When a volatile chemical (alcohol) is dissolved in a liquid (blood) and is brought to equilibrium with air (alveolar breath), there is a fixed ratio between the concentration of the volatile compound (alcohol) in air (alveolar breath) and its concentration in the liquid (blood), and this ratio is constant for a given temperature.**

The temperature at which the breath leaves the mouth is normally 34°C. **At this temperature, experimental evidence has shown that the ratio of alcohol in the blood to alcohol in alveoli air is approximately 2,100 to 1. In other words, 1 milliliter of blood will contain**

nearly the same amount of alcohol as 2,100 milliliters of alveolar breath. Henry's law thus becomes a basis for relating breath to blood-alcohol concentration.

Now let's return to the circulating blood. After emerging from the lungs, the oxygenated blood is rushed back to the upper left chamber of the heart (left atrium) by the pulmonary vein. When the left atrium contracts, it forces the blood through a valve into the left ventricle, which is the lower left chamber of the heart. The left ventricle then pumps the freshly oxygenated blood into the arteries, which carry the blood to all parts of the body. Each of these arteries, in turn, branches into smaller arteries, which eventually connect with the numerous tiny capillaries embedded in the tissues. Here the alcohol moves out of the blood and into the tissues. The blood then runs from the capillaries into tiny veins that fuse to form larger veins. These veins eventually lead back to the heart to complete the circuit.

During absorption, the concentration of alcohol in the arterial blood is considerably higher than the concentration of alcohol in the venous blood. One typical study revealed a subject's arterial blood-alcohol level to be 41 percent higher than the venous level thirty minutes after the last drink.[2] This difference is thought to exist because of the rapid diffusion of alcohol into the body tissues from venous blood during the early phases of absorption. Because the administration of a blood test requires drawing venous blood from the arm, this test is clearly to the advantage of a subject who may still be in the absorption stage. However, once absorption is complete, the alcohol becomes equally distributed throughout the blood system.

A breath test reflects the alcohol concentration in the pulmonary artery. Breath-test results obtained during the absorption phase may be higher than results obtained from a simultaneous direct analysis of venous blood. However, the former are more reflective of the concentration of alcohol reaching the brain and therefore more accurately reflect the effects of alcohol on the sub-

ject. Again, once absorption is complete, the difference between a blood test and a breath test should be minimal.

Breath-Test Instruments

From a practical point of view, the idea of drawing blood from a vein to test motorists suspected of being under the influence of alcohol simply does not provide a convenient method for monitoring alcoholic drivers. Having the suspect transported to a location where a medically qualified person can draw blood would be costly and time consuming, considering the hundreds of tests that the average police department must conduct every year. Thus, breath analysis serves a very useful purpose in providing an easily obtainable specimen along with a rapid and accurate result. A breath tester is simply a device for collecting and measuring the alcohol content of alveolar breath. The first successful commercial breath-test device, known as *the Breathalyzer,* was developed in 1954 by R. K. Borkenstein, who was a captain in the Indiana State Police. The Breathalyzer required the subject to blow into a disposable mouthpiece that led into a metal cylinder. The last portion of breath (alveolar breath) was trapped in the cylinder. The amount of breath collected in this manner was 52.5 milliliters, or 1/40 of 2,100 milliliters.[3] We have already seen that the amount of alcohol in 2,100 milliliters of alveolar breath approximates that in 1 milliliter of blood. Hence, in essence, the Breathalyzer was designed to measure alcohol concentration present in 1/40 of a milliliter of blood.

The quantity of alcohol in the trapped breath was measured by passing the breath into a glass ampoule containing potassium dichromate, sulfuric acid, and water. Any alcohol in the breath immediately dissolves in the dichromate solution and is oxidized to acetic acid. In the oxidation

process, potassium dichromate is also destroyed. The extent of this destruction is measured by the Breathalyzer and is related to the quantity of alcohol passed into the ampoule.

Basically, the Breathalyzer is a spectrophotometer (see Chapter 5) designed to measure the absorption of light passing through the potassium dichromate solution at a single wavelength. A schematic diagram of a Breathalyzer is shown in Figure 10–4. To better understand its operation, let's examine what is happening in the ampoule when alcohol is converted to acetic acid. Whenever a chemical reaction occurs between two or more substances, chemists use a chemical equation as a shorthand method to describe the changes taking place. The equation serves two purposes: it identifies the participants, and it describes the quantitative aspects of the reaction.

The following equation depicts the chemical reaction taking place in the ampoule:

$2K_2Cr_2O_7$	+	$3C_2H_5OH$	+	$8H_2SO_4$	$\rightarrow$
potassium dichromate		ethyl alcohol		sulfuric acid	yields

$2Cr_2(SO_4)_3$	+	$2K_2SO_4$	+	$3CH_3COOH$	+	$11H_2O$
chromium sulfate		potassium sulfate		acetic acid		water

From this chemical equation, we can see that there is always a fixed relationship between the number of potassium dichromate molecules reacting with the alcohol. Two molecules of potassium dichromate always combine with three molecules of ethyl alcohol. Hence, determining the amount of potassium dichromate consumed is an indirect way of determining the quantity of alcohol originally present. Silver nitrate is also present in the Breathalyzer ampoule; however, this

substance acts only as a **catalyst** to speed up the rate of reaction between potassium dichromate and ethyl alcohol. As a catalyst, silver nitrate undergoes no net change itself during the reaction.

Starting in the 1970s, the Breathalyzer was phased out and replaced by the computerized breath-alcohol instruments that dominate the field today. Interestingly, these instruments still have one thing in common with the old Breathalyzer: they measure the alcoholic content of alveolar breath. Like the Breathalyzer, they assume that the ratio of alcohol in the blood to alcohol in alveoli air is 2,100 to 1 at a mouth temperature of 34°C. Unlike the Breathalyzer, modern breath testers are free of chemicals. Most of these devices aim beams of infrared radiation at the sample cell containing the alveolar breath to detect and measure alcohol.

An evidential testing instrument that incorporates the principle of infrared light absorption is shown in Figure 10–5. In principle, these instruments operate no differently from the spectrophotometers described on pp. 147–149. Any alcohol in the subject's breath is passed into the instrument's breath chamber. As shown in Figure 10–6, a beam of infrared light is aimed through the chamber. A filter is used to select a wavelength of infrared light at which alcohol will absorb. As the infrared light passes through the chamber, it interacts with the alcohol and causes the light to decrease in intensity. The decrease in light intensity is measured by a photoelectric detector that gives a signal proportional to the concentration of alcohol present in the captured breath sample. This information is processed by an electronic microprocessor, and the percent blood-alcohol concentration is displayed on a digital readout. Also, the blood-alcohol level is printed on a card to produce a permanent record of the test result. Most infrared breath testers aim a second infrared beam into the same chamber to check for acetone or other chemical interferences on the breath. If the instrument detects differences in the relative response of the two infrared radiations

that does not conform to ethyl alcohol, the operator is immediately informed of the presence of an “interferant.”

Another approach for measuring alcohol in breath is to use a **fuel cell detector.** A fuel cell converts a fuel and an oxidant into an electrical current. In evidential breath-testing devices that use this concept, breath alcohol is the fuel and atmospheric oxygen is the oxidant. Alcohol is converted in the fuel cell into acetic acid, generating a current that is proportional to the quantity of alcohol present in the breath.

Infrared and fuel-cell-based breath testers are microprocessor controlled so that all an operator has to do is press a start button and the instrument automatically moves through a sequence of steps that produce a printout of the subject’s test results. These instruments also perform self-diagnostic tests to ascertain whether the instrument is in proper operating condition.

Considerations in Breath Testing

An important feature of these instruments is that they can be connected to an external alcohol standard or simulator in the form of either a liquid or a gas. The liquid simulator comprises a known concentration of alcohol in water. It is heated to a controlled temperature and the vapor formed above the liquid is pumped into the instrument. Dry-gas standards typically consist of a known concentration of alcohol mixed with an inert gas and compressed in cylinders. The external standard is automatically sampled by the breath-test instrument before and/or after the subject’s breath sample is taken and recorded. Thus the operator can check the accuracy of the instrument against the known alcohol standard.

The key to the accuracy of a breath-testing device is to ensure that the unit measures the alcohol in the alveolar breath (deep-lung breath) of the subject. This is typically accomplished by

programming the unit to accept no less than 1.5 liters of breath from the subject. Also, the subject must blow for a minimum time (such as 6 seconds) with a minimum breath flow rate (such as 3 liters per minute).

Another feature of these instruments is the *slope detector*. As the subject blows into the instrument, the breath-alcohol concentration initially will rise steadily as a function of time. The instrument accepts a breath sample only when consecutive breath measurements show little or no rate of change in breath alcohol concentration. This approach ensures that the breath sample being measured is alveolar or deep-lung breath and thus most closely relates to the true blood-alcohol concentration of the subject being tested.

A breath-test operator must take other steps to ensure that the breath-test result truly reflects the actual blood-alcohol concentration of the subject. A major consideration is to avoid measuring “mouth alcohol” resulting from regurgitation, belching, or recent intake of an alcoholic beverage. Also, the recent gargling of an alcohol-containing mouthwash can lead to the presence of mouth alcohol. As a result, the alcohol concentration detected in the exhaled breath is higher than the concentration in the alveolar breath. To avoid this possibility, the operator must not allow the subject to take any foreign material into his or her mouth for a minimum of fifteen to twenty minutes prior to the breath test. Likewise, the subject should be observed not to have belched or regurgitated during this period of time. Mouth alcohol has been shown to dissipate after fifteen to twenty minutes from its inception.

Independent measurement of duplicate breath samples taken within a few minutes of each other is another extremely important check of the integrity of the breath test. Acceptable agreement between the two tests taken minutes apart significantly reduces the possibility of errors

arising from the operator, mouth alcohol, instrument component failures, and spurious electric signals.

Field Sobriety Testing

A police officer who suspects that an individual is under the influence of alcohol usually conducts a series of preliminary tests before ordering the suspect to submit to an evidential breath or blood test. **These preliminary, or field sobriety, tests are normally performed to ascertain the degree of the suspect's physical impairment and whether an evidential test is justified.** Field sobriety tests usually consist of a series of psychophysical tests and a preliminary breath test (if such devices are authorized and available for use). A portable handheld roadside breath tester is shown in Figure 10–7. This pocket-sized device weighs 5 ounces and uses a fuel cell to measure the alcohol content of a breath sample. The fuel cell absorbs the alcohol from the breath sample, oxidizes it, and produces an electrical current proportional to the breath-alcohol content. This instrument can typically perform for three to five years before the fuel cell needs to be replaced. Breath-test results obtained with devices such as those shown in Figure 10–7 must be considered preliminary and nonevidential in nature. They should only establish probable cause for requiring an individual to submit to a more thorough breath or blood test.

Horizontal-gaze nystagmus, walk and turn, and the one-leg stand constitute a series of reliable and effective psychophysical tests. Horizontal-gaze nystagmus is an involuntary jerking of the eye as it moves to the side. A person experiencing nystagmus is usually unaware that the jerking is happening and is unable to stop or control it. The subject being tested is asked to follow a penlight or some other object with his or her eye as far to the side as the eye can go. The more intoxicated the person is, the less the eye has to move toward the side before jerking or

nystagmus begins. Usually, when a person's blood-alcohol concentration is in the range of 0.10 percent, the jerking begins before the eyeball has moved 45 degrees to the side (see Figure 10–8). Higher blood-alcohol concentration causes jerking at smaller angles. Also, if the suspect has taken a drug that also causes nystagmus (such as phencyclidine, barbiturates, and other depressants), the nystagmus onset angle may occur much earlier than would be expected from alcohol alone.

Walk and turn and the one-leg stand are divided-attention tasks, testing the subject's ability to comprehend and execute two or more simple instructions at one time. The ability to understand and simultaneously carry out more than two instructions is significantly affected by increasing blood-alcohol levels. Walk and turn requires the suspect to maintain balance while standing heel-to-toe and at the same time listening to and comprehending the test instructions. During the walking stage, the suspect must walk a straight line, touching heel-to-toe for nine steps, then turn around on the line and repeat the process. The one-leg stand requires the suspect to maintain balance while standing with heels together listening to the instructions. During the balancing stage, the suspect must stand on one foot while holding the other foot several inches off the ground for 30 seconds; simultaneously, the suspect must count out loud during the 30-second time period.

The Analysis of Blood for Alcohol

Gas chromatography offers the toxicologist the most widely used approach for determining alcohol levels in blood. Under proper gas chromatographic conditions, alcohol can be separated from other volatiles in the blood. By comparing the resultant alcohol peak area to ones obtained with

known blood-alcohol standards, the investigator can calculate the alcohol level with a high degree of accuracy (see Figure 10–9).

Another procedure for alcohol analysis involves the oxidation of alcohol to acetaldehyde. This reaction is carried out in the presence of the enzyme alcohol dehydrogenase and the coenzyme nicotin-amide-adenine dinucleotide (NAD). As the oxidation proceeds, NAD is converted into another chemical species, NADH. The extent of this conversion is measured spectrophotometrically and is related to alcohol concentration. This approach to blood-alcohol testing is normally associated with instruments used in a clinical or hospital setting. On the other hand, forensic laboratories normally use gas chromatography for determining blood-alcohol content.

Collection and Preservation of Blood

Blood must always be drawn under medically accepted conditions by a qualified individual. It is important to apply a nonalcoholic disinfectant before the suspect's skin is penetrated with a sterile needle or lancet, to negate any argument that an alcoholic disinfectant may have inadvertently contributed to a falsely high blood-alcohol result. Nonalcoholic disinfectants such as aqueous benzalkonium chloride (Zepiran), aqueous mercuric chloride, or povidone-iodine (Betadine) are recommended for this purpose.

Once blood is removed from an individual, it is best preserved sealed in an airtight container after adding an anticoagulant and a preservative. The blood should be stored in a refrigerator until delivery to the toxicology laboratory. The addition of an **anticoagulant**, such as EDTA or potassium oxalate, prevents clotting; a **preservative**, such as sodium fluoride, inhibits the growth of microorganisms capable of destroying alcohol.

One study performed to determine the stability of alcohol in blood removed from living individuals found that the most significant factors affecting alcohol's stability in blood are storage temperature, the presence of a preservative, and the time of storage.[4] Not a single blood specimen examined showed an increase in alcohol level with time. Failure to keep the blood refrigerated or to add sodium fluoride resulted in a substantial decline in alcohol concentration. Longer storage times also reduced blood-alcohol levels. Hence, failure to adhere to any of the proper preservation requirements for blood works to the benefit of the suspect and to the detriment of society.

Collection of postmortem blood samples for alcohol determination requires added precautions as compared to collection from living subjects. Ethyl alcohol may be generated in a deceased individual as a result of bacterial action. Therefore, it is best to collect a number of blood samples from different body sites. For example, blood may be removed from the heart and from the femoral (leg) and cubital (arm) veins. Each sample should be placed in a clean, airtight container containing an anticoagulant and sodium fluoride preservative and should be refrigerated. Blood-alcohol levels attributed solely to alcohol consumption should result in nearly similar results for all blood samples collected from the same person. Alternatively, collection of vitreous humor and urine is recommended. Vitreous humor and urine usually do not suffer from postmortem ethyl alcohol production to any significant extent.

Alcohol and the Law

Constitutionally, every state in the United States is charged with establishing and administering statutes regulating the operation of motor vehicles. Although such an arrangement might encourage diverse laws defining permissible blood-alcohol levels, this has not been the case. Both the

American Medical Association and the National Safety Council have exerted considerable influence in convincing the states to establish uniform and reasonable blood-alcohol standards.

Between 1939 and 1964, thirty-nine states and the District of Columbia enacted legislation that followed the recommendations of the American Medical Association and the National Safety Council in specifying that a person with a blood-alcohol concentration in excess of 0.15 percent w/v was to be considered under the influence of alcohol.[5] However, continued experimental studies have since shown that there is a clear correlation between drinking and driving impairment for blood-alcohol levels much below 0.15 percent w/v. As a result of these studies, in 1960 the American Medical Association and in 1965 the National Safety Council recommended lowering the presumptive level at which an individual was considered to be under the influence of alcohol to 0.10 percent w/v. All the states, as well as the District of Columbia and most possessions of the United States, have complied with this recommendation. In fact, all states have now established *per se laws*, meaning that any individual meeting or exceeding a defined blood-alcohol level (usually 0.08 percent) shall be deemed intoxicated. No other proof of alcohol impairment is necessary. As shown in Figure 10–10, one is about four times as likely to become involved in an automobile accident at the 0.08 percent level as compared to a sober individual. At the 0.15 percent level, the chances are 25 times as much for involvement in an automobile accident as compared to a sober driver. The reader can *estimate* the relationship of blood-alcohol levels to body weight and the quantity of 80-proof liquor consumed by referring to Figure 10–11.

The trend toward lowering the impairment level continues; in 1972, the Committee on Alcohol and Drugs of the National Safety Council suggested that a blood concentration of 0.08 percent w/v indicates impairment in driving performance. In 1992, the U.S. Department of Trans-

portation (DOT) recommended that states adopt 0.08 percent blood-alcohol concentration as the legal measure of drunk driving. This recommendation was enacted into federal law in 2000. The 0.08 percent level applies only to noncommercial drivers, as the federal government has set the maximum allowable blood-alcohol concentration for commercial truck and bus drivers at 0.04 percent.

Several Western countries have also set 0.08 percent w/v as the blood-alcohol level above which it is an offense to drive a motor vehicle. Those countries include Canada, Italy, Switzerland, and the United Kingdom. Finland, France, Germany, Ireland, Japan, the Netherlands, and Norway have a 0.05 percent limit. Australian states have adopted a 0.05 percent blood-alcohol concentration level. Sweden has lowered its blood-alcohol concentration limit to 0.02 percent.

To prevent a person's refusal to take a test for alcohol intoxication on the constitutional grounds of self-incrimination, the National Highway Traffic Safety Administration recommended an "implied consent" law. By 1973, all the states had complied with this recommendation. In accordance with this statute, operating a motor vehicle on a public highway automatically carries with it the stipulation that the driver must either submit to a test for alcohol intoxication if requested or lose his or her license for some designated period—usually six months to one year.

The leading case relating to the constitutionality of collecting a blood specimen for alcohol testing, as well as for obtaining other types of physical evidence from a suspect without consent, is *Schmerber* v. *California*.[6] While being treated at a Los Angeles hospital for injuries sustained in an automobile collision, Schmerber was arrested for driving under the influence of alcohol. A physician took a blood sample from Schmerber at the direction of the police, over the objection of the defendant. On appeal to the U.S. Supreme Court, the defendant argued that his privilege

against self-incrimination had been violated by the introduction of the results of the blood test at his trial. The Court ruled against the defendant, reasoning that the Fifth Amendment only prohibits compelling a suspect to give "testimonial" evidence that may be self-incriminating; being compelled to furnish "physical" evidence, such as fingerprints, photographs, measurements, and blood samples, the Court ruled, was not protected by the Fifth Amendment.

The Court also addressed the question of whether Schmerber was subjected to an unreasonable search and seizure by the taking of a blood specimen without a search warrant. The Court upheld the blood removal, reasoning in this case that the police were confronted with an emergency situation. By the time police officials would have obtained the warrant, the blood levels would have declined significantly as a result of natural body elimination processes. In effect, the evidence would have been destroyed. The Court also emphasized that the blood specimen was taken in a medically accepted manner and without unreasonable force.

This opinion in no way condones warrantless taking of blood for alcohol or drug testing under all circumstances. The reasonableness of actions a police officer may take to compel an individual to yield evidence can be judged only on a case-by-case basis.

THE ROLE OF THE TOXICOLOGIST

Once the forensic toxicologist ventures beyond the analysis of alcohol, he or she encounters an encyclopedic maze of drugs and poisons. Even a cursory discussion of the problems and handicaps imposed on toxicologists is enough to develop a sense of appreciation for their accomplishments and ingenuity. The toxicologist is presented with body fluids and/or organs and asked to examine them for the presence of drugs and poisons. If he or she is fortunate, which is not often, some clue to the type of toxic substance present may develop from the victim's symptoms, a

postmortem pathological examination, an examination of the victim's personal effects, or the nearby presence of empty drug containers or household chemicals. Without such supportive information, the toxicologist must use general screening procedures with the hope of narrowing thousands of possibilities to one.

If this task does not seem monumental, consider that the toxicologist is not dealing with drugs at the concentration levels found in powders and pills. By the time a drug specimen reaches the toxicology laboratory, it has been dissipated and distributed throughout the body. Where the drug analyst may have gram or milligram quantities of material to work with, the toxicologist must be satisfied with nanogram or at best microgram amounts, acquired only after careful extraction from body fluids and organs.

Furthermore, the body is an active chemistry laboratory, and no one can appreciate this observation more than a toxicologist. Few substances enter and completely leave the body in the same chemical state. The drug that is injected is not always the substance extracted from the body tissues. Therefore, a thorough understanding of how the body alters or **metabolizes** the chemical structure of a drug is essential in detecting its presence. It would, for example, be futile and frustrating to search exhaustively for heroin in the human body. This drug is almost immediately metabolized to morphine on entering the bloodstream. Even with this information, the search may still prove impossible unless the examiner also knows that only a small percentage of morphine is excreted unchanged in urine. For the most part, morphine becomes chemically bonded to body carbohydrates before elimination in urine. Thus, successful detection of morphine requires that its extraction be planned in accordance with a knowledge of its chemical fate in the body.

Last, when and if the toxicologist has surmounted all of these obstacles and has finally detected, identified, and quantitated a drug or poison, he or she must assess the substance's toxicity. Fortunately, there is published information relating to the toxic levels of most drugs; however, when such data are available, their interpretation must assume that the victim's physiological behavior agrees with that of the subjects of previous studies. In some cases, such an assumption may not be entirely valid without knowing the subject's case history. No experienced toxicologist would be surprised to find an individual tolerating a toxic level of a drug that would have killed most other people.

Toxicology is made infinitely easier once it is recognized that the toxicologist's capabilities are directly dependent on the input received from the attending physician, medical examiner, and police investigator. It is a tribute to forensic toxicologists, who must often labor under conditions that do not afford such cooperation, that they can achieve such a high level of proficiency.

Generally, with a deceased person, the medical examiner decides what biological specimens must be shipped to the toxicology laboratory for analysis. However, a living person suspected of being under the influence of a drug presents a completely different problem, and few options are available. When possible, both blood and urine are taken from any suspected drug user. The entire urine void is collected and submitted for toxicological analysis. Preferably, two consecutive voids should be collected in separate specimen containers. When a licensed physician or registered nurse is available, a sample of blood should also be collected. The amount of blood taken depends on the type of examination to be conducted. Comprehensive toxicological tests for drugs and poisons can conveniently be carried out on a minimum of 10 cc of blood. A determination solely for the presence of alcohol will require much less—approximately 5 cc of blood. However, many therapeutic drugs, such as tranquilizers and barbiturates, when taken in combi-

nation with a small, nonintoxicating amount of alcohol, produce behavioral patterns resembling alcohol intoxication. For this reason, the toxicologist must be given an adequate amount of blood so he or she will have the option of performing a comprehensive analysis for drugs in cases of low alcohol concentrations.

TECHNIQUES USED IN TOXICOLOGY

For the toxicologist, the upsurge in drug use and abuse has meant that the overwhelming majority of fatal and nonfatal toxic agents are drugs. Not surprisingly, a relatively small number of drugs—namely, those discussed in Chapter 9—comprise nearly all the toxic agents encountered. Of these, alcohol and cocaine normally account for 90 percent or more of the drugs encountered in a typical toxicology laboratory.

Like the drug analyst, the toxicologist must devise an analytical scheme to detect, isolate, and identify a toxic substance. The first chore is to selectively remove and isolate drugs and other toxic agents from the biological materials submitted as evidence. Because drugs constitute a large portion of the toxic materials found, a good deal of effort must be devoted to their extraction and detection. The procedures are numerous, and a useful description of them would be too detailed for this text. We can best understand the underlying principle of drug extraction by observing that many drugs fall into the categories of **acids** and **bases**.

Although several definitions exist for these two classes, a simple one states that an acid is a compound that sheds a hydrogen ion (or a hydrogen atom minus its electron) with reasonable ease. Conversely, a base is a compound that can pick up a hydrogen ion shed by an acid. The idea of acidity and basicity can be expressed in terms of a simple numerical value that relates to

the concentration of the hydrogen ion (H^+) in a liquid medium such as water. Chemists use the **pH scale** to do this. This scale runs from 0 to 14:

pH = 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

← Increasing acidity — Neutral — Increasing basicity →

Normally, water is neither acid nor basic—in other words, it is neutral, with a pH of 7. However, when an acidic substance—for example, sulfuric acid or hydrochloric acid—is added to the water, it adds excess hydrogen ions, and the pH value becomes less than 7. The lower the number, the more acidic the water. Similarly, when a basic substance—for example, sodium hydroxide or ammonium hydroxide—is added to water, it removes hydrogen ions, thus making water basic. The more basic the water, the higher its pH value.

By controlling the pH of a water solution into which blood, urine, or tissues are dissolved, the toxicologist can conveniently control the type of drug that is recovered. For example, acid drugs are easily extracted from an acidified water solution (pH less than 7) with organic solvents such as chloroform. Similarly, basic drugs are readily removed from a basic water solution (pH greater than 7) with organic solvents. This simple approach gives the toxicologist a general technique for extracting and categorizing drugs. Some of the more commonly encountered drugs may be classified as follows:

Acid Drugs	**Basic Drugs**
Barbiturates	Phencyclidine
Acetylsalicylic acid (aspirin)	Methadone
	Amphetamines

Cocaine

Once the specimen has been extracted and divided into acidic and basic fractions, the toxicologist can identify the drugs present. The strategy for identifying abused drugs entails a two-step approach: *screening* and *confirmation* (see Figure 10–12). A screening test is normally employed to give the analyst quick insight into the likelihood that a specimen contains a drug substance. This test allows a toxicologist to examine a large number of specimens within a short period of time for a wide range of drugs. Any positive results from a screening test are tentative at best and must be verified with a confirmation test.

The three most widely used screening tests are thin-layer chromatography (TLC), gas chromatography (GC), and immunoassay. The techniques of GC and TLC have already been described on pp. 135–138 and 138–142, respectively. Immunoassay has proven to be a useful screening tool in toxicology laboratories. Its principles are very different from any of the analytical techniques we have discussed so far. Basically, immunoassay is based on specific drug antibody reactions. We will learn about this concept in Chapter 12. The primary advantage of immunoassay is its ability to detect small concentrations of drugs in body fluids and organs. In fact, this technique provides the best approach for detecting the low drug levels normally associated with smoking marijuana.

The necessity of eliminating the possibility that a positive screening test may be due to a substance's having a close chemical structure to an abused drug requires the toxicologist to follow up a positive screening test with a confirmation test. Because of the potential impact of the results of a drug finding on an individual, only the most conclusive confirmation procedures should be used. **Gas chromatography/mass spectrometry is generally accepted as the con-**

firmation test of choice. The combination of gas chromatography and mass spectrometry provides the toxicologist with a one-step confirmation test of unequaled sensitivity and specificity (see pp. 150–153). As shown in Figure 10–13, the sample is separated into its components by the gas chromatograph. When the separated sample component leaves the column of the gas chromatograph, it enters the mass spectrometer, where it is bombarded with high-energy electrons. This bombardment causes the sample to break up into fragments, producing a fragmentation pattern or mass spectrum for each sample. For most compounds, the mass spectrum represents a unique "fingerprint" pattern that can be used for identification.

There is tremendous interest in drug-testing programs conducted not only in criminal matters but for industry and government as well. Urine testing for drugs is becoming common for job applicants and employees in the workplace. Likewise, the U.S. military has an extensive drug urine-testing program for its members. Many urine-testing programs rely on private laboratories to perform the analyses. In any case, when the test results form the basis for taking action against an individual, both a screening and confirmation test must be incorporated into the testing protocol to ensure the integrity of the laboratory's conclusions.

The forensic toxicologist only occasionally encounters a group of poisons known as *heavy metals.* These include arsenic, bismuth, antimony, mercury, and thallium. To screen for many of these metals, the investigator may dissolve the suspect body fluid or tissue in a hydrochloric acid solution and insert a copper strip into the solution (the Reinsch test). The appearance of a silvery or dark coating on the copper indicates the presence of a heavy metal. Such a finding must be confirmed by the use of analytical techniques suitable for inorganic analysis—namely, atomic absorption spectrophotometry, emission spectroscopy, or X-ray diffraction.

Carbon monoxide still represents one of the most common poisons encountered in a forensic laboratory. When carbon monoxide enters the human body, it is primarily absorbed by the red blood cells, where it combines with hemoglobin to form carboxyhemoglobin. An average red blood cell contains about 280 million molecules of hemoglobin. Oxygen normally combines with hemoglobin, which transports the oxygen throughout the body. However, if a high percentage of the hemoglobin combines with carbon monoxide, not enough is left to carry sufficient oxygen to the tissues, and death by asphyxiation quickly follows.

There are two basic methods for measuring the concentration of carbon monoxide in the blood. Spectrophotometric methods examine the visible spectrum of blood to determine the amount of carboxyhemoglobin relative to oxyhemoglobin or total hemoglobin; or a volume of blood can be treated with a reagent to liberate the carbon monoxide, which is then measured by gas chromatography.

The amount of carbon monoxide in blood is generally expressed as “percent saturation.” This represents the extent to which the available hemoglobin has been converted to carboxyhemoglobin. The transition from normal or occupational levels of carbon monoxide to toxic levels is not sharply defined. It depends, among other things, on the age, health, and general fitness of each individual. In a healthy middle-aged individual, a carbon monoxide blood saturation greater than 50 to 60 percent is considered fatal. However, in combination with alcohol or other depressants, fatal levels may be significantly lower. For instance, a carbon monoxide saturation of 35 to 40 percent may prove fatal in the presence of a blood-alcohol concentration of 0.20 percent w/v. Interestingly, chain smokers may have a constant carbon monoxide level of 8 to 10 percent from the carbon monoxide in cigarette smoke.

Inhaling automobile fumes is a relatively common way to commit suicide. A garden or vacuum cleaner hose is often used to connect the tailpipe with the vehicle's interior, or the engine is allowed to run in a closed garage. A level of carbon monoxide sufficient to cause death accumulates in five to ten minutes in a closed single-car garage.

The level of carbon monoxide in the blood of a victim found dead at the scene of a fire is significant in ascertaining whether foul play has occurred. High levels of carbon monoxide in the blood prove that the victim breathed the combustion products of the fire and was alive when the fire began. Many attempts at covering up a murder by setting fire to a victim's house or car have been uncovered in this manner.

THE SIGNIFICANCE OF TOXICOLOGICAL FINDINGS

Once a drug is found and identified, the toxicologist assesses its influence on the behavior of the individual. Interpreting the results of a toxicology find is one of the toxicologist's more difficult chores. Recall that many of the world's countries have designated a specific blood-alcohol level at which an individual is deemed under the influence of alcohol. These levels were established as a result of numerous studies conducted over several years to measure the effects of alcohol levels on driving performance. However, no such legal guidelines are available to the toxicologist who must judge how a drug other than alcohol affects an individual's performance or physical state.

For many drugs, blood concentration levels are readily determined and can be used to *estimate* the pharmacological effects of the drug on the individual. Often, when dealing with a living person, the toxicologist has the added benefit of knowing what a police officer may have observed about an individual's behavior and motor skills, as well as the outcome of a drug influence evaluation conducted by a police officer trained to be a drug recognition expert (discussed

shortly). For a deceased person, drug levels in various body organs and tissues provide additional information about the individual's state at the time of death. However, before conclusions can be drawn about a drug-induced death, other factors must also be considered, including the age, physical condition, and tolerance of the drug user. With prolonged use of a drug, an individual may become less responsive to a drug's effects and tolerate blood-drug concentrations that would kill a casual drug user. Therefore, knowledge of an individual's history of drug use is important in evaluating drug concentrations. Another consideration is additive or synergistic effects of the interaction of two or more drugs, which may produce a highly intoxicated or comatose state even though none of the drugs alone is present at high or toxic levels. The combination of alcohol with tranquilizers or narcotics is a common example of a potentially lethal drug combination.

The concentration of a drug present in urine is a poor indicator of how extensively an individual's behavior or state is influenced by the drug. Urine is formed outside the body's circulatory system, and consequently drug levels can build up in it over a long period. Some drugs are found in the urine one to three days after they have been taken and long after their effects on the user have disappeared. Nevertheless, the value of this information should not be discounted. Urine drug levels, like blood levels, are best used by law enforcement authorities and the courts to corroborate other investigative and medical findings regarding an individual's condition. Hence, for an individual who is arrested for suspicion of being under the influence of a drug, a toxicologist's determinations supplement the observations of the arresting officer, including the results of a drug influence evaluation (discussed next). For a deceased person, the responsibility for establishing a cause of death rests with the medical examiner or coroner. However, before a conclusive determination is made, the examining physician depends on the forensic toxicologist

to demonstrate the presence or absence of a drug or poison in the tissues or body fluids of the deceased. Only through the combined efforts of the toxicologist and the medical examiner (or coroner) can society be assured that death investigations achieve high professional and legal standards.

THE DRUG RECOGNITION EXPERT

While recognizing alcohol-impaired performance is an expertise generally accorded to police officers by the courts, recognizing drug-induced intoxication is much more difficult and generally not part of police training. During the 1970s, the Los Angeles Police Department developed and tested a series of clinical and psychophysical examinations that a trained police officer could use to identify and differentiate between types of drug impairment. This program has evolved into a national program to train police as *drug recognition experts.* Normally, a three- to five-month training program is required to certify an officer as a drug recognition expert (DRE).

The DRE program incorporates standardized methods for examining suspects to determine whether they have taken one or more drugs. The process is systematic and standard; to ensure that each subject has been tested in a routine fashion, each DRE must complete a standard Drug Influence Evaluation form (see Figure 10–14). The entire drug evaluation takes approximately thirty to forty minutes. The components of the twelve-step process are summarized in Table 10–1.

The DRE evaluation process can suggest the presence of the following seven broad categories of drugs:

1. Central nervous system depressants
2. Central nervous system stimulants

3. Hallucinogens
4. Phencyclidine
5. Inhalants
6. Narcotic analgesics
7. Cannabis

The DRE program is not designed to be a substitute for toxicological testing. The toxicologist can often determine that a suspect has a particular drug in his or her body. But the toxicologist often cannot infer with reasonable certainty that the suspect was impaired at a specific time. On the other hand, the DRE can supply credible evidence that the suspect was impaired at a specific time and that the nature of the impairment was consistent with a particular family of drugs. But the DRE program usually cannot determine which specific drug was ingested. Proving drug intoxication requires a coordinated effort and the production of competent data from both the DRE and the forensic toxicologist.

Table 10–1 Components of the Drug Recognition Process

1. *The Breath-Alcohol Test.* By obtaining an accurate and immediate measurement of the suspect's blood-alcohol concentration, the drug recognition expert (DRE) can determine whether alcohol may be contributing to the suspect's observable impairment and whether the concentration of alcohol is sufficient to be the sole cause of that impairment.
2. *Interview with the Arresting Officer.* Spending a few minutes with the arresting officer often enables the DRE to determine the most promising areas of investigation.

3. *The Preliminary Examination.* This structured series of questions, specific observations, and simple tests provides the first opportunity to examine the suspect closely. It is designed to determine whether the suspect is suffering from an injury or from another condition unrelated to drug consumption. It also affords an opportunity to begin assessing the suspect's appearance and behavior for signs of possible drug influence.

4. *The Eye Examination.* Certain categories of drugs induce nystagmus, an involuntary, spasmodic motion of the eyeball. Nystagmus is an indicator of drug-induced impairment. The inability of the eyes to converge toward the bridge of the nose also indicates the possible presence of certain types of drugs.

5. *Divided-Attention Psychophysical Tests.* These tests check balance and physical orientation and include the walk and turn, the one-leg stand, the Romberg balance, and the finger-to-nose.

6. *Vital Signs Examinations.* Precise measurements of blood pressure, pulse rate, and body temperature are taken. Certain drugs elevate these signs; others depress them.

7. *Dark Room Examinations.* The size of the suspect's pupils in room light, near-total darkness, indirect light, and direct light is checked. Some drugs cause the pupils to either dilate or constrict.

8. *Examination for Muscle Rigidity.* Certain categories of drugs cause the muscles to become hypertense and quite rigid. Others may cause the muscles to relax and become flaccid.

9. *Examination for Injection Sites.* Users of certain categories of drugs routinely or occasionally inject their drugs. Evidence of needle use may be found on veins along the neck, arms, and hands.

10. *Suspect's Statements and Other Observations.* The next step is to attempt to interview the suspect concerning the drug or drugs he or she has ingested. Of course, the interview must be conducted in full compliance of the suspect's constitutional rights.

11. *Opinions of the Evaluator.* Using the information obtained in the previous ten steps, the DRE is able to make an informed decision about whether the suspect is impaired by drugs and, if so, what category or combination of categories is the probable cause of the impairment.

12. *The Toxicological Examination.* The DRE should obtain a blood or urine sample from the suspect for laboratory analysis in order to secure scientific, admissible evidence to substantiate his or her conclusions.

Chapter Summary

Toxicologists detect and identify the presence of drugs and poisons in body fluids, tissues, and organs. A major branch of forensic toxicology deals with the measurement of alcohol in the body for matters that pertain to violations of criminal law. Alcohol appears in the blood within minutes after it has been taken by mouth and slowly increases in concentration while it is being absorbed from the stomach and the small intestine into the bloodstream. When all the alcohol has been absorbed, a maximum alcohol level is reached in the blood and the postabsorption period begins. Then the alcohol concentration slowly decreases until a zero level is again reached. Alcohol is eliminated from the body through oxidation and excretion. Oxidation takes place almost entirely in the liver, while alcohol is excreted unchanged in the breath, urine, and perspiration. The extent to which an individual is under the influence of alcohol is usually determined by measuring the quantity of alcohol in the blood or the breath. Breath testers that operate on the

principle of infrared light absorption are becoming increasingly popular within the law enforcement community.

Many types of breath testers analyze a set volume of breath. The sampled breath is exposed to infrared light. The degree of interaction of the light with alcohol in the breath sample allows the instrument to measure a blood alcohol concentration in breath. These breath-testing devices operate on the principle that the ratio between the concentration of alcohol in deep-lung or alveolar breath and its concentration in blood is fixed. Most breath-test devices have set the ratio of alcohol in the blood to alcohol in alveolar air at 2,100 to 1.

Law enforcement officers typically use field sobriety tests to estimate a motorist's degree of physical impairment by alcohol and whether an evidential test for alcohol is justified. The horizontal-gaze nystagmus test, walk and turn, and the one-leg stand are all reliable and effective psychophysical tests.

Gas chromatography is the most widely used approach for determining alcohol levels in blood. Blood must always be drawn under medically accepted conditions by a qualified individual. A nonalcoholic disinfectant must be applied before the suspect's skin is penetrated with a sterile needle or lancet. Once blood is removed from an individual, it is best preserved sealed in an airtight container after adding an anticoagulant and a preservative.

The forensic toxicologist must devise an analytical scheme to detect, isolate, and identify toxic drug substances. Once the drug has been extracted from appropriate biological fluids, tissues, and organs, the forensic toxicologist can identify the drug substance. The strategy for identifying abused drugs entails a two-step approach: screening and confirmation. A screening test gives the analyst quick insight into the likelihood that a specimen contains a drug substance.

Positive results from a screening test are tentative at best and must be verified with a confirmation test. The most widely used screening tests are thin-layer chromatography, gas chromatography, and immunoassay. Gas chromatography/mass spectrometry is generally accepted as the confirmation test of choice. Once the drug is extracted and identified, the toxicologist may be required to judge the drug's effect on an individual's natural performance or physical state. The Drug Recognition Expert program incorporates standardized methods for examining automobile drivers suspected of being under the influence of drugs. But the DRE program usually cannot determine which specific drug was ingested. Hence, reliable data from both the DRE and the forensic toxicologist are required to prove drug intoxication.

Review Questions

1. The most heavily abused drug in the Western world is _____.
2. True or False: Toxicologists are employed only by crime laboratories. _____
3. The amount of alcohol in the blood (is, is not) directly proportional to the concentration of alcohol in the brain.
4. True or False: Blood levels have become the accepted standard for relating alcohol intake to its effect on the body. _____
5. Alcohol consumed on an empty stomach is absorbed (faster, slower) than an equivalent amount of alcohol taken when there is food in the stomach.
6. Under normal drinking conditions, alcohol concentration in the blood peaks in _____ to _____ minutes.

7. In the postabsorption period, alcohol is distributed uniformly among the _____ portions of the body.

8. Alcohol is eliminated from the body by _____ and _____.

9. Ninety-five to 98 percent of the alcohol is _____ to carbon dioxide and water.

10. Oxidation of alcohol takes place almost entirely in the _____.

11. The amount of alcohol exhaled in the _____ is directly proportional to the concentration of alcohol in the blood.

12. Alcohol is eliminated from the blood at an average rate of _____ percent w/v.

13. Alcohol is absorbed into the blood from the _____ and _____.

14. A(n) _____ carries blood away from the heart; a(n) _____ carries blood back to the heart.

15. The _____ artery carries deoxygenated blood from the heart to the lungs.

16. Alcohol passes from the blood capillaries into the _____ sacs in the lungs.

17. One milliliter of blood contains the same amount of alcohol as approximately _____ milliliters of alveolar breath.

18. When alcohol is being absorbed into the blood, the alcohol concentration in venous blood is (higher, lower) than that in arterial blood.

19. The Breathalyzer and similar devices are designed to measure the alcohol content of _____ breath.

20. Most modern breath testers use _____ radiation to detect and measure alcohol in the breath.

21. To avoid the possibility of “mouth alcohol” the operator of a breath tester must not allow the subject to take any foreign materials into the mouth for _____ minutes prior to the test.

22. Alcohol can be separated from other volatiles in blood and quantitated by the technique of _____.

23. Roadside breath testers that utilize a _____ detector are becoming increasingly popular with the law enforcement community.

24. True or False: Portable handheld roadside breath testers for alcohol provide evidential test results. _____

25. Usually, when a person’s blood-alcohol concentration is in the range of 0.10 percent, horizontal-gaze nystagmus begins before the eyeball has moved _____ degrees to the side.

26. When drawing blood for alcohol testing, the suspect’s skin must first be wiped with a _____ disinfectant.

27. Failure to add a preservative, such as sodium fluoride, to blood removed from a living person may lead to a(n) (decline, increase) in alcohol concentration.

28. Most states have established _____ percent w/v as the impairment limit for blood-alcohol concentration.

29. In the case of _____, the Supreme Court ruled that taking nontestimonial evidence, such as a blood sample, did not violate a suspect's Fifth Amendment rights.

30. Heroin is changed upon entering the body into _____.

31. The body fluids _____ and _____ are both desirable for the toxicological examination of a living person suspected of being under the influence of a drug.

32. A large number of drugs can be classified chemically as _____ and _____.

33. Water with a pH value (less, greater) than 7 is basic.

34. Barbiturates are classified as _____ drugs.

35. Drugs are extracted from body fluids and tissues by carefully controlling the _____ of the medium in which the sample has been dissolved.

36. The technique of _____ is based on specific drug antibody reactions.

37. Both _____ and _____ tests must be incorporated into the drug-testing protocol of a toxicology laboratory to ensure the correctness of the laboratory's conclusions.

38. The gas _____ combines with hemoglobin in the blood to form carboxyhemoglobin, thus interfering with the transportation of oxygen in the blood.

39. The amount of carbon monoxide in blood is usually expressed as _____.

40. True or False: Blood levels of drugs can alone be used to draw definitive conclusions about the effects of a drug on an individual. _____

41. Interaction of alcohol and barbiturates in the body can produce a(n) _____ effect.

42. The level of a drug present in the urine is by itself a (good, poor) indicator of how extensively an individual is affected by a drug.

43. Urine and blood drug levels are best used by law enforcement authorities and the courts to _____ other investigative and medical findings pertaining to an individual's condition.

44. The _____ program incorporates standardized methods for examining suspects to determine whether they have taken one or more drugs.

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Absorption

Passage of alcohol across the wall of the stomach and small intestine into the bloodstream.

Oxidation

The combination of oxygen with other substances to produce new products.

Excretion

Elimination of alcohol from the body in an unchanged state; alcohol is normally excreted in breath and urine.

Artery

A blood vessel that carries blood away from the heart.

Vein

A blood vessel that transports blood toward the heart.

Capillary

A tiny blood vessel across whose walls exchange of materials between the blood and the tissues takes place; receives blood from arteries and carries it to veins.

Alveoli

Small sacs in the lungs through whose walls air and other vapors are exchanged between the breath and the blood.

Catalyst

A substance that accelerates the rate of a chemical reaction but is not itself permanently changed by the reaction.

Fuel Cell Detector

A detector in which chemical reactions produce electricity.

Anticoagulant

A substance that prevents coagulation or clotting of blood.

Preservative

A substance that stops the growth of microorganisms in blood.

WebExtra 10.1

Calculate Your Blood Alcohol Level

www.prenhall.com/Saferstein

WebExtra 10.2

See How Alcohol Affects Your Behavior

www.prenhall.com/Saferstein

Metabolize

To transform a chemical in the body to another chemical to facilitate its elimination from the body.

Acid

A compound capable of donating a hydrogen ion (H^+) to another compound.

Base

A compound capable of accepting a hydrogen ion (H^+).

pH Scale

A scale used to express the basicity or acidity of a substance. A pH of 7 is neutral; lower values are acidic and higher values are basic.

Figure 10–1 Blood-alcohol concentrations after ingestion of 2 ounces of pure alcohol mixed in 8 ounces of water (equivalent to about 5 ounces of 80-proof vodka). *Courtesy U.S. Department of Transportation, Washington, D.C.*

Figure 10–2 Simplified diagram of the human circulatory system. Dark vessels contain oxygenated blood; light vessels contain deoxygenated blood.

Figure 10–3a Gas exchange in the lungs. Blood flows from the pulmonary artery into vessels that lie close to the walls of the alveoli sacs. Here the blood gives up its carbon dioxide and absorbs oxygen. The oxygenated blood leaves the lungs via the pulmonary vein and returns to the heart.

Figure 10–3b The respiratory system. The trachea connects the nose and mouth to the bronchial tubes. The bronchial tubes divide into numerous branches that terminate in the alveoli sacs in the lungs.

Figure 10–4 Schematic diagram of a Breathalyzer. *Courtesy Draeger Safety, Inc., Breathalyzer Division, Durango, Colo.*

Figure 10–5 (a) An infrared breath-testing instrument—the Data Master DMT. (b) A subject blowing into the DMT breath tester. *Courtesy National Patent Analytical Systems, Inc., Mansfield, Ohio, www.npas.com*

(a)

(b)

Figure 10–6 Schematic diagram of an infrared breath-testing instrument.

Figure 10–7 (a) The Alco-Sensor FST. (b) A subject blowing into the roadside tester device. *Courtesy Intoximeters, Inc., St. Louis, Mo., www.intox.com*

(a)

(b)

Figure 10–8 When a person's blood-alcohol level is in the range of 0.10 percent, jerking of the eye during the horizontal-gaze nystagmus test begins before the eyeball has moved 45 degrees to the side.

Figure 10–9 Gas chromatogram showing ethyl alcohol (ethanol) in whole blood. *Courtesy Varian Inc., Walnut Creek, Calif.*

Figure 10–10 Diagram of increased driving risk in relation to blood-alcohol concentration. *Courtesy U.S. Department of Transportation, Washington, D.C.*

Figure 10–11 To use this diagram, lay a straightedge across your weight and the number of ounces of liquor you've consumed on an empty or full stomach. The point where the edge hits the right-hand column is your maximum blood-alcohol level. The rate of elimination of alcohol from the bloodstream is approximately 0.015 percent per hour. Therefore,

to calculate your actual blood-alcohol level, subtract 0.015 from the number in the right-hand column for each hour from the start of drinking.

Figure 10–12 Biological fluids and tissues are extracted for acidic and basic drugs by controlling the pH of a water solution in which they are dissolved. Once this is accomplished, the toxicologist analyzes for drugs by using screening and confirmation test procedures.

Figure 10–13 The combination of the gas chromatograph and the mass spectrometer enables forensic toxicologists to separate the components of a drug mixture and provides specific identification of a drug substance.

Figure 10–14 Drug Influence Evaluation form.

[1] In the United States, laws that define blood-alcohol levels almost exclusively use the unit *percent weight per volume*—percent w/v. Hence, 0.015 percent w/v is equivalent to 0.015 grams of alcohol per 100 milliliters of blood, or 15 milligrams of alcohol per 100 milliliters.

[2] R. B. Forney et al., "Alcohol Distribution in the Vascular System: Concentrations of Orally Administered Alcohol in Blood from Various Points in the Vascular System and in Rebreathed Air during Absorption," *Quarterly Journal of Studies on Alcohol* 25 (1964): 205.

[3] Actually, the collection cylinder is designed to hold 56.5 milliliters of breath. This is because, having left the mouth at 34°C, the breath will expand when heated to 50°C in the cylinder. Furthermore, added breath is needed to compensate for the air that remains in the delivery tube leading to the test ampoule.

[4] G. A. Brown et al., "The Stability of Ethanol in Stored Blood," *Analytica Chemica Acta* 66 (1973): 271.

[5] 0.15 percent w/v is equivalent to 0.15 grams of alcohol per 100 milliliters of blood, or 150 milligrams per 100 milliliters.

[6] 384 U.S. 757 (1966).