Learning Objectives

After studying this chapter you should be able to:

- Compare and contrast psychological and physical dependence
- Name and classify the commonly abused drugs
- Describe the laboratory tests normally used to perform a routine drug identification analysis
- Describe and explain the process of chromatography
- Explain the difference between thin-layer chromatography and gas chromatography
- Describe the utility of ultraviolet and infrared spectroscopy for the identification of organic compounds
- Describe the concept and utility of mass spectrometry for identification analysis
- Understand the proper collection and preservation of drug evidence

National Science Content Standards


Scientific Inquiry


Physical Science


Life Science


Science and Technology


Science in Personal and Social Perspective

Pablo Escobar, Drug Lord

In 1989, *Forbes* magazine listed Pablo Escobar as the seventh richest man in the world. Escobar began his climb to wealth as a teenage car thief in the streets of Medellin, Colombia, and eventually moved into the cocaine-smuggling business. At the peak of his power in the mid-1980s, he was shipping as much as 11 tons of cocaine per flight in jetliners to the United States. Law enforcement officials estimate that the Medellin cartel controlled 80 percent of the world's cocaine market and was taking in about $25 billion annually.

Escobar ruthlessly ruled by the gun: murdering, assassinating, and kidnapping. He was responsible for killing three presidential candidates in Colombia as well as the storming of the Colombian Supreme Court, which resulted in the murder of half the justices. All the while, Escobar curried favor with the Colombian general public by cultivating a Robin Hood image and distributing money to the poor.

In 1991, hoping to avoid extradition to the United States, Escobar turned himself in to the Colombian government and agreed to be sent to prison. However, the prison compound could easily be mistaken for a country club. There he continued his high-flying lifestyle, trafficking by telephone and even murdering a few associates. When the Colombian government attempted to move Escobar to another jail, he escaped, again fearing extradition to the United States.

Pressured by the U.S. government, Colombia organized a task force dedicated to apprehending Escobar. The manhunt for Escobar ended on December 2, 1993, when he was cornered on the roof of one of his hideouts. A shootout ensued and Escobar was fatally wounded by a bullet behind his ear.

Drugs

Key Terms

anabolic steroids
analgesic
chromatography
confirmation
depressant
hallucinogen
infrared
ion
microcrystalline test
monochromator
narcotic
physical dependence
psychological dependence
screening test
spectrophotometry
stimulant
ultraviolet

A *drug* can be defined as a natural or synthetic substance that is used to produce physiological or psychological effects in humans or other higher-order animals. However, this colorless clinical definition does not really tell us what drugs are; in their modern context, drugs mean something different to each person. To some, drugs are a necessity for sustaining and prolonging life; to others, drugs provide an escape from the pressures of life; to still others, they are a means of ending it.

Considering the wide application and acceptance of drugs in our society, it was perhaps inevitable that a segment of our population would abuse them. During the 1960s, successive waves of hallucinogens, amphetamines, and barbiturates found their way out of laboratories, pharmacies, and medicine chests and into the streets. During this decade, marijuana became the most widely used illicit drug in the United States, and alcohol consumption continued to rise—today 90 million Americans drink alcohol regularly, and 10 million of these are hopelessly addicted or have severe problems in coping with their drinking habits. In the 1970s, heroin addiction emerged as a national problem, and today the United States is in the midst of an epidemic of cocaine abuse.

FIGURE 5–1
Drug bust.
Courtesy Syracuse Newspapers/The Image Works

Drug abuse has grown from a problem generally associated with members of the lower end of the socioeconomic ladder to one that cuts across all social and ethnic classes of society. Today, approximately 23 million people in the United States use illicit drugs, including about a half million heroin addicts and nearly six million users of cocaine. In the United States, more than 75 percent of the evidence evaluated in crime laboratories is drug related. The deluge of drug specimens has forced the expansion of existing crime laboratories and the creation of new ones. For many concerned forensic scientists, the crime laboratory's preoccupation with drug evidence represents a serious distraction from time that could be devoted to evaluating evidence related to homicides and other types of serious crimes. However, the increasing caseloads associated with drug evidence have justified the expansion of forensic laboratory services. This expansion has increased the overall analytical capabilities of crime laboratories.

Drug Dependence

In assessing the potential danger of drugs, society has become particularly conscious of their effects on human behavior. In fact, the first drugs to be regulated by law in the early years of the twentieth century were those deemed to have "habit-forming" properties. The early laws were aimed primarily at controlling opium and its derivatives, cocaine, and later marijuana. The ability of a drug to induce dependence after repeated use is submerged in a complex array of physiological and social factors.

Dependence on drugs exists in numerous patterns and in all degrees of intensity, depending on the nature of the drug, the route of administration, the dose, the frequency of administration, and the individual's rate of metabolism. Furthermore, nondrug factors play an equally crucial role in determining the behavioral patterns associated with drug use. The personal characteristics of the user, his or her expectations about the drug experience, society's attitudes and possible responses, and the setting in which the drug is used are all major determinants of drug dependence.

The question of how to define and measure a drug's influence on the individual and its danger to society is difficult to assess. The nature and significance of drug dependence must be considered from two overlapping points of view: the interaction of the drug with the individual, and the drug's impact on society. It will be useful to approach the problem from two distinctly different aspects of human behavior—**psychological dependence** and **physical dependence**.

psychological dependence
The conditioned use of a drug caused by underlying emotional needs

physical dependence
Physiological need for a drug brought about by its regular use and characterized by withdrawal sickness when administration of the drug abruptly stops

Psychological Dependence

The common denominator that characterizes all types of repeated drug use is the creation of a psychological dependence for continued use of the drug. It is important to discard the unrealistic image that all drug users are hopeless "addicts" who are social dropouts. Most users present quite a normal appearance and remain both socially and economically integrated in the life of the community.

The reasons why some people abstain from drugs while others become moderately or heavily involved are difficult if not impossible to delineate. Psychological needs arise from numerous personal and social factors that inevitably stem

from the individual's desire to create a sense of well-being and to escape from reality. In some cases, the individual may seek relief from personal problems or stressful situations, or may be trying to sustain a physical and emotional state that permits an improved level of performance. Whatever the reasons, the underlying psychological needs and the desire to fulfill them create a conditioned pattern of drug abuse (see Figure 5–2).

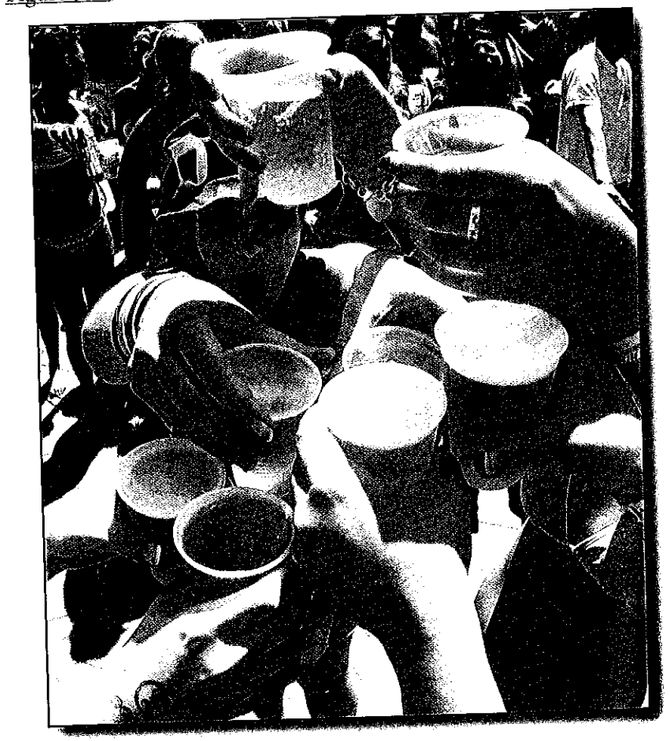


FIGURE 5–2
Young people drinking.
Courtesy Daytona Beach News-Journal/Jim Tiller/ AP Wide World Photos

The intensity of the psychological dependence associated with a drug's use is difficult to define and largely depends on the nature of the drug used. For drugs such as alcohol, heroin, amphetamines, barbiturates, and cocaine, continued use will likely result in a high degree of involvement. Other drugs, such as marijuana and codeine, appear to have a considerably lower potential for the development of psychological dependence. However, this does not imply that repeated abuse of drugs deemed to have a low potential for psychological dependence is safe or will always produce low psychological dependence. We have no precise way to measure or predict the impact of drug abuse on the individual. Even if a system could be devised for controlling the many possible variables affecting a user's response, the unpredictability of the human personality would still have to be considered.

Our general knowledge of alcohol consumption should warn us of the fallacy of generalizing when attempting to describe the danger of drug abuse. Obviously, not all alcohol drinkers are psychologically addicted to the drug; most are "social" drinkers who drink in reasonable amounts and on an irregular basis. Many people have progressed beyond this stage and consider alcohol a necessary crutch for

dealing with life's stresses and anxieties. However, alcohol abusers exhibit a wide range of behavioral patterns, and to a large extent the determination of the degree of psychological dependence must be made individually. Likewise, it would be wrong to generalize that all users of marijuana can at worst develop a low degree of dependence on the drug. A wide range of factors also influence marijuana's effect, and heavy users of the drug expose themselves to the danger of developing a high degree of psychological dependence.

Physical Dependence

Although emotional well-being is the primary motive leading to repeated and intensive use of a drug, certain drugs, taken in sufficient dose and frequency, can produce physiological changes that encourage their continued use. Once the user abstains from such a drug, severe physical illness follows. The desire to avoid this withdrawal sickness, or abstinence syndrome, ultimately causes physical dependence, or addiction. Hence, for the addict who is accustomed to receiving large doses of heroin, the thought of abstaining and encountering body chills, vomiting, stomach cramps, convulsions, insomnia, pain, and hallucinations is a powerful inducement for continued drug use.

Interestingly, some of the more widely abused drugs have little or no potential for creating physical dependence. Drugs such as marijuana, LSD, and cocaine create strong anxieties when their repeated use is discontinued; however, no medical evidence attributes these discomforts to physiological reactions that accompany withdrawal sickness. On the other hand, use of alcohol, heroin, and barbiturates can result in development of physical dependence.

Physical dependence develops only when the drug user adheres to a regular schedule of drug intake; that is, the interval between doses must be short enough so that the effects of the drug never wear off completely. For example, the interval between injections of heroin for the drug addict probably does not exceed six to eight hours. Beyond this time the addict begins to experience the uncomfortable symptoms of withdrawal. Many heroin users avoid taking the drug regularly for fear of becoming physically addicted to its use. Similarly, the risk of developing physical dependence on alcohol becomes greatest when the consumption is characterized by a continuing pattern of daily use in large quantities.

Table 5–1 categorizes some of the more commonly abused drugs according to their effect on the body and summarizes their tendency to produce psychological dependence and to induce physical dependence with repeated use.

Societal Aspects of Drug Use

The social impact of drug dependence is directly related to the extent to which the user has become preoccupied with the drug. Here, the most important element is the extent to which drug use has become interwoven in the fabric of the user's life. The more frequently the drug satisfies the person's need, the greater the likelihood that he or she will become preoccupied with its use, with a consequent neglect of individual and social responsibilities. Personal health, economic relationships, and family obligations may all suffer as the drug-seeking behavior increases in frequency and intensity and dominates the individual's life. Extreme drug dependence may lead to behavior that has serious implications for the public safety, health, and welfare.

Table 5–1
The Potential of Some Commonly Abused Drugs to Produce Dependence with Regular Use

Drug	Psychological Dependence	Physical Dependence
Narcotics		
Morphine	High	Yes
Heroin	High	Yes
Methadone	High	Yes
Codeine	Low	Yes
Depressants		
Barbiturates (short-acting)	High	Yes
Barbiturates (long-acting)	Low	Yes
Alcohol	High	Yes
Methaqualone (Quaalude)	High	Yes
Meprobamate (Miltown, Equanil)	Moderate	Yes
Diazepam (Valium)	Moderate	Yes
Chlordiazepoxide (Librium)	Moderate	Yes
Stimulants		
Amphetamines	High	Unknown
Cocaine	High	No
Caffeine	Low	No
Nicotine	High	Yes
Hallucinogens		
Marijuana	Low	No
LSD	Low	No
Phencyclidine (PCP)	High	No

Drug dependence in its broadest sense involves much of the world's population. As a result, a complex array of individual, social, cultural, legal, and medical factors ultimately influence society's decision to prohibit or impose strict controls on a drug's distribution and use. Invariably, society must weigh the beneficial aspects of the drug against the ultimate harm its abuse will do to the individual and to society as a whole. Obviously, many forms of drug dependence do not carry sufficient adverse social consequences to warrant their prohibition, as illustrated by the widespread use of such drug-containing substances as tobacco and coffee. Although the heavy and prolonged use of these drugs may eventually damage body organs and injure an individual's health, there is no evidence that they result in antisocial behavior, even with prolonged or excessive use. Hence, society is willing to accept the widespread use of these substances.

We are certainly all aware of the disastrous failure in the United States to prohibit the use of alcohol during the 1920s and the current debate on whether marijuana should be legalized. Each of these issues emphasizes the delicate balance between individual desires and needs and society's concern with the consequences of drug abuse; moreover, this balance is continuously subject to change and re-evaluation.

Quick Review

- A drug is a natural or synthetic substance that is used to produce physiological or psychological effects in humans or other animals.
- Nondrug factors that play a part in drug dependence include the personal characteristics of the user, his or her expectations about the drug experience, society's attitudes and possible responses, and the setting in which the drug is used.
- Physical dependence is defined as the physiological need for a drug that has been brought about by its regular use. Psychological dependence is the conditioned use of a drug caused by underlying emotional needs.

Types of Drugs

Narcotic Drugs

narcotic
A drug that induces sleep and depresses vital body functions such as blood pressure, pulse rate, and breathing rate

The term **narcotic** is derived from the Greek word *narkotikos*, meaning numbness or deadening. Although pharmacologists classify narcotic drugs as substances that relieve pain and produce sleep, the term narcotic has become popularly associated with any drug that is socially unacceptable. As a consequence of this incorrect usage, many drugs are improperly called narcotics.

This confusion has produced legal definitions that differ from the pharmacological actions of many drugs. For example, until the early 1970s, most drug laws in the United States incorrectly designated marijuana as a narcotic. Even today, federal law classifies cocaine as a narcotic drug, although pharmacologically, cocaine is actually a powerful central nervous system stimulant, possessing properties opposite those normally associated with the depressant effects of a narcotic.

Opiates Medical professionals apply the term opiate to most of the drugs properly classified as narcotics. Opiates behave pharmacologically like morphine, a painkiller derived from opium—a gummy, milky juice exuded through a cut made in the unripe pod of the Asian poppy (Papaver somniferium). Although morphine is readily extracted from opium, the most commonly used opium-based drug is heroin, which is produced by reacting morphine with acetic anhydride or acetyl chloride (see Figure 5–3). Heroin's high solubility in water makes its street preparation for intravenous administration rather simple, because only by injection are heroin's effects felt almost instantaneously and with maximum sensitivity. The solution is drawn into a syringe or eyedropper for injection under the skin (see Figure 5–4).

FIGURE 5–3
The opium poppy and its derivatives. Shown are the poppy plant, crude and smoking opium, codeine, heroin, and morphine.
Courtesy Pearson Education/PH College

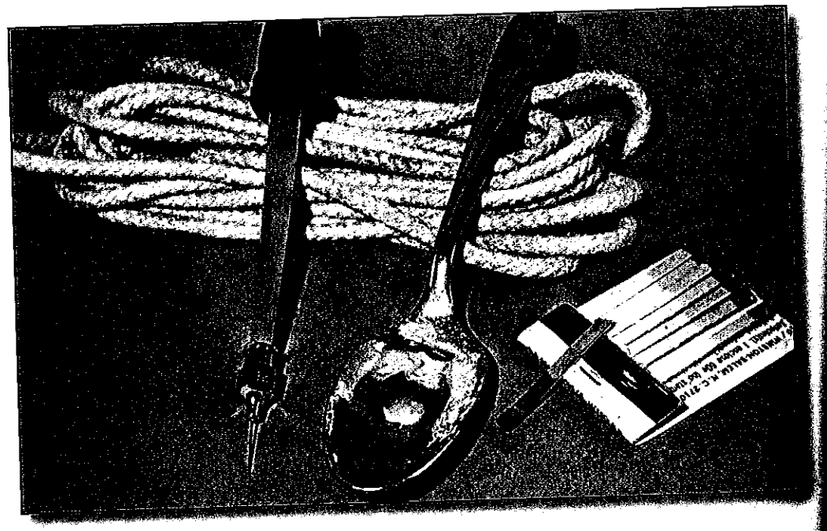


FIGURE 5–4
Heroin paraphernalia.
Courtesy Drug Enforcement Administration, Washington, D.C.

analgesic
A substance that lessens or eliminates pain

Heroin and other narcotic drugs are **analgesics**—that is, they relieve pain by depressing the central nervous system. Besides being a powerful analgesic, heroin produces a "high" that is accompanied by drowsiness and a deep sense of well-being. The effect is short, generally lasting only three to four hours. Regular use of heroin—or any other narcotic drug—invariably leads to physical dependence, with all of its dire consequences.

Codeine is also present in opium, but it is usually prepared synthetically from morphine. It is commonly used as a cough suppressant in prescription cough syrup. Codeine, only one-sixth as strong as morphine, is not an attractive street drug for addicts.

Inside the Science

What's in That Bag?

The content of a typical heroin bag is an excellent example of the uncertainty attached to buying illicit drugs. For many years into the 1960s and early 1970s, the average bag contained 15 to 20 percent heroin. Currently, the average purity of heroin obtained in the illicit U.S. market is approximately 35 percent. The addict rarely knows or cares what comprises the other 65 percent or so of the material. Traditionally, quinine has been the most common diluent of heroin. Like heroin, it has a bitter taste and was probably originally used to obscure the actual potency of a heroin preparation from those who wished to taste-test the material before buying it. Other diluents commonly added to heroin are starch, lactose, procaine (Novocain), and mannitol.

Synthetic Opiates A number of narcotic drugs are not naturally derived from opium. However, because they have similar physiological effects on the body as the opium narcotics, they are also commonly referred to as opiates.

Methadone is perhaps the best known synthetic opiate. In the 1960s, scientists discovered that a person who received periodic doses of methadone would not get high if he or she then took heroin or morphine. Although methadone is pharmacologically related to heroin, its administration appears to eliminate the addict's desire for heroin, with minimal side effects. These discoveries led to the establishment of controversial methadone maintenance programs in which heroin addicts receive methadone to reduce or prevent future heroin use. Physicians increasingly prescribe methadone for pain relief. Unfortunately the wide availability of methadone for legitimate medical purposes has recently led to greater quantities of the drug being diverted into the illicit market.

In 1995, the U.S. Food and Drug Administration (FDA) approved for use the pain-killing drug OxyContin. The active ingredient in OxyContin is oxycodone, a synthetic closely related to morphine and heroin in its chemical structure. OxyContin is an analgesic narcotic that has effects similar to those of heroin. It is prescribed to a million patients for treatment of chronic pain, with doctors writing close to seven million OxyContin prescriptions each year. The drug is compounded with a time-release formulation that the manufacturer initially believed would reduce the risk of abuse and addiction. This has not turned out to be the case. It is estimated that close to a quarter of a million individuals abuse the drug.

Because it is a legal drug that is diverted from legitimate sources, OxyContin is obtained differently from illegal drugs. Pharmacy robberies, forged prescriptions, and theft of the drug from patients with a legitimate prescription are ways in which abusers access OxyContin. Some abusers visit numerous doctors and receive prescriptions even though their medical condition may not warrant it.

hallucinogen
A substance that induces changes in normal thought processes, perceptions, and moods

Hallucinogens are drugs that can cause marked alterations in normal thought processes, perceptions, and moods. Perhaps the most popular and controversial member of this class of drugs is marijuana.

Marijuana Marijuana easily qualifies as the most widely used illicit drug in the United States today. For instance, more than 43 million Americans have tried marijuana, according to the latest surveys, and almost half that number may be regular users. Marijuana is a preparation derived from the plant Cannabis. Most botanists believe there is only one species of the plant, Cannabis sativa L. The marijuana preparation normally consists of crushed leaves mixed in varying proportions with the plant's flower, stem, and seed. The plant secretes a sticky resin known as hashish. The resinous material can also be extracted from the plant by soaking in a solvent such as alcohol. On the illicit-drug market, hashish usually appears in the form of compressed vegetation containing a high percentage of resin. A potent form of marijuana is known as sinsemilla. This is made from the unfertilized flowering tops of the female Cannabis plants, attained by removing all male plants from the growing field at the first sign of their appearance. It follows that the production of sinsemilla requires a great deal of attention and care, and the plant is therefore cultivated on small plots.

The Cannabis plant contains a chemical known as tetrahydrocannabinol, or THC, which produces the psychoactive effects experienced by users. The THC content of Cannabis varies in different parts of the plant. The greatest concentration is usually found in the resin. Declining concentrations are typically found in the flowers and leaves, respectively. Little THC is found in the stem, roots, or seeds of the plant. The potency and resulting effect of the drug fluctuate, depending on the relative proportion of these plant parts in the marijuana mixture consumed by the user. The most common method of administration is by smoking either the dried flowers and leaves, or various preparations of hashish (see Figure 5–5). Marijuana is also occasionally taken orally, typically baked in sweets such as brownies or cookies.

Any study of marijuana's effect on humans must consider the potency of the marijuana preparation. An interesting insight into the relationship between dosage level and marijuana's pharmacological effect was presented in the first report of the National Commission on Marijuana and Drug Abuse:

> *At low, usual "social" doses. the user may experience an increased sense of well-being; initial restlessness and hilarity followed by a dreamy, carefree state of relaxation; alteration of sensory perceptions including expansion of space and time; a more vivid sense of touch, sight, smell, taste, and sound; a feeling of hunger, especially a craving for sweets; and subtle changes in thought formation and expression. To an unknowing observer, an individual in this state of consciousness would not appear noticeably different from his normal state.*
>
> *At higher, moderate doses these same reactions are intensified but the changes in the individual would still be scarcely noticeable to an observer. At very high doses, psychotomimetic phenomena may be experienced. These include distortion of body image, loss of personal identity, sensory and mental illusions, fantasies, and hallucinations.*[1]

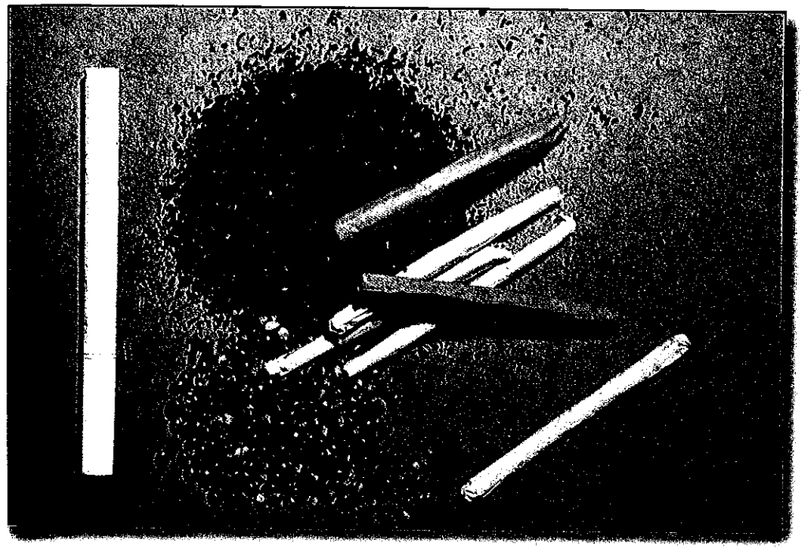


FIGURE 5-5
Several rolled marijuana cigarettes lie on a pile of crushed dried marijuana leaves next to a tobacco cigarette. *Courtesy Drug Enforcement Administration, Washington, D.C.*

In addition to its widespread illegal use, accumulating evidence suggests that marijuana has potential medical uses. Two promising areas of research are marijuana's reduction of excessive eye pressure in glaucoma and the lessening of nausea caused by powerful anticancer drugs. Marijuana may also be useful as a muscle relaxant.

No current evidence suggests that experimental or intermittent use causes physical or psychological harm. Marijuana does not cause physical dependence. However, the risk of harm lies instead in heavy, long-term use, particularly of the more potent preparations. Heavy users can develop a strong psychological dependence on the drug. Some effects of marijuana use include increased heart rate, dry mouth, reddened eyes, impaired motor skills and concentration, and, frequently, hunger and an increased desire for sweets.

Other Hallucinogens A substantial number of other substances with widely varying chemical compositions are also used recreationally because of their hallucinogenic properties. These include both naturally occurring substances such as mescaline and psilocybin and synthetically created drugs including lysergic acid diethylamide (LSD) and phencyclidine (PCP).

Inside the Science

Marijuana and Hashish

Marijuana is a weed that grows wild under most climatic conditions. The plant grows to a height of 5 to 15 feet and is characterized by an odd number of leaflets on each leaf. Normally, each leaf contains five to nine leaflets, all with serrated or saw-tooth edges (see Figure 1).

The potency of marijuana depends on its form. Marijuana in the form of loose vegetation has an average THC content of about 3–4.5 percent. The more potent sinsemilla form averages about 6–12 percent in THC content.

Hashish preparations average about 2–8 percent THC. On the illicit-drug market, hashish usually appears in the form of compressed vegetation containing a high percentage of resin (see Figure 2). A particularly potent form of hashish is known as *liquid hashish* or *hashish oil*. Hashish in this form is normally a viscous substance, dark green with a tarry consistency.

FIGURE 1 The marijuana leaf. *Courtesy Drug Enforcement Administration, Washington, D.C.*

FIGURE 2 Blocks of hashish leaves and flowering tops of the marijuana plant. *Courtesy James King-Holmes, Photo Researchers, Inc.*

Liquid hashish is produced by efficiently extracting the THC-rich resin from the marijuana plant with an appropriate solvent, such as alcohol. Liquid hashish typically varies between 8–22 percent in THC content. Because of its extraordinary potency, one drop of the material can produce a "high."

Case Files

A Brief History of Marijuana

Marijuana and its related products have been in use legally and illegally for almost three thousand years. The first reference to medical use of marijuana is in a pharmacy book written about 2737 B.C. by the Chinese emperor Shen Nung, who recommended it for "female weakness, gout, rheumatism, malaria, beriberi, constipation, and absent-mindedness." In China, at that time, and even today, the marijuana or hemp plant was also a major source of fiber for rope production. Marijuana's mood-altering powers probably did not receive wide attention until about 1000 B.C., when it became an integral part of Hindu culture in India. After A.D. 500, marijuana began creeping westward, and references to it began to appear in Persian and Arabian literature.

The plant was probably brought to Europe by Napoleon's soldiers when they returned from Egypt in the early 19th century. In Europe, the drug excited the interest of many physicians who foresaw its application for treating a wide range of ailments. At this time, it also found some use as a painkiller and mild sedative. In later years, these applications were either forgotten or ignored.

Marijuana was first introduced into the United States around 1920. The weed was smuggled by Mexican laborers across the border into Texas. American soldiers also brought the plant in from the ports of Havana, Tampico, and Veracruz. Although its use was confined to a small segment of the population, its popularity quickly spread from the border and Gulf states into most major U.S. cities. By 1937, the federal government and 46 states had laws prohibiting the use or possession of marijuana. Under most of these laws, marijuana was subject to the same rigorous penalties applicable to morphine, heroin, and cocaine and was often erroneously designated a narcotic.

LSD is synthesized from lysergic acid, a substance derived from ergot, which is a type of fungus that attacks certain grasses and grains. The drug appears in a variety of forms—as a pill, added to a cube of sugar, or absorbed onto a small piece of paper—and is taken orally. Its hallucinogenic effects were first described by the Swiss chemist Albert Hofmann after he accidentally ingested some of the material in his laboratory in 1943. LSD produces marked changes in mood, leading to laughing or crying at the slightest provocation. Feelings of anxiety and tension almost always accompany LSD use. LSD is very potent; as little as 25 micrograms is enough to start vivid visual hallucinations that can last for about 12 hours. Although physical dependence does not develop with continued use, the individual user may be prone to flashbacks and psychotic reactions even after use is discontinued.

Abuse of the hallucinogen phencyclidine, commonly called PCP, has recently grown to alarming proportions. Because this drug can be synthesized by simple chemical processes, it is manufactured surreptitiously for the illicit market in so-called clandestine laboratories (see Figure 5–6). These laboratories range from large, sophisticated operations to small labs located in a garage or bathroom. Small-time operators normally have little or no training in chemistry and employ "cookbook" methods to synthesize the drug. Some of the more knowledgeable and experienced operators have been able to achieve clandestine production levels that approach a commercial level of operation.

FIGURE 5–6
Scene from a clandestine drug laboratory. *Courtesy Drug Enforcement Administration, Washington, D.C.*

Phencyclidine is often mixed with other drugs, such as LSD or amphetamines, and is sold as a powder ("angel dust"), capsule, or tablet, or as a liquid sprayed on plant leaves. The drug is smoked, ingested, or sniffed. Following oral intake of moderate doses (1–6 milligrams), the user first experiences feelings of strength and invulnerability, along with a dreamy sense of detachment. However, the user soon becomes unresponsive, confused, and agitated. Depression, irritability, feelings of isolation, audio and visual hallucinations, and sometimes paranoia accompany PCP use. Severe depression, tendencies toward violence, and suicide accompany long-term daily use of the drug. In some cases, the PCP user experiences sudden schizophrenic behavior days after the drug has been taken.

Depressants

depressant
A substance that slows down, or depresses, the functions of the central nervous system

Depressants are drugs that slow down, or depress, the central nervous system. Several types of drugs fall under this category, including the most widely used drug in the United States—alcohol.

Alcohol (Ethyl Alcohol) Many people overlook the fact that alcohol is a drug; its major behavioral effects derive from its depressant action on the central nervous system. In the United States, the alcohol industry annually produces more than one billion gallons of spirits, wine, and beer for which 90 million consumers pay nearly $40 billion. Unquestionably, these and other statistics support the fact that alcohol is the most widely used and abused drug.

The behavioral patterns of alcohol intoxication vary and depend in part on such factors as social setting, amount consumed, and the personal expectation of the individual with regard to alcohol. When alcohol enters the body's bloodstream, it quickly travels to the brain, where it suppresses the brain's control of thought processes and muscle coordination.

Low doses of alcohol tend to inhibit the mental processes of judgment, memory, and concentration. The drinker's personality becomes expansive, and he or

FIGURE 5–7
Rows of alcohol bottles behind a bar. *Courtesy Jeremy Liebman/Stone/Getty Images*

she exudes confidence. When taken in moderate doses, alcohol reduces coordination substantially, inhibits orderly thought processes and speech patterns, and slows reaction times. Under these conditions, the ability to walk or drive becomes noticeably impaired. In the next chapter, we examine in greater detail the relationship between alcohol blood levels and driving ability. Higher doses of alcohol may cause the user to become highly irritable and emotional; displays of anger and crying are not uncommon. Extremely high doses may cause an individual to lapse into unconsciousness or even a comatose state that may precede a fatal depression of circulatory and respiratory functions.

Barbiturates Barbiturates are derivatives of barbituric acid, a substance first synthesized by a German chemist, Adolf von Bayer, more than a hundred years ago. They are commonly referred to as "downers" because they relax the user, create a feeling of well-being, and produce sleep. Like alcohol, barbiturates suppress the vital functions of the central nervous system. Twenty-five barbiturate derivatives are currently used in medical practice in the United States; however, five—amobarbital, secobarbital, phenobarbital, pentobarbital, and butabarbital—tend to be used for most medical applications.

Normally, barbiturate users take these drugs orally. The average sedative dose is about 10–70 milligrams. When taken in this fashion, the drug enters the blood through the walls of the small intestine. Some barbiturates, such as phenobarbital, are classified as long-acting barbiturates. They are absorbed into the bloodstream more slowly than others and therefore produce less pronounced effects than faster-acting barbiturates. The slow action of phenobarbital accounts for its low incidence of abuse. Apparently, barbiturate abusers prefer the faster-acting varieties—secobarbital, pentobarbital, and amobarbital.

Since the early 1970s, a nonbarbiturate depressant, methaqualone (Quaalude), has appeared on the illicit-drug scene. Methaqualone is a powerful sedative and muscle relaxant that possesses many of the depressant properties of barbiturates.

When taken in prescribed amounts, barbiturates are relatively safe, but in instances of extensive and prolonged use, physical dependence can develop.

Antipsychotics and Antianxiety Drugs Although antipsychotics and antianxiety drugs can be considered depressants, they differ from barbiturates in the extent of their actions on the central nervous system. Generally, these drugs produce a relaxing tranquility without impairing high-thinking faculties or inducing sleep. Antipsychotics such as reserpine and chlorpromazine have been used to reduce the anxieties and tensions of mental patients. Antianxiety drugs are commonly prescribed to deal with the everyday tensions of many healthy people. These drugs include meprobamate (Miltown), chlordiazepoxide (Librium), and diazepam (Valium).

In the past 35 years, the use of these drugs—particularly antianxiety drugs—has grown dramatically. Medical evidence shows that these drugs produce psychological and physical dependence with repeated and high levels of usage. For this reason, the widespread prescribing of antianxiety drugs to overcome the pressures and tensions of life has worried many who fear the creation of a legalized drug culture.

"Huffing" Since the early 1960s, "huffing," the practice of sniffing materials containing volatile solvents (airplane glue or model cement, for example), has grown in popularity. Another dimension has recently been added to the problem with the increasing number of incidents involving the sniffing of aerosol gas propellants, such as freon. All materials abused by huffing contain volatile or gaseous substances that are primarily central nervous system depressants. Although toluene (a solvent used in airplane glue) seems to be the most popular solvent to sniff, others can produce comparable physiological effects. These chemicals include naphtha, methyl ethyl ketone (antifreeze), gasoline, and trichloroethylene (dry-cleaning solvent).

The usual immediate effects of huffing are a feeling of exhilaration and euphoria combined with slurred speech, impaired judgment, and double vision. Finally, the user may experience drowsiness and stupor, with these depressant effects slowly wearing off as the user returns to a normal state. Most experts believe that users become physiologically dependent on the effects achieved by huffing. However, little evidence suggests that solvent inhalation is addictive. But huffers expose themselves to the dangers of liver, heart, and brain damage from the chemicals they have inhaled. Even worse, sniffing of some solvents, particularly halogenated hydrocarbons such as freon and related gases, is accompanied by a significant risk of death.

Stimulants

stimulant
A substance that speeds up, or stimulates, the central nervous system

The term **stimulant** refers to a range of drugs that stimulate, or speed up, the central nervous system.

Amphetamines Amphetamines are a group of synthetic stimulants that share a similar chemical structure and are commonly referred to in the terminology of the drug culture as "uppers" or "speed." They are typically taken either orally or via intravenous injection and provide a feeling of well-being and increased alert-

ness that is followed by a decrease in fatigue and a loss of appetite. However, these apparent benefits of the drug are accompanied by restlessness and instability or apprehension, and once the stimulant effect wears off, depression may set in.

In the United States, the most serious form of amphetamine abuse stems from intravenous injection of amphetamine or its chemical derivative, methamphetamine (see Figure 5–8). The desire for a more intense amphetamine experience is the primary motive for this route of administration. The initial sensation of a "flash" or "rush," followed by an intense feeling of pleasure, constitutes the principal appeal of the intravenous route for the user. During a "speed binge," the individual may inject 500–1,000 milligrams of amphetamines every two to three hours. Users have reported experiencing a euphoria that produces hyperactivity, with a feeling of clarity of vision as well as hallucinations. As the effect of the amphetamines wears off, the individual lapses into a period of exhaustion and may sleep continuously for one or two days. Following this, the user often experiences a prolonged period of severe depression, lasting from days to weeks.

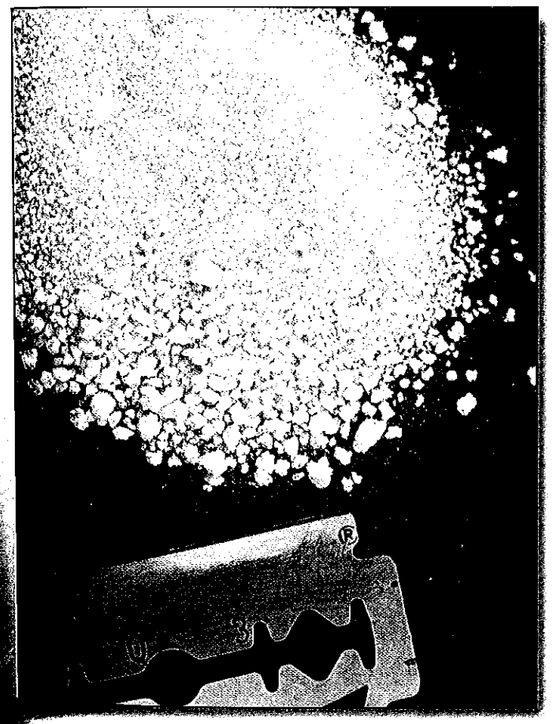


FIGURE 5–8
Granular amphetamine beside a razor blade. *Courtesy Cordelia Molloy, Photo Researchers, Inc.*

A smokable form of methamphetamine known as "ice" is reportedly in heavy demand in some areas of the United States. Ice is prepared by slowly evaporating a methamphetamine solution to produce large, crystal-clear "rocks." Like crack cocaine (discussed next), ice is smoked and produces effects similar to those of crack cocaine, but the effects last longer. Once the effects of ice wear off, users often become depressed and may sleep for days. Chronic users exhibit violent

destructive behavior and acute psychosis similar to paranoid schizophrenia. Repeated use of amphetamines leads to a strong psychological dependence, which encourages their continued administration.

Cocaine Between 1884 and 1887, pioneering psychologist Sigmund Freud created something of a sensation in European medical circles by describing his experiments with a new drug. He reported a substance of seemingly limitless potential as a source of "exhilaration and lasting euphoria" that permitted "intensive mental or physical work [to be] performed without fatigue. . . . It is as though the need for food and sleep was completely banished."

The object of Freud's enthusiasm was cocaine, a drug stimulant extracted from the leaves of *Erythroxylon coca*, a plant grown in tropical Asia and the Andes mountains of South America (see Figure 5–9). At one time, cocaine had wide medical application as a local painkiller or anesthetic. However, this function has now been largely replaced by other drugs, primarily procaine and lidocaine. Cocaine is also a powerful stimulant to the central nervous system, and its effects resemble those caused by the amphetamines—namely, increased alertness and vigor, accompanied by the suppression of hunger, fatigue, and boredom. Most commonly, cocaine is sniffed or "snorted" and is absorbed into the body through the mucous membranes of the nose.

FIGURE 5–9
Coca leaves and illicit forms of cocaine.
Courtesy Drug Enforcement Administration, Washington, D.C.

One form of cocaine that has gained widespread popularity in the drug culture is known as *crack*. The process used to make crack is simple. Ordinary cocaine is mixed with baking soda and water into a solution that is then heated in

a pot. This material is then dried and broken into tiny chunks that dealers sell as crack rocks. Crack is freebase cocaine and is sufficiently volatile to be smoked, usually in glass pipes. Crack, like cocaine that is snorted, produces a feeling of euphoria by stimulating a pleasure center in the base of the brain, in an area connected to nerves that are responsible for emotions.

Cocaine stimulates this pleasure center to a far greater degree than it would ever normally be stimulated. The result is euphoria—a feeling of increased energy, of being mentally more alert, of feeling really good. The faster the cocaine level rises in the brain, the greater the euphoria, and the surest way to obtain a fast rise in the brain's cocaine level is to smoke crack. Inhaling the cocaine vapor gets a large wallop of the drug to the brain in less than 15 seconds—about as fast as injecting it and much faster than snorting it. The dark side of crack, however, is that the euphoria fades quickly as cocaine levels drop, leaving the user feeling depressed, anxious, pleasureless. The desire to return to a euphoric feeling is so intense that crack users quickly develop a habit for the drug that is almost impossible to overcome. Only a small percentage of crack abusers will ever be cured of this drug habit.

In the United States, cocaine abuse is on the rise. Many people are apparently using cocaine to improve their ability to work and to keep going when tired. Although there is no evidence of physical dependency accompanying cocaine's repeated use, abstention from cocaine after prolonged use brings on severe bouts of mental depression, which produce a strong compulsion to resume using the drug. In fact, laboratory experiments with animals have demonstrated that of all the commonly abused drugs, cocaine produces the strongest psychological compulsions for continued use.

The United States spends millions of dollars annually in attempting to control cultivation of the coca leaf in various South American countries and to prevent cocaine trafficking into the United States. Three-quarters of the cocaine smuggled into the United States is refined in clandestine laboratories in Colombia. The profits are astronomical. Peruvian farmers may be paid $200 for enough coca leaves to make one pound of cocaine. The refined cocaine is worth $1,000 when it leaves Colombia and sells at retail in the United States for up to $20,000.

Club Drugs

The term *club drugs* refers to synthetic drugs that are often used at nightclubs, bars, and raves (all-night dance parties). Substances that are used as club drugs include, but are not limited to, MDMA (Ecstasy, see Figure 5–10), GHB (gamma hydroxybutyrate), Rohypnol "Roofies" (flunitrazepam), ketamine, and methamphetamine. These drugs have become popular at the dance scene as a way to stimulate the rave experience. A high incidence of use has been found among teens and young adults.

GHB and Rohypnol are central nervous system depressants that are often connected with drug-facilitated sexual assault, rape, and robbery. Effects accompanying the use of GHB include dizziness, sedation, headache, and nausea. Recreational users have reported euphoria, relaxation, disinhibition, and increased libido (sex drive). Rohypnol causes muscle relaxation, loss of consciousness, and inability to remember what happened during the hours after ingesting the

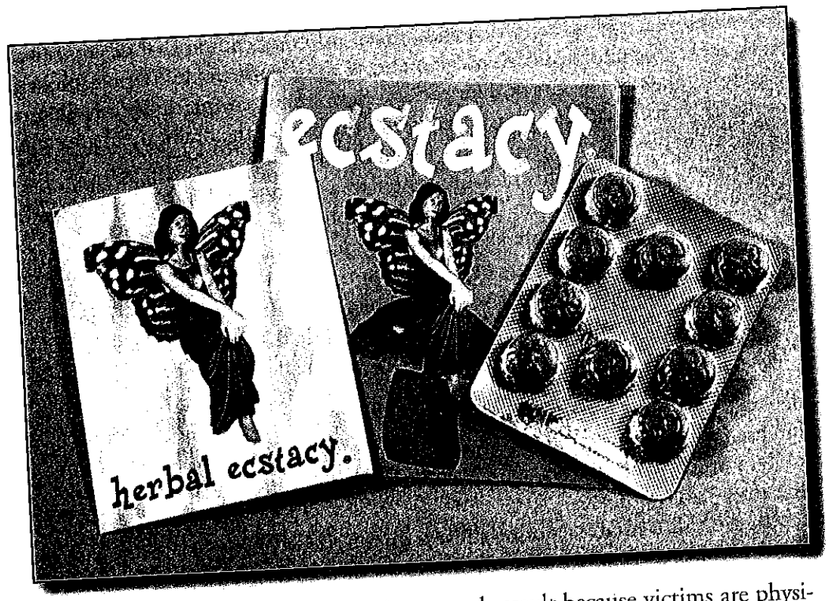


FIGURE 5–10
Ecstasy, a popular club drug. *Courtesy Rusty Kennedy, AP Wide World Photos*

drug. This is particularly a concern in a sexual assault because victims are physically unable to resist the attack. Unsuspecting victims become drowsy or dizzy. Effects are even stronger when the drug is combined with alcohol because the user experiences memory loss, blackouts, and disinhibition. Drugs such as Rohypnol and GHB are odorless, colorless, and tasteless, and thus remain undetected when slipped into a drink.

Methylenedioxymethamphetamine, also known as MDMA or Ecstasy, is a synthetic, mind-altering drug that exhibits many hallucinogenic and amphetamine-like effects. Ecstasy was originally patented as an appetite suppressant and was later discovered to induce feelings of happiness and relaxation. Recreational drug users find that Ecstasy enhances self-awareness and decreases inhibitions. However, seizures, muscle breakdown, stroke, kidney failure, and cardiovascular system failure often accompany chronic abuse of Ecstasy. In addition, chronic use of Ecstasy leads to serious damage to the areas of the brain responsible for thought and memory. Ecstasy increases heart rate and blood pressure; produces muscle tension, teeth grinding, and nausea; and causes psychological difficulties such as confusion, severe anxiety, and paranoia. The drug can cause significant increases in body temperature from the combination of the drug's stimulant effect with the often hot, crowded atmosphere of a rave club.

Ketamine is primarily used in veterinary medicine as an animal anesthetic. When used by humans, the drug can cause euphoria and feelings of unreality accompanied by visual hallucinations. Ketamine can also cause impaired motor function, high blood pressure, amnesia, and mild respiratory depression.

Anabolic Steroids

anabolic steroids Synthetic compounds, chemically related to the male sex hormone testosterone, that are used to promote muscle growth

Anabolic steroids are synthetic compounds that are chemically related to the male sex hormone testosterone. Testosterone has two different effects on the body. It promotes the development of secondary male characteristics (androgenic effects), and it accelerates muscle growth (anabolic effects). Efforts to promote muscle growth and to minimize the hormone's androgenic effects have led to the synthesis of numerous anabolic steroids. However, a steroid free of the accompanying harmful side effects of an androgen drug has not yet been developed.

Incidence of steroid abuse first received widespread public attention when both amateur and professional athletes were discovered using these substances to enhance their performance. Interestingly, current research on male athletes given anabolic steroids has generally found little or, at best, marginal evidence of enhanced strength or performance. Although the full extent of anabolic steroid abuse by the general public is not fully known, the U.S. government is sufficiently concerned to regulate the availability of these drugs to the general population and to severely punish individuals for illegal possession and distribution of anabolic steroids. In 1991, anabolic steroids were classified as controlled dangerous substances, and the Drug Enforcement Administration was given enforcement power to prevent their illegal use and distribution (see Figure 5–11).

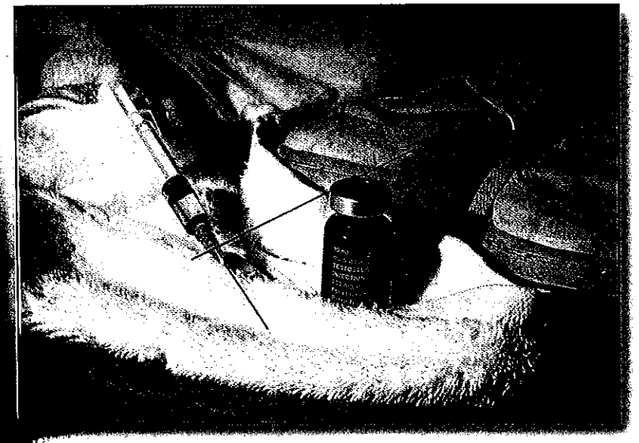


FIGURE 5–11
Anabolic steroids: a vial of testosterone and a syringe. Testosterone, the male sex hormone, is sometimes abused by athletes for its protein-building (anabolic) effect. *Courtesy Photo Researchers Inc.*

Anabolic steroids are usually taken by individuals who are unfamiliar with the harmful medical side effects. Liver cancer and other liver malfunctions have been linked to steroid use. These drugs also cause masculinizing effects in females, infertility, and diminished sex drive in males. For teenagers, anabolic steroids result in premature halting of bone growth. Anabolic steroids can also cause unpredictable effects on mood and personality, leading to unprovoked acts of anger and destructive behavior. Depression is also a frequent side effect of anabolic steroid abuse.

Quick Review

- Narcotic drugs are analgesics, meaning they relieve pain by depressing the central nervous system.
- The most common source for narcotic drugs is opium. Morphine is extracted from opium and used to synthesize heroin.
- Opiates are not derived from opium or morphine, but they have the same physiological effects on the body. Examples of opiates include methadone and OxyContin (oxycodone).
- Hallucinogens cause marked changes in normal thought processes, perceptions, and moods. Marijuana is the most well-known drug in this class. Other hallucinogens include LSD, mescaline, PCP, psilocybin, and MDMA (Ecstasy).
- Depressants decrease the activity of the central nervous system, calm irritability and excitability, and produce sleep. Depressants include alcohol (ethanol), barbiturates, tranquilizers, and various substances that can be sniffed, such as airplane glue or model cement.
- Stimulants increase the activity of the central nervous system and are taken to increase alertness and activity. Stimulants include amphetamines, sometimes known as "uppers" or "speed," and cocaine, which in its freebase form is known as *crack*.
- Club drugs are synthetic drugs that are used at nightclubs, bars, and raves (all-night dance parties). Some club drugs act as stimulants; others have depressant effects.
- Anabolic steroids are synthetic compounds that are chemically related to the male sex hormone testosterone. Anabolic steroids are often abused by individuals who are interested in accelerating muscle growth.

Drug-Control Laws

The provisions of drug laws are of particular interest to the criminalist, because they may impose specific analytical requirements on drug analysis. For example, the severity of a penalty associated with the manufacture, distribution, possession, and use of a drug may depend on the weight of the drug or its concentration in a mixture. In such cases, the chemist's report must contain all information that is needed to properly charge a suspect under the provisions of the existing law.

The provisions of any drug-control law are an outgrowth of national and local law enforcement requirements and customs, as well as the result of moral and political philosophies. These factors have produced a wide spectrum of national and local drug-control laws. Although their detailed discussion is beyond the intended scope of this book, a brief description of the U.S. federal law known as the Controlled Substances Act will illustrate a legal drug classification system that has been created to prevent and control drug abuse. Many states have modeled their own drug-control laws after this act, an important step in establishing uniform drug-control laws throughout the United States.

The federal law establishes five schedules of classification for controlled dangerous substances on the basis of a drug's potential for abuse, potential for physical and psychological dependence, and medical value. This classification system is extremely flexible in that the U.S. attorney general has the authority to add, delete, or reschedule a drug as more information becomes available.

Schedule I. Schedule I drugs have a high potential for abuse, have no currently accepted medical use in the United States, and/or lack accepted safety for use in treatment under medical supervision. Drugs controlled under this schedule include heroin, marijuana, methaqualone, and LSD.

Schedule II. Schedule II drugs have a high potential for abuse, a currently accepted medical use or a medical use with severe restrictions, and a potential for severe psychological or physical dependence. Schedule II drugs include opium and its derivatives not listed in schedule I, cocaine, methadone, phencyclidine (PCP), most amphetamine preparations, and most barbiturate preparations containing amobarbital, secobarbital, and pentobarbital. Dronabinol, the synthetic equivalent of the active ingredient in marijuana, has been placed in schedule II in recognition of its growing medical uses in treating glaucoma and chemotherapy patients.

Schedule III. Schedule III drugs have less potential for abuse than those in schedules I and II, a currently accepted medical use in the United States, and a potential for low or moderate physical dependence or high psychological dependence. Schedule III controls, among other substances, all barbiturate preparations (except phenobarbital) not covered under schedule II and certain codeine preparations. Anabolic steroids were added to this schedule in 1991.

Schedule IV. Schedule IV drugs have a low potential for abuse relative to schedule III drugs and have a current medical use in the United States; their abuse may lead to limited dependence relative to schedule III drugs. Drugs controlled in this schedule include propoxyphene (Darvon), phenobarbital, and tranquilizers such as meprobamate (Miltown), diazepam (Valium), and chlordiazepoxide (Librium).

Schedule V. Schedule V drugs must show low abuse potential, have medical use in the United States, and have less potential for producing dependence than schedule IV drugs. Schedule V controls certain opiate drug mixtures that contain nonnarcotic medicinal ingredients.

Controlled dangerous substances listed in schedules I and II are subject to manufacturing quotas set by the attorney general. For example, eight billion dosages of amphetamines were manufactured in the United States in 1971. In 1972, production quotas were established reducing amphetamine production approximately 80 percent below 1971 levels.

Table 5–2
Control Mechanisms of the Controlled Substances Act

Schedule	Registration	Record Keeping	Manufacturing Quotas	Distribution Restrictions	Dispensing Limits	Import–Export		Security	Manufacturer/Distributor Enforcement Administration	Criminal Penalties for Individual Trafficking (First Offense)
						Narcotic	Nonnarcotic			
I	Required	Separate	Yes	Order forms	Research use only	Permit	Permit	Vault/safe	Yes	0–20 years/$1 million
II	Required	Separate	Yes	Order forms	Rx: written; no Refills	Permit	Permit	Vault/safe	Yes	0–20 years/$1 million
III	Required	Readily retrievable	No, but some drugs limited by schedule II quotas	Records required	Rx: written or oral; with medical authorization refills up to 5 times in 6 months	Permit	Declaration	Secure storage area	Yes, narcotic No, nonnarcotic	0–5 years/$250,000
IV	Required	Readily retrievable	No, but some drugs limited by schedule II quotas	Records required	Rx: written or oral; with medical authorization refills up to 5 times in 6 months	Permit	Declaration	Secure storage area	Manufacturer only, narcotic No, nonnarcotic	0–3 years/$250,000
V	Required	Readily retrievable	No, but some drugs limited by schedule II quotas	Records required	Over-the-counter (Rx drugs limited to MD's order) refills up to 5 times	Permit to import; declaration to export	Declaration	Secure storage area	Manufacturer only, narcotic No, nonnarcotic	0–1 year/$100,000

Source: Drug Enforcement Administration, Washington, D.C.

The criminal penalties for unauthorized manufacture, sale, or possession of controlled dangerous substances are related to the schedules as well. The most severe penalties are associated with drugs listed in schedules I and II. For example, for drugs included in schedules I and II, a first offense is punishable by up to 20 years in prison and/or a fine of up to $1 million for an individual or up to $5 million for other than individuals. Table 5–2 summarizes the control mechanisms and penalties for each schedule of the Controlled Substances Act.

The Controlled Substances Act stipulates that an offense involving a controlled substance *analog*, a chemical substance substantially similar in chemical structure to a controlled substance, triggers penalties as if it were a controlled substance listed in schedule I. This section is designed to combat the proliferation of so-called *designer drugs*—substances that are chemically related to some controlled drugs and are pharmacologically very potent. These substances are manufactured by skilled individuals in clandestine laboratories, with the knowledge that their products will not be covered by the schedules of the Controlled Substances Act. For instance, fentanyl is a powerful narcotic that is commercially marketed for medical use and is also listed as a controlled dangerous substance. This drug is about one hundred times as potent as morphine. A number of substances chemically related to fentanyl have been synthesized by underground chemists and sold on the street. The first such substance encountered was sold under the street name China White. These drugs have been responsible for more than a hundred overdose deaths in California and nearly 20 deaths in western Pennsylvania. As designer drugs, such as China White, are identified and linked to drug abuse, they are placed in appropriate schedules.

The Controlled Substances Act also reflects an effort to decrease the prevalence of clandestine drug laboratories designed to manufacture controlled substances. The act regulates the manufacture and distribution of *precursors*, the chemical compounds used by clandestine drug laboratories to synthesize abused drugs. Targeted precursor chemicals are listed in the definition section of the Controlled Substances Act. Severe penalties are provided for a person who possesses a listed precursor chemical with the intent to manufacture a controlled substance or who possesses or distributes a listed chemical knowing, or having reasonable cause to believe, that the listed chemical will be used to manufacture a controlled substance. In addition, precursors to PCP, amphetamines, and methamphetamines are enumerated specifically in schedule II, making them subject to regulation in the same manner as other schedule II substances.

Quick Review

- Federal law establishes five schedules of classification for controlled dangerous substances on the basis of a drug's potential for abuse, potential for physical and psychological dependence, and medical value.

Forensic Drug Analysis

One only has to look into the evidence vaults of crime laboratories to appreciate the assortment of drug specimens that confront the criminalist. The presence of a huge array of powders, tablets, capsules, vegetable matter, liquids, pipes, cigarettes, cookers, and syringes is testimony to the vitality and sophistication of the illicit-drug market. If outward appearance is not evidence enough of the difficult analytical chore facing the forensic chemist, consider the complexity of the drug preparations themselves. Usually these contain active drug ingredients of unknown origin and identity, as well as additives—for example, sugar, starch, and quinine—that dilute their potency and stretch their value on the illicit-drug market. Do not forget that illicit-drug dealers are not hampered by government regulations that ensure the quality and consistency of a product.

When a forensic chemist picks up a drug specimen for analysis, he or she should be prepared for all contingencies. The analysis must leave no room for error, because its results will have a direct bearing on the process of determining the guilt or innocence of a defendant. There is no middle ground in drug identification—either the specimen is a specific drug or it is not—and once a positive conclusion is drawn, the chemist must be prepared to support and defend the validity of the results in a court of law.

Screening and Confirmation

The challenge or difficulty of forensic drug identification comes in selecting analytical procedures that will ensure specific identification of a drug. Presented with a substance of unknown origin and composition, the forensic chemist must develop a plan of action that will ultimately yield the drug's identity. This plan, or scheme of analysis, is divided into two phases.

screening test
A preliminary test used to reduce the number of possible identities of an unknown substance

First, faced with the prospect that the unknown substance may be any one of a thousand or more commonly encountered drugs, the analyst must use **screening tests** to reduce these possibilities to a small and manageable number. This objective is often accomplished by subjecting the material to a series of color tests that produce characteristic colors for the more commonly encountered illicit drugs. Even if these tests produce negative results, their value lies in having excluded certain drugs from further consideration.

Once the number of possibilities has been reduced substantially, the second phase of the analysis is devoted to pinpointing and confirming the drug's identity. In an era in which crime laboratories receive voluminous quantities of drug evidence, it is impractical to subject a drug to all the chemical and instrumental tests available. Indeed, it is more realistic to view these techniques as a large analytical arsenal. The chemist, aided by training and experience, must choose tests that will most conveniently identify a particular drug.

confirmation
A single test that specifically identifies a substance

Forensic chemists often use a specific test to identify a drug substance by the exclusion of all other known chemical substances. A single test that identifies a substance is known as a **confirmation**. The analytical scheme sometimes consists of a series of nonspecific or presumptive tests. Each test in itself is insufficient to prove the drug's identity; however, the proper analytical scheme encompasses a combination of test results that characterize one and only one chemical

substance—the drug under investigation. Furthermore, experimental evidence must confirm that the probability of any other substance responding in an identical manner to the scheme selected is so small as to be beyond any reasonable scientific certainty.

Another consideration in selecting an analytical technique is the need for either a *qualitative* or a *quantitative* determination. The former relates just to the identity of the material, whereas the latter refers to the percentage combination of the components of a mixture. Hence, a qualitative identification of a powder may reveal the presence of heroin and quinine, whereas a quantitative analysis may conclude the presence of 10 percent heroin and 90 percent quinine.

Obviously, a qualitative identification must precede any attempt at quantitation, for little value is served by attempting to quantitate a material without first determining its identity. Essentially, a qualitative analysis of a material requires the determination of numerous properties using a variety of analytical techniques. On the other hand, a quantitative measurement is usually accomplished by precise measurement of a single property of the material.

Forensic chemists normally rely on several tests for a routine drug-identification scheme: color tests, microcrystalline tests, chromatography, spectrophotometry, and mass spectrometry.

Color Tests

Many drugs yield characteristic colors when brought into contact with specific chemical reagents. Not only do these tests provide a useful indicator of a drug's presence, but they are also used by investigators in the field to examine materials suspected of containing a drug (see Figure 5–12).[2] However, color tests are useful for screening purposes only and are never taken as conclusive identification of unknown drugs.

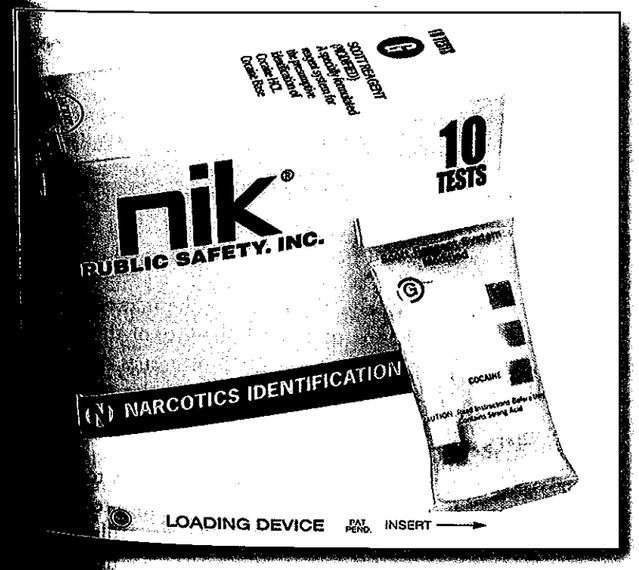


FIGURE 5–12
A field color test kit for cocaine. The suspect drug is placed in the plastic pouch. Tubes containing chemicals are broken open, and the color of the chemical reaction is observed. *Courtesy Tri-Tech, Inc., Southport, N.C., www.tritechusa.com*

Five primary color test reagents are as follows:

1. **Marquis.** The reagent turns purple in the presence of heroin and morphine and most opium derivatives. Marquis also becomes orange-brown when mixed with amphetamines and methamphetamines.
2. **Dillie-Koppanyi.** This is a valuable screening test for barbiturates, in whose presence the reagent turns violet-blue in color.
3. **Duquenois-Levine.** This is a valuable color test for marijuana, performed by adding a series of chemical solutions, to the suspect vegetation. A positive result is shown by a purple color when chloroform is added.
4. **Van Urk.** The reagent turns blue-purple in the presence of LSD. However, owing to the extremely small quantities of LSD in illicit preparations, this test is difficult to conduct under field conditions.
5. **Scott Test.** This is a color test for cocaine. A powder containing cocaine turns a cobalt thiocyanate solution blue. Upon addition of hydrochloric acid, the blue color is transformed to a clear pink color. Upon addition of chloroform, if cocaine is present, the blue color reappears in the chloroform layer.

Quick Review

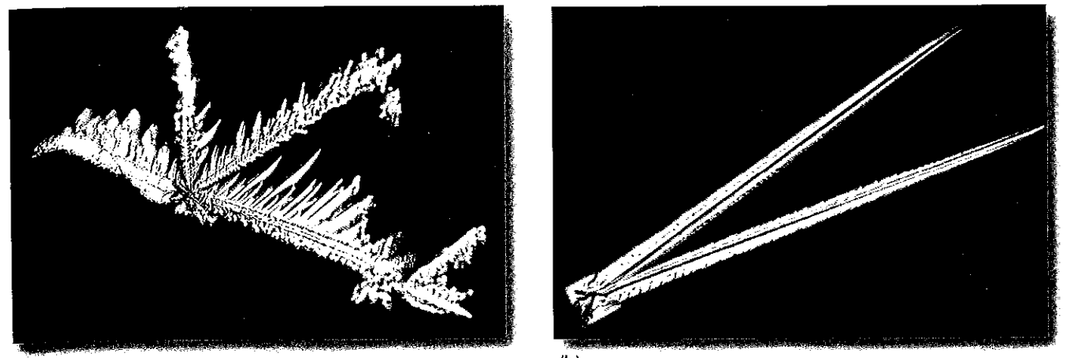
- Analysts use screening tests to determine the identity of drugs present in a sample. These tests reduce the number of possible drugs to a small and manageable number.
- A series of color tests produce characteristic colors for the more commonly encountered illicit drugs.
- After preliminary testing, forensic chemists use more specific tests to identify a drug substance to the exclusion of all other known chemical substances.

Microcrystalline Tests

microcrystalline test
A test that identifies a specific substance based on the color and shape of crystals formed when the substance is mixed with specific reagents

A technique considerably more specific than color tests is the **microcrystalline test**. A drop of a chemical reagent is added to a small quantity of the drug on a microscopic slide. After a short time, a chemical reaction ensues, producing a crystalline precipitate. The size and shape of the crystals, under microscopic examination, are highly characteristic of the drug. Crystal tests for cocaine and methamphetamine are illustrated in Figure 5–13.

Over the years, analysts have developed hundreds of crystal tests to characterize the most commonly abused drugs. These tests are rapid and often do not require the isolation of a drug from its diluents; however, because diluents can sometimes alter or modify the shape of the crystal, the examiner must develop experience in interpreting the results of the test.



(a) (b)

FIGURE 5–13 (a) A photograph of a cocaine crystal formed in platinum chloride (400x). (b) A photomicrograph of a methamphetamine crystal formed in gold chloride (400x). *Courtesy David P. Blackburn, San Bermardino County Sheriff's Department, San Bernardino, Calif.*

Most color and crystal tests are largely empirical—that is, scientists do not fully understand why they produce the results that they do. From the forensic chemist's point of view, this is not important. When the tests are properly chosen and used in proper combination, their results constitute an analytical scheme that is characteristic for one and only one drug.

Chromatography

chromatography
Any of several analytical techniques for separating organic mixtures into their components by attraction to a stationary phase while being propelled by a moving phase

Chromatography is a means of separating and tentatively identifying the components of a mixture. It is particularly useful for analyzing drug specimens, which may be diluted with practically any material in order to increase the quantity of the product available to prospective customers. The task of identifying an illicit-drug preparation would be arduous without the aid of chromatographic methods to first separate the mixture into its components.

Theory of Chromatography The theory of chromatography is based on the fact that chemical substances tend to partially escape into the surrounding environment when dissolved in a liquid or when absorbed on a solid surface. For example, if a beaker of water is covered with a bell jar, as shown in Figure 5–14, gas molecules (represented by green balls) escape from the water into the surrounding enclosed air. The molecules that remain are said to be in the liquid phase; the molecules that have escaped into the air are said to be in the gas phase.

As the gas molecules escape into the surrounding air, they accumulate above the water; random motion carries some of them back into the water. Eventually, a point is reached at which the number of molecules leaving the water equals the number returning. At this time, the liquid and gas phases are in equilibrium. If the temperature of the water is increased, the equilibrium state readjusts itself to a point at which more gas molecules move into the gas phase.

This behavior was first observed in 1803 by British chemist William Henry. His explanation of this phenomenon, known appropriately as Henry's law, may be stated as follows: **When a volatile chemical compound is dissolved in a**

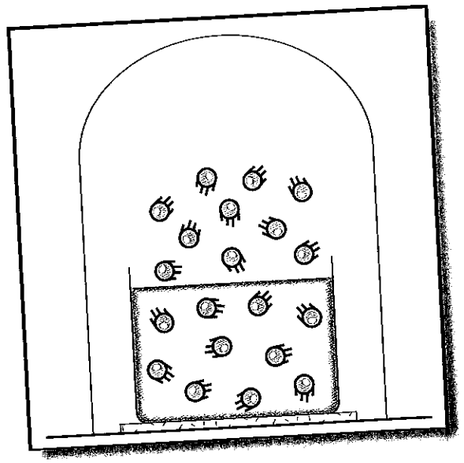


FIGURE 5–14
Evaporation of a liquid.

liquid and is brought to equilibrium with air, there is a fixed ratio between the concentration of the volatile compound in air and its concentration in the liquid, and this ratio remains constant for a given temperature.

The distribution of a gas between the liquid and gas phases is determined by the solubility of the gas; that is, how easily the gas dissolves in the liquid. The higher its solubility, the greater the tendency of the gas molecules to remain in the liquid phase. If two different gases are simultaneously dissolved in the same liquid, each reaches a state of equilibrium with the surrounding air independently of the other. For example, as shown in Figure 5–15, gas A (green molecules) and gas B (blue molecules) are both dissolved in water. At equilibrium, gas A has a greater number of molecules dissolved in the water than does gas B. This is so because gas A is more soluble in water than gas B.

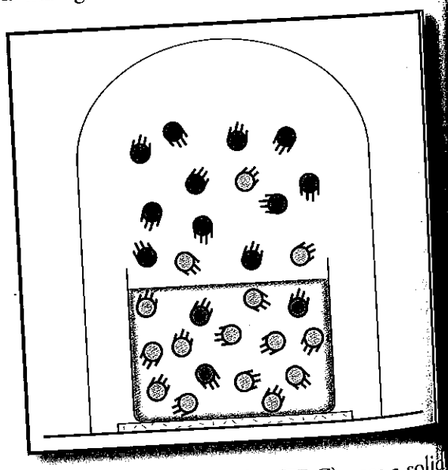


FIGURE 5–15
At equilibrium, there are more gas A molecules (green molecules) than gas B molecules (blue molecules) in the liquid phase.

Thin-Layer Chromatography Thin-layer chromatography (TLC) uses a solid stationary phase and a moving liquid phase to separate the constituents of a mixture. Thin-layer chromatography is a powerful tool for solving many of the analytical problems presented to the forensic scientist. The method is both rapid and

Inside the Science

The Chromatographic Process

In Figures 5–14 and 5–15, both phases—liquid and gas—were kept stationary; that is, they were not moving. During a chromatographic process, however, this is not the case. Instead, one phase is always made to move continuously in one direction over a stationary or fixed phase. For example, in Figure 5–15, chromatography will occur only when the air is forced to move continuously in one direction over the water. Because gas B (blue molecules) has a greater percentage of its molecules in the moving phase than does gas A (green molecules), the molecules of gas B will travel over the liquid at a faster pace than those of gas A. Eventually, when the moving phase has advanced a reasonable distance, the molecules of gas B will become entirely separated from those of gas A, and the chromatographic process will be complete. This process is illustrated in Figure 1.

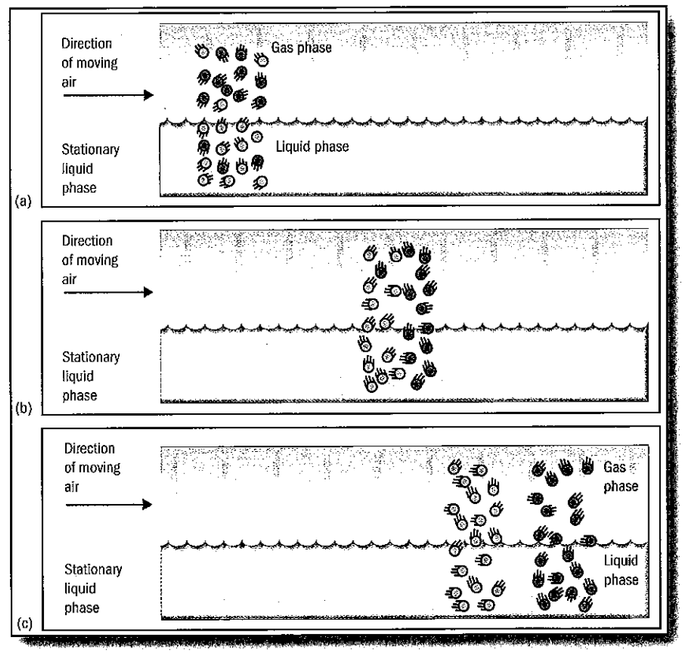


FIGURE 1 In this illustration of chromatography, the blue molecules have a greater affinity for the upper phase and hence will be pushed along at a faster rate by the moving air. Eventually, the two sets of molecules will separate from each other, completing the chromatographic process.

Inside the Science (CONTINUED)

Simply, we can think of chromatography as being analogous to a race between chemical compounds. At the starting line, all the participating substances are mixed together; however, as the race progresses, materials that prefer the moving phase slowly pull ahead of those substances that prefer to remain in the stationary phase. Finally, at the end of the race, all the participants are separated, each crossing the finish line at different times.

The different types of chromatographic systems are as varied as the number of stationary and moving-phase combinations that can be devised. However, two chromatographic processes—gas chromatography and thin-layer chromatography—are most applicable for solving many analytical problems in the crime laboratory.

sensitive; moreover, less than 100 micrograms of suspect material are required for the analysis. In addition, the equipment necessary for TLC work has minimal cost and space requirements. Importantly, numerous samples can be analyzed simultaneously on one thin-layer plate. This technique is principally used to detect and identify components in complex mixtures.

Theory of Thin-Layer Chromatography. In TLC, the components of a suspect mixture are separated as they travel up a glass plate, eventually appearing as a series of dark or colored spots on the plate. This action is then compared to a standard sample separation of a specific drug, such as heroin. If both the standard and the suspect substance travel the same distance up the plate, they can tentatively be identified as being produced by the same substance.

Figure 5–16 shows a sample suspected of containing heroin and quinine that has been chromatographed alongside known heroin and quinine standards. The distance the unknown material migrated up the suspect plate is compared to the distances that heroin and quinine migrated up a standard sample plate. If the distances are the same, a tentative identification can be made. However, such an identification cannot be considered definitive, because numerous other substances can migrate the same distance up the plate when chromatographed under similar conditions. Thus, thin-layer chromatography alone cannot provide an absolute identification; it must be used in conjunction with other testing procedures to prove absolute identity.

TLC in Practice. A thin-layer plate is prepared by coating a glass plate or plastic backing with a thin film of a granular material, usually silica gel or aluminum oxide. This granular material serves as the solid stationary phase and is usually held in place on the plate with a binding agent such as plaster of Paris. If the sample to be analyzed is a solid, it must first be dissolved in a suitable solvent and a few microliters of the solution spotted with a capillary tube onto the granular surface near the

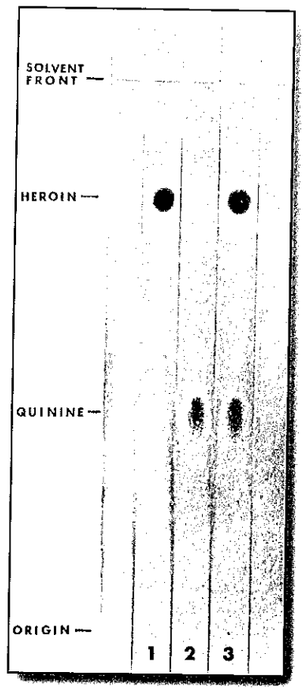


FIGURE 5–16
Chromatograms of known heroin (1) and quinine (2) standards alongside suspect sample (3).

lower edge of the plate. A liquid sample may be applied directly to the plate in the same manner. The plate is then placed upright into a closed chamber that contains a selected liquid, with care that the liquid does not touch the sample spot.

The liquid slowly rises up the plate by capillary action. This rising liquid is the moving phase in thin-layer chromatography. As the liquid moves past the sample spot, the components of the sample become distributed between the stationary solid phase and the moving liquid phase. The components with the greatest affinity for the moving phase travel up the plate faster than those that have greater affinity for the stationary phase. When the liquid front has moved a sufficient distance (usually 10 cm), the development is complete, and the plate is removed from the chamber and dried (see Figure 5–17). An example of the chromatographic separation of ink is shown in Figure 5–18.

Because most compounds are colorless, no separation will be noticed after development unless the materials are visualized. To accomplish this, the plates are placed under ultraviolet light, revealing fluorescent materials (those that emit visible light when exposed to light of a shorter wavelength) as bright spots on a dark background. When a fluorescent dye has been incorporated into the solid phase, nonfluorescent substances appear as dark spots against a fluorescent background when exposed to the ultraviolet light.

In a second method of visualization, the plate is sprayed with a chemical reagent that reacts with the separated substances and causes them to form colored spots. Figure 5–19 shows the chromatogram of a marijuana extract that has been separated into its components by TLC and visualized by having been sprayed with a chemical reagent.

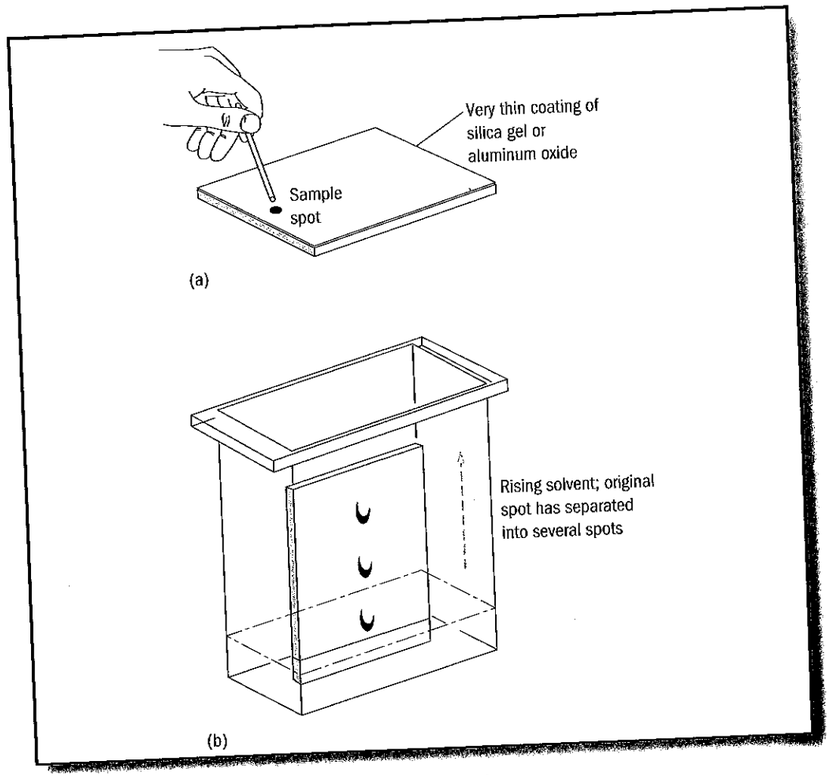


FIGURE 5–17
(a) In thin-layer chromatography, a liquid sample is spotted onto the granular surface of a gel-coated plate. (b) The plate is placed into a closed chamber that contains a liquid. As the liquid rises up the plate, the components of the sample distribute themselves between the coating and the moving liquid. The mixture is separated, with substances with a greater affinity for the moving liquid traveling up the plate at a faster speed.

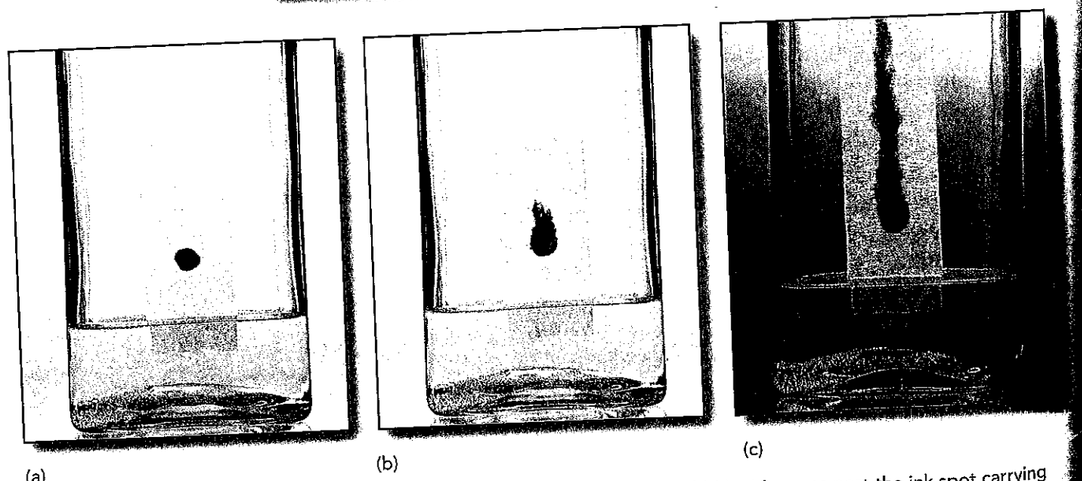


FIGURE 5–18 (a) The liquid phase begins to move up the stationary phase. (b) Liquid moves past the ink spot carrying the ink components up the stationary phase. (c) The moving liquid has separated the ink into its several components.
Courtesy Richard Megna/Fundamental Photographs, NYC, Photos a and b

The distance a spot has traveled up a thin-layer plate can be assigned a numerical value known as the R_f value. This value is defined as the distance traveled by the component divided by the distance traveled by the moving liquid phase. For example, in Figure 5–16 the moving phase traveled 10 centimeters up the plate before the plate was removed from the tank. After visualization, the heroin spot moved 8 centimeters, for an R_f value of 0.8; the quinine migrated 4 centimeters, for an R_f value of 0.4.

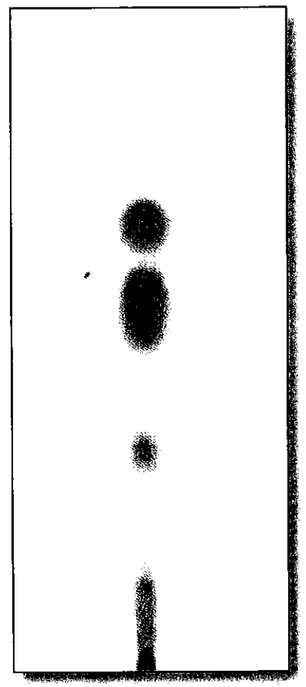


FIGURE 5–19
Thin-layer chromatogram of a marijuana extract.
Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com

Gas Chromatography (GC) Gas chromatography (GC) separates mixtures based on their distribution between a stationary liquid phase and a moving gas phase. In gas chromatography, the moving phase is called the *carrier gas*, which flows through a column constructed of stainless steel or glass. The stationary phase is a thin film of liquid within the column.

Two types of columns are used: the *packed column* and the *capillary column*. With the packed column, the stationary phase is a thin film of liquid fixed onto small granular particles packed into the column. This column, usually constructed of stainless steel or glass, is 2 to 6 meters long and about 3 millimeters in diameter. Capillary columns are composed of glass and are much longer than packed columns—15 to 60 meters long. These types of columns are very narrow, ranging from 0.25 to 0.75 millimeter in diameter. Capillary columns can be made narrower than packed columns because their stationary liquid phase is actually coated as a very thin film directly onto the column's inner wall.

As the carrier gas flows through the packed or capillary column, it carries with it the components of a mixture that have been injected into the column.

Components with a greater affinity for the moving gas phase travel through the column more quickly than those with a greater affinity for the stationary liquid phase. Eventually, after the mixture has traversed the length of the column, it emerges separated into its components.

The time required for a component to emerge from the column from the time of its injection into the column is known as the *retention time*, which is a useful identifying characteristic of a material. Figure 5–20(a) shows the chromatogram of two barbiturates; each barbiturate has tentatively been identified by comparing its retention time to those of known barbiturates, shown in Figure 5–20(b). However, because other substances may have comparable retention times under similar chromatographic conditions, gas chromatography cannot be considered an absolute means of identification. Conclusions derived from this technique must be confirmed by other testing procedures.

MyCrimeKit: WebExtra 5.1
Watch Animated Depictions of Thin-Layer Chromatography and Gas Chromatography
www.mycrimekit.com

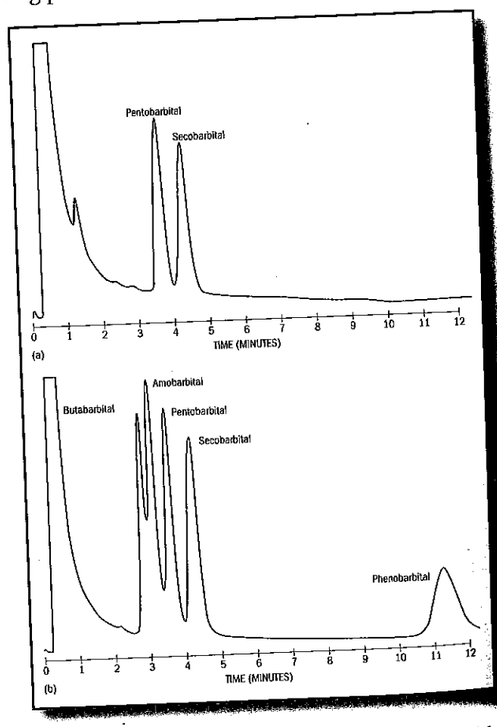


FIGURE 5–20
(a) An unknown mixture of barbiturates is identified by comparing its retention times to (b), a known mixture of barbiturates. *Courtesy Varian Inc., Palo Alto, Calif.*

MyCrimeKit: WebExtra 5.2
Watch the Gas Chromatograph at Work
www.mycrimekit.com

Gas chromatography is widely used because of its ability to resolve a highly complex mixture into its components, usually within minutes. It has an added advantage in that it is extremely sensitive and can yield quantitative results. Gas chromatography has sufficient sensitivity to detect and quantitate materials at the nanogram (0.000000001 gram or 1×10^9 gram) level.[3]

Inside the Science

The Gas Chromatograph

A simplified scheme of the gas chromatograph is shown in Figure 5–21. The operation of the instrument can be summed up briefly as follows: The carrier gas is fed into the column at a constant rate. The carrier gas is chemically inert and is generally nitrogen or helium. The sample under investigation is injected as a liquid into a heated injection port with a syringe, where it is immediately vaporized and swept into the column by the carrier gas. The column itself is heated in an oven in order to keep the sample in a vapor state as it travels through the column. In the column, the components of the sample travel in the direction of the carrier gas flow at speeds that are determined by their distribution between the stationary and moving phases. If the analyst has selected the proper liquid phase and has made the column long enough, the components of the sample will be completely separated as they emerge from the column.

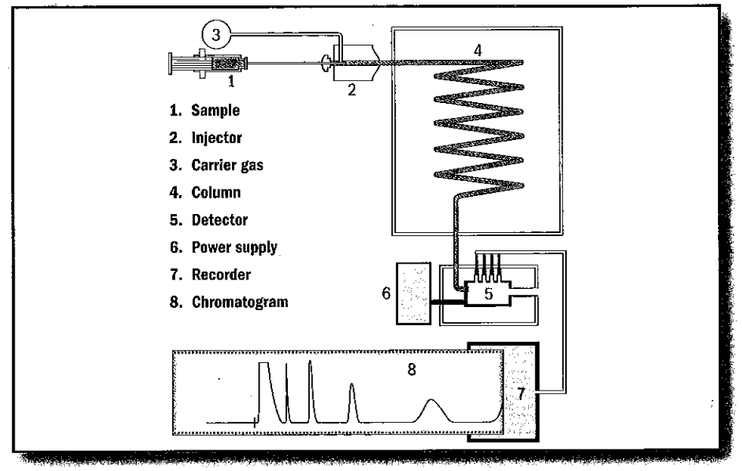


FIGURE 5–21 Basic gas chromatography. Gas chromatography permits rapid separation of complex mixtures into individual compounds and allows identification and quantitative determination of each compound. As shown, a sample is introduced by a syringe (1) into a heated injection chamber (2). A constant stream of nitrogen gas (3) flows through the injector, carrying the sample into the column (4), which contains a thin film of liquid. The sample is separated in the column, and the carrier gas and separated components emerge from the column and enter the detector (5). Signals developed by the detector activate the recorder (7), which makes a permanent record of the separation by tracing a series of peaks on the chromatograph (8). The time of elution identifies the component present, and the peak area identifies the concentration.
Courtesy Varian Inc., Palo Alto, Calif.

Inside the Science (CONTINUED)

As each component emerges from the column, it enters a detector. One type of detector uses a flame to ionize the emerging chemical substance, thus generating an electrical signal. The signal is recorded on a strip-chart recorder as a function of time. This written record of the separation is called a chromatogram. A gas chromatogram is a plot of the recorder response (vertical axis) versus time (horizontal axis). A typical chromatogram shows a series of peaks, each peak corresponding to one component of the mixture.

The technique of chromatography is particularly suited for analyzing illicit drugs, because it can separate a drug from other substances that may be present in the drug preparation. However, chromatography has the drawback of not being able to specifically identify the material under investigation. For this reason, other analytical tools are frequently used to identify drugs. These include the technique of **spectrophotometry**, which can identify a substance by exposing it to a specific type of electromagnetic radiation.

spectrophotometry
An analytical method for identifying a substance by its selective absorption of different wavelengths of light

Theory of Spectrophotometry We have already observed in the description of color that an object does not absorb all the visible light it is exposed to; instead, it selectively absorbs some frequencies and reflects or transmits others. Similarly, the absorption of other types of electromagnetic radiation by chemical substances is also selective. Selective absorption of a substance is measured by an instrument called a *spectrophotometer*, which produces a graph or *absorption spectrum* that depicts the absorption of light as a function of wavelength or frequency. The absorption of ultraviolet (UV), visible, and infrared (IR) radiation is particularly applicable for obtaining qualitative data pertaining to the identification of drugs.

Absorption at a single wavelength or frequency of light is not 100 percent complete—some radiation is transmitted or reflected by the material. Just how much radiation a substance absorbs is defined by a fundamental relationship known as Beer's law, shown in Equation (5–1):

$$A = kc$$

EQUATION 5-1

Here, A symbolizes the absorption or the quantity of light taken up at a single frequency, c is the concentration of the absorbing material, and k is a proportionality constant. This relationship shows that the quantity of light absorbed at any frequency is directly proportional to the concentration of the absorbing species; the more material you have, the more radiation it will absorb. By defining the relationship between absorbance and concentration, Beer's law permits spectrophotometry to be used as a technique for quantification.

Ultraviolet and Visible Spectrophotometry **Ultraviolet** (UV) and visible spectrophotometry measure the absorbance of UV and visible light as a function of wavelength or frequency. For example, the UV absorption spectrum of heroin shows a maximum absorption band at a wavelength of 278 nanometers (see Figure 5–22). This shows that the simplicity of a UV spectrum facilitates its use as a tool for determining a material's probable identity. For instance, a white powder may have a UV spectrum comparable to heroin and therefore may be tentatively identified as such. (Fortunately, sugar and starch, common diluents of heroin, do not absorb UV light.)

ultraviolet
Invisible long frequencies of light beyond violet in the visible spectrum

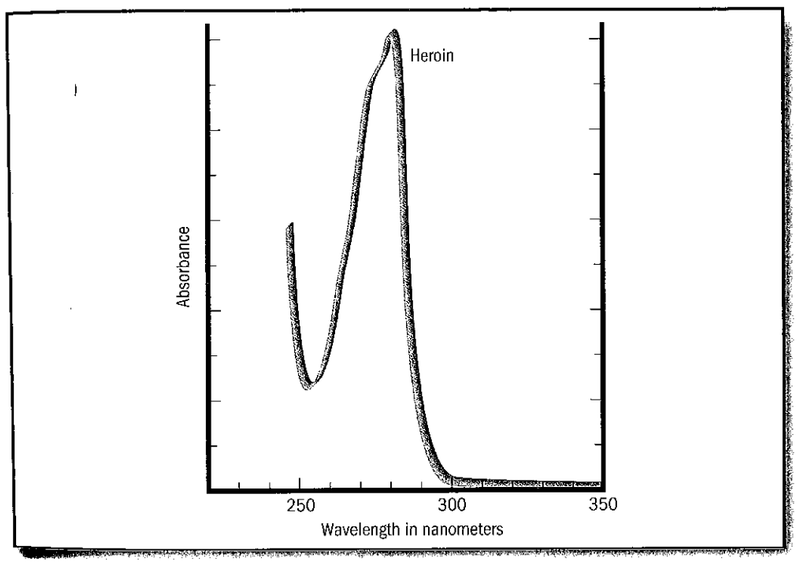


FIGURE 5–22
Ultraviolet spectrum of heroin.

This technique, however, does not provide a definitive result; other drugs or materials may have a UV absorption spectrum similar to that of heroin. Nevertheless, UV spectrophotometry is often useful in establishing the probable identity of a drug. For example, if an unknown substance yields a UV spectrum that resembles that of amphetamine (see Figure 5–23), thousands of substances are immediately eliminated from consideration, and the analyst can begin to identify the material from a relatively small number of possibilities. A comprehensive collection of UV drug spectra provides an index that can rapidly be searched in order to tentatively identify a drug or, failing that, at least to exclude certain drugs from consideration.

Infrared Spectrophotometry In contrast to the simplicity of a UV spectrum, absorption in the **infrared** region provides a far more complex pattern. Figure 5–24 depicts the IR spectra of heroin and secobarbital. Here, the absorption bands are so numerous that each spectrum can provide enough characteristics to identify a substance specifically. Different materials always have distinctively

infrared
Invisible short frequencies of light before red in the visible spectrum

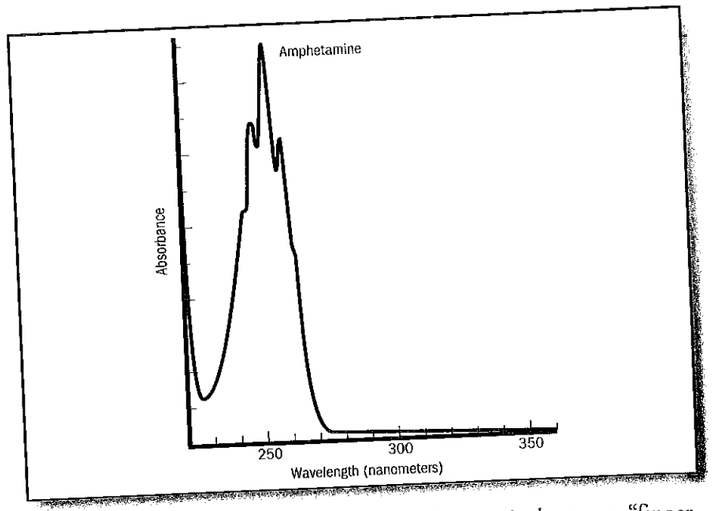


FIGURE 5–23
Ultraviolet spectrum of amphetamine.

different infrared spectra; each IR spectrum is therefore equivalent to a "fingerprint" of that substance and no other. This technique is one of the few tests available to the forensic scientist that can be considered specific in itself for identification. The IR spectra of thousands of organic compounds have been collected, indexed, and cataloged as invaluable references for identifying organic substances. The selective absorption of light by drugs in the UV and IR regions of the electromagnetic spectrum provides a valuable technique for characterizing drugs.

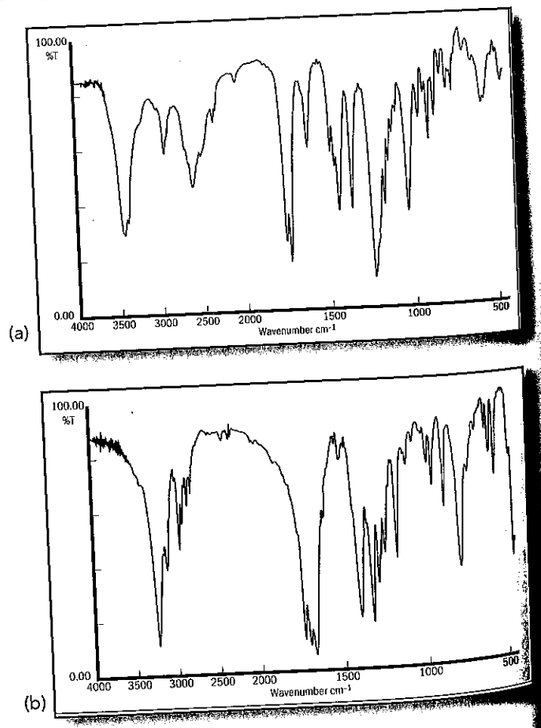
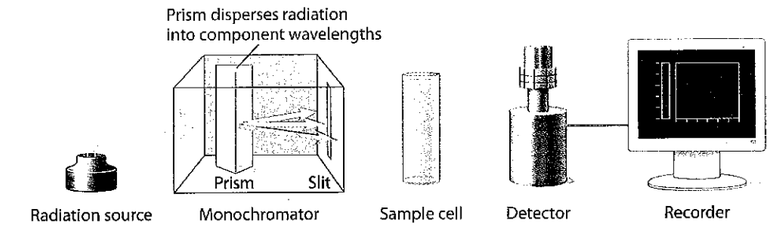


FIGURE 5-24
(a) Infrared spectrum of heroin.
(b) Infrared spectrum of secobarbital.

MyCrimeKit: WebExtra 5.3
See How a Spectrophotometer Works
www.mycrimekit.com

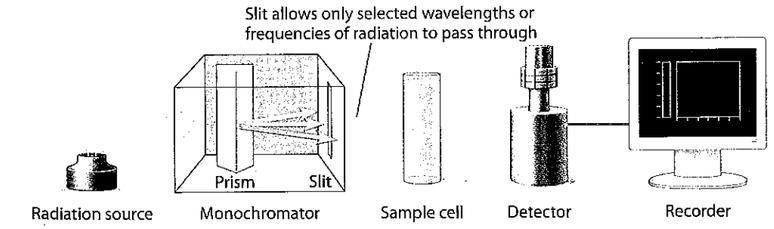
Inside the Science

The Spectrophotometer



The spectrophotometer measures and records the absorption spectrum of a chemical. The basic components of a simple spectrophotometer are the same regardless of whether it is designed to measure the absorption of UV, visible, or IR radiation. These components are illustrated diagrammatically in the figure above. They include (1) a radiation source, (2) a monochromator or frequency selector, (3) a sample holder, (4) a detector to convert electromagnetic radiation into an electrical signal, and (5) a recorder to produce a record of the signal.

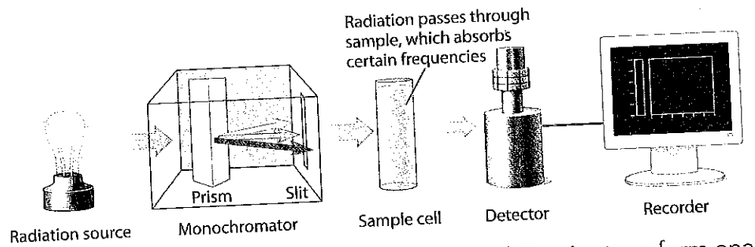
The choice of source varies with the type of radiation desired. For visible radiation, an ordinary tungsten bulb provides a convenient source of radiation. In the UV region, a hydrogen or deuterium discharge lamp is normally used, and a heated molded rod containing a mixture of rare-earth oxides is a good source of IR light.



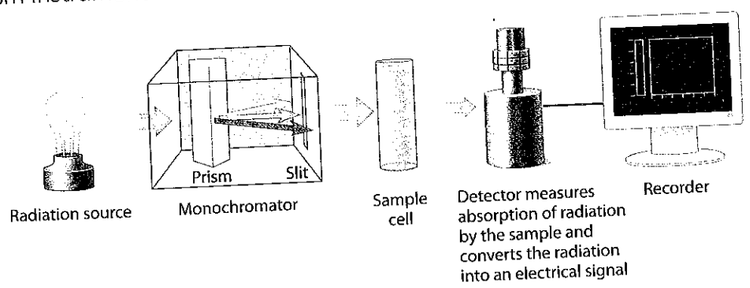
The function of the **monochromator** is to select a single wavelength or frequency of light from the source—monochromatic light. Some inexpensive spectrophotometers pass the light through colored glass filters to remove all radiation from the beam except for a desired range of wavelengths.

Inside the Science (CONTINUED)

More precise spectrophotometers may use a prism or diffraction grating to disperse radiation into its component wavelengths or frequencies. A diffraction grating is made by scratching thousands of parallel lines on a transparent surface such as glass. As light passes through the narrow spacings between the lines, it spreads out and produces a spectrum similar to that formed by a prism. The desired wavelength is obtained when the dispersed radiation is focused onto a narrow slit that permits only selected wavelengths to pass through.

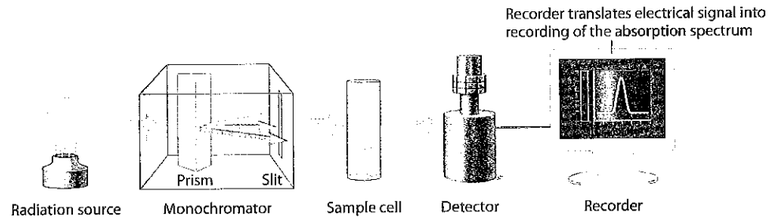


Most laboratory infrared spectrophotometers use Fourier transform analysis to measure the wavelengths of light at which a material absorbs in the infrared spectrum. This approach does not use any dispersive elements that select single wavelengths or frequencies of light emitted from a source; instead, the heart of a Fourier transform infrared (FT-IR) spectrometer is the Michelson interferometer. The interferometer uses a beam-splitting prism and two mirrors, one movable and one stationary, to direct light toward a sample. As the wavelengths pass through the sample and reach a detector, they are all measured simultaneously. A mathematical operation, the Fourier transform method, is used to decode the measured signals and record the wavelength data. These Fourier calculations are rapidly carried out by a computer. In a matter of seconds, a computer-operated FT-IR instrument can produce an infrared absorption pattern compatible to one generated by a prism instrument.



Inside the Science (CONTINUED)

Sample preparation varies with the type of radiation being studied. Absorption spectra in the UV and visible regions are usually obtained from samples that have been dissolved in an appropriate solvent. Because the cells holding the solution must be transparent to the light being measured, glass cells are used in the visible region and quartz cells in the ultraviolet region. Practically all substances absorb in some region of the IR spectrum, so sampling techniques must be modified to measure absorption in this spectral region; special cells made out of sodium chloride or potassium bromide are commonly used because they do not absorb light over a wide range of the IR portion of the electromagnetic spectrum.



The absorption spectrum of a chemical substance allows spectrophotometry to be used for identification.

The detector measures the quantity of radiation that passes through the sample by converting it to an electrical signal. UV and visible spectrophotometers use photoelectric tube detectors. A signal is generated when the photons strike the tube surface to produce a current that is directly proportional to the intensity of the light transmitted through the sample. When this signal is compared to the intensity of light that is transmitted to the detector in the absence of an absorbing material, the absorbance of a substance can be determined at each wavelength or frequency of light selected. The signal from the detection system is then fed into a recorder, which plots absorbance as a function of wavelength or frequency. Modern spectrophotometers are designed to trace an entire absorption spectrum automatically.

monochromator
A device for isolating individual wavelengths or frequencies of light

A previous section discussed the operation of the gas chromatograph. This instrument is one of the most important tools in a crime laboratory. Its ability to separate the components of a complex mixture is unsurpassed. However, gas chromatography has one important drawback—its inability to produce specific identification. A forensic chemist cannot unequivocally state the identification of a substance based solely on a retention time as determined by the gas chromatograph. Fortunately, coupling the gas chromatograph to a mass spectrometer has largely overcome this problem.

A mixture's components are first separated on the gas chromatograph. A direct connection between the gas chromatograph column and the mass spectrometer then allows each component to flow into the spectrometer as it emerges from the gas chromatograph. In the mass spectrometer, the material enters a high-vacuum chamber where a beam of high-energy electrons is aimed at the sample molecules. The electrons collide with the molecules, causing them to lose electrons and to acquire a positive charge. These positively charged molecules, or **ions**, are unstable or are formed with excess energy and almost instantaneously decompose into numerous smaller fragments. The fragments then pass through an electric or magnetic field, where they are separated according to their masses. The unique feature of mass spectrometry is that under carefully controlled conditions, no two substances produce the same fragmentation pattern. In essence, one can think of this pattern as a "fingerprint" of the substance being examined (see Figure 5–25).

ion
An atom or molecule bearing a positive or negative charge

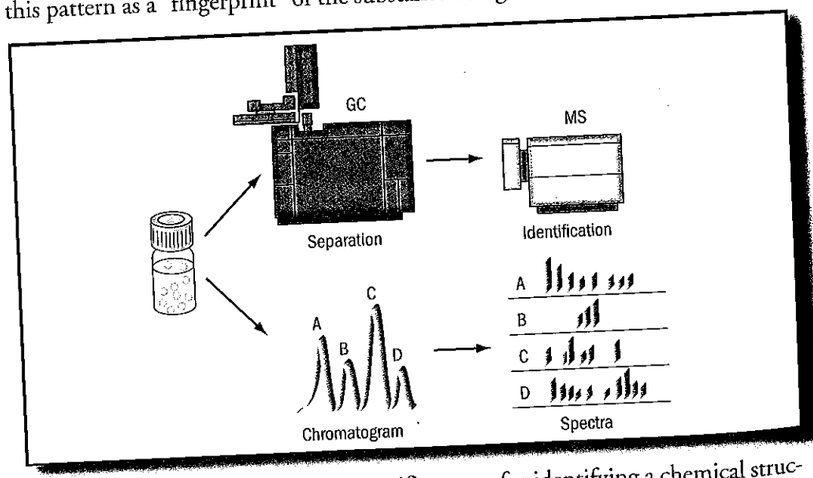


FIGURE 5–25
How GC/MS works. Left to right, the sample is separated into its components by the gas chromatograph, and then the components are ionized and identified by characteristic fragmentation patterns of the spectra produced by the mass spectrometer.
Courtesy Agilent Technologies, Inc., Palo Alto, Calif.

The technique thus provides a specific means for identifying a chemical structure. It is also sensitive to minute concentrations. Mass spectrometry is most widely used to identify drugs; however, further research is expected to yield significant applications to identifying other types of physical evidence. Figure 5–26 illustrates the mass spectra of heroin and cocaine; here, each line represents a fragment of a different mass (actually the ratio of mass to charge), and the line height reflects the relative abundance of each fragment. Note how different the fragmentation patterns of heroin and cocaine are. Each mass spectrum is unique to each drug and therefore provides a specific test for identifying that substance.

The combination of the gas chromatograph and mass spectrometer (GC/MS) is further enhanced when a computer is added to the system. The integrated gas chromatograph/mass spectrometer/computer system provides the ultimate in speed, accuracy, and sensitivity. With the ability to record and store in its memory several hundred mass spectra, such a system can detect and identify substances present in only one-millionth-of-a-gram quantities. Furthermore, the computer can be programmed to compare an unknown spectrum against a comprehensive library of mass spectra stored in its memory. The advent of personal computers and microcircuitry has made it possible to design mass spectrometer systems that can fit on a small table. Such a unit is pictured in Figure 5–27. With data obtained from a GC/MS determination, a forensic analyst can, with one instrument, separate the components of a complex drug mixture and then unequivocally identify each substance present in the mixture. (see Figure 5–28).

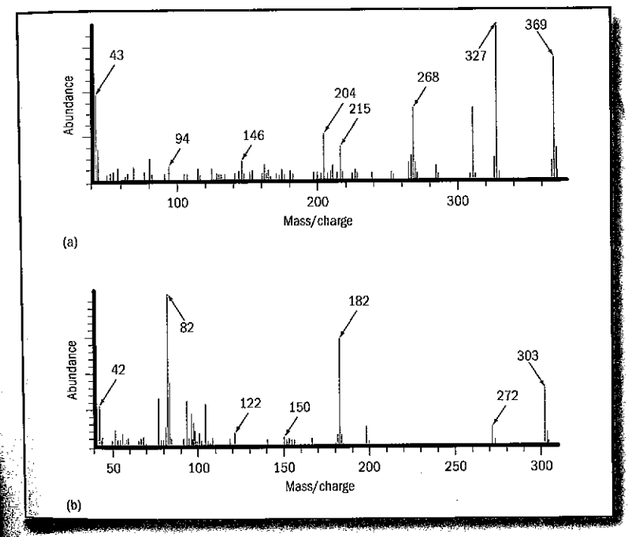


FIGURE 5–26
(a) Mass spectrum of heroin.
(b) Mass spectrum of cocaine.

The Identification of Marijuana

Enforcement of laws prohibiting the sale and use of marijuana accounts for a high percentage of drug arrests in the United States. Any trial or hearing involving a seizure of marijuana requires identification of the material before the issue of guilt or innocence can be decided.

Unlike most other drugs received by the crime laboratory, marijuana (Cannabis sativa L.) possesses botanical features that impart identifiable characteristics. Because most marijuana specimens consist of small leaf fragments, their identification must be partially based on botanical features observed under the microscope by a trained expert. This approach is further augmented with a chemical test that will independently confirm the findings of the botanical examination.

The identification of marijuana by microscopic methods depends largely on observing short hairs shaped like "bear claws" on the upper side of the leaf (see the SEM photo in Figure 7–14). These hairs are known as cystolithic hairs. Further

MyCrimeKit: WebExtra 5.4
Watch an Animation of a Mass Spectrometer
www.mycrimekit.com

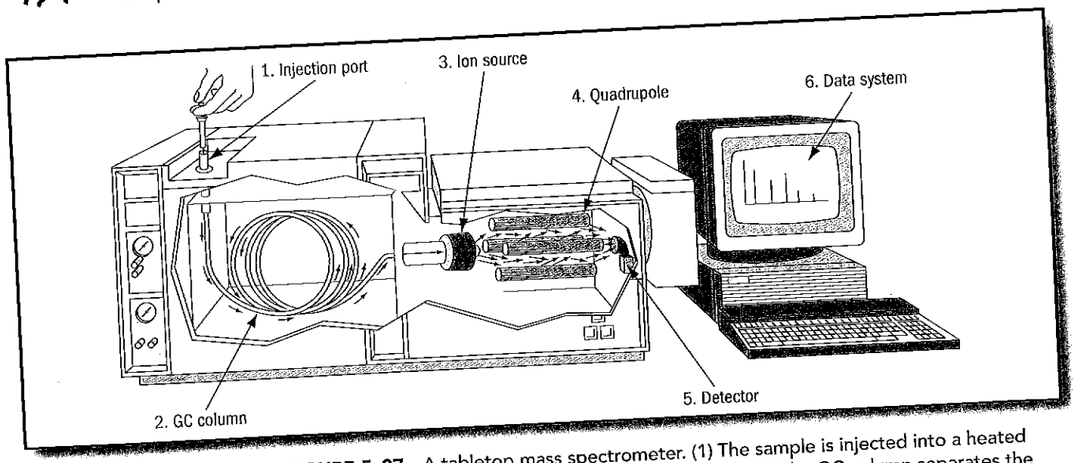


FIGURE 5–27 A tabletop mass spectrometer. (1) The sample is injected into a heated inlet port, and a carrier gas sweeps it into the column. (2) The GC column separates the mixture into its components. (3) In the ion source, a filament wire emits electrons that strike the sample molecules, causing them to fragment as they leave the GC column. (4) The quadrupole, consisting of four rods, separates the fragments according to their mass. (5) The detector counts the fragments passing through the quadrupole. The signal is small and must be amplified. (6) The data system is responsible for total control of the entire GC/MS system. It detects and measures the abundance of each fragment and displays the mass spectrum. *Courtesy Agilent Technologies, Inc., Palo Alto, Calif.*

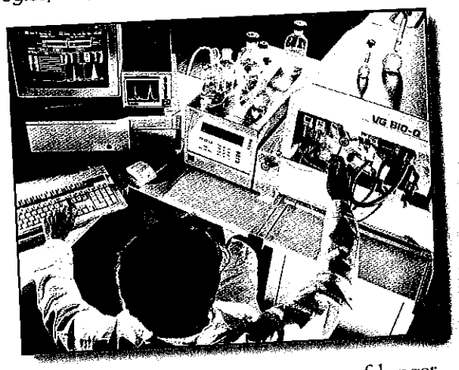


FIGURE 5–28
A gas chromatograph interfaced to a mass spectrometer in a forensic laboratory. A sample injection robot transfers samples from small vials to the gas chromatograph

verification of the identity of marijuana is confirmed by the presence of longer, nonglandular hairs on the opposite side of the leaf.

The Duquenois-Levine color test, described earlier in this chapter, is a highly but not totally specific test for marijuana. However, when used in combination with a botanical examination, the results constitute a specific identification of marijuana. In addition, the analyst may be unable to obtain a microscopic identification of the marijuana leaf, as in the case of hashish or hashish oil. Here, the color test has to be supplemented by another examination, preferably thin-layer chromatography. This method involves separating chemical constituents found in the suspect resin on a thin-layer plate. The separated components are compared on the same plate to those obtained from a known marijuana extract, as shown in Figure 5–19. In this manner, a positive TLC comparison, used in conjunction with the Duquenois-Levine color test, constitutes a specific identification for marijuana.

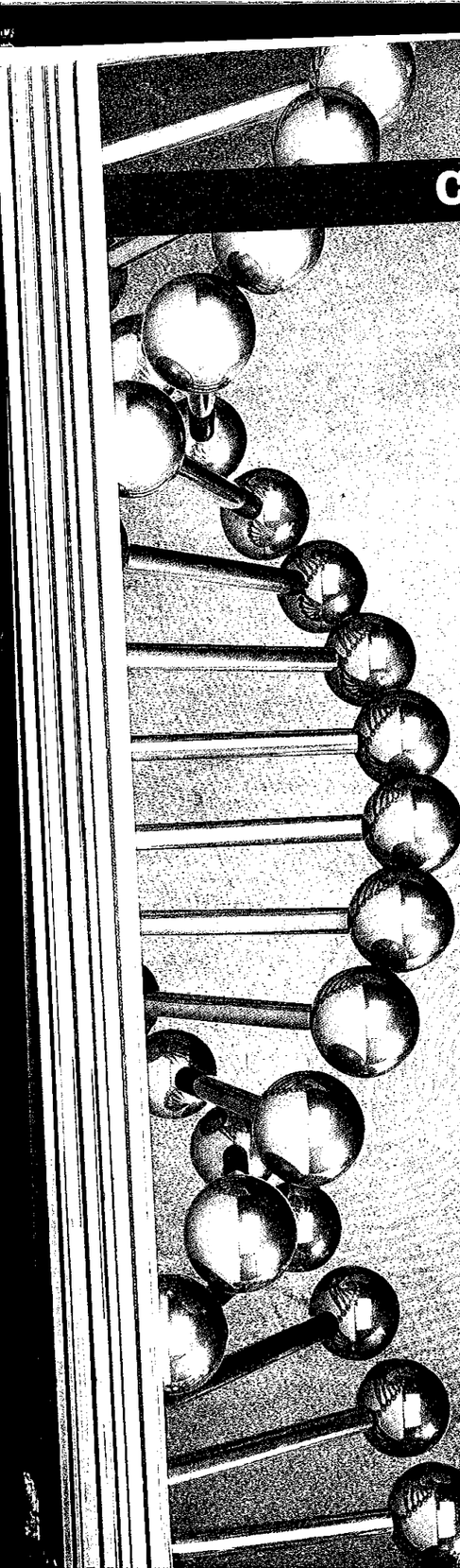
Quick Review

- Chromatography is a means of separating and tentatively identifying the components of a mixture.
- TLC uses a solid stationary phase, usually coated onto a glass plate, and a mobile liquid phase to separate the components of the mixture.
- Gas chromatography (GC) separates mixtures on the basis of their distribution between a stationary liquid phase and a mobile gas phase.
- Spectrophotometry is the study of the absorption of light by chemical substances.
- Most forensic laboratories use ultraviolet (UV) and infrared (IR) spectrophotometers to characterize chemical compounds.
- IR spectrophotometry provides a far more complex pattern than UV spectrophotometry. Because different materials have distinctively different infrared spectra, each IR spectrum is equivalent to a "fingerprint" of that substance.
- Mass spectrometry characterizes organic molecules by observing their fragmentation pattern after their collision with a beam of high-energy electrons.
- Infrared spectrophotometry and mass spectrophotometry typically are used to specifically identify a drug substance.

Collection and Preservation of Drug Evidence

Preparation of drug evidence for submission to the crime laboratory is normally relatively simple, accomplished with minimal precautions in the field. The field investigator must ensure that the evidence is properly packaged and labeled for delivery to the laboratory. Considering the countless forms and varieties of drug evidence seized, it is not practical to prescribe any single packaging procedure for fulfilling these requirements. Generally, common sense is the best guide in such situations, keeping in mind that the package must prevent loss and/or cross-contamination of the contents. Often, the original container in which the drug was seized will suffice to meet these requirements. Specimens suspected of containing volatile solvents, such as those involved in glue-sniffing cases, must be packaged in an airtight container to prevent evaporation of the solvent. All packages must be marked with sufficient information to ensure identification by the officer in future legal proceedings and to establish the chain of custody.

To aid the drug analyst, the investigator should supply any background information that may relate to a drug's identity. Analysis time can be markedly reduced when the chemist has this information. For the same reason, the results of drug-screening tests used in the field must also be transmitted to the laboratory. However, although these tests may indicate the presence of a drug and may help the officer establish probable cause to search and arrest a suspect, they do not offer conclusive evidence of a drug's identity.



Chapter Review

- A drug is a natural or synthetic substance that is used to produce physiological or psychological effects in humans or other animals.
- Nondrug factors that play a part in drug dependence include the personal characteristics of the user, his or her expectations about the drug experience, society's attitudes and possible responses, and the setting in which the drug is used.
- Physical dependence is defined as the physiological need for a drug that has been brought about by its regular use. Psychological dependence is the conditioned use of a drug caused by underlying emotional needs.
- Narcotic drugs are analgesics, meaning they relieve pain by depressing the central nervous system.
- The most common source for narcotic drugs is opium. Morphine is extracted from opium and used to synthesize heroin.
- Opiates are not derived from opium or morphine, but they have the same physiological effects on the body. Examples of opiates include methadone and OxyContin (oxycodone).
- Hallucinogens cause marked changes in normal thought processes, perceptions, and moods. Marijuana is the most well-known drug in this class. Other hallucinogens include LSD, mescaline, PCP, psilocybin, and MDMA (Ecstasy).
- Depressants decrease the activity of the central nervous system, calm irritability and excitability, and produce sleep. Depressants include alcohol (ethanol), barbiturates, tranquilizers, and various substances that can be sniffed, such as airplane glue or model cement.
- Stimulants increase the activity of the central nervous system and are taken to increase alertness and activity. Stimulants include amphetamines, sometimes known as "uppers" or "speed," and cocaine, which in its freebase form is known as crack.
- Club drugs are synthetic drugs that are used at nightclubs, bars, and raves (all-night dance parties). Some club drugs act as stimulants; others have depressant effects.
- Anabolic steroids are synthetic compounds that are chemically related to the male sex hormone testosterone. Anabolic steroids are often abused by individuals who are interested in accelerating muscle growth.
- Federal law establishes five schedules of classification for controlled dangerous substances on the basis of a drug's potential for abuse, potential for physical and psychological dependence, and medical value.
- Analysts use screening tests to determine the identity of drugs present in a sample. These tests reduce the number of possible drugs to a small and manageable number.

- A series of color tests produce characteristic colors for the more commonly encountered illicit drugs.
- After preliminary testing, forensic chemists use more specific tests to identify a drug substance to the exclusion of all other known chemical substances.
- Chromatography is a means of separating and tentatively identifying the components of a mixture.
- TLC uses a solid stationary phase, usually coated onto a glass plate, and a mobile liquid phase to separate the components of the mixture.
- Gas chromatography (GC) separates mixtures on the basis of their distribution between a stationary liquid phase and a mobile gas phase.
- Spectrophotometry is the study of the absorption of light by chemical substances.
- Most forensic laboratories use ultraviolet (UV) and infrared (IR) spectrophotometers to characterize chemical compounds.
- IR spectrophotometry provides a far more complex pattern than UV spectrophotometry. Because different materials have distinctively different infrared spectra, each IR spectrum is equivalent to a "fingerprint" of that substance.
- Mass spectrometry characterizes organic molecules by observing their fragmentation pattern after their collision with a beam of high-energy electrons.
- Infrared spectrophotometry and mass spectrophotometry typically are used to specifically identify a drug substance.

Quick Lab: Chromatography

Materials:

Roll of chromatography paper
5 different types of markers/pens
Thin piece of wire about 5 inches long
Beaker
Water

Procedure:

Chromatography is a process that can be used to identify different substances that make up a mixture. In forensics this process can be used on many types of evidence. In this activity you will perform paper chromatography to identify the components of different types of ink. Cut a piece of chromatography paper that is [illegible] inches long. Select one of the markers/pens and place a dot at one end of the paper, leaving a small gap between the dot and end of paper. At the other end, [illegible] the wire through the paper so that the paper is hanging off of the wire with the dot end down. Fill the bottom of the beaker with water. Place the wire across

the top of the beaker with the paper hanging in the beaker so that the dot end of the paper is in the water, but the dot is just above the water. Allow 5 minutes for the separation to occur. When the ink has stopped separating, take the paper out of the beaker and let it dry. Repeat the process for all the markers/pens. Your teacher could give you an unknown ink to test and compare to the samples you have just tested.

Follow-Up Questions:

1. Did all of the inks separate during the process? If not, why do you think certain inks did not separate?
2. Besides ink, what other types of evidence could chromatography be used with?
3. Did you find a match to the unknown ink? Was it exactly the same as one of the other inks? If not, what was different?

Quick Lab: Drug Screening Test

Materials:

Ward's Natural Science Crime Scene Drug Bust Kit

Procedure:

Often drugs are part of an investigation in forensics. Suspects may need to be tested to see if they have been using or may be on some type of drug. To do this, a screening test is completed. Follow the directions of the kit to see how some screening tests are completed.

Follow-up questions can be found in the kit handout section.

Quick Lab: What Is the White Powder?

Materials:

Table salt
Baking soda
Cornstarch
Sugar
Flour
Water
Vinegar
Iodine
Bunsen burner/candle
Aluminum foil
Tongs
Slides
Toothpicks

Procedure:

Unknown substances may be found at crime scenes. When this happens, it is important to be able to identify what substance is actually present. In this activity you will test five white powders to look for differences among them in order to identify an unknown sample. First, mix each powder individually with water. Do this by placing a small amount of the powder on a slide and adding a drop of water to it; mix with a toothpick. Record what you observe. Do this for each powder. Repeat this process twice more, once using vinegar and once using iodine instead of water. Do not get iodine on anything but the slide; it stains! Next create a foil tray that will hold a small sample of powder. Carefully light the candle or the Bunsen burner; be sure to have eye protection on for this part of the activity. Place a small amount of the powder on the tray and use the tongs to hold it over the candle for a minute. Record your observations. Repeat this for each powder. When you are finished, your teacher may choose to give you an unknown powder sample for you to test and determine which powder it is.

Follow-Up Questions:

1. Of the different tests performed, which one would be the best to use to identify an unknown powder?
2. In this activity you tested pure samples. Would this be the case if you were investigating a crime in the real world? Explain your answer.
3. Were you able to identify the unknown sample provided by your teacher?

Review Questions

1. In chromatography, the distribution of a gas between the liquid and gas phases is determined by
   a. the solubility of the gas in the liquid.
   b. the volume of the gas in the container.
   c. the density of the gas relative to the liquid.
   d. the mass of the gas relative to the liquid.

2. Spectrophotometry uses which light source?
   a. visible
   b. UV
   c. Infrared
   d. all of the above

3. The higher the solubility of a gas in a liquid, the greater the tendency of the gas molecules to
   a. move from a liquid phase to a gaseous or vapor phase.
   b. remain in the liquid phase.
   c. move from a liquid phase to a solid state.
   d. disperse.

4. All of the following are chromatographic processes found to be applicable for solving analytical problems encountered in the crime laboratory except:
   a. thin-layer chromatography
   b. gas chromatography
   c. GC/MS
   d. solid-state chromatography

5. Which of the following tests can be considered specific in itself for identification purposes?
   a. mass spectrometry
   b. gas spectrometry
   c. gas chromatography
   d. electromagnetic radiation

6. True or False: Although cocaine is legally classified as a narcotic, pharmacologically it is actually a powerful central nervous system stimulant.

7. True or False: The quantity of a substance separated by gas chromatography can be determined by its R_f value.

8. True or False: The gas chromatography/mass spectrometry (GC/MS) combination produces a fragmentation pattern that serves as a virtual "fingerprint" of a chemical substance because, with few exceptions, no two substances fragment in the same fashion.

9. True or False: Chromatography is a means of separating and tentatively identifying the components of a mixture.

10. True or False: Infrared spectrophotometry allows for the identification of different materials because different organic substances always produce distinctive infrared spectra.

11. What is a drug? How has drug use affected the growth of crime laboratories in the United States?

12. Name three nondrug factors that play a part in drug dependence.

13. Define physical dependence and psychological dependence.

14. What is the pharmacological definition of a narcotic?

15. What is the source of most narcotic analgesics? Name two popular drugs prepared from this substance.

16. Name two synthetic opiates and describe the purpose for which each typically is used.

17. What is a hallucinogen? Name three commonly used hallucinogens.

18. What is the most widely used illicit drug in the United States? What is the active ingredient in this drug?

19. Arrange the following parts or products of the Cannabis plant in order of THC content, from highest to lowest concentration of THC: flowers, leaves, resin, seeds, stem.

20. List three potential medical uses of marijuana.

21. What is angel dust and what are the negative consequences of long-term use?

22. What is the most widely abused drug in the United States?

23. In what class of drugs do alcohol and barbiturates belong? What is the main physiological effect of such drugs?

24. What is a stimulant? Name two widely used stimulants.

25. Name two potent forms of methamphetamine. How is each of these drugs typically taken into the body?

26. What popular stimulant is derived from a plant that grows in the Andes mountains of South America?

27. What is crack, and how is it produced?

28. Name club drugs belonging to three different classes of drugs and indicate the class to which each belongs.

29. What are anabolic steroids, and why were they developed?

30. What is the difference between a screening test and a confirmation test?

31. Name two types of empirical tests used to identify drugs. Why are these tests referred to as empirical?

32. What is the difference between a qualitative evaluation and a quantitative evaluation?

33. Why is chromatography particularly well suited to the needs of a drug analyst?

34. Name three distinct advantages of gas chromatography in the identification of drugs.

35. What is the main drawback of gas chromatography in the identification of drugs?

36. What phenomenon forms the basis of spectrophotometry?

37. What is the main advantage of infrared spectrophotometry over ultraviolet or visible-light spectrophotometry?

38. With what analytical device is a gas chromatograph often connected to analyze drug mixtures, and why?

Application and Critical Thinking

1. An individual who has been using a drug for an extended period of time suddenly finds himself unable to secure more of the drug. He acts nervous and irritable and is hyperactive. He seems almost desperate to find more of the drug, but experiences no sickness, pain, or other outward physical discomfort. Based on his behavior, what drugs might he possibly have been using? Explain your answer.

2. Following are descriptions of behavior that are characteristic among users of certain classes of drugs. For each description, indicate the class of drug (narcotics, stimulants, and so on) for which the behavior is most characteristic. For each description, also name at least one drug that produces the described effects.

a. slurred speech, slow reaction time, impaired judgment, reduced coordination
b. intense emotional responses, anxiety, altered sensory perceptions
c. alertness, feelings of strength and confidence, rapid speech and movement, decreased appetite
d. drowsiness, intense feeling of well-being, relief from pain

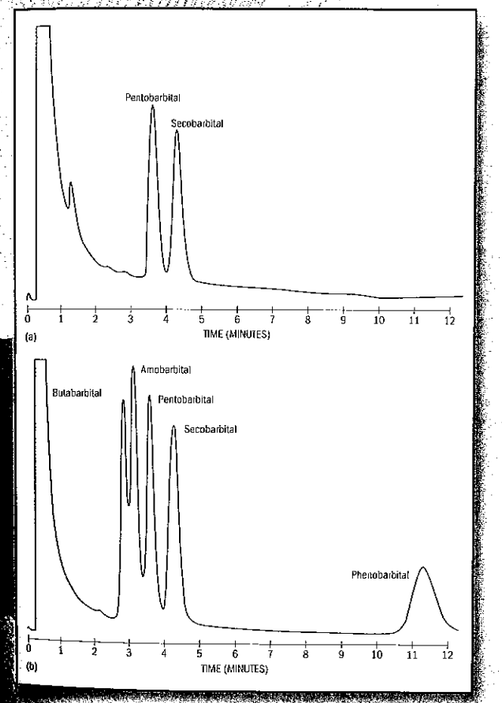
3. Following are descriptions of four hypothetical drugs. According to the Controlled Substances Act, under which drug schedule would each substance be classified?

a. This drug has a high potential for psychological dependence, it currently has accepted medical uses in the United States, and the distributor is not required to report to the U.S. Drug Enforcement Administration.
b. This drug has medical use in the United States, is not limited by manufacturing quotas, and may be exported without a permit.
c. This drug must be stored in a vault or safe, requires separate record keeping, and may be distributed with a prescription.
d. This drug may not be imported or exported without a permit, is subject to manufacturing quotas, and currently has no medical use in the United States.

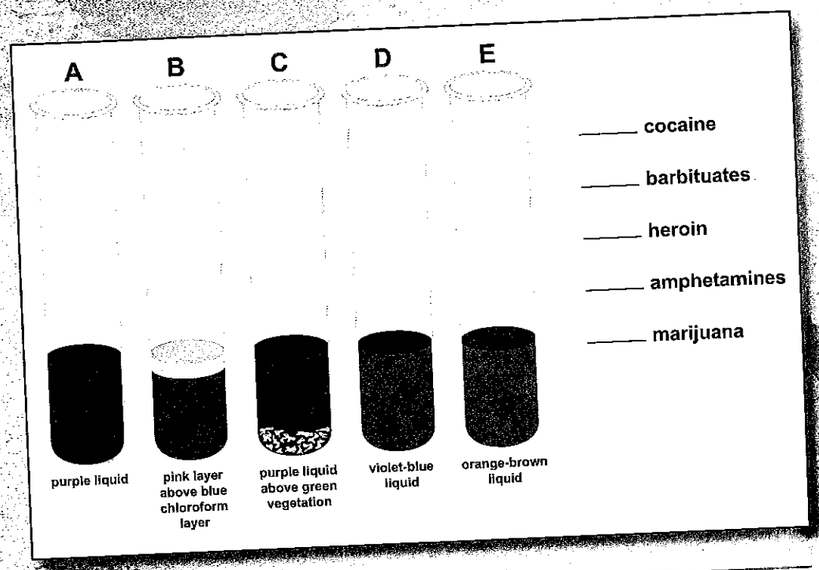
4. A police officer stops a motorist who is driving erratically and notices a bag of white powder on the front seat of the car that he suspects contains heroin. The officer brings the bag to you, a forensic scientist in the local crime lab. Name one screening test that you might perform to determine the presence of heroin. Assuming the powder tests positive for heroin, what should you do next?

5. The figure below shows a chromatogram of a known mixture of barbiturates. Based on this figure, answer the following questions:

a. What barbiturate detected by the chromatogram had the longest retention time?
b. Which barbiturate had the shortest retention time?
c. What is the approximate retention time of amobarbital?



6. When investigating a potential warehouse for storing illegal drugs, the police collected a variety of drugs. The drugs were tested with presumptive color tests to determine their possible identity. The test tubes shown in the figure display the positive color tests. Match the drug on the right with the color test on the left and name the test.



Virtual Lab: Thin-Layer Chromatography

To perform a virtual thin-layer chromatography lab, go to www.pearsoncustom.com/us/vlm

Virtual Lab: Drug Identification

To perform a virtual drug identification, go to www.pearsoncustom.com/us/vlm

Endnotes

1. *Marijuana—A Signal of Misunderstanding* (Washington, D.C.: U.S. Government Printing Office, 1972), p. 56.
2. Field-test color kits for drugs can be purchased from various commercial manufacturers.
3. Powers of 10 are quite useful and simple for handling large or small numbers. The exponent expresses the number of places the decimal point must be moved. If it is positive, the decimal point is moved to the right; if it is negative, the decimal point is moved to the left. Thus, to express 1×10^{-9} as a number, the decimal point is simply moved nine places to the left of 1.