
Laboratory Manual

Preface

The goal of this laboratory manual is to provide the student with an enjoyable experience that is both informative and challenging. It is our hope that the thrill of “seeing” theoretical principles “come to life” in the laboratory will enhance your overall understanding, as well as stimulate and develop critical thinking skills. Although there has always been considerable debate over the most effective methods of instruction; many agree that lecture topics supported by practical exercises are a proven model to create a successful learning environment. We embrace the spirit of this model in the *Forensic Chemistry Laboratory Manual*. Our approach is to correlate laboratory exercises to the theoretical and investigative principles of forensic chemistry. This will provide the student with valuable hands-on experience while adding clarity and continuity to lecture topics. This laboratory manual was written within the framework of each of the following areas.

Level and Audience

The *Forensic Chemistry Laboratory Manual* covers the laboratory component of a one semester class in forensic chemistry. It is not designed to be a stand-alone laboratory manual. It was specifically written to complement *Basic Principles in Forensic Chemistry*, the required text for a one semester class offered as part of our forensic certificate program. The course requires no prerequisite and is designed for students with little, if any, background in chemistry or forensics. The laboratory exercises are designed to provide practical experience in forensic investigative techniques. Emphasis is on the development of proper technique, handling of evidence, and interpretation of data and results. Although there is brief exposure to more sophisticated chemical principles, it is not the main focus of the manual. It is possible to perform complex procedures and reliably interpret results without an in-depth understanding of the complex reaction mechanisms involved.

Forensic Investigation

Investigative techniques are developed using evidence and test results from actual case studies. Students learn to exercise due diligence in the formulation of hypotheses, preparation of courtroom testimony, and presentation of results. “Moot” courts are used to develop proper courtroom demeanor, i.e., giving testimony, presenting evidence, jury interaction, etc. In addition, students are exposed to proper format and writing techniques typically used in the submission of case reports.

Stockroom Preparation

It was important to develop experiments that require chemicals and laboratory equipment that is both inexpensive and readily available.

Safety

Forensic chemical analysis is often performed by highly trained scientists in a controlled environment. Consequently, a few procedures used in forensic investigation have been intentionally omitted. These omissions may be based on reagent cost or availability, lack of analytical instrumentation or specialized glassware, or safety concerns when working with potentially dangerous chemicals. In these few cases, data and/or test results are provided for interpretation and presentation purposes only. Strict adherence to all safety procedures is highly stressed.

To The Student

We wish you success as you begin your journey into forensic chemistry. This manual was specifically designed to illustrate principles and techniques commonly used in forensic investigation. All too often, students fail to realize (or appreciate) the importance of practical laboratory experience and its relationship to theoretical principles. Lost in the topics presented in lecture are the long hours scientists spend in the laboratory developing and proving these theories. As you perform the experiments in this manual, you will learn proper experimental technique and develop an appreciation of the correlation that exists between theory and practice. We hope that your laboratory experience is enjoyable and informative.

Strict adherence to safety procedures will create a relatively safe and hazard free laboratory environment. It is the responsibility of each student to contribute to this safe environment by following all safety rules and regulations. The following list of safety procedures should be followed at all times. Your laboratory may have specific safety rules and practices, in addition to those below, that will be thoroughly explained by your laboratory instructor.

Wear approved safety glasses or goggles at all times

If you have contact lenses, nonvented goggles are required.

Prepare for lab

Read the experiment carefully and be aware of potential hazards before coming to lab.

Dress for lab

No loose fitting cloths, no shorts, no open-toed shoes, no tank tops. Tie long hair back to prevent contact with an open-flame. Lab coats or aprons are highly recommended and may be available in lab.

No food or drinks are allowed in the laboratory

Chemicals may adhere to food or liquids and may cause illness. If you take a break to eat, wash your hands thoroughly.

Know the location and proper use of all safety equipment

Survey the lab and locate all exits, safety showers, fire extinguishers, fire blankets, eye wash facilities, emergency gas shut-off valves, emergency phones, etc.

No unauthorized experiments

Closely follow the instructions given in this manual. Do not deviate from the procedures or techniques explained.

Practice proper laboratory behavior at all time

Do not take unnecessary risks. Playing or "horsing around" in lab will not be tolerated and will result in your expulsion.

Handle all chemicals properly

Never taste chemicals or inhale chemical vapors.

Avoid direct contact of chemicals with skin.

Never pour excess chemicals back into the original container.

Your instructor will advise you in the proper disposal of waste material.

Keep your work area neat and organized

Do not clutter your work area with excessive chemicals, glassware, and books.

Smoking is not permitted in the laboratory

Report all accidents to your instructor

Report all accidents, no matter how small, to your laboratory instructor. This information may be used to further develop and/or refine existing safety procedures.

If you have questions ASK YOUR INSTRUCTOR

Your instructor is a trained professional who is very familiar with the procedures performed in each experiment. If you have questions or require clarification, do not hesitate to ask.

The above represents a list of minimum safety precautions that should be followed to create a safe laboratory environment. Following these procedures will not guarantee a safe, accident-free environment, nor are they intended to represent a complete list of all safety rules and regulations. The possibility of accident and/or injury is always present in the lab; however, strict adherence to proper safety procedures at all times will minimize the risk for such occurrences.

Laboratory Manual Table of contents

Experiment	Topic
1	Introduction and Safety
2	Forensic/Scientific Investigation and Atomic Structure
3	Properties of Elements
4	Mixtures and Compounds
5	Chemical Formulas and Nomenclature
6	Solubility
7	Molecular Geometry
8	Organic Chemistry and Functional Groups
9	Microcrystallography
10	Chemical Extraction
11	Chromatography
12	Interpretation of GCMS Spectra
13	IR Spectroscopy
14	Examination of Marijuana (moot)
15	Examination of Controlled Substances: Primary and Secondary Amines (moot)
16	Examination of Controlled Substances: Tertiary Amines and Opiates (moot)
17	Examination of Controlled Substances: Tryptamines (moot)
18	Examination of Anabolic Steroids (moot)
19	Examination of Miscellaneous Controlled Substances (moot)
20	Clandestine Manufacturing of Methamphetamine (moot)

Experiment # 2

Name _____

Forensic/Scientific Investigation and Atomic Structure

Reference: Chapters 1 and 2

Objectives: Students will gain practical experience using the scientific method to develop conclusions. Students will become familiar with atomic structure and writing electron configurations for ground state neutral atoms and ions.

Introduction:

Scientific discoveries are usually the result of a systematic approach to a good idea or an unexplained observation. Although many variations of this “systematic” approach exist, it often involves a stepwise process called the *scientific method*. The *scientific method* is a procedure used to develop technical theories and generally includes four phases; *observation, hypothesis, experimentation, and theory*. It begins with the observation of some type of unexplained phenomenon. A possible cause of the observation is proposed during the hypothesis phase. Experiments are then specifically designed in order to prove the hypothesis. If experimental results do not support the hypothesis another possibility is considered and tested. If experimental results confirm the hypothesis, and are consistently reproducible, a formal explanation is developed and subsequently offered as a theory. The theory is then presented to the scientific community where it may be accepted or rejected. If accepted, it may become a *principle* or a *law*.

Part: A: Forensic/ Scientific Investigation

Observation: Different types of cell phone ring tones.

Hypothesis: No cell phones are currently set to identical ring tones

Experiment: Each student that has a cell phone will play their ring tone. Record the results.

Theory:

Part B: Atomic Structure

Complete the following table

Symbol	# Protons	# Neutrons	# Electrons	Atomic Mass
H				1
	19		19	
K ⁺				39
B		6		11
	5		2	
Cl			17	
Cl ⁻	17			

Part C: Electron Configuration

Write the electron configuration for each of the following.

Mg (atomic mass = 24)

Mg²⁺ (atomic mass = 24)

C (atomic mass = 12)

N³⁻ (atomic mass = 14)

Ca (atomic mass = 40)

Cl⁻ (atomic mass = 35.45)

H (atomic mass = 1)

Experiment # 3

Name _____

Properties of Elements

Reference: Chapter 3

Objectives: Students will distinguish the difference between a chemical property and a physical property. Students will gain practical experience in the use of properties to identify elements and compounds.

Materials: 1M hydroiodic acid (HI), 1M hydrochloric acid (HCl), 0.3M hypophosphorous acid (H_3PO_2), 0.5M sulfuric acid (H_2SO_4), 1M acetic acid ($\text{HC}_2\text{H}_3\text{O}_2$), 3% silver nitrate solution (AgNO_3), 1% iodine solution in water, chloroform (CHCl_3), starch (sugar), sodium nitrite (NaNO_2), test tubes, matches, and wax pencils.

Introduction:

There are fundamental properties associated with all forms of matter. These *distinguishing characteristics* may be physical or chemical in nature, and are commonly used to identify and classify a particular substance. A *physical property* is anything that can be measured or observed without changing chemical composition. The melting point and boiling point of water are examples of physical properties because these temperatures can be measured without changing the chemical composition of water. A *physical change* is a change in the state of matter, but not its chemical composition. There are three accepted states of matter; solid, liquid, and gas (although some would argue *plasma* is also a state). Other physical properties commonly used in the forensic identification of elements and compounds are: color, odor, density, solubility, conductivity, and sublimation.

Chemical properties are a measure of the ability of a substance to produce new substances, or simply, a measure of the reactivity of a substance. *Chemical changes* are transformations that produce products chemically and physically different from the starting material. A solution containing silver nitrate will produce a white precipitate (solid) in the presence of chloride ions and a yellow precipitate in the presence of iodide ions. These observations illustrate the chemical changes that result from the reactivity (chemical properties) of silver nitrate. Physical and chemical properties are commonly used to identify elements and compounds in the field of forensic science. Consequently, these properties may be used to support or reject specific parts of an investigation.

Part A:

Clean five test tubes and label each with the name of an acid shown below. Place 10 drops (approx. $\frac{1}{2}$ ml) of the corresponding acid into each of the labeled test tubes. Add 1–2 drops of 3% silver nitrate solution (AgNO_3) to each test tube and observe the results. If a precipitate (solid) forms, record the color below next to the corresponding acid. If no precipitate is observed, write “none.”

Acid	Color of Precipitate
Hydroiodic acid	_____
Hydrochloric acid	_____
Hypophosphorous acid	_____
Sulfuric acid	_____
Acetic acid	_____

Conclusion:

Part B:

Strike a matchstick on the following surfaces and record your observations.

Nature of Surface	Ignite (yes/no)
Wood	
Cement	
Metal	
Plastic	
Paper	
Course sandpaper (matchbox)	

Conclusion:**Part C:**

Clean three test tubes and label each with a reagent shown below. Place ten drops (approx. $\frac{1}{2}$ ml) of 1% iodine solution in each test tube and add the corresponding reagent. Record your observations.

Reagent	Add	Observation
Starch	Approx. "½ pea size" of starch	
Chloroform	1 ml chloroform	
Acetic acid	1 ml acetic acid	

Conclusion:

Experiment # 4

Name _____

Mixtures and Compounds

Reference: Chapters 1, 2, and 3

Objective: Students will observe common properties of mixtures and compounds.

Materials: methanol, DI water, sugar, salt, analytical balance, watch glass, and oven.

Introduction:

Elements and compounds may exist as pure substances or as mixtures. *Pure substances* contain only one component and have the same composition throughout, i.e., pure gold, pure sugar, pure water, etc. *Mixtures* contain two or more pure substances and may be homogeneous or heterogeneous. *Homogeneous mixtures* have the same composition and properties throughout. However, they are not pure substances because they contain more than one component. *Heterogeneous mixtures* have distinctly different properties within the mixture; water and sand would be an example. In any *binary solution* (a solution that contains only two components), the *solvent* is the component present in greatest amount and the *solute* is the component present in least amount.

The following mixtures will be provided. Classify each mixture by circling homogeneous or heterogeneous.

Solution #1	Sugar in water (sat.)	homogeneous or heterogeneous
Solution #2	Salt in water (sat.)	homogeneous or heterogeneous
Solution #3	Sugar in methanol (sat.)	homogeneous or heterogeneous
Solution #4	Salt in methanol (sat.)	homogeneous or heterogeneous

Part A:

Clean and dry four watch glasses and label each 1, 2, 3, or 4. Weigh each empty watch glass on an analytical balance and record the mass in the table below under “watch glass.” Be sure to weigh the watch glasses after they are labeled! Place 1.0 ml of the corresponding solutions above on each of the labeled watch glasses, i.e., place 1.0 ml of solution #1 on watch glass labeled 1, etc. Using the same analytical balance that was used to weigh the empty watch glasses, carefully weigh the watch glasses containing each solution. Determine the mixture mass for each solution by subtracting the mass of the empty watch glass from the mass of the watch glass containing solution. Record the mass of each mixture in the table below under “mixture mass.” Save the watch glasses containing each solution for Part B. Clean and dry two small test tubes and place one test tube into a small beaker. Place the test tube/beaker on the analytical balance and *tare* the balance (zero the balance with the test tube/beaker on the pan). Place 1.0 ml of water into the test tube and record the mass in the table below under Solvent Mass for water. Repeat the procedure using the other test tube and 1.0 ml of methanol. Record the mass below under Solvent Mass for methanol (water is the solvent in solutions 1 and 2, methanol is the solvent in solutions 3 and 4). Subtract the solvent mass from the mixture mass and record the difference in the table below under “solute mass.”

Watch Glass	Mixture Mass	Solvent Mass	Solute mass
#1-		Water-	
#2-		Water-	
#3-		Methanol-	
#4-		Methanol-	

What is the mass of sugar in mixture #1?

What is the mass of salt in mixture #2?

What is the mass of sugar in mixture #3?

What is the mass of salt in mixture #4?

Did the mixture mass exceed the solvent mass in any solution? If so, explain.

Did the solvent mass exceed the mixture mass in any solution? If so, explain.

Did the solvent mass equal the mixture mass in any solution? If so, explain.

Explain your observed results using your knowledge of homogeneous and heterogeneous mixtures.

Part B:

Carefully place the watch glasses containing each solution in the oven and evaporate the solvent to dryness. When evaporation is complete, weigh each watch glass and record the mass in the table below under “watch glass/residue.” Determine the mass of the residue by subtracting the mass of the empty watch glass (measured in Part A) from the mass of the watch glass/residue. The residue is the actual mass of solute contained in each solution. Record the residue mass in the table below under “solute mass (actual).”

Watch Glass/Residue	Solute Mass (actual)
_____	_____
_____	_____
_____	_____

What is the actual mass of sugar in mixture #1?

What is the actual mass of salt in mixture #2?

What is the actual mass of sugar in mixture #3?

What is the actual mass of salt in mixture #4?

Conclusion: (Hint: Definition of solution; did any of the 1.0 ml solutions actually contain 1.0 ml of solvent?)

Experiment # 5

Name _____

Chemical Formulas and Nomenclature

Reference: Chapters 2 and 3

Objective: Students will gain experience writing chemical formulas for ionic compounds. Students will learn formal procedures used to name ionic and covalent compounds.

Introduction:

Substances are either elements or compounds. A *compound* is a substance that consists of two or more elements bonded together in a specific way. The forces that hold atoms together in a compound are called *chemical bonds*. An *ionic bond* involves the *transfer* of electrons from a *metal* to a *nonmetal*. A *covalent bond* consists of a pair of electrons *shared* between two *nonmetals*.

Ions and the Octet Rule

Atoms are electrically neutral because they have an equal number of electrons and protons. An atom can be converted into a charged particle called an *ion* by losing or gaining one or more electrons. The loss of electron(s) from a neutral atom produces a *positively* charged ion called a *cation* (pronounced cat-ion). The gain of electron(s) by a neutral atom produces a *negatively* charged ion called an *anion* (pronounced an-ion).

Generally, the charge on an ion can be predicted from the position of the element on the periodic table. The metals (on the left-hand side of the table) lose electrons to form cations. The Group IA elements lose ONE electron to achieve an octet and take a charge of 1 positive. This is correctly written using a superscript “+” attached to the upper right side of the elemental symbol, i.e., Na⁺. Notice that the number “1” is *not* written when the cation carries a positive *one* charge. The Group IIA elements lose TWO electrons and take a charge of 2 positives. This is correctly written using a superscript “2+” attached to the upper right side of the elemental symbol, i.e., Mg²⁺. When cations carry a charge greater than one, the number is written first, followed by the sign. The Group IIIA elements lose THREE electrons and take a charge of 3 positives which is written as a superscript “3+”, i.e., Al³⁺.

The nonmetals (on the right-hand side of the table) gain electrons to form anions. The Group VIIA elements gain ONE electron to achieve an octet and take a charge of 1 negative. This is written using a superscript “-“ attached to the elemental symbol, i.e., Cl⁻. Once again, the “1” is *not* written. The Group VIA elements gain TWO electrons and take a charge of 2 negatives which is written as a superscript “2-“, i.e., O²⁻. The Group VA elements gain THREE electrons and take a charge of 3 negatives which is written as superscript “3-“, i.e., N³⁻. Some transition metals and metals in Group IVA have variable charges (more than one positive ion is possible). See table below.

Some common ions and their location on the periodic table.

IA	IIA										IIIA	IVA	VA	VIA	VIIA	
H ⁺																
Li ⁺	Be ²⁺												N ³⁻	O ²⁻	F ⁻	
Na ⁺	Mg ²⁺										Al ³⁺		P ³⁻	S ²⁻	Cl ⁻	
K ⁺	Ca ²⁺					Fe ²⁺	Co ²⁺	Ni ²⁺	Cu ⁺	Zn ²⁺						Br ⁻
						Fe ³⁺	Co ³⁺		Cu ²⁺							
Rb ⁺	Sr ²⁺								Ag ⁺			Sn ²⁺				I ⁻
												Sn ⁴⁺				
Cs ⁺	Ba ²⁺									Hg ₂ ²⁺		Pb ²⁺				
										Hg ²⁺		Pb ⁴⁺				

Writing Formulas for Ionic Compounds

Ionic compounds are electrically neutral. Therefore, when writing formulas, the cations (positive) and anions (negative) must combine to produce a net charge of zero. In the formula, the cation (metal) is always written first, followed by the anion (nonmetal). The number and types of each element must be clearly shown in the formula; the type of element is indicated using the elemental symbol, and the number of each element is indicated using a subscript attached at the lower right side of the symbol. The number “1” is not written in cases requiring only a single element. Formulas for ionic compounds are called *formula units*.

The correct ratio required to produce a net charge of zero when Na^+ ions combine with Cl^- ions is one to one because one Na^+ cancels one Cl^- . Therefore, the formula is NaCl . Notice this is not written Na_1Cl_1 .

The correct ratio when Na^+ ions combine with O^{2-} ions is two to one because two Na^+ are required to cancel one O^{2-} . The 2 atoms of Na are indicated in the formula using a subscript “2” directly attached to Na. The formula is Na_2O .

The correct combining ratio when Na^+ ions and P^{3-} ions combine is: Na_3P (three to one).

Practice Examples:

Write the formula for the ionic compound that is formed when each of the following pairs of ions interact:

- K^+ and S^{2-}
- Mg^{2+} and O^{2-}
- Ca^{2+} and I^-
- Li^+ and N^{3-}
- Al^{3+} and S^{2-}

Solution

- (a) The cation has a charge of 1+ because K is a member of Group IA. The anion has a charge of 2- because S is member of Group VIA. Thus, two positive ions (2+) are required for each negative ion (2-) to produce an electrically *neutral* formula unit.

The formula is K_2S .

- (b) The cation has a charge of 2+ and anion has a charge of 2-. The ratio is 1:1. The formula is MgO .
- (c) The cation has a charge of 2+ and anion has a charge of 1-. Two negative ions are required for each positive ion. The formula is CaI_2 .
- (d) The cation has a charge of 1+ and anion has a charge of 3-. Three positive ions are required for each negative ion. The formula is Li_3N .
- (e) The cation has a charge of 3+ and anion has a charge of 2-. Two positive ions are required for three negative ions. Here, the lowest common factor of 3+ and 2- is 6 (without sign). The formula is Al_2S_3 .

Naming Ions

The names of cations and anions are determined by a system developed by the International Union of Pure and Applied Chemistry (IUPAC).

Metals That Form Only One Type of Positive Ion

Elements in Groups IA, IIA, IIIA, and some transition elements form only one type of cation. For these ions, the name of the cation is the elemental name of the metal followed by the word “ion.” Cations can now be differentiated from their corresponding neutral forms using specific names. For example, K is potassium (neutral form) and K^+ is potassium ion (cationic form).

Na^+	sodium ion	K^+	potassium ion	Mg^{2+}	magnesium ion
Al^{3+}	aluminum ion	Ag^+	silver ion	Zn^{2+}	zinc ion

Metals That Form Two Different Positive Ions

Metals in Group IVA, and most transition metals, form more than one type of cation and the charge must be included in the name. For these ions, the name of the cation is the elemental name of the metal followed by a Roman numeral in parentheses, *with no space* after the name. The Roman numeral indicates the positive charge on the ion. Technically, the names do not end with the word “ion,” although some still prefer to include it.

Sn ²⁺	tin(II)	Sn ⁴⁺	tin(IV)
Pb ²⁺	lead(II)	Pb ⁴⁺	lead(IV)
Cu ⁺	copper(I)	Cu ²⁺	copper(II)
Fe ²⁺	iron(II)	Fe ³⁺	iron(III)
Co ²⁺	cobalt(II)	Co ³⁺	cobalt(III)
Hg ₂ ²⁺	mercury(I)	Hg ²⁺	mercury(II)

Naming Anions

Anions are named by replacing the last part of the elemental name with the suffix *-ide*, and adding the word “ion”. Anions can now be differentiated from their corresponding neutral forms using specific names. For example, S is sulfur (neutral form) and S²⁻ is *sulfide* (anionic form).

F ⁻	fluoride ion	Cl ⁻	chloride ion	Br ⁻	bromide ion	I ⁻	iodide ion
O ²⁻	oxide ion	S ²⁻	sulfide ion	N ³⁻	nitride ion	P ³⁻	phosphide ion

Polyatomic Ions

A *polyatomic ion* is an ion that contains two or more elements. It is recommended that you memorize the names and formulas of the following polyatomic ions:

NH ₄ ⁺	ammonium	SO ₃ ²⁻	sulfite
CN ⁻	cyanide	SO ₄ ²⁻	sulfate
OH ⁻	hydroxide	HSO ₃ ⁻	hydrogen sulfite
C ₂ H ₃ O ₂ ⁻	acetate	HSO ₄ ⁻	hydrogen sulfate
CrO ₄ ²⁻	chromate	PO ₃ ³⁻	phosphite
Cr ₂ O ₇ ²⁻	dichromate	PO ₄ ³⁻	phosphate
MnO ₄ ⁻	permanganate	HPO ₄ ²⁻	hydrogen phosphate
NO ₂ ⁻	nitrite	ClO ⁻	hypochlorite
NO ₃ ⁻	nitrate	ClO ₂ ⁻	chlorite
CO ₃ ²⁻	carbonate	ClO ₃ ⁻	chlorate
HCO ₃ ⁻	hydrogen carbonate	ClO ₄ ⁻	perchlorate

The common name for HCO₃⁻, HSO₃⁻, and HSO₄⁻ are bicarbonate, bisulfite, and bisulfate respectively.

Naming Ionic Compounds

Binary ionic compounds containing metals that form only one type of positive ion

These compounds contain only *two types* of elements; a metal ion and a nonmetal ion. Note: binary refers to element types, not total number of atoms. For example; MgBr₂ contains 3 total atoms, 1 Mg and 2 Br's, but it contains only two types, Mg and Br. Also, recall all elemental symbols begin with capital letters, if you have a binary compound, your formula contains only two capital letters. The metal is always named first using the elemental name of the metal. The nonmetal is named second using the anionic name of the nonmetal (elemental name modified with the suffix *-ide*).

Practice Examples:

Name the following binary ionic compounds:



Solution

NaCl	sodium chloride	K ₂ S	potassium sulfide
MgBr ₂	magnesium bromide	SrF ₂	strontium fluoride
AlP	aluminum phosphide	ZnI ₂	zinc iodide

Binary ionic compounds containing metals that form two different positive ions

These compounds are essentially named using the same procedure developed for metals forming only one type of cation. The distinction is that the charge on the cation must be written as a Roman numeral in parentheses immediately after (with no space) the metal name.

Practice Examples:

Name the following binary ionic compounds:

**Solution**

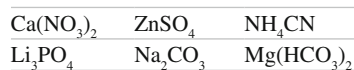
FeBr ₃	iron(III) bromide	PbI ₄	lead(IV) iodide
CoF ₂	cobalt(II) fluoride	HgS	mercury(II) sulfide
SnO	tin(II) oxide	Cu ₃ P	copper(I) phosphide

Ionic compounds containing polyatomic ions

Identifying compounds containing polyatomic ions is somewhat simplified by the fact that all elemental symbols begin with capital letters. If you identify more than two capital letters in the formula, your compound contains a polyatomic ion that you must immediately recognize (the value of memorizing!). Naming these compounds is simply based on your familiarity with the polyatomic ions. The cation is named first using its elemental name, followed by the name of the polyatomic ion.

Practice Examples:

Name the following polyatomic ionic compounds:

**Solution**

Ca(NO ₃) ₂	calcium nitrate
ZnSO ₄	zinc sulfate
NH ₄ CN	ammonium cyanide
Li ₃ PO ₄	lithium phosphate
Na ₂ CO ₃	sodium carbonate
Mg(HCO ₃) ₂	magnesium hydrogen carbonate

Compounds containing only nonmetals (molecular compounds)

This type of compound contains covalent bonds, so the concept of cations and anions is somewhat obscure and does not necessarily apply. Regardless, they are essentially named using the previously developed procedure for naming binary compounds containing a metal. The first element is named using its elemental name and the second is named using its anionic name. The difference is the use of Greek prefixes attached to each name, which indicate the number of each element present in the formula. There is one important exception; the prefix “mono” is never attached to the name of the first element in the formula. Let us look at SF₆ as an example. You should immediately notice that S and F are nonmetals because both are located in the nonmetal section of the periodic table (right side). This observation should immediately trigger “prefixes” in your mind. SF₆ is sulfur hexafluoride because the formula indicates one sulfur (note the absence of the subscript “1” attached to S) and 6 fluorides (subscript 6 attached to F). This is not monosulfur hexafluoride because “mono” is never used with the first element. It is possible, however, to attach all other prefixes to the name of the first element, i.e., N₂O₅ is dinitrogen pentoxide. The Greek prefixes are listed below, note that all end in a vowel. When the prefix ends with an “a” or “o”, and the elemental name begins with an “a” or “o”, the vowel of the prefix is usually dropped to simplify pronunciation. Notice in our N₂O₅ example above, the name of the anion is pentoxide, not pentaoxide.

Greek prefixes

1 (mono-)	2 (di-)	3 (tri-)	4 (tetra-)	5 (penta-)
6 (hexa-)	7 (hepta-)	8 (octa-)	9 (nona-)	10 (deca-)

Practice Examples:

Name the following binary molecular compounds:



Formula	Name
BaSO ₄	_____
Sn(NO ₃) ₂	_____
AgClO ₃	_____
Cu(HSO ₃) ₂	_____

Molecular Compounds

Name each of the following compounds.

Formula	Name
BBr ₃	_____
Br ₃ O ₈	_____
Cl ₄	_____
C ₃ O ₂	_____
Cl ₂ O ₇	_____
IF ₅	_____
I ₂ O ₅	_____
NCl ₃	_____
N ₂ O ₅	_____
OF ₂	_____
P ₄ S ₃	_____
P ₄ S ₉	_____
P ₄ O ₁₀	_____
SF ₆	_____
S ₂ Cl ₂	_____
SiS ₂	_____
SiBr ₄	_____
XeF ₂	_____
XeO ₄	_____
XeF ₆	_____

Experiment # 6

Name _____

Solubility

Reference: Chapter 3

Objective: Students will test the solvent properties of various liquids to observe and understand the chemical nature of solubility and miscibility.

Materials: acetone, chloroform, ammonia, methanol, water, test tubes, and pipettes.

Introduction:

Water is a common solvent in many solutions and substances like salt and sugar readily dissolve in water. Any substance that dissolves appreciatively in a specified solvent is said to be *soluble* in that solvent. Technically, the term *solubility* refers to a quantitative maximum amount of substance that can dissolve in a given volume of solvent at a specific temperature. The ability of a substance to dissolve in a particular solvent depends on the identity of both the solvent and the substance; the general rule is “likes dissolve likes.” Water is a polar covalent molecule and, as a solvent, can dissolve similar molecules (polar covalent). The polarity of water is responsible for its remarkable solvent properties and explains why ionic compounds (i.e., NaCl) and polar covalent compounds (i.e., sucrose, ammonia) are soluble, whereas nonpolar molecules (i.e., organic, gasoline, oils) are not. Terms such as soluble, slightly soluble, insoluble, and solubility are used to describe the ability of a substance to dissolve in a solvent. Intuitively, we associate the term “dissolving” with solids and liquids; however, a liquid may also be soluble in another liquid. For example, when 25.0 ml of ether is added to 25.0 ml of water, the resulting total volume is not 50.0 ml, in fact, it is slightly less (approx. 48.5 ml). This is the result of solubility; ether and water are slightly soluble in one another and consequently, the volumes are not additive. The solubility of one liquid in another is difficult to determine and is usually not readily observed upon mixing. For this reason, liquids are often characterized using *their ability to mix with other liquids* rather than their *solubility* in other liquids. The degree of mixing between two liquids is described using the terms *miscible* and *immiscible*. Two liquids are miscible (soluble) if a uniform solution results after mixing (i.e., water and ammonia). Two liquids are immiscible (insoluble) if two distinct layers form after mixing (i.e., oil and water). Water is miscible in polar liquids and immiscible in nonpolar (organic) liquids.

Part A:

Add 1.0 ml of each of the following reagents to four separate, clean, and dried test tubes: chloroform, ammonia, methanol, water. Add 1.0 ml of acetone to each test tube and mix. Observe the results and characterize the liquids as miscible (**M**) or immiscible (**I**). Record your results in the table below under the corresponding reagents. Clean and dry three test tubes and add 1.0 ml of each of the following reagents to separate test tubes: ammonia, methanol, water. Add 1.0 ml of chloroform to each test tube and mix. Record your results in the table below under the corresponding reagents. Clean and dry two test tubes and add 1.0 ml of each of the following reagents to separate test tubes: methanol, water. Add 1.0 ml of ammonia to each test tube and mix. Record your results in the table below under the corresponding reagents. Clean and dry one test tube and add 1.0 ml of methanol and 1.0 ml of water to the test tube and mix. Record your results in the table below under the corresponding reagents.

Reagents	Chloroform	Ammonia	Methanol	Water
Acetone				
Chloroform	-----			
Ammonia	-----	-----		
Methanol	-----	-----	-----	

Identify the organic liquids:

Identify the inorganic liquids:

What liquids are polar?

What liquids appear to be non-polar?

List the liquid-pairs that are miscible:

List the liquid-pairs that are immiscible:

Are immiscible liquids soluble in one another? Briefly explain.

Are miscible liquids soluble in one another? Briefly explain.

Experiment # 7

Name _____

Molecular Geometry

Reference: Chapter 3**Objective:** To illustrate the geometric structures of simple molecules and to demonstrate the relationship between bonding and molecular geometry.**Materials:** Molecular model kits.**Introduction:**

In recent years, advancements in research and technology have provided precise information on molecular geometry, i.e., bond distances, angles, and energies. Structural theory has advanced far beyond the simple electron dot representation and now rests securely on the foundations of quantum and wave mechanics. Although problems involving only simple molecules can be solved through rigorous mathematical calculations, approximations such as Valence Bond Theory (VBT) and Molecular Orbital Theory (MOT) are very successful in providing results that agree favorably with experimental measurements. This exercise will utilize Valence Bond Theory to illustrate the geometry of a variety of simple molecules. This will be accomplished through the use of model kits that show the correct angles formed between atoms in the molecule. The first covalent bond formed between any two atoms is always a sigma-bond (σ -bond). This type of bond has electrons distributed symmetrically about the bond axis and is used to define the bond axis. Additional bonds (double or triple) formed between the same two atoms will be pi-bonds (π -bonds). These bonds are perpendicular to the defined σ -bond and do not influence geometry. It is the σ -bonds, and any lone pairs of electrons occupying sigma hybrid orbitals, that determine molecular geometry.

Model kits are a necessary and integral part of the study of molecular geometry. They are tools that allow students to transcend the inherent difficulties that arise from visualizing a three dimensional structure on a two dimensional piece of paper. A complete understanding of the capabilities and limitations of model kits is essential in their successful use as a visual aid. Open your model kits and carefully read the instructions. Inventory the various pieces contained in your kit and pay special attention to the color codes used to designate specific atoms. It is important that you take the time now to familiarize yourself with all the components contained in your kit. This will allow you to concentrate on the structure or concept currently under study and prevent wasted time (and confusion) that may result from constantly referring back to the instructions. A table is included at the end of the lab for reference.

Methane (CH₄)

Construct a model of methane using your model kit. Locate a tetrahedral center (a carbon atom) and attach four rods (bonds) in each hole of the atom. Attach 4 balls (hydrogen atoms) of the same color to each rod extending from your structure.

Sketch the model using the solid/dashed wedge convention and name the geometry.

Write the structural formula.

Write the condensed structural formula.

What are the H–C–H bond angles? _____

How many σ -bonds are on the central carbon? _____

Identify the two planes present in this molecule. Do the planes divide the molecule into equal halves? _____

How many atoms, including carbon, are in the same plane? _____

Ammonia (NH₃)

Construct a model of ammonia using your model kit.

Sketch the model, including the lone pair of electrons, and name the geometry.

Write the structural formula.

Write the condensed structural formula.

What is the H–N–H bond angle? _____

How many σ -bonds are on the central nitrogen? _____

How many lone pairs are on the central nitrogen? _____

Are any atoms in ammonia in the same plane? _____

Suggest a reason why the H–N–H bond angles in ammonia differ from the H–C–H bond angles observed in methane.

Water (H₂O)

Construct a model of water using your model kit.

Sketch the model, including lone pairs of electrons, and name the geometry.

Write the structural formula.

Write the condensed structural formula.

What is the H–O–H bond angle? _____

How many σ -bonds are on the central oxygen? _____

How many lone pairs are on the central oxygen? _____

How many atoms, including oxygen, are in the same plane? _____

Why is the H–O–H bond angle slightly smaller than the bond angles observed in ammonia and methane?

What conclusions can be made on how lone pairs affect molecular geometry?

Sulfur Hexafluoride (SF₆)

Construct a model of sulfur hexafluoride using your model kit.

Sketch the model and name the geometry.

Write the structural formula.

Write the condensed structural formula.

What are the F–S–F bond angles? _____

How many σ -bonds are on the central sulfur? _____

How many lone pairs are on the central sulfur? _____

How many atoms, including sulfur, are in the same plane? _____

Carbon Dioxide (CO₂)

Construct a model of carbon dioxide using your model kit.

Sketch the model and name the geometry.

Write the structural formula.

Write the condensed structural formula.


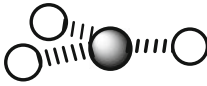
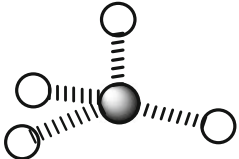
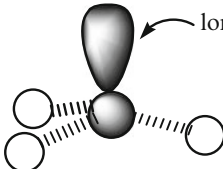
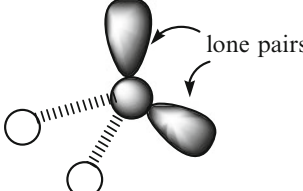
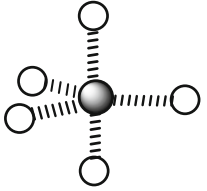
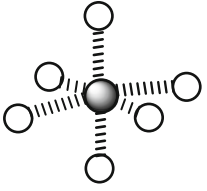
What is the O–C–O bond angle? _____

How many σ -bonds are on the central carbon? _____

How many π -bonds are on the central carbon? _____

How many lone pairs are on the central carbon? _____

How many atoms are in the same plane? _____

Lone pairs	Bonded atoms ^a	Geometry	Molecular Shape	Examples
0	2	Linear		$\text{Cl}-\overset{180^\circ}{\text{Be}}-\text{Cl}$ $\text{O}=\overset{180^\circ}{\text{C}}=\text{O}$
0	3	Trigonal Planar		$\text{F}-\overset{120^\circ}{\text{B}}-\text{F}$
0	4	Tetrahedral		$\text{H}-\overset{109.5^\circ}{\text{C}}-\text{H}$
1	3	Trigonal Pyramidal	 lone pair	$\text{H}-\overset{107^\circ}{\text{N}}-\text{H}$
2	2	Angular (bent)	 lone pairs	$\text{H}-\overset{104.5^\circ}{\text{O}}-\text{H}$
0	5	Trigonal Bipyramidal		$\text{F}-\overset{120^\circ}{\text{P}}-\text{F}$
0	6	Octahedral		$\text{F}-\overset{90^\circ}{\text{S}}-\text{F}$

^aTechnically this should read # of σ -bonds. A single bond contains 1 σ -bond and 0 π -bonds, double bonds contain 1 σ - and 1 π -bond, triple bonds contain 1 σ - and 2 π -bonds. Therefore, when counting bonded atoms to determine molecular geometry, count single bonds as 1, double bonds as 1, and triple bonds as 1. See CO_2 example above.

Experiment # 8

Name _____

Organic Chemistry and Functional Groups

Reference: Chapter 4

Objective: Students will gain experience in the basic recognition of functional groups present in a variety of organic molecules.

Materials: Molecular model kits.

Introduction:

Organic chemistry is the study of the properties, structure, and function of compounds containing carbon. Although the defining element in organic molecules is carbon, it is common practice to define them by the obligate presence of both carbon and hydrogen. This does not mean that organic molecules contain only carbon and hydrogen; elements such as nitrogen, oxygen, sulfur, phosphorous, and chlorine may also be present. The study of organic chemistry does not involve the individual study of the vast number of organic compounds. Instead, organic compounds are divided into broad classes based on the presence of a *functional group*. Functional groups are atoms, groups of atoms, or common structural features used to classify organic molecules. In general, functional groups will react in a unique, predictive manner and this chemical behavior is similar in all compounds containing a specific group. It is possible, and quite common indeed, to have more than one functional group on a single molecule. In these cases, the molecule will exhibit chemical and physical properties of all groups present. The study of functional groups is the most effective and efficient approach to the study of organic chemistry. A wide range of functional groups can be found on various types of controlled substances.

Part A:

Use model kits to construct the following molecules using their chemical formulas. Rotate each structure in space and observe the geometry from different perspectives. Compare the structures of different molecules and determine some factors that influence geometry, i.e., number and types of bonds present, bond orientation on central atom, number of atoms in the molecule, etc. Draw the structures of each molecule.

Alkanes:		
Name	Formula	Structure
Methane	CH ₄	
Ethane	C ₂ H ₆	
Propane	C ₃ H ₈	
Butane	C ₄ H ₁₀	

Alkenes:		
Name	Formula	Structure
Ethene	C ₂ H ₄	
Propene	C ₃ H ₆	
1-Butene	C ₄ H ₈	
2-Butene	C ₄ H ₈	

1-Butene and 2-Butene are positional isomers because they have the same molecular formula and differ only in the location of the double bond.

Alkynes:		
Name	Formula	Structure
Acetylene (Ethyne)	C_2H_2	
Propyne	C_3H_4	
1-Butyne	C_4H_6	
2-Butyne	C_4H_6	

Note: acetylene does not contain a double bond despite its "ene" ending.

Alcohols:		
Name	Formula	Structure
Ethanol	C_2H_5OH	
Propanol	C_3H_7OH	
Isopropanol (Isopropyl alcohol)	C_3H_7OH	
1-Butanol	C_4H_9OH	
2-Butanol	C_4H_9OH	

Aldehydes:		
Name	Formula	Structure
Formaldehyde (Methanal)	HCHO	
Acetaldehyde (Ethanal)	CH_3CHO	
Propanal	CH_3CH_2CHO	
Butanal	$CH_3CH_2CH_2CHO$	

Note: The location of the aldehyde functional group will always be carbon # 1.

Carboxylic Acids:		
Name	Formula	Structure
Formic Acid	HCOOH	
Acetic Acid (Ethanoic Acid)	CH_3COOH	
Propanoic Acid	CH_3CH_2COOH	
Butanoic Acid	$CH_3CH_2CH_2COOH$	

Others:		
Name	Formula	Structure
Chloroform	$CHCl_3$	
Benzene	C_6H_6	
Cyclohexane	C_6H_{12}	

Draw structures for the following:

1-bromo-2,2-dichloropentane

2-methyl-3-heptene

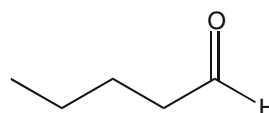
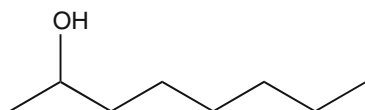
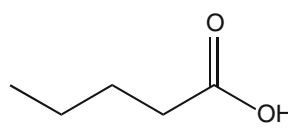
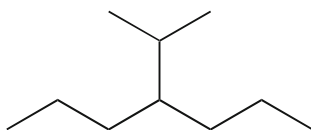
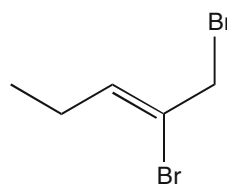
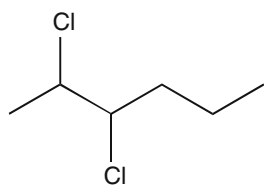
1-chloro-1-pentanol

3-isopropyloctane

3-methylbutanal

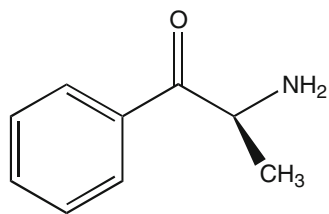
4-chloropentanoic acid

Name the following:

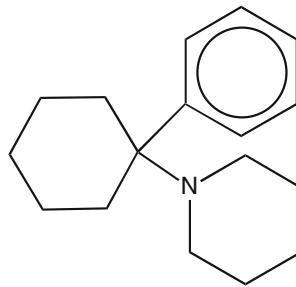


Part B:

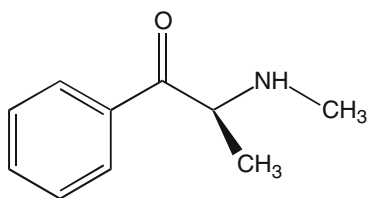
Circle and name all functional groups present in each of the following compounds. A table of functional groups is provided on the last page of the lab.



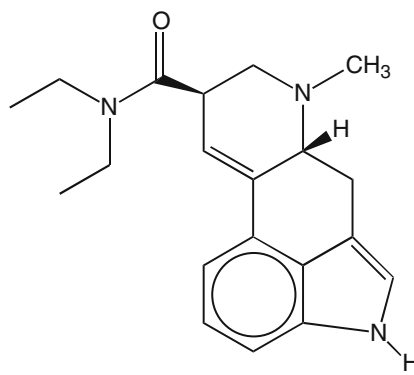
Cathinone



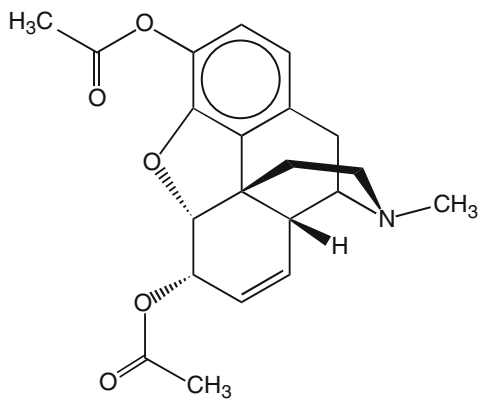
PCP



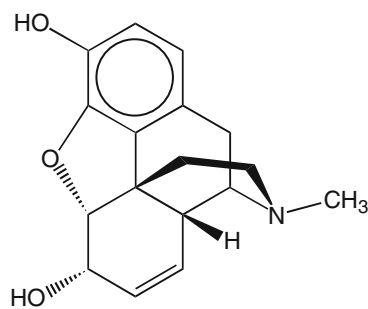
Methcathinone



LSD



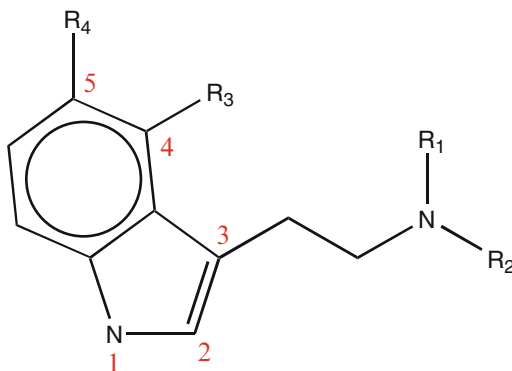
Heroin



Morphine

Part C:

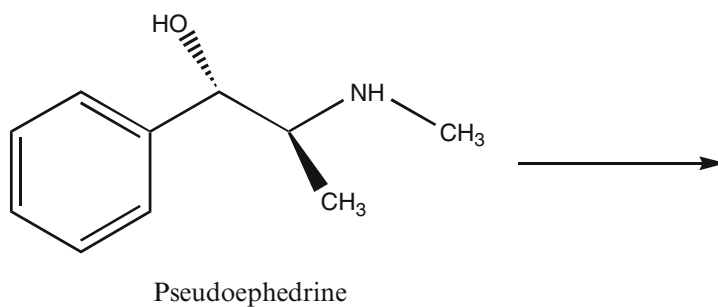
The structure below is tryptamine when all R-groups are hydrogen (H). Substitute the groups indicated in the table below for each corresponding "R" and name the resulting compounds (reference Chap. 15).

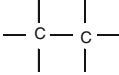

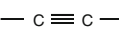








R ₁	R ₂	R ₃	R ₄	Name
H	H	H	H	Tryptamine
CH ₃	CH ₃	H	H	
CH ₃	CH ₃	H	OH	
CH ₃	CH ₃	OH	H	
CH ₃	CH ₃	PO ₄ ³⁻	H	
C ₂ H ₅	C ₂ H ₅	H	H	
CH ₃	CH ₃	H	OCH ₃	

Part D:

Use your model kit to construct pseudoephedrine as shown below. Replace the "OH" functional group with "H" and draw the resulting structure. Name the new compound (reference Chap. 13).



Class	Functional Group	IUPAC ending
Alkane		"-ane"
Alkene		"-ene"
Alkyne		"-yne"
Alcohol	$R-OH$	"-ol"
Ketone		"-one"
Aldehyde		"-al"
Carboxylic Acid		"-oic acid"
Ester		
Nitro Compounds	$R-NO_2$	
Amines	$R-NH_2$ 1°  2°  3°	"-amine"

Experiment # 9

Name _____

Microcrystallography

Reference: Chapter 8

Objective: Students will gain experience in the forensic identification of elements using microcrystalline technique.

Materials: Solid form and 5% solutions of the following: NH_4Cl , NaCl , LiCl , ammonium molybdate (AMM-hydrate or anhydrous), and NaOH .

5% solutions of the following: $\text{Mg}(\text{C}_2\text{H}_3\text{O}_2)_2$, $\text{Mg}(\text{NO}_3)_2$, Na_2HPO_4 and KMnO_4 (or alternatively, NaMnO_4).

Acids: 5M HCl and 5M HClO_4 (perchloric acid).

Others: KCl (solid), CaCO_3 (sat. solution), and MgO (sat. solution), Microscope, microscope slides, droppers.

Solutions: Prepare 5% (m/v) solutions by dissolving 5 g of solid in 100 ml total volume. Alternatively, methanol may be used as solvent, however water forms slightly more stable crystals. KMnO_4 should be prepared fresh. If NaMnO_4 is used instead of KMnO_4 , you will need to add a few drops of H_2SO_4 (5% v/v) to solution to increase solubility.

Part A:

Technique 1: Mount a slide on the microscope, place a few crystals of NaCl on the slide using a small spatula, and focus the solid in the microscope. Add a drop of Na_2HPO_4 solution directly on the solid and observe crystal formation using the microscope without mixing. Record your results below. Repeat with other solids and solutions listed below.

Solid	Solution	Crystals (Yes/No)	Sketch Crystals (if yes)
NaCl	Na_2HPO_4		
NaOH	$\text{Mg}(\text{NO}_3)_2$		
KCl	HClO_4		
AMM	HCl		
LiCl	KMnO_4		

Conclusion:

Part B:

Technique 2: Mount a slide on the microscope, place a drop of Na_2HPO_4 solution on the slide, and focus the drop in the microscope. Add a few crystals of NH_4Cl to the drop and, without mixing, observe crystal formation using the microscope. Record your results below. Repeat with other solutions and solids listed below.

Solids	Solutions	Crystals (Yes/No)	Sketch Crystals (if yes)
NH_4Cl	Na_2HPO_4		
NaOH	$\text{Mg}(\text{NO}_3)_2$		
KCl	HClO_4		
AMM	HCl		
LiCl	KMnO_4		

Conclusion:

Part C: Micro Test Technique

Technique 3: Mount a slide on the microscope, place a drop of solution-I on the slide and focus the drop in the microscope. Add a drop of solution-II to first drop and, without mixing, observe crystal formation using the microscope. Record your results below. Repeat with other solutions listed below.

Solutions-I	Solutions-II	Crystals (Yes/No)	Sketch Crystals (if yes)
NH_4Cl	Na_2HPO_4		
CaCO_3	$\text{Mg}(\text{C}_2\text{H}_3\text{O}_2)_2$		
MgO	HClO_4		
$\text{Mg}(\text{NO}_3)_2$	HCl		
MgO	KMnO_4		

Conclusion:

Part D: Macro Test Technique

Technique 4: Mount a slide on the microscope, place a drop of solution-I on the slide, and focus the drop in the microscope. Add a drop of solution-II to first drop and, without mixing, observe crystal formation using the microscope. Record your results below. Repeat with other solutions listed below.

Solution I	Solution II	Crystals (Yes/No)	Sketch Crystals (if yes)
NaOH	HClO_4		
NaCl	HClO_4		
AMM	Na_2HPO_4		
KMnO_4	Na_2HPO_4		
LiCl	Na_2HPO_4		

Conclusion:

Experiment # 10

Name _____

Chemical Extraction

Reference: Chapter 9

Objective: Students will gain practical experience using forensic extraction techniques to isolate solids from mixtures.

Materials: NaHCO₃ (sodium bicarbonate, saturated solution), 0.1 M HCl, starch, aspirin, acetaminophen, H₂SO₄ (concentrated), formaldehyde, 1% iodine solution acidified with glacial acetic acid, chloroform, hexane, vortex, spot plates, 5 ml test-tubes, droppers, and centrifuge.

Prepare a sample mixture containing 100 parts starch:1 part aspirin: 1 part acetaminophen, provide each group with a 1 g sample of the mixture.

Part I: Extraction:

- 1) Place about 0.25 g of sample in a 5 ml test tube labeled "A."
- 2) Add 1.0 ml (approx. 20 drops) of 0.1 M HCl.
- 3) Vortex the mixture and centrifuge.
- 4) Remove the top liquid using a dropper and place in a clean 5 ml test tube labeled "B." Be careful not to disturb the solid pellet at the bottom of test tube "A".
- 5) Save test tube "A" for Part-II.
- 6) Add a few drops of NaHCO₃ (sat.) to test tube "B" and vortex the mixture.
- 7) Add 1.0 ml of hexane and vortex the mixture.
- 8) Carefully transfer the organic layer using a dropper to a clean test tube labeled "C." Save test tube "C" for Part-II. The organic layer is hexane and should be the top layer, but check using solubility in DI water.
- 9) Add 1.0 ml chloroform to test tube "B" and vortex the mixture.
- 10) Carefully transfer the organic layer using a dropper to a clean test tube labeled "D." Save test tube "D" for Part-II. The organic layer is chloroform (CHCl₃) and should be the bottom layer, but check using solubility in DI water.

Part II: Screening Tests:

Perform the screening tests below on the samples contained in test tubes A (solid pellet), B (aqueous layer), C (organic layer, hexane), and D (organic layer, chloroform). The best results are obtained when the tests are run side-by-side as opposed to in sequence (reference Chap. 7). Starch test is positive when blue color appears with iodine. Concentrated sulfuric acid and formaldehyde produce red color with aspirin.

Test 1: Reference

Place a small sample (1/2 pea size) of the original mixture of starch, aspirin, and acetaminophen mixture (100:1:1) into each of two clean, separate wells of a spot plate. These wells will be your reference, so do not empty or clean after the tests are performed.

Starch Test:

Add one drop of 1% iodine solution to the first well containing the sample and record the color change: _____. Do not empty or clean the well.

Aspirin Test:

Add one drop of formaldehyde and three drops of concentrated sulfuric acid to the second well containing the sample and record the color change: _____. Do not empty or clean the well.

Test 2:

Place a small amount of solid from test tube “A” into each of two clean, separate wells of the spot plate. Repeat the tests above and record your results. Compare the intensity of the colors produced to the colors in the reference.

Result of starch test: _____

Result of aspirin test: _____

Test 3:

Place 3 three drops of solution in test tube “B” into each of two clean, separate wells of the spot plate. Evaporate the solvent and repeat the tests above. Record your results below and compare the relative intensity of the colors produced to the colors in the reference.

Result of starch test: _____

Result of aspirin test: _____

Test 4:

Place 3 three drops of solution in test tube “C” into each of two clean, separate wells of the spot plate. Evaporate the solvent and repeat the tests above. Record your results below and compare the relative intensity of the colors produced to the colors in the reference.

Result of starch test: _____

Result of aspirin test: _____

Test 5:

Place 3 three drops of solution in test tube “D” into each of two clean, separate wells of the spot plate. Evaporate the solvent and repeat the tests above. Record your results below and compare the relative intensity of the colors produced to the colors in the reference.

Result of starch test: _____

Result of aspirin test: _____

Summarize your conclusions based on the test results:

Experiment # 11

Name _____

Chromatography

Reference: Chapter 10

Objective: Students gain practical experience using paper chromatography to separate the components of a variety of mixtures.

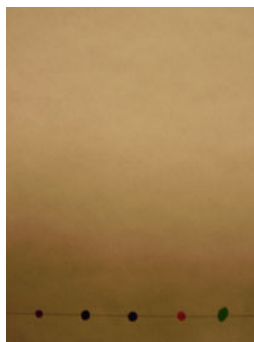
Materials: Red, blue, green, brown, and black felt tip pens, chromatographic paper, 1-butanol, 1-propanol, saran wrap.

Introduction:

Chromatography is a technique that utilizes a stationary phase and a mobile phase to separate the components of a mixture. The separation process is based on the fact that a given component (molecule) will exhibit a higher affinity for one of the phases and will either move in the mobile phase or remain in place on the stationary phase. Affinity is influenced by several factors, but size and polarity often play key roles. In this experiment, paper chromatography will be used to separate the components of ink commonly found in felt-tipped pens. The mixture (ink) will be spotted on the chromatographic paper (stationary phase) and placed in a developing chamber containing the mobile phase (solvent mixture). The mobile phase will migrate up the paper and contact each of the ink mixtures. The components in the ink that are soluble in the mobile phase will move up the stationary phase (paper) at different rates depending on size and polarity. The components that are not soluble will remain in place on the stationary phase. There are many types of chromatographic techniques and several factors must be considered when choosing a particular method. Thin-layer chromatography (TLC), for example, is simple, quick, and relatively inexpensive; however, it provides only qualitative results. High-performance liquid chromatography (HPLC) is more complex and requires sophisticated instrumentation, but it provides extremely accurate quantitative results. Other forms of chromatography include column chromatography, liquid chromatography (LC), and gas chromatography (GC).

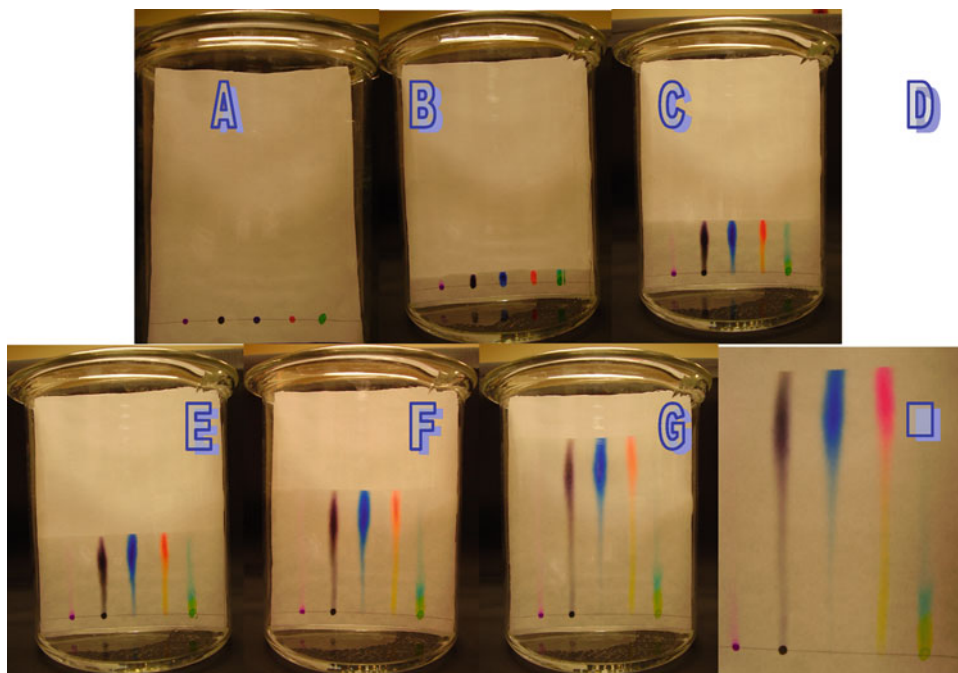
Procedure:

1. Place 15.0 mL of 1-propanol, 15.0 mL of 1-butanol, and 15.0 mL of deionized water in a clean, dry 600 ml beaker. Cover the top of the beaker tightly with saran wrap. A rubber band may be used to secure the plastic wrapping. Lightly swirl the beaker to mix the contents. This will be used as the developing chamber.
2. Obtain a 10 cm × 15 cm piece of chromatographic paper. *Handle the chromatographic paper using the edges at all times.* Touching the paper with bare hands may deposit oils and dirt that will affect your results.
3. Using a ruler and a lead pencil, draw a straight line across the entire 10 cm width, 1.5 cm up from the bottom edge of the paper. *Do not use a pen to draw this line.*
4. Mark five small dots on the line with a pencil at 1.5 cm intervals.
5. Spot each dot with a different colored pen and allow the spots to dry.



6. Remove the saran wrap cover on the developing chamber and carefully place the chromatographic paper in the beaker with the edge nearest the samples placed downward in the solvent (handle the paper using the edges only). Important: Be sure that the samples are NOT immersed in the solvent. Replace the saran wrap cover.

7. The developing solvent will begin to migrate up the paper. Allow the system to stand undisturbed until the solvent has run close to the top of the paper, or for a period of 60 min. Do not allow the solvent to reach the top of the paper.



8. Remove the paper from the developing chamber and draw a line across the solvent front using a pencil. Allow the paper to dry.
9. Answer the following questions:
- What colors have properties similar to the solvent?
 - What colors have properties that are different from the solvent?
 - What pens contain components that are similar?
 - How many components are contained in the red ink?
 - How many components are contained in the blue ink?
 - How many components are contained in the black ink?
 - What components appear to be common in the pens tested?
 - Do you believe your results would be different if ink pens from another manufacturer were used? Explain.

Experiment # 12

Name _____

GCMS Interpretation

Reference: Chapter 10

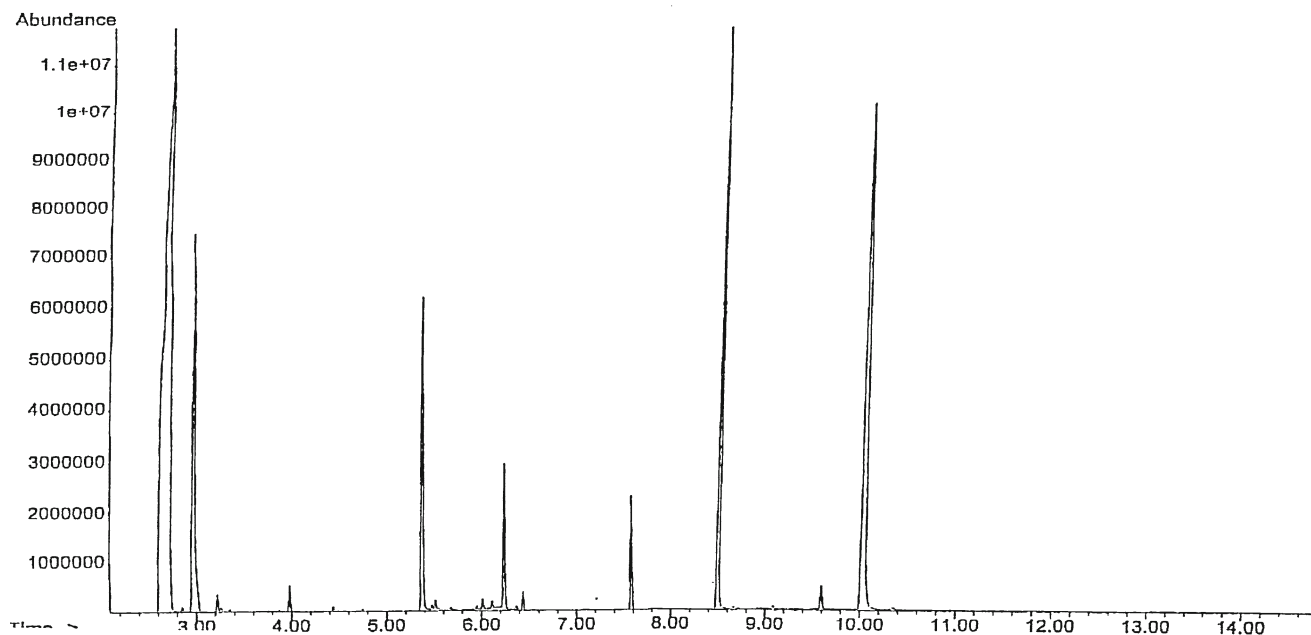
Objective: Students will gain experience in the interpretation of data provided by GCMS analysis.

Introduction:

Gas chromatography (GC) can be combined with mass spectrometry (MS) to provide scientists with an extremely valuable technique used to identify the components present in a gaseous mixture (GCMS). A sample of the mixture under analysis is injected into the gas chromatograph where it is immediately vaporized in the injection port. A carrier gas (mobile phase, usually N_2 or He) passes the vaporized sample through a column contained in the GC (stationary phase). The individual components in the gaseous mixture interact with the column to accomplish separation. In gas chromatography, the separation process is usually size dependent; smaller molecules interact less with the column and arrive at the detector faster than larger ones. The *time required for a particular component to travel from the injection port to the detector* is called the *retention time*. Retention times are basically the time each component spends in the column and are specific to that component. The detector records each component eluting off the column as a peak on a *chromatogram* at specific retention times. Although a GC does not routinely provide quantitative data, it does give important information about the components in a gaseous mixture. Since each component is recorded as a peak on the chromatogram, the number of components present in the mixture is easily determined by simply counting the number of observable peaks. Most modern GCs are automated and contain software that calculates the area under each peak. These calculations are used to determine the relative amounts of each component. For example, if the area under one peak is twice the area under another, that component is present in twice the quantity. The exact amounts are not known, but the relative concentrations are. Retention times can be used to determine the relative size of each component present. Peaks observed at low retention times represent smaller molecules, while those with greater times represent larger ones. Once again, the actual size of each component is not known, but the relative sizes are easily determined. The identity of each component is determined through mass spectrometry. The separated components from GC are passed into a mass spectrometer coupled directly to the GC. In the mass spectrometer, each component is bombarded with a beam of high-energy electrons that fragment the molecule into positively charged ions. The fragmented ions are recorded on a *mass spectrum* by mass (specifically charge/mass). The *base peak* is the most intense (highest) and represents the *base ion*; usually the most stable ion formed (the one formed the easiest). The base peak is assigned 100% and the intensities of the other peaks are recorded as percentages of the base peak. Tables identifying ions of specific mass are used to reassemble the molecule from the ion fragments. The base peak and the molecular ion peak often play key roles in the identification process. The *molecular ion* is formed when a single electron is ejected from the molecule by the imposed high-energy beam. This peak commonly represents the mass of the molecule under investigation. In some cases, the molecular ion may be the base peak; however, this is not a requirement and should not be considered a standard.

Part A:

Interpret the gas chromatogram below and answer the following questions.



1. Identify each component in the mixture using retention times. How many different components are present? (Hint: peaks below Abundance 1000000 are not considered components).
2. Identify the peak representing the component of smallest mass.
3. Identify the peak representing the component of greatest mass.
4. Predict the peak representing the molecule present in greatest abundance.
5. Predict the peak representing the molecule present in least abundance.

Part B:

Identify each of the following using the MS data provided. You will need to reference additional information from your text.

Name	Molecular Ion (m/z)	Base Ion (m/z)	Other Prominent Ions
1)	135	044	91, 92, 65, 120, 134, 77
2)	303	082	182, 83, 77, 94, 105
3)	369	327	268, 204, 310, 315
4)	237	180	182, 209, 152, 138
5)	243	200	91, 242, 243, 186

Part C:

List the mass (m/z) of the major ion fragments formed from each the following. Draw the structure of each fragment.

1) Methamphetamine:

2) MDMA:

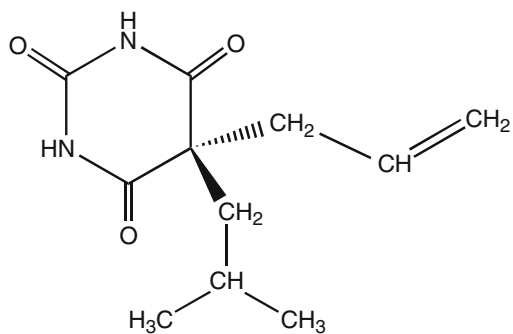
3) Psilocin/psilocybin:

4) THC:

5) Pseudoephedrine:

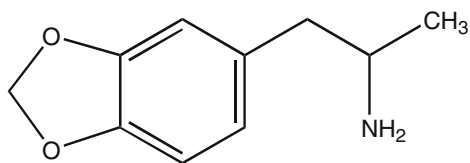
Part D:

Draw the ion fragments represented in the MS data provided for each of the following molecules.



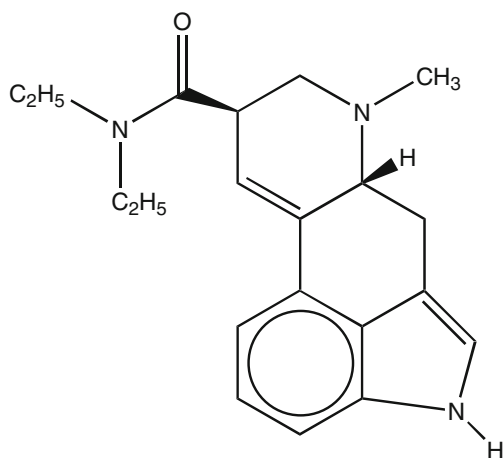
Molecular weight = 244
Base peak = 168
Prominant peaks:
97, 124, 141, 153, 167, 181

Butalbital



Molecular weight = 179
Base peak = 44
Prominant peaks:
51, 77, 81, 135, 136

MDA



Molecular weight = 323
Base peak = 221
Prominant peaks:
72, 167, 181, 196, 207

Experiment # 13

Name _____

IR Spectroscopy

Reference: Chapter 11

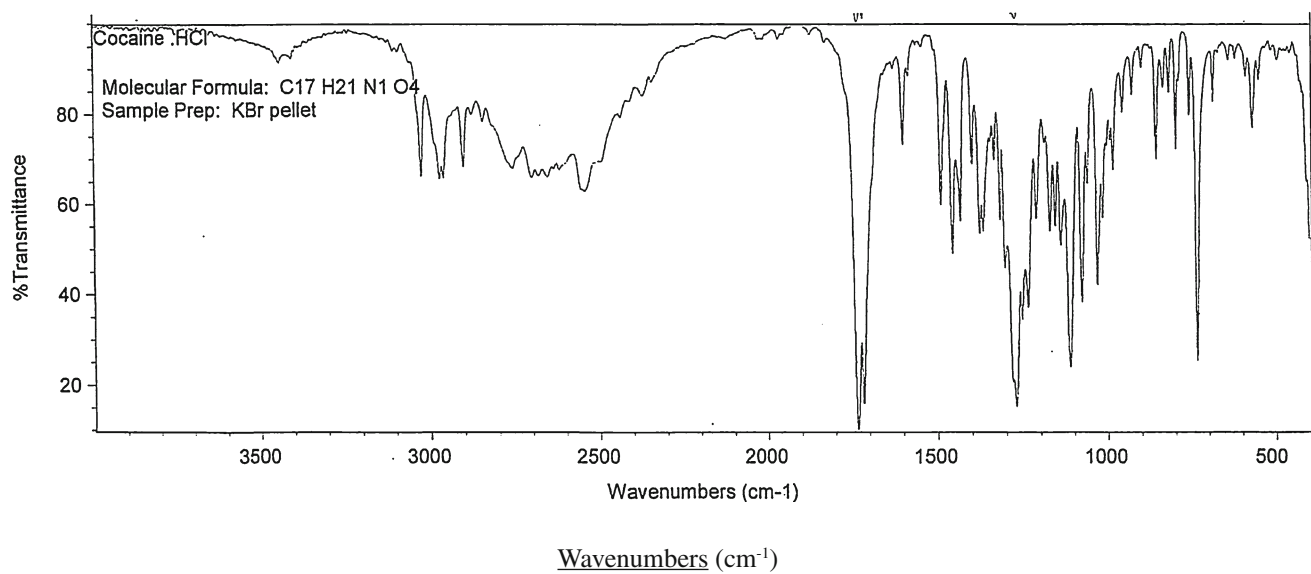
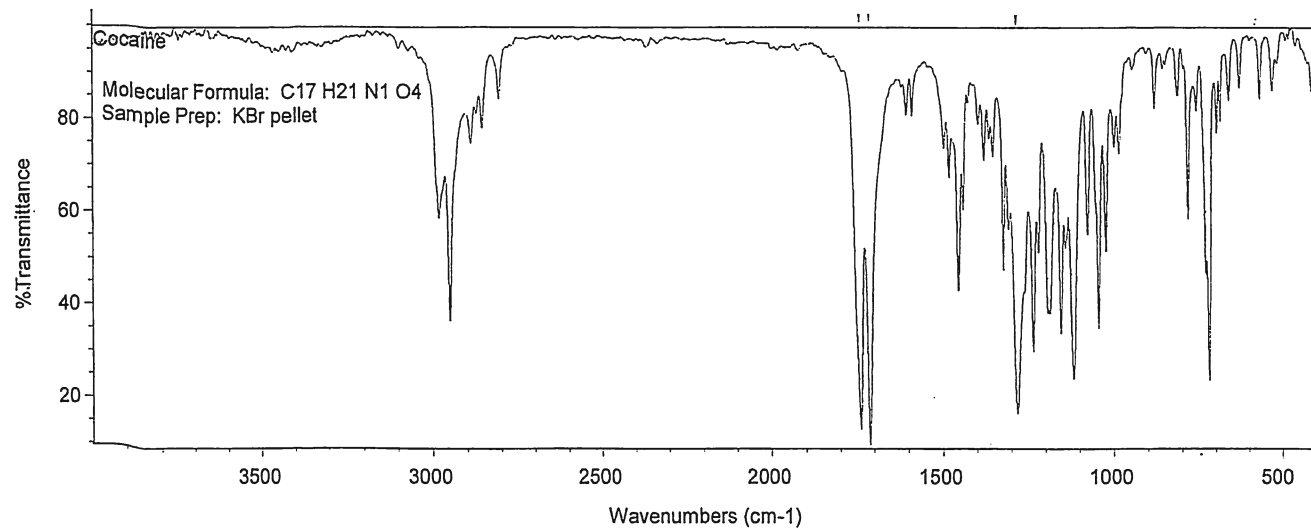
Objective: The student will gain experience in the interpretation of infrared spectra.

Introduction:

Spectroscopy is the study of the interaction of atoms and molecules with electromagnetic radiation. These interactions often involve the emission or absorption of discrete amounts of energy, which is detected using analytical instrumentation. When energy, in the form of infrared radiation (IR), is absorbed by a particular substance, it produces measurable effects that are detected using an *infrared spectrometer*. Infrared radiation is a low energy form of radiation that is best described as “heat.” When we feel the warmth of the sun, we are actually responding to infrared radiation. The heat emitted from the sun is absorbed by our bodies and stimulates molecules in our skin to vibrate. We interpret this vibrational energy as “warmth.” A similar activity is observed in molecules. When infrared radiation is absorbed by a molecule, the chemical bonds convert the energy into molecular vibrations. IR spectroscopy measures the frequency of the radiation absorbed by a particular bond and records this as a band on an *infrared spectrum*. Tables containing bond vibrational frequencies are used to identify the bond from the absorption bands observed on the spectrum. The location of absorption bands on spectra are commonly represented in units of *wavenumbers* or *wavelengths*. The *wavenumber unit* (cm^{-1} , reciprocal centimeters) is used most often because it is directly proportional to vibrational energy and most modern spectrometers are linear in the wavenumber scale. Identification of a molecule based solely on an infrared spectrum is rare because IR spectroscopy is used to *identify specific bonds in a molecule*. For example, a carbonyl group (carbon–oxygen double bond) is easily identified by a characteristic absorption band present on the spectrum; however, ketones, aldehydes, carboxylic acids, and esters all contain a carbonyl group. Therefore, absolute confirmation of identity will require information from other analytical methods. Nonetheless, IR spectroscopy is often an important source of supporting evidence in the identification process.

Part A:

The IR spectrum of cocaine base and cocaine HCl are provided. Compare the two spectra and identify absorption bands common to both and those distinct to each spectrum (uncommon bands). Identify each band using wavenumber region and record your observations in the table below.



Common Bands

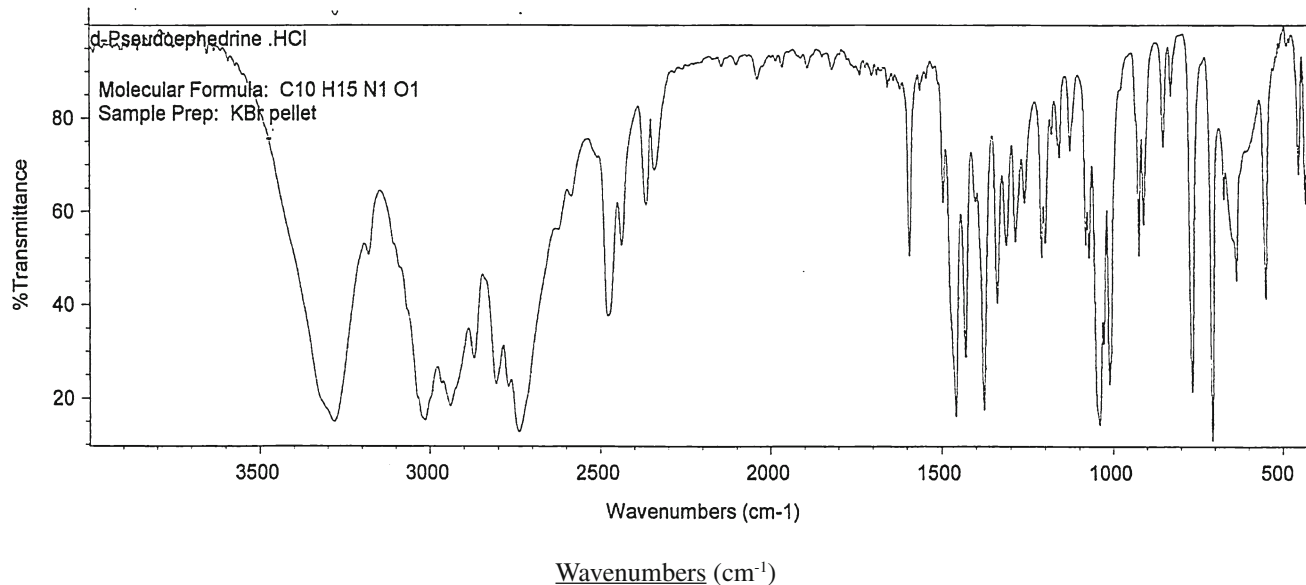
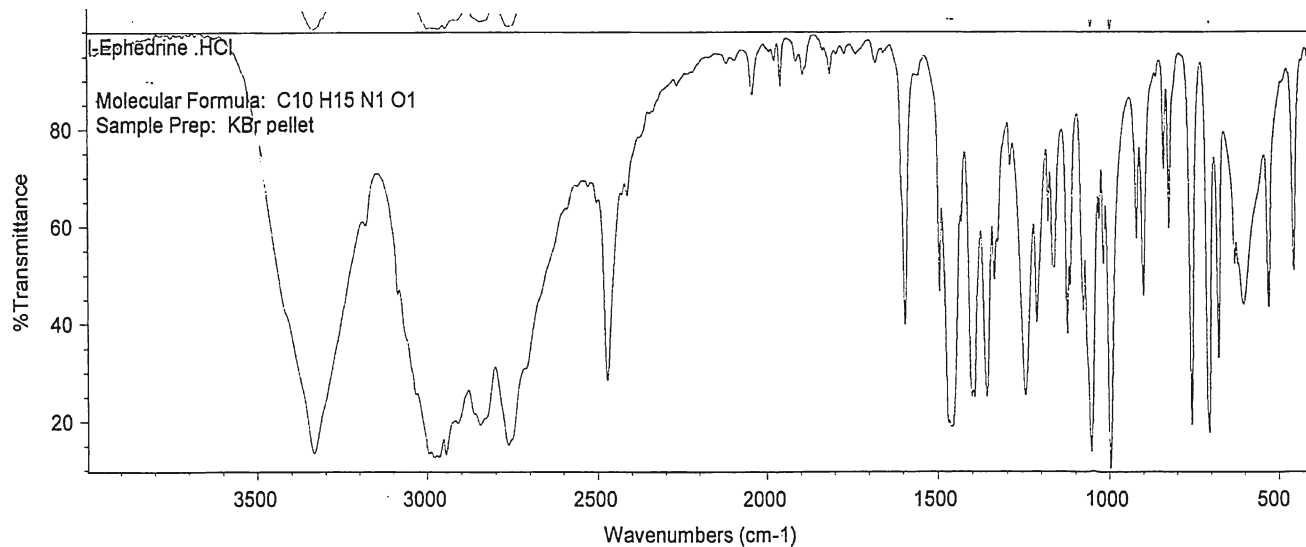
Distinct Bands

Cocaine HCl

Cocaine Base

Part B:

The IR spectrum of ephedrine and pseudoephedrine are provided. Compare the two spectra and identify absorption bands common to both and those distinct to each spectrum (uncommon bands). Identify each band using wavenumber region and record your observations in the table below.



Common Bands

Distinct Bands

Ephedrine

Pseudoephedrine

Experiment # 14

Name _____

Examination of Marijuana (moot)

Reference: Chapter 12

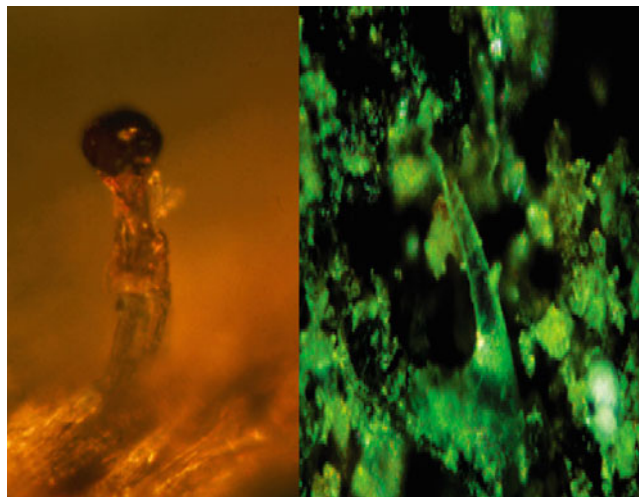
Objectives: The student will gain experience in the forensic identification of marijuana plants. A report of findings will also be written and presented.

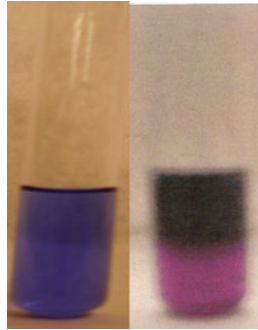
A plant material case submission contains following information/evidence.

Visual Inspection:



Microscopic Investigation:



Chemical Investigation: Duquenois-Levine test results**Questions:**

1. Describe the physical characteristics of the leaves based on visual inspection.
2. Describe the physical characteristics of the seeds based on visual inspection.
3. Describe your observations from microscopic investigation. What types of hairs are visible?
4. The Duquenois-Levine test was performed as part of the chemical investigation.
 - (a) What reagents are found in the top layer of the Duquenois-Levine test?
 - (b) What reagents are found in the bottom layer of the Duquenois-Levine test?
 - (c) What is the result of the Duquenois-Levine test?
5. What conclusions can be made based on your results in this investigation?

Experiment # 15

Name _____

Examination of Controlled Substances: Primary and Secondary Amines (moot)

Reference: Chapter 13

Objective: Students will gain experience in the forensic identification of controlled substances classified as primary and secondary amines using case data.

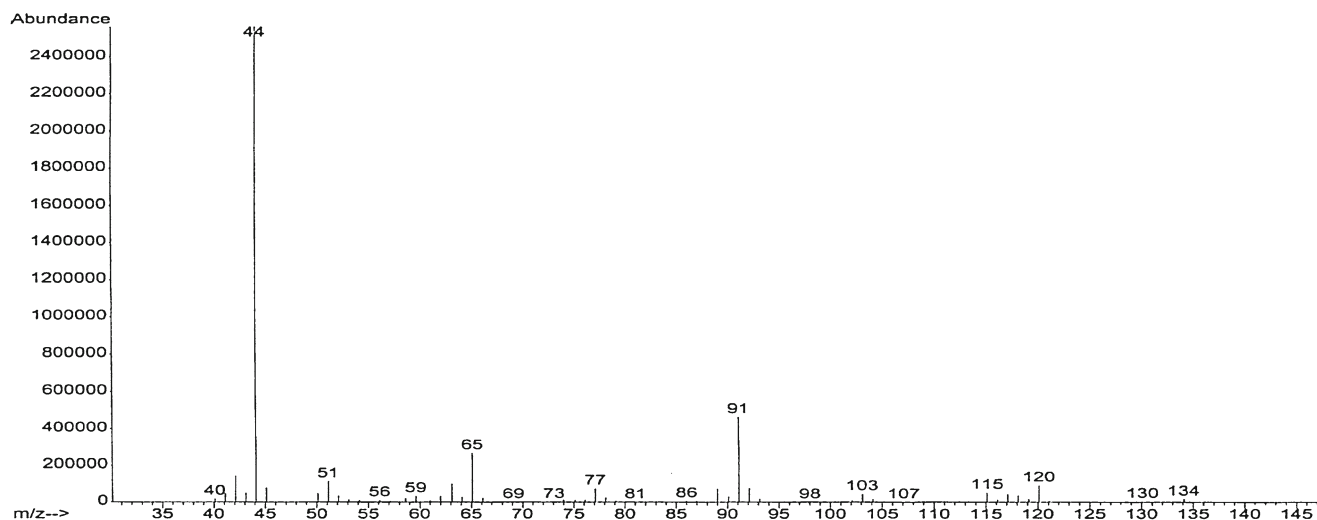
You are provided forensic data for three separate examination scenarios. Carefully study the information and predict the controlled substance(s) in each profile. Write a report of your findings.

Part A:

White Crystals:



Mass Spectrum:

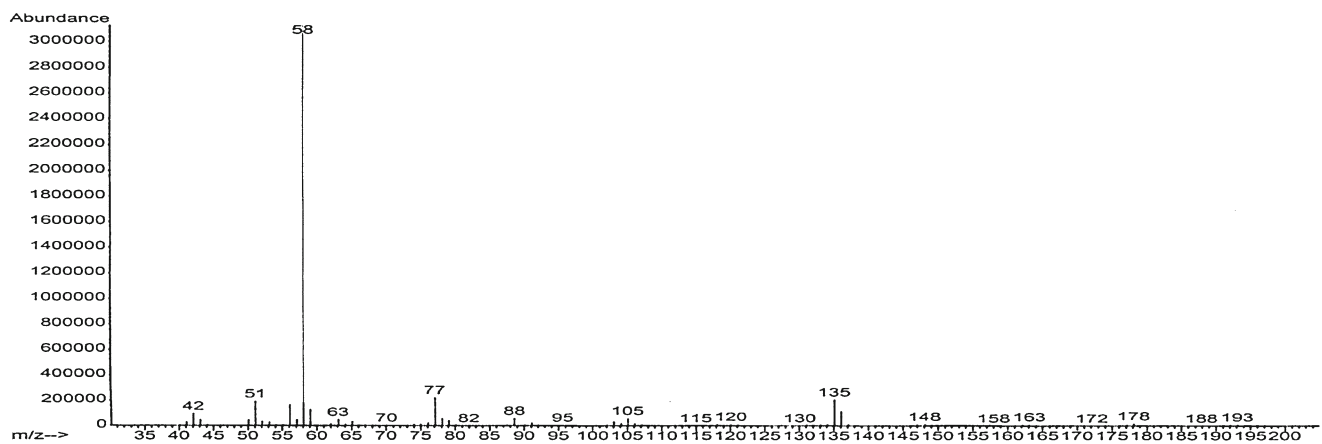


Questions:

1. Name the color-screening tests that you would perform in this case.
2. Predict the results of the screening tests in question 1.
3. Describe the method you would use as a confirmatory examination.
4. What type of extraction would be performed to prepare a sample for GCMS analysis?
5. Identify the controlled substance and provide supporting data for your conclusion.

Part B:

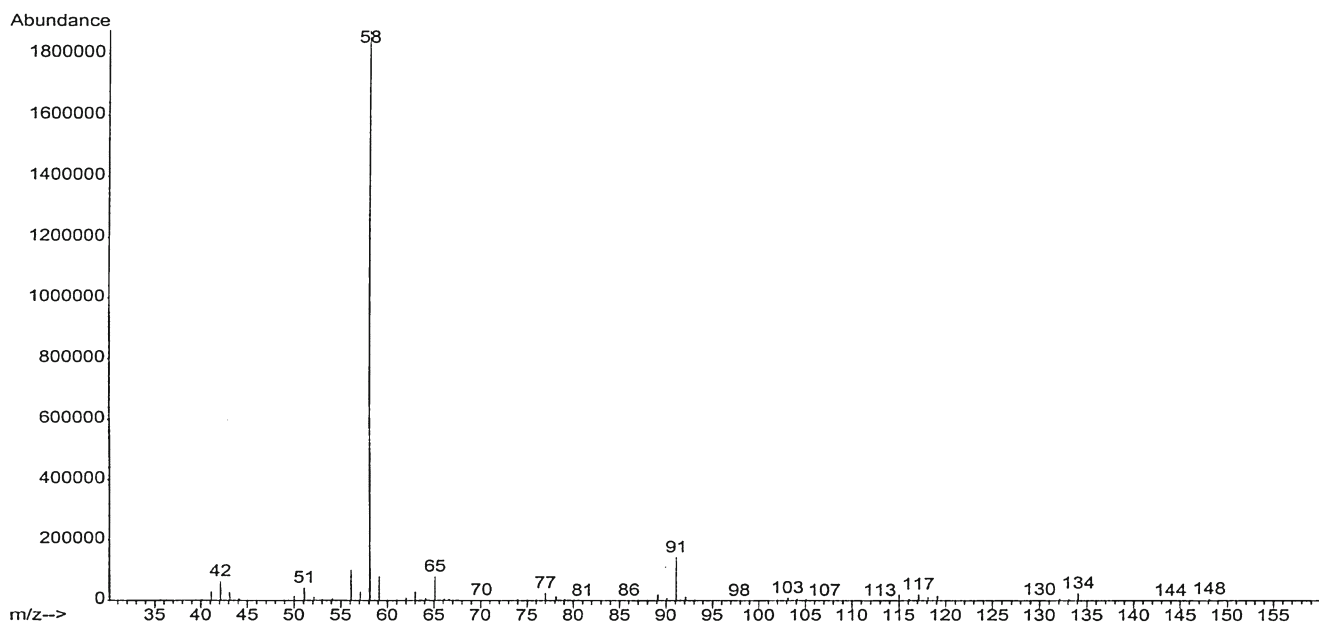
Red Tablets

**Mass Spectrum****Questions:**

1. Name the color-screening tests that you would perform in this case.
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Part C:

Light Brown Powder

**Mass Spectrum****Questions:**

1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. What type of extraction would you perform to prepare a sample for GCMS analysis?
5. Identify the controlled substance and provide supporting data for your conclusion.

Experiment # 16

Name _____

Examination of Controlled Substances: Tertiary Amines and Opiates (moot)

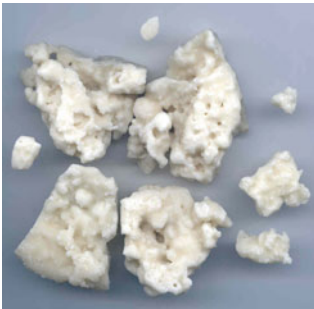
Reference: Chapter 14

Objective: Students will gain experience in the forensic identification of the tertiary amine class of controlled substances using case data provided.

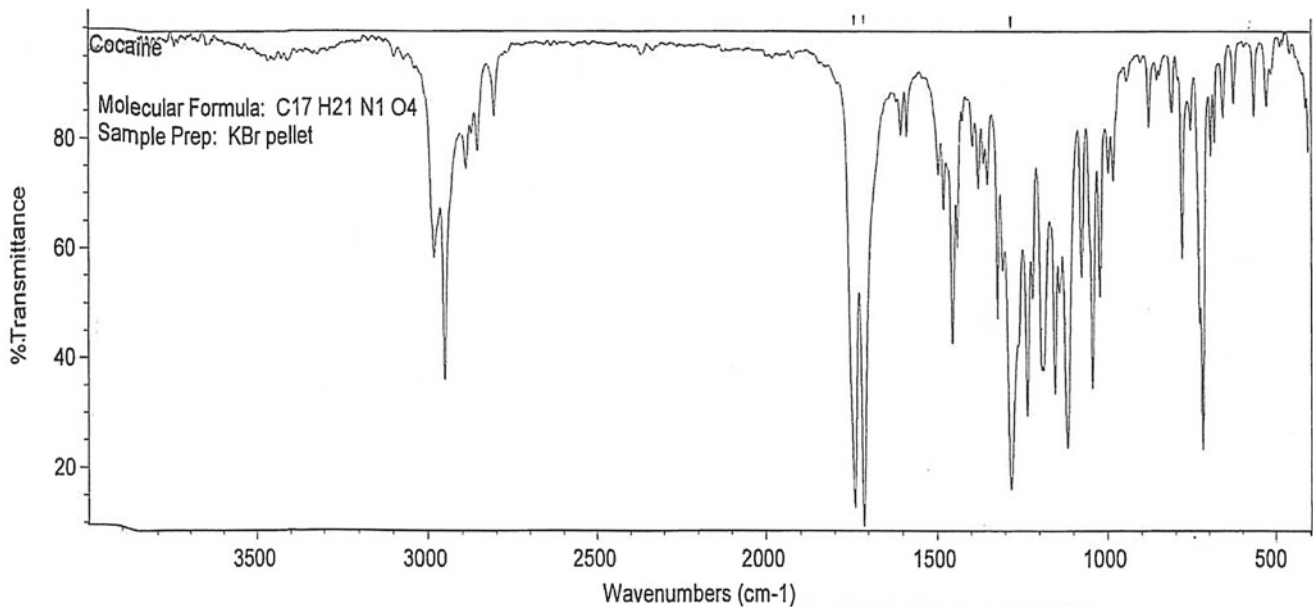
You are provided forensic data for three separate examination scenarios. Carefully study the information and predict the controlled substance(s) in each profile. Write a report of your findings.

Part A:

Chunks of Tan/White Substance



IR Spectrum

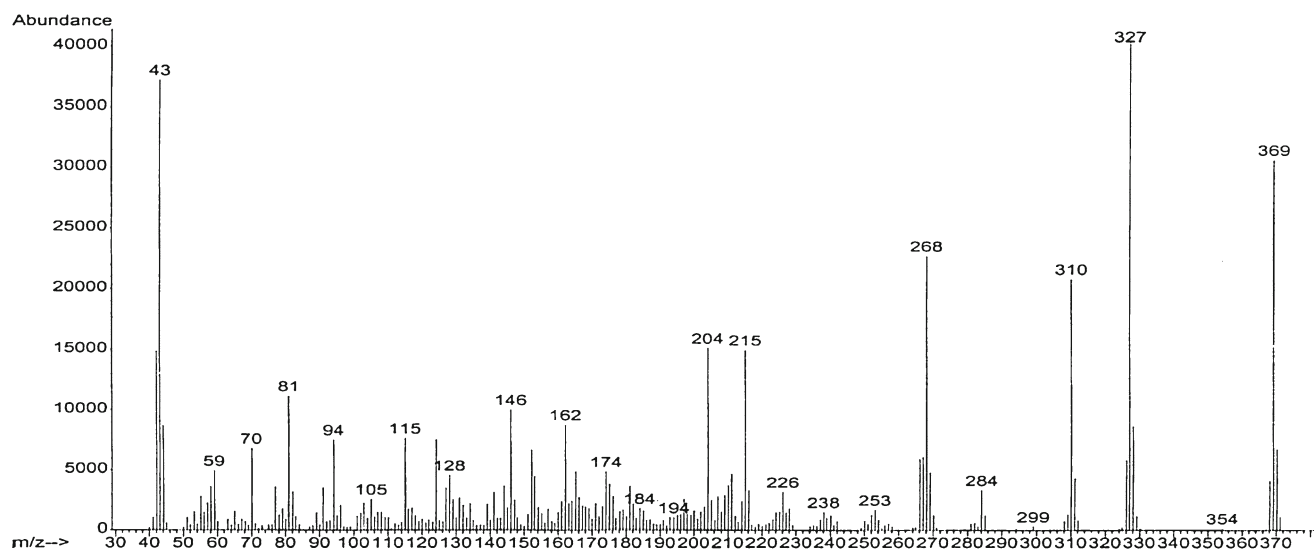


Questions:

1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Part B:

Black Chunk

**Mass Spectrum**

Questions:

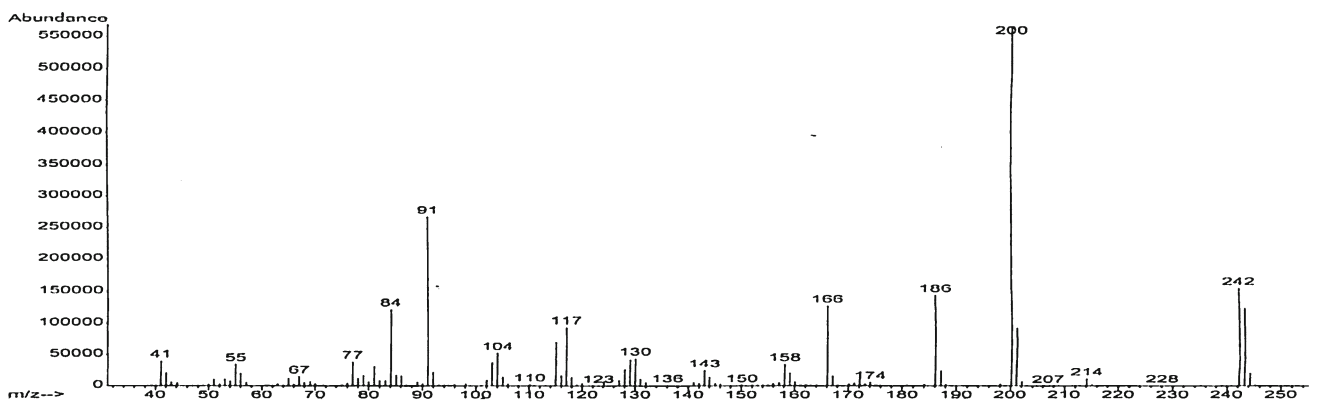
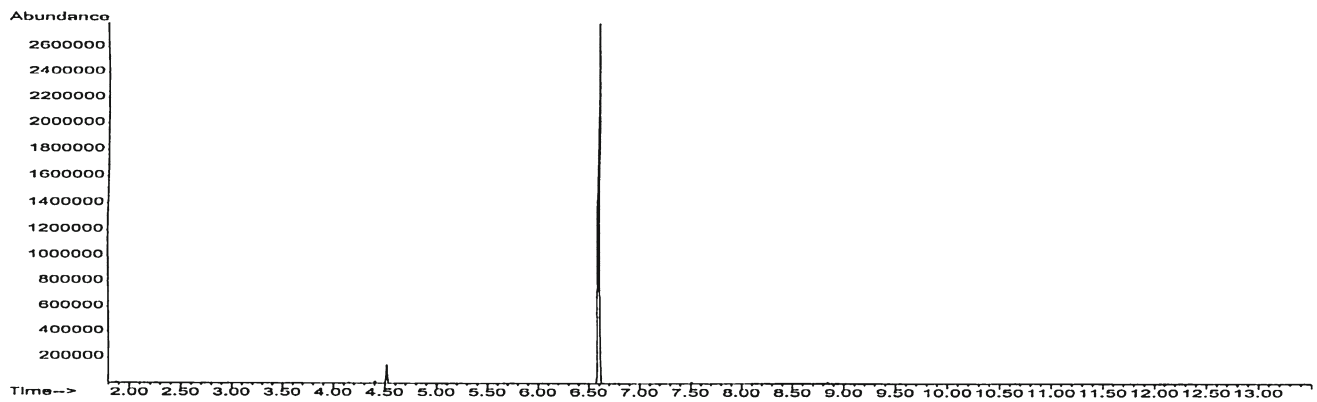
1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Part C:

Stained Cigarette and Yellow Oil



GCMS spectra



Questions:

1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Experiment # 17

Name _____

Examination of Controlled Substances: Tryptamines (moot)

Reference: Chapter 15

Objective: Students will gain experience in the forensic identification of the tryptamine class of controlled substances.

You are provided forensic data for three separate examination scenarios. Carefully study the information and predict the controlled substance(s) in each profile. Write a report of your findings.

Part A:

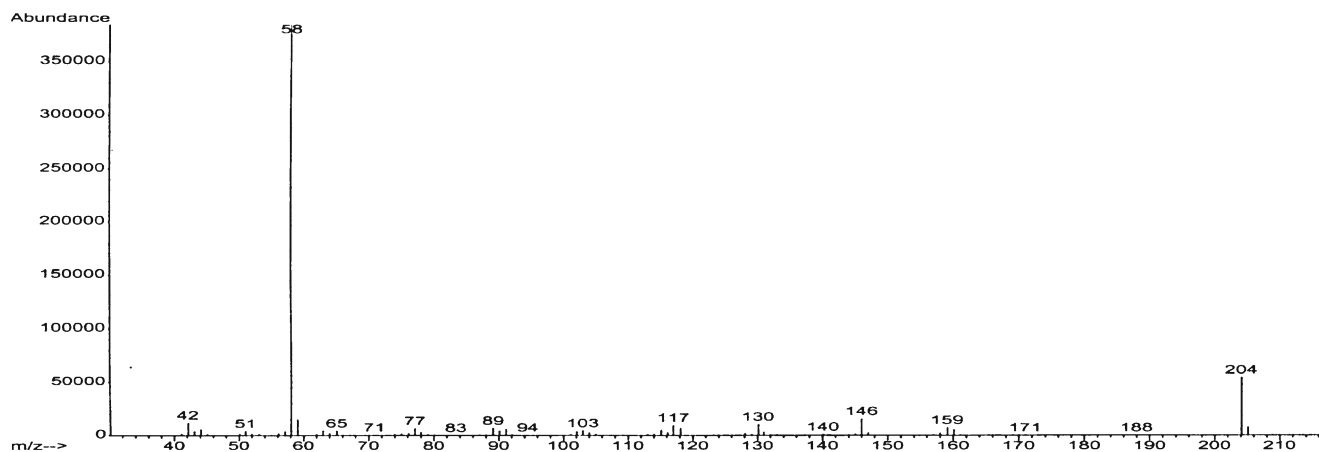
Mushrooms



Results of Thin-Layer Chromatography (TLC)



Mass Spectrum:

**Questions:**

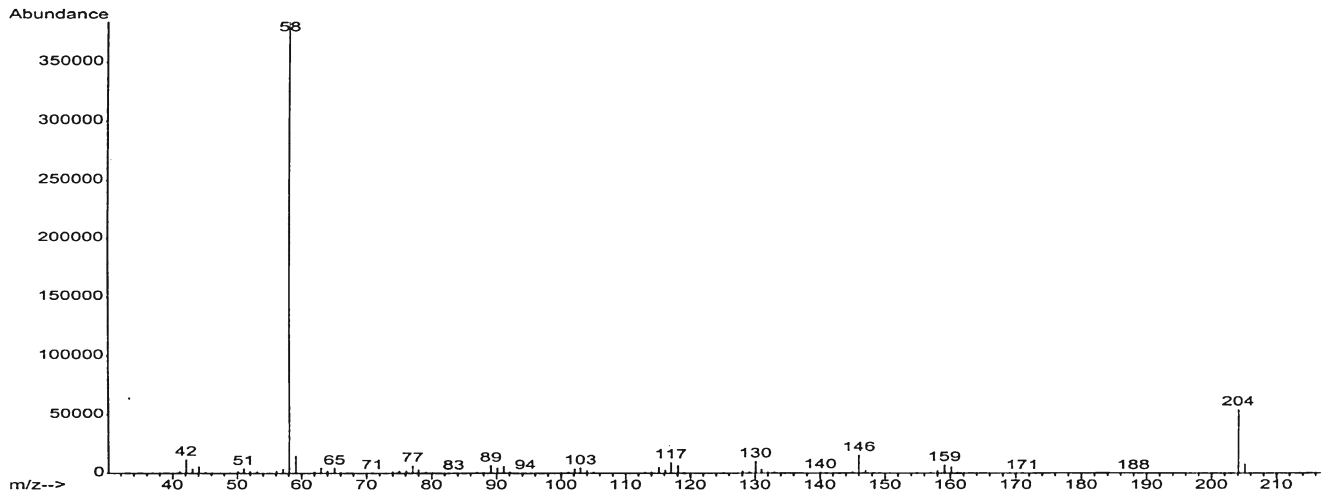
1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Part B:

Plant Material



Mass Spectrum:

**Questions:**

1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Experiment # 18

Name _____

Examination of Anabolic Steroids (moot)

Reference: Chapter 16

Objective: Students will be exposed to the forensic identification of anabolic steroids.

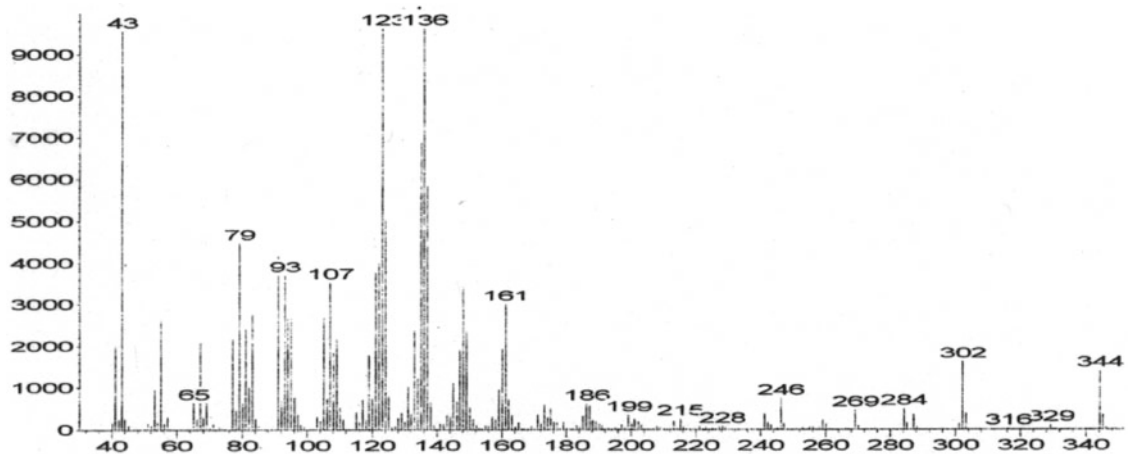
You are provided forensic data for three separate examination scenarios. Carefully study the information and predict the controlled substance(s) in each profile. Write a report of your findings.

Part A:

Red Capsules



Mass Spectrum



Questions:

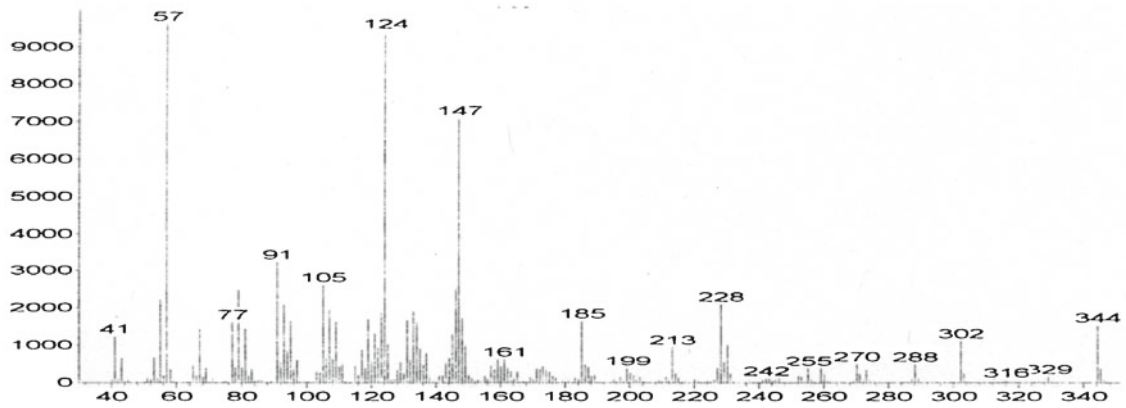
1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Part B:

Injection Vial



Mass Spectrum:

**Questions:**

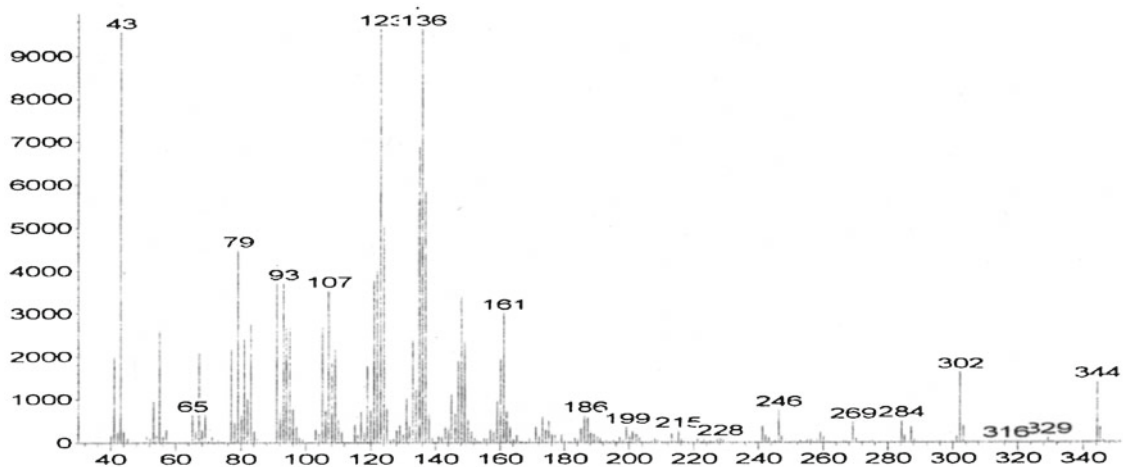
1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Part C:

Tablets



Mass Spectrum:



Questions:

1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Experiment # 19

Name _____

Examination of Miscellaneous Controlled Substances (moot)

Reference: Chapter 17

Objective: Students will gain experience in the forensic identification of various functional groups present in different controlled substances.

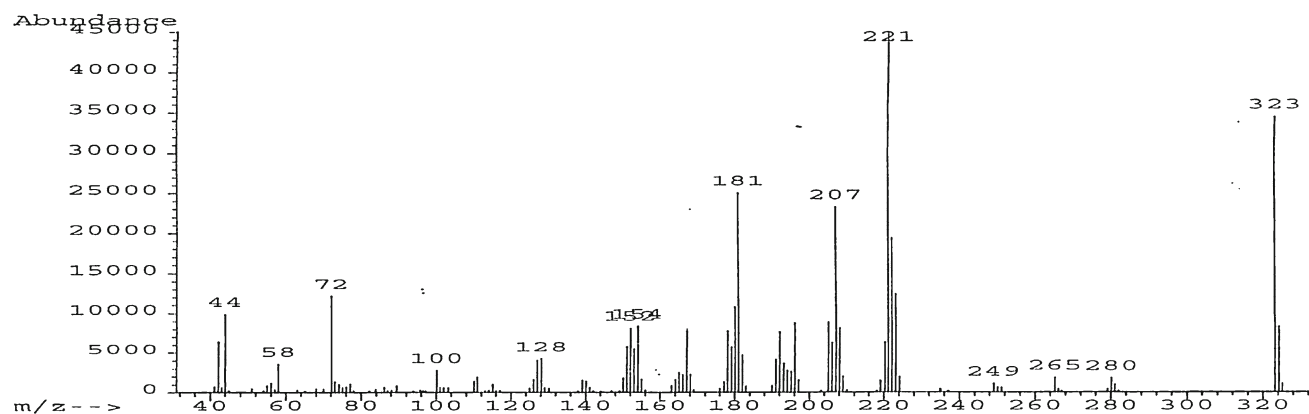
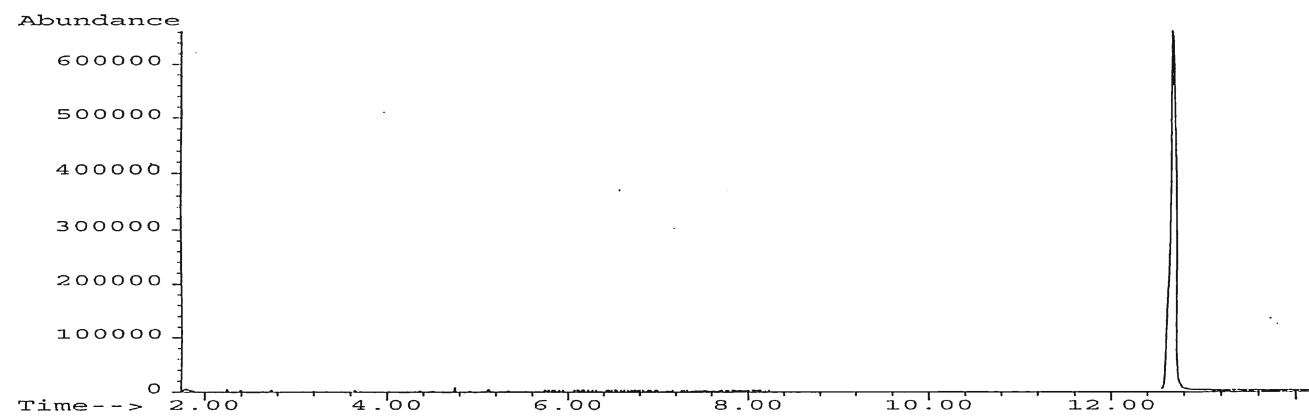
You are provided forensic data for three separate examination scenarios. Carefully study the information and predict the controlled substance(s) in each profile. Write a report of your findings.

Part A:

Paper Tabs



GSMS Spectra



Questions:

1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Part B:

Capsules

**Questions:**

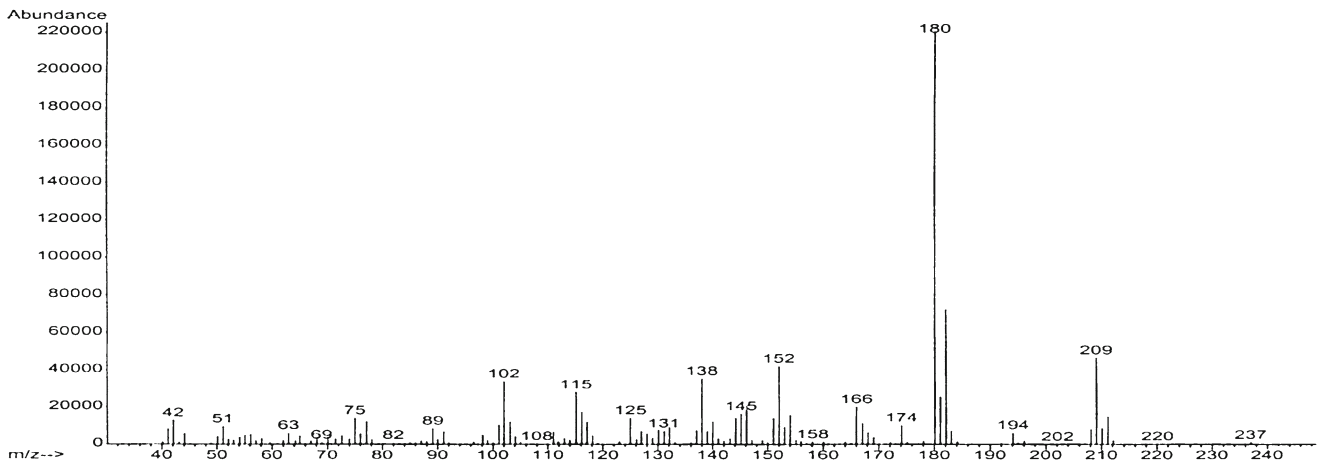
1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Part C:

Tablets



Mass Spectrum:

**Questions:**

1. What color-screening tests would you perform in this case?
2. Predict the results of the screening tests in question 1.
3. Describe the confirmatory method that you would use to identify this substance.
4. Identify the controlled substance and provide supporting data for your conclusion.

Experiment # 20

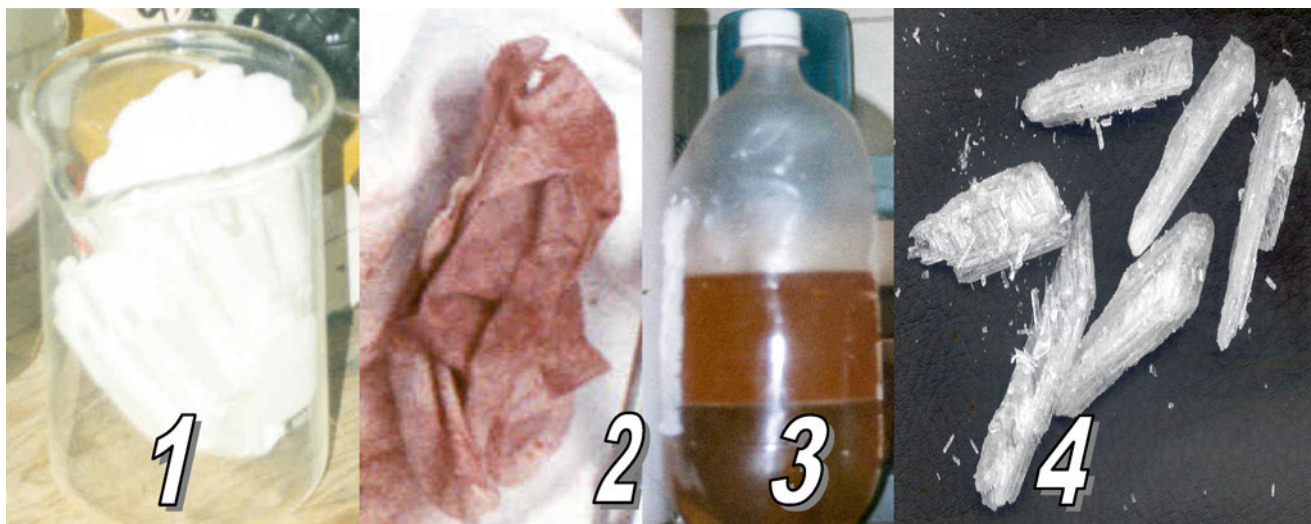
Name _____

Clandestine Manufacturing of Methamphetamine (moot)

Reference: Chapters 18, 19, and 20

Objectives: Students will gain experience in the forensic identification of case evidence collected at clandestine lab sites. This will be extended to include the association of distinctive evidence to specific synthetic steps used in the illegal production of methamphetamine.

Carefully study the photographs below and answer the following questions based on your observations. You will need to refer to your text.



1. Identify the method used in the production of methamphetamine. Justify your answer.
2. What chemicals are required for the method in question 1?
3. List the synthetic steps used in the production of methamphetamine using this method.
4. What synthetic step is indicated by the evidence shown in photograph 1?
5. List the chemical(s) required to prove this step.

6. Briefly outline the procedure you would use in the forensic examination of the evidence shown in photograph 1.

7. Summarize your conclusion on this piece of evidence.

8. What synthetic step is indicated by the evidence shown in photograph 2?

9. List the chemical(s) required to prove this step.

10. Briefly outline the procedure you would use in the forensic examination of the evidence shown in photograph 2.

11. Summarize your conclusion on this piece of evidence.

12. What synthetic step is indicated by the evidence shown in photograph 3?

13. List the chemical(s) required to prove this step.

14. Briefly outline the procedure you would use in the forensic examination of the evidence shown in photograph 3.

15. Summarize your conclusion on this piece of evidence.

16. What synthetic step is indicated by the evidence shown in photograph 4?

Index

A

Acid and anionic test techniques, 95

Acid–base extraction, 101–102

AET. *See* Alpha (α)-ethyltryptamine

Alcohols

 bufotenine and psilocin, 43

 butanol, 43

 classification, 42

 conversion, ergot alkaloid, 245

 denatured, 258, 261, 262

 designer drugs, 43

 dimethyltryptamine (DMT), 43, 44

 ephedrine and pseudoephedrine, 44

 ethanol, 41

 fire hazard, 253

 glycerol, 42

 hydroxyl functional group (-OH), 41

 clandestine manufacturing, controlled substances, 43

 polar organic solvents, 43

 pseudoephedrine, 261–262

 Red Devil Lye, 257

Aldehydes

 acetaldehyde, 47, 86, 87

 chemical and physical properties, 47

 formaldehyde, 47, 84

Alkanes

 alkyl groups, 36

 butane, 32, 33

 carbon tetravalency, 33

 chemical formulas, 32

 2-chloropentane, 35

 cycloalkanes, 36–37

 definition, 32

 methane, 34

 naming rules, 35–36

 physical properties, 36

 skeletal structure, 34

 stereochemistry, 34

 tetrahedral geometry, 34

Alkenes

 butene, 38

 chemical formulas, 38

 condensed structural formula, 37

 cycloalkenes

 benzene, 41–42

 PCP, 39

 hexene, 37

Alkynes

 chemical formulas, 39

C_nH_{2n-2} , 39

 cycloalkynes, 40

 hexyne, 39

 linear acetylene, 39

Alpha (α)-ethyltryptamine (AET), 197

Alpha (α)-methylfentanyl (AMF), 226

The American Society of Crime Laboratory Directors

(ASCLD), 3–4

AMF. *See* Alpha (α)-methylfentanyl

Amines

 functional groups, 109

 ketamine (*see* Ketamine)

 lysergic acid diethylamide (LSD), 52

 3,4-methylenedioxyamphetamine (MDA), 52

 organic derivatives, ammonia, 51–52

 phenethyl (*see* Phenethylamines)

 primary, 52, 86, 95, 119

 secondary, 52–53, 86, 95, 119

 tertiary, 53–54, 86

 tryptamines (*see* Tryptamines)

Amphetamine

 addictive and tolerance, 159

α -carbon, 159

 forms and street names, 159

 history, 158–159

 short-term and long-term

 physical effects, 159

 psychological effects, 159

Anabolic steroids

 administration methods, 211

 analytical methods

 GCMS, 213–214

 mass spectra, commonly encountered steroids, 214–221

 visual inspections, 213

 description, 207

 frequently encountered steroids, 212

 general structure, 210–211

 naturally occurring steroid hormones

 androgen, 209

 classes, 208

 mineralocorticoids and glucocorticoids, 209

 oral contraceptives, 209

 nomenclature

 androst, parts, 211

 beta (β) and alpha (α) substitutions, 212

Anabolic steroids (*continued*)

- ketone functional groups, 212
- saturated and unsaturated hydrocarbons, 211
- physical and psychological effects
 - damaging side effects, 211
 - mood disturbances/disorders, 211
 - skeletal muscle and bone tissue, 211

Anadenanthera peregrina. *See* Yopo seeds

Androgen, 209

Aqueous test reagents

- gold chloride test, 95
- mercuric chloride test, 96
- mercuric iodide test, 96
- phosphoric acid test, 95
- platinum chloride test, 96
- potassium permanganate test, 96
- sodium acetate test, 96

Aromatic compounds

- benzene, C₆H₆, 40
- naphthalene, 41
- unusual stability, 41

ASCLD. *See* The American Society of Crime Laboratory Directors

Atomic structure

- electron configurations
 - aufbau principle and triangle, 13–14
 - calculation, ions, 15
 - description, valence electrons, 15
 - distribution, atomic orbital, 17
 - ground state vs. most stable state, 16
 - group I, II and IV elements, 15
 - negative vs. positive ions, 15
 - neon (Ne) and helium (He), 16
 - neutral Na, 14
 - octet rule, 16
 - principle energy level, orbitals, 16
 - stable state, valence electrons, 16
 - valence electrons, Na, 14
 - electrons arrangement
 - emission, high-intensity light, 12
 - energy, 13
 - experimentation, lightning bugs, 12, 13
 - orbitals, 12
 - principle energy levels, 13
 - probability, 13
 - elements
 - and atoms, 10
 - forensic interest, 20
 - isotopes
 - description, 18
 - instability, 18
 - mole and molar mass, 20
 - nuclear radiation, 19–20
 - nucleus, subatomic particles, 11
 - periodic table, 9–10
 - periodic trends
 - atomic radius, 17
 - electronegativity, 17
 - elements, atomic radii, 17, 18
 - radioactivity
 - description, 18
 - emission, sample material, 18, 19
 - types, nuclear radiation, 18
 - subatomic particles, 11–12
 - types, radioactive decay, 19
- Aufbau principle, 13–14

B

Barbiturates

- capsules and tablets, 224
- common medical practice, 225
- derivation, 223
- schedule IV long-acting, 224
- ultra-short acting, 223
- use, 223

Biphasic solutions examination

- acidic layers, 275
- basic layers, 275
- neutral layers, 275, 276

Bufotenin

- bufotoxin, 194
- description, 193
- hallucinogenic dose, 194
- isolation, 194
- species, Bufo toads, 194
- Yopo seeds (*Anadenanthera peregrina*), 194–195

C

Cannabis

- description, Marijuana and tetrahydrocannabinol (THC), 145
- documentation, 154, 156
- forensic identification, Marijuana
 - botanical identification, 149
 - description, 149
 - Duquenois-Levine test, 151–153
 - macroscopic properties, 149, 150
 - microscopic identification, 151, 152
- forms
 - Marijuana and Hashish, 147
 - types, 147, 148
- Marijuana history
 - classification, Controlled Substances Act, 146
 - DEA, 146
 - as euphoric drug, 145
 - regional names, 146
 - USP, 146
- packaging
 - decayed plants, 147
 - use, paper bags/envelopes, 147
- programs, tetrahydrocannabinol (THC), 145
- psychoactive ingredient
 - description, 147
 - structure, *Cannabinoids*, 147, 148
 - structure, *trans*-D⁸-isomer and *trans*-D⁹-isomer, 147, 149
 - terpenes and phenol, 147
 - trans*-D⁹- and *trans*-D⁸-tetrahydrocannabinol, 147
 - trans*-D⁹-isomer, 145
 - visual and preliminary examination, 145

Carboxylic acids

- gamma-hydroxybutyric acid (GHB), 49
- protinated and deprotinated forms, 48

Case notes

- content, 74
- dissemination, 75
- format, 75
- purpose, 74
- types
 - ambiguity, 72, 73
 - cocaine pricks samples, 72
 - correction chain, 72, 73
 - unacceptable corrections, 72, 74

- Case report
 - examples, 76
 - format and content, 75
 - purpose, 75
- Chain of custody
 - mass spectrometry, 71
 - theoretical basis, instrument's operation, 71
- Chemical bonding
 - covalent, 24–25
 - hydrogen, 26
 - ionic, 23–24
 - multiple, 26–27
 - polar, 25
- Chemical color tests
 - Chen's test, 82–83
 - Dille–Koppanyi's test, 83
 - Froehde's test, 87
 - Janovsky test, 87
 - limitations, 81
 - Marquis' test, 84–85
 - Mecke's test, 83–84
 - methods
 - positive and negative controls, 81
 - spot plate, 81, 82
 - nitric acid test, 85
 - primary amine test, 86
 - secondary amine test, 86
 - tertiary amine test, 86
 - Van-Urk's test, 86–87
 - Weber test, 88
- Chemical extractions
 - acid–base extraction infrared modification I and II, 105
 - dry extraction gas chromatography modification, 104
 - gas chromatography modifications, 104
 - GCMS, 103
 - infrared (IR) spectroscopy, 104
 - methanol
 - GCMS, 105
 - screening methods, 105
 - sample preparation, 103
 - techniques
 - acid-base, 101–102
 - liquid-liquid, 100–101
 - neutral compound, 102–103
 - solid-liquid, 99–100
 - temperature, 99
- Chemical properties
 - aldehydes, 47
 - alkanes, 37
 - burning, 7
 - description, 6
 - enantiomers, 55, 92
 - instrumental analysis, 92
 - silver nitrate test, 6–7
 - solid formation, 7
 - sublimation, iodine crystals, 5, 6
 - substance reactivity, 6–7
- Chemical screening
 - color formation, 79–81
 - color tests (*see* Chemical color tests)
 - color transitions and instabilities, 79
 - documentation, 82
 - limitations, color tests, 81
 - methods, 79
 - screening tests results, 88, 89
 - tertiary amines
 - flow chart, 183, 185
 - testing method, 183
- Chirality, 55–56, 65, 92
- Chromatography
 - chromatogram peaks, 115
 - column
 - packing process, 110
 - TLC, 110
 - GC (*see* Gas chromatography)
 - GCMS-advantages and disadvantages, 124
 - HPLC, 111–112
 - IEC, 110–111
 - limitations, 115
 - mass spectrometry (*see* Mass spectrometry)
 - paper, 107–109
 - physical method, separation, 107
 - thin-layer (TLC), 109
 - types, 107
- Clandestine operations
 - cocaine synthesis
 - native coca leaves, 242
 - potassium permanganate, 242
 - collection, washes
 - methanol, 266
 - remnants, clandestine operations, 266
 - drug enforcement agency (DEA), 241
 - drug synthesis, 241
 - encountered solutions, 260, 262, 263
 - evidence collection
 - bilayer liquids, 263, 265
 - heating mantles, 263, 265
 - icing stage, 264, 266
 - methamphetamine production, 263, 265
 - examination, washes, 278
 - fentanyl synthesis, 242, 243
 - forensic analogy, 257
 - forensic chemist role
 - advisory, 254
 - evidence collection, 254
 - γ -hydroxybutyric acid (GHB), 242–244
 - heroin, 244–245
 - identification, related evidence
 - clandestine drug manufacturing, 258, 259
 - discovery, catalysts, 258, 259
 - equipment, 258, 260
 - illicit drug production, 258, 260
 - pseudoephedrine, 258, 261
 - solvents, 258, 259
 - LSD synthesis, 245
 - MDMA, 246–247
 - methamphetamine production
 - confirmatory examination, 274
 - Ephedra plant, precursor, 279–281
 - evidence type, 269–270
 - examination, 269–270
 - extraction, pseudoephedrine, 262–263
 - HI-red phosphorus method, 279, 280
 - icing, methamphetamine, 263–264
 - manufacturing methamphetamine, 261, 262
 - processing methamphetamine, 263, 264
 - signature GCMS, Nazi method, 279
 - methcathinone, 279
 - N,N*-dimethyltryptamine (DMT), 248–249
 - opium poppy, morphine, 245
 - PCP synthesis, 249
 - potential hazard, 253

- Clandestine operations (*continued*)
 prove extraction
 evidence type, 269–270
 examination, 217–280
 prove icing, 275, 276
 prove processing, methamphetamine
 biphasic solutions, 275
 evidence type, 274
 safety equipment, 253
 signs
 operators, 257, 258
 red phosphorus, 257, 258
 stains, 257
 stains
 examination, 277
 methamphetamine, 227
- Cocaine, tertiary amines natural
 Amazon and Trujillo coca, 179
 cause, excessive use, 178
 characterization, 178
 chewing coca counters, 179
 Colombian coca, 179
 description, 177
 Huanuco/Bolivian coca, 179
 novocaine and xylocaine, 178
 octopamine, 179
 origin, 178
 scientific classification, 179
 short-and long-term effects, 178
 structure, 178
- Color formation
 Chen's test, 81
 electrons orientation, 79
 3,4-methylenedioxymethamphetamine (MDMA), 81
 visible light, 79
- Column chromatography, 110
- Controlled substances
 analytical methods
 chemical screening tests, 230, 231
 GCMS, 191, 230, 232–236
 visual identification, 229–230
 barbiturates, 223–225
 fentanyl, 225–226
 GHB, 226–227
 ketamine, 227–228
 LSD, 228–229
- Controlled Substances Act (CSA), 66
- Covalent bonds
 H₂ and NaCl models, 25
 hydrogen atoms, 25
 polarity, 24–25
- Cycloalkanes, 36–37
 Cycloalkenes, 38–39
 Cycloalkynes, 40
- D**
 DEA. *See* Drug Enforcement Administration
 DET. *See* Diethyltryptamine
 Deuterated triglycine sulfate (DTGS), 133
 Diethyltryptamine (DET)
 structure, 194
 synthetic analogs, 197
 Dispersive infrared spectrometer
 components
 monochromator and slits, 131
 optical layout, 129, 131
 radiation sources, 131
 thermal and photon detectors, 131
 design
 double-beam, 131
 radiation path, 131
 limitations, 132
 Drug Enforcement Administration (DEA),
 146, 241
 DTGS. *See* Deuterated triglycine sulfate
 Duquenois–Levine test
 proposed reaction mechanism, 151
 reagents, 152
- E**
 Electron configurations. *See* Atomic structure
 Ephedra plant
 appetite and metabolism, 164
 ma huang (*Ephedra sinica*), 164
 use, clandestine manufacture, 164
 Ephedrine/pseudoephedrine
 description and production, 163
 dextrose fermentation, 163
 Ephedra plants, 163
 methyl and hydroxyl groups, 163
 physical and psychological effects, 163–164
- Esters
 alkoxy group (-OR), 49
 systematic naming, 49
- F**
 Fentanyl
 AMF, 226
 description, 225
 heroin and cocaine, 226
 “lollypop” form and duragesic, 225
 safety measures and clinical effects, 225
 tablets, patches, lollypops, and injections, 225, 226
 Forensic chemist, 71, 74
 Forensic chemistry
 ASCLD, 3–4
 chemical properties, 6–7
 chirality, 55–56
 crime-scene investigation and forensic
 analysis, 3
 description, 3
 esters, 49–50
 gas chromatograph, 4
 physical properties, 5–6
 properties, matter
 elements and compounds, 5
 homogeneous and heterogeneous mixtures, 5
 mass and weight, 5
 solid, liquid and gas, 5
 scientific investigation, 4
 space programs, 4
 technical procedures and lab quality manual, 3
 Forensic documentation
 case note, 72–75
 case report, 75
 chain of custody, 71
 replication, and research advancement, 71
 Forensic identification, Marijuana

- botanical identification
 - Cannabis sativa*, 149
 - physical transformation, 149, 150
 - scientific classification, 149
- description, 149
- Duquenois-Levine test
 - proposed reaction mechanism, 151
 - reagents, 152
 - technique, 152–153
- GCMS, 154, 155
- macroscopic properties
 - flowers and stem, 151
 - seeds and leaves, 149, 150
- microscopic identification
 - glandular and cystolith hairs, 151, 152
 - low-power magnification, 151
- TLC
 - description, 153
 - reagents, 153
 - visualization, 154
- Forensic investigation
 - charges and offenses, controlled substance, 67, 68
 - controlled substance laws
 - Schedule I, 66
 - Schedule II, 66–67
 - Schedule III, 67
 - Schedule IV, 67
 - Schedule V, 67
 - controlled substance submission, 67
 - court testimony, 69
 - CSA, 66
 - definition, drugs, 61
 - drug abuse, 63
 - drug cases, crime laboratories, 68
 - examination, controlled substances, 67, 68
 - narcotics
 - natural drugs, 61
 - psychotropic drugs, 61–62
 - synthetic drugs, 61
 - physical dependence, 62
 - psychological dependence, 62
 - structural relationship
 - analogs, 64
 - designer drugs, 64–65
 - isomers, 65
 - usable quantity, 69
- Fourier transform infrared spectroscopy (FTIR)
 - advantages, 134
 - bufotenin, 200, 203
 - components
 - beam path, radiation, 133
 - detector signal, 133
 - DTGS and MCT, 133
 - interferometer, 133
 - design, 133–134
 - methoxy/5OHDMT, 200, 204
 - modern design, 132
 - phenethylamines, 172, 174
 - psilocin/psilocybin, 200, 201
 - sample preparation techniques
 - liquid/vapor phase, 134
 - solid-sample, 134–135
 - synthetic tryptamines, 200, 205
 - tertiary amine
 - C-H and C-N stretching bands, 185
 - description, 185
 - spectra, bands, 185, 186
- FTIR. *See* Fourier transform infrared spectroscopy
- Functional groups
 - alcohols, 41–44
 - aldehydes, 46–47
 - alkanes, 32–37
 - alkenes, 37–39
 - alkynes, 39–40
 - amines, 51–54
 - aromatic compounds, 40–41
 - carboxylic acids, 47–49
 - classification, 31
 - esters, 49–50
 - ketones, 44–46
 - methyl group, 54
 - multiple, 54–55
 - nitro compounds, 50–51
- G**
- Gamma (γ)-hydroxybutyric acid (GHB)
 - activity, 226–227
 - “date-rape” drug, 227
 - injections and tablets, 227
 - neuroprotective nutrient, 227
 - street names, 227
- Gas chromatography (GC)
 - analogy, 114
 - automated gas chromatographs, 112, 113
 - capillary, 113
 - coin-separating machines, 114
 - interpretation, 115–116
 - packed-column, 113
 - vapor-phase chromatography (VPC), 112
- Gas chromatography mass spectrometry (GCMS)
 - advantages, 124
 - anabolic steroids, 213–214
 - analysis, 103
 - bufotenin and synthetic tryptamines
 - analogs, plant species, 200, 202
 - and FTIR spectrum, spectral data, 200, 201
 - mass spectrum and FTIR spectrum, 200, 203
 - toadstools, 200, 202
 - controlled substances, identification
 - allyl-cyclopentenyl-barbiteric acid, 230, 235
 - barbital, 230, 234
 - demerol and GBL/GHB, 230, 233
 - description, 230
 - ketamine, 230, 232
 - LSD and fentanyl, 230, 236
 - secobarbital, 230, 235
 - disadvantages, 124
 - dry extraction, 104
 - methanol, 105
 - mushrooms examination, tryptamines
 - description, 199
 - spectral data, 200, 201
 - phenethylamines, 172, 173
 - tertiary amine
 - cocaine HCL and base, 186, 187
 - description, 186
 - heroin, 186, 188
 - PCP, 186, 189
- GCMS. *See* Gas chromatography mass spectrometry
- Glucocorticoids, 109

- H**
 High-performance liquid chromatography (HPLC)
 liquid chromatograph, 111
 normal phase, 112
 retention time, 112
 reverse-phase, 112
 structural isomers differentiation, 111
 HPLC. *See* High-performance liquid chromatography
 Hydrogen bonding, 27, 45, 52, 85
- I**
 Infrared (IR) spectroscopy
 forensic identification, instrument selection, 137–138
 FTIR spectrometer
 advantages, 134
 components, 133
 design, 133–134
 sample preparation techniques, 134–135
 FTIR spectrophotometer, 127
 FTIR spectroscopy
 advantages and disadvantages, 137
 spectra, ephedrine and pseudoephedrine, 137
 inorganic analysis
 anions and absorption wave numbers, 139
 sample preparation and peak identification, 138
 stand-alone technique, 138
 instrumentation
 dispersive, 129
 integrated computer workstations, 129, 130
 organic analysis
 extensive purification, 139
 free-base cocaine vs. cocaine hydrochloride, 139, 140
 free-base forms, 139
 HCl and methamphetamine, 139, 140
 reflectance, 137
 sampling techniques
 cast film A, 136
 cast film B, 136
 Nujol Mull, 136
 pellets, 136
 synthetic membrane sample cards, 137
 spectrum
 absorbance and transmittance formats, 129, 130
 description, 129
 transmittance, 129
 use and conversion, absorbance, 129
 theory
 bond activity, molecules, 128
 frequency ranges, 128
 observed absorption bands, 128, 129
 radiation and spectrum, 127
 wave numbers and frequency, 128
 transverse waves and wavelength, 127
 and ultraviolet (UV) regions, 127
 Ion-exchange chromatography (IEC)
 automated computer workstation, 110, 111
 cation-exchange, 110
 Ionic bonds
 crystal lattice, 24
 description, 23
 electron transfer, 23, 24
 Ion trap mass analyzers
 applications, 124
 benefits, 123
 limitations, 124
- IR spectroscopy. *See* Infrared (IR) spectroscopy
 Isotopes, 18
- K**
 Ketamine
 chronic use, 228
 description, 227
 dissociative anesthetic, 227–228
 effects and cause, 228
 injections and tablets, 228
 schedule III controlled substance, 228
 street names, 228
 Ketones
 acetone, 45
 carbonyl group (R-CO-R), 44–45
 cathinone
 effects, 165
 occurrence and isolation, 164–165
 reduction, 165
 description, 164
 functional groups, anabolic steroids, 212
 khat
 classification, 165, 166
 consumption, 165
 harvested and packaged form, 165, 166
 marijuana and alkaloids, 166
 methcathinone, 46, 165
 oxidation, 164
- L**
 Liquid–liquid extraction, 100–101
 LSD. *See* Lysergic acid diethylamide
 Lysergic acid diethylamide (LSD)
 alkaloid ergonovine, 229
 clandestine production, 241
 description, 228–229
 occurrence, 229
 sclerotium, 229
 synthesis, rye ergot, 245–246
 tablet and capsule, 229
- M**
 Magnetic sector mass analyzers
 applications, 123
 benefits, 123
 limitations, 123
 MAOIs. *See* Monoamine oxidase inhibitors
 Mass spectra, anabolic steroids
 comparison and parent ion peak (M^+) identification, 214, 216–221
 description, 214
 Mass spectrometry
 analyzers, 119
 chemical ionization (CI)
 advantages, 118
 electron-impact, 118
 drugs identification, 117
 electron impact, 117–118
 GCMS, 116–117
 ionization, 117
 ion trap analyzers, 123
 magnetic sector analyzers, 123
 quadrupole analyzers, 119, 122
 spectral fragmentation

- amphetamine, 119–121
- identification process, 118
- magnetic field strength, 123
- peaks, drugs, 119, 122
- phentermine and methamphetamine, 119–121
- primary amines, 118–119
- MCT. *See* Mercury cadmium telluride
- MDMA. *See* 3,4-Methylenedioxyamphetamine
- 5MeODIPT. *See* 5-Methoxy-*N,N*-diisopropyltryptamine
- 5MeODMT. *See* 5-Methoxy-*N,N*-dimethyltryptamine
- Mercury cadmium telluride (MCT), 133
- Mescaline
 - classification, 169
 - hallucinogen, 169
 - occurrence, 168–169
 - peyote plants, 169
 - side effects, 169
- Methamphetamine
 - clandestine
 - extraction, pseudoephedrine, 261, 262
 - icing, methamphetamine, 263, 264
 - manufacturing methamphetamine, 262–263
 - processing methamphetamine, 263, 264
 - pseudoephedrine-containing cold tablets, 261, 262
 - Red-Devil Lye, 263, 264
 - Red Phosphorus-HI Method, 261
 - round-bottomed flask, 262–263
 - cold method, 249–251
 - element identification, 271
 - flame-test, red phosphorus, 271–272
 - history, 159–160
 - hot method, 251–252
 - hydrogen gas, 251
 - iodine crystals, 272
 - iodine identification, 272–273
 - as medication, depression and obesity, 160
 - Nazi method, 272
 - physical and psychological effects
 - description, 160
 - oral ingestion/snorting, 160
 - short-term and long-term abuse, 160
 - street names, 161
 - tolerance, 160–161
 - red phosphorus, 271–272
 - regulation, household items, 249, 250
 - silver nitrate test, 273
- Methanol extraction, 105
- Methoxy derivatives, tryptamines
 - 5MeODIPT and 5MeODMT, 195
 - plants list, analogs
 - acanthaceae and agaricaceae, 195
 - aizoaceae and gramineae, 195–196
 - leguminosae, 196
 - malpighiaceae and myristicaceae, 196
 - ochraceae and polygonaceae, 196
 - rubiaceae and rutaceae, 197
 - snuff preparation, 195
- 5-Methoxy-*N,N*-diisopropyltryptamine (5MeODIPT), 195
- 5-Methoxy-*N,N*-dimethyltryptamine (5MeODMT), 195
- 3,4-Methylenedioxyamphetamine (MDA). *See* Methylenedioxy derivatives
- Methylenedioxy derivatives
 - MDA
 - capsule/pill, 167
 - production, 167
 - profound relaxation, 167
 - psychedelic stimulant and empathogen-entactogen, 167
 - MDMA
 - description, 167
 - “ecstasy”, 168
 - relaxation state and use, 168
 - tablet, 168
 - rings and bond angles, 166
- 3,4-Methylenedioxyamphetamine (MDMA) *See also*
 - Methylenedioxy derivatives
 - isosafrole, 246
 - synthesis (ecstasy), 246–247
- Microcrystal techniques
 - acid and anionic, 95
 - advantages, 91–92
 - aqueous, 94
 - critical considerations, 96–97
 - disadvantages
 - compounds identification, 92
 - thin-layer chromatography, 92
 - documentation, 92–93
 - GCMS/Fourier transform infrared (FTIR) spectroscopy, 91
 - test reagents (*see* Aqueous test reagents)
 - volatility, 95
- Mineralocorticoids, 209
- Molarity, 28
- Molar mass, 27–28
- Mole and molar mass, 20
- Molecules
 - bond types prediction
 - hydrogen, 27
 - ionic, 27
 - nonpolar covalent, 27
 - polar covalent, 27
 - chemical bonding, 23–27
 - chemical reactions, 28–29
 - compounds, 23
 - molarity, 28
 - molar mass, 27–28
- Monoamine oxidase inhibitors (MAOIs), 197
- Multiple bonds
 - double, 26
 - single, 26
 - triple, 27
- N**
- Narcotics
 - natural drugs, 61
 - psychotropic drugs, 61–62
 - synthetic drugs, 61
- Natural drugs, 61
- Neutral compound extraction, 102–103
- Nitro compounds
 - chemical formula, R-NO₂, 50
 - illegal drugs, 50–51
- Nonpolar covalent bonds, 27
- Nuclear radiation, 19–20
- O**
- Opiates, natural tertiary amines
 - codeine
 - description, 180
 - use, 180
 - description, 179
 - heroin

- Opiates, natural tertiary amines (*continued*)
 characterization, 181
 description, 181
 inhalation and injection, 181
 short- and long-term side effects, 181
 morphine
 description, 179–180
 inhalation and symptoms, 180
 poppy
 corn, 182
 description, 181
 flowers and seed capsules, 181
 latex and seeds, 182
 significance, 182
 use, medicinal purposes, 182
- P**
- Paper chromatography
 capillary action, 108
 samples separation, 108
 solid–liquid, 109
- PCP. *See* Phenylcyclohexylpiperidine
- Periodic table, atomic structure
 elements, 9, 10
 groups and periods, 9
 law, 9
 metalloids/semi-metallics, 10
 symbols, 9
- Phenethylamines
 analytical methods
 chemical screening, 170, 171
 confirmatory examination, 172–174
 extraction techniques, 171
 FTIR, 172, 174
 GCMS, 172, 173
 mescaline extraction, 172
 microcrystal tests, 170, 171
 visual inspection, 170
 bronchodilators, 157
 description, 157
 hydroxyl derivatives
 ephedra plant, 164
 ephedrine/pseudoephedrine, 163–164
 phenylpropanolamine, 162–163
 innovative techniques, 157
 ketone derivatives
 cathinone, 164–165
 description and oxidation, 164
 khat, 165–166
 methcathinone, 165
 lists, 157, 158
 methoxy derivatives
 description, 168
 mescaline, 168–169
 methyl derivatives
 addition, 157
 amphetamine, 158–159
 methamphetamine, 159–161
 phentermine, 161–162
 methylenedioxy derivatives
 MDA, 167
 MDMA, 167–168
 rings and bond angles, 166
 α -/ β -position, 1-amino-2-phenylethane, 157
- Phentermine
 history
 fenfluramine/dexfenfluramine, 161
 fen-phen and dexfen-phen, 161
 salt form, 161
 physical and psychological effects, 162
 side effects, 162
- Phenylcyclohexylpiperidine (PCP)
 contaminates, 183
 description, 182
 as drug of abuse, 183
 effects and causes, 183
 structure, 182
- Phenylpropanolamine
 α and β carbons, 162
 physical and psychological effects, 163–164
 substitution, methyl and hydroxyl group, 162
 use, clandestine drug manufacture, 164
- Physical properties
 aldehydes, 46–47
 alkanes, 36
 description, 5–6
 enantiomers, 55, 92
 instrumental analysis, 92
 melting and boiling point, 5
- Polar bonds, 25
- Polar covalent bonds, 27
- Psilocin and psilocybin
 classification, psychoactive mushrooms, 192, 193
 effects, serotonin, 193
 occurrence, 192
 preparations, dried/brewed mushrooms, 193
 psychoactive “magic” mushrooms, 192
 schedule I hallucinogens, 192
- Psychotropic drugs, 61–62
- Q**
- Quadrupole mass analyzers
 applications, 123
 benefits, 123
 limitations, 123
 mass-to-charge, 119, 122
- R**
- Radioactivity. *See* Atomic structure
- S**
- Scientific investigation
 experimentation and conclusion/theory, 4
 observation and hypothesis, 4
- Solid–liquid extraction, 99–100
- Solid-sample FTIR spectrometer
 cocaine comparison, 135
 crystal-lattice effect, 134
 molecule vibration and polymorphism, 135
 structure limits, 134
 variations, IR spectra, 135
- Steroids. *See* Anabolic steroids
- Subatomic particles, atomic structure
 charges, protons and electrons, 11
 electrons, 11
 isotopes, 11

mass number, 11
net charge, protons and electrons, 11, 12
nucleus, 11
protons and neutrons, 11
Synthetic drugs, 61

T

Tertiary amines
analytical methods
chemical screening, 183, 185
confirmatory examination, 185–189
visual inspections, 183, 184
description, 177
natural
cocaine, 177–179
opiates, 179–182
synthetic, PCP
contaminates, 183
description, 182
as drug of abuse, 183
effects and causes, 183
structure, 182, 183
Thin-layer chromatography (TLC)
Cannabis
description, 153
interpretation, 154
plate and sample preparation, 153
reagents, 154
separation, 154–155
visualization, 154
tryptamines
description, 199
interpretation, 199
procedure, 199
TLC. *See* Thin-layer chromatography
Tryptamines
analogs, 191
analytical methods
chemical screening tests, Weber test, 198
GCMS, 199–205
psilocin and psilocybin extraction, 199
TLC, 199
visual identification, 197–198
description, 191
indole derivative, 191

natural
bufotenin, 193–195
methoxy derivatives, 195–197
psilocin and psilocybin, 192–193
occurrence, 191
synthetic
DET, Foxy Methoxy and AET, 197
MAOIs, 197
scientific research purpose, 197

U

United States Pharmacopoeia (USP), 146
USP. *See* United States Pharmacopoeia

V

Visual identification
controlled substances
color-screening test, 230, 231
common forms, 229, 230
description, 229
tryptamines
description, 197
identification, psychoactive mushrooms, 197–198
Visual inspections
anabolic steroids
description, 213
representative forms, 213, 214
tertiary amines
description, 183
procedure, 183, 184
Volatility test technique, 95

W

Weber test, tryptamines
methanol extraction, 198
reagent 1 and 2, 198

Y

Yopo seeds
description, 195
leaf and seeds, 194, 195
use, *cohoba snuff*, 194