Forensic Chemistry

Expert Witnesses - Forensic Case Studies for Practicing Scientists

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Lecture Objective

Provide an introduction to the fundamentals of chemistry as applied to forensics, using a framework of case studies and key chemical principles

- Necessary background & concepts
- Terminology & chemical process involved
- Critical role of chemicals-Interactions and changing physical properties

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Lecture Outline

- **Expert Witness-Preparation and Analysis**
- **Investigative Reports and Scientific Evidence**
- **Chemical Warning Labels & Common Flaws in Warning Labels**
- **Dangerous Properties of Chemicals and Materials**
- **Legal Case Reviews**
- **Principles of Chemical Safety**

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Outline Overview

Chemistry - An Overview

- **Applications & case studies**
- **Fundamentals and Basics**
- **Learning the *Language* of Chemistry**
- **Using Chemistry to Support litigation**

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Forensic Chemistry Definition

- **Forensic Chemistry is the use of Chemistry to support litigation in Civil and Criminal Law Cases.**
- **2010 Forensic Chemistry is focused on Analytical Chemistry in assisting legal cases or examining scientific evidence.**

Forensic Science

Forensic Science……..application of scientific principles, methods & techniques within the legal arena

- Civil 
- Criminal 

Forensic Science

Forensic…… → **Death?** **Crime?** **Investigation?** ***Public*** ***Debate*** ***Legal***

Forensic Science

Interdisciplinary

Forensic….. → Anthropology, **Biology**, ***Chemistry***, **Toxicology**, ***Engineering, Mathematics, Statistics***, **Medicine**, **Pathology**, **Pharmacology** **Psychology**, Psychiatry

….applied to examination of physical evidence

The Forensic Chemist = Expert Witness

- ***The Forensic Chemist*** **employs analytical methods for determining within a reasonable degree of scientific certainty the proximate cause of an accident or product failure.**
- **The *Modern Forensic Chemist* employs Analytical Instruments in assisting legal cases or examining scientific evidence.**

Expert Witness - Role & Preparation (1)

- **Role of Chemist or Material Scientist**
- **Technical Knowledge**
- **Communication & Reporting Preparation for Testimony in Court**
- **In the Courtroom**

Expert Witness - Role (2)

⇒ **Add credibility to cases when his or her testimony is supported by**

- Relevant, published literature
- Other authorities in field of expertise
- relevant professional organizations

⇒ **Assist judicial with respect to questions involving damage, liability, Intellectual Property or Criminology**

Expert Witness Case Study(1)

- **A Bic Lighter was manufactured with a defect that allowed the butane to leak out of the lighter. The "fluid"-covered lighter ignited when the lighter produced a spark.**
- **The consumer was burned significantly on the hand and face**

Case 2: Air Bag Prematurely Explodes

- Man in TX strikes a curb at 25 miles/hour.
- Air bag is deployed.
- Sodium azide (poison) is the chemical in air bags - Reacts to produce a large volume of nitrogen -air bag inflates, pressure increases
- ***Air bag ruptures***
  - Sodium Azide sprayed out and causes severe burns to the driver's face.
    - The temperature of the gas increases with air pressure –ideal gas law

Expert Witness – Knowledge (3)

- Chemistry & influencing factors
- Specific principles and terminology involved in chemistry or forensics
- Applicable chemical tests, methods of analysis or standard protocols

Expert Witness – Knowledge (4)

- Knowledge & experience provide basis for conclusions
- > 64% = one standard deviation or within a reasonable degree of scientific or engineering certainty

Expert Witness – Communication (5)

- Communicates freely with his or her attorney
- And with his or her opposing attorney only as required
- Presents, reviews technical info, forensic report with his or her attorney in clear, concise & simple manner

Expert Witness – Communication (6)

- **Exercises effective writing, reporting strategies**
- **Emphasizes logic & technical judgment**
- **Conclusions are supported by written report or record**

Expert Witness – Preparation (7)

- **Reviews all forensic reports prepared, including those from opposing expert witness**
- **Reviews all applicable medical records, police reports, etc.**
- **Consider what is openly reported and how it supports his or her conclusions**
- **Anticipates questions from the opposition to gain info or construct counter scenario**

Expert Witness – Preparation(8)

Must be aware of potential for attack by opposition in an effort to discredit

- **credentials**
- **ethics & integrity**
- **judgement**
- **knowledge, scientific ability**

•in the eyes of judge or jury

Expert Witness - In the Courtroom (9)

- Should be comfortable, project confidence
- **Adopts a "chess-like" strategy - thinks ahead**
  - anticipates questions
  - formulates answers commensurate with forensic report
- Only answers questions that he or she fully understands

Expert Witness - In the Courtroom (10)

- **Uses technical terminology to support his or her conclusions**
- **Has full command of all terms used**
- **Makes full use of diagrams and other visual aids in clarifying and explaining conclusions**

Investigative Record (1)

Objectives:

- **outline investigative procedure**
- **track chemical analysis and results**
- **prepare permanent record & report**

Investigative Record (2)

Reporting Requirements:

- clear, logical presentation
- presentation of a well organized records is extremely important
- application of strict scientific methods

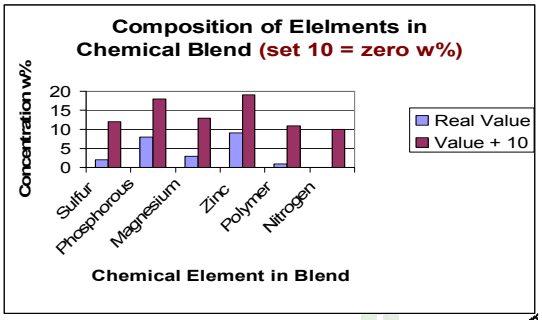
Investigative Record (3)

- **clear conclusions, and/or recommendations *Chemical Product Liability* – proximate cause of accident within a reasonable degree of scientific certainty (>64%, one standard deviation)**

Case3: Cuyahoga County Court 2002

- **Present to Court a comparison of chemical compositions of two chemical blends**
- **Employ a 2D Histogram to differentiate side by side comparisons**
- **Set Zero composition equal to 10 in order to easily demonstrate nitrogen *not* present**
- **Case settled by Judge who ruled the chemical blends were definitively different based on the histogram of the two blends**

Case 3. Cuyahoga County Court 2002



Steps to achieve #1 objective

Chemistry influenced the outcome of real world cases

Chemistry and health
- Poisons
- Carcinogens

Reactivity
- Explosive reactions

Product failure
- Corrosives-pH
- Over-pressurized

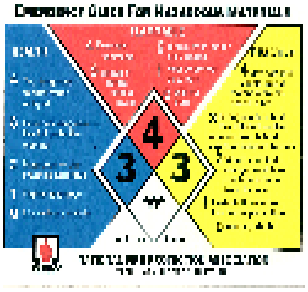
Safety Issues
- Procedures
- Labels

Instructions & Warning Labels Rules (1)

- **Material products**
- **Documentation**
- **Written instructions**
- **Common Flaws**
- **Good Instructions**
- **Warning Labels**

Warning Labels Rules (2)

- Chemical products
- Warning Labels
- Guide lines
- Good Format
- Color Codes



Chemical Product Warnings & Instructions (3)

Relative to the use of chemical products- A chemist – technical writer must:

- develop and write instructions
- write warning labels
- work or cooperate with technical writer
  - **operate & assess designed chemical product**
- identify potential hazards

Chemical Product Instructions (4)

Guidelines for writing chemical product instructions

- **provide adequate level of instruction for chemicals involved**
- **clarity in explanation of proper use**
- **technical accuracy**
- **provide required information for both operation & care of chemical products**

Dangerous Chemical: Sodium Hydroxide

Chemical Product Instructions (6)

Good Instructions - the basics

- Provide instructions in the order to be followed
- **Clearly separate warning labels from other material**
- Provide general information before specific information
- **Put instructions in parallel form**

Case 4: Chemical Product Instructions

- **County Fair Ride at Lake County Fair**
  - ***Dodgem ride***
    - **Boy was electrocuted**
    - **Riders wait for ride standing on metal housing that covers high voltage lines**
      - **Were labels on housing?**
      - **High voltage lines should not be near public**
      - **Fair and Ride owners were found guilty**
        - **» Fines and Jail time were delivered**

Chemical Product Warning Labels (7)

Chemical Product Warning Labels (8)

Guidelines for writing warning labels

- **failure to warn properly of risks and hazards associated with use of a chemicals can be considered a defect**
- **manufacturer has legal obligation to warn of risks or hazards associated with use of chemicals**
- **manufacturer must warn of hazard even though it may result from using chemical product in an unintended way**

Chemical Product Instructions (9)

Common flaws in written instructions

- assume too much
- use of ambiguous language (dangerous!)
- confusing structure or organization
- may not be applicable to specific chemical product
- fail to take into account audience
- specialized terminology not defined early on in protocol

Chemical Product Warning Labels (10)

Warning Hazardous Chemicals (11)

- A chemical with one or more of the following hazard ratings as defined by NFPA 704, standard System for the identification of the Hazards of Materials for Emergency Response:
  - **Health 2,3 or 4**
  - **Flammability 2, 3 or 4**
  - **Reactivity 2, 3 or 4**

National Fire Protection Association, 704, 2003

Chemical Product Warning Labels (12)

Development of warning labels

- develop a good format and follow it consistently

1.Danger (red)	Possible severe injury or death
2. Warning (orange)	possible serious Injury
3. Caution (yellow)	probable minor injury or product damage

Chemical Hazard Control

- Concept
- Identifying Responsible Persons
- Identifying Hazardous Chemicals
- Hazard Communication Program
- Sources of Hazard Information

Dangerous Properties of Chemicals (1)

Determine the following information-

1. Chemical Name and Synonym
2. Department of Transportation DOT four digit code
3. Molecular Formula and Weight
4. Physical Properties, including solubility and flammability data
5. American Chemical Society Chemical Abstract service number CAS

Dangerous Properties of Chemicals (2)

Determine the following information

6. Toxicity Data for skin and eye irritation, mutation, tetraogenic, reproductive, carcinogenic, human and acute lethal effects
7. Hazard Rating- relative hazard for toxicity, fire and reactivity
8. Analytical methods- Referenced by OSHA and NIOSH Occupational analytical methods

Dangerous Properties of Sulfuric Acid (3)

Sulfuric Acid CAS:7664-93-9

DOT: UN 1830/un 1832

Mf: H_2SO_4 MW:98.08

PROP: viscous, colorless oily liquid: odorless mp:10:49°C, d: 1.834, vap press: 1 mm @

SYNS: acide surfurique (french) acido solforico (italian)

TOXICITY DATA with reference

Eye rbt 1380 µg SEV AJOPAA 29,1363,46

Hazardous Chemicals (4)

- Any substance which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating or otherwise harmful, is like to cause death or injury
- National Fire Protection Association, 853, Code 2113, 2003.
- A substance, solid, liquid or gas, that when released is capable of creating harm to people, the environment and property.
- National Fire Protection Association, 472, 2003

Case 5: Garfield Alloys Fire

Metal fabricating plant burns for 3 days
Magnesium metal scraps ignite/burn

- Explosive Reaction
  - Magnesium + water = explosion

How do metals burn?
Why does magnesium react with water?
What explodes?
What remains after the explosions?
What remains in the environment?

Acid Rain in Ohio

Case 6: Zero pH Wrong!!

Case 6 - Narrative & Review

- Proposed government regulation
  - Congressman wants zero pH!
  - ***Right or Wrong?***
- Acid Rain effect on human, plant life and public property
- Who is liable? What is pH?

Historic Public Statue

Acid Rain Degrades Historic Public Statue

What exactly is acid rain?

- **Rain contaminated with acids from industrial sources is termed "acid rain".**
  - **Sulfuric acid is the key ingredient in acid rain**
  - **Sulfur in coal is burned during combustion in power plants and forms Sulfur dioxide.**
  - **Sulfur dioxides react with water and rain to form sulfuric acid (pH =1-2).**
- **pH is a measure of acidity:**
  - **pH 1-3 very acidic**
  - **pH 4-6 acidic; pH 7 neutral;**
  - **pH 8-14 basic**
  - **pH of tap water in Cleveland is typically 6.0**

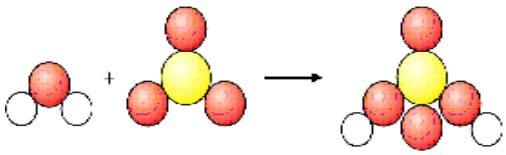
Molarity and pH= acid rain & corrosion

- **pH: A scale ranging from 0 to 14, which is used to determine how acidic or basic a substance is.**
  - **How The pH of a substance is determined**
    - **Negative of the logarithm of the molar hydrogen-ion concentration (pH= - log [H+]).**
- **Pure water has a pH of 7.**
  - **Substances with a pH less than 7 are acids**
  - **Substances with a pH greater than 7 are bases.**

Reaction to form Sulfuric Acid

$2S_{coal} + 3O_2 \rightarrow 2SO_{3\,(gas)}$

$H_2O + SO_3 \longrightarrow H_2SO_4$



Case 6: I want my water to be zero pH!

Congressman in US Congress states

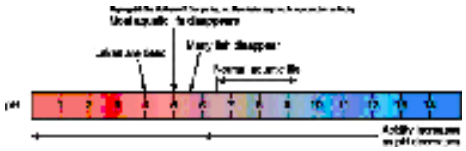
" I want my water to be zero pH!"

Chemical and Acid/base knowledge

is lacking! What he wanted was neutral water, neither acidic or basic, with a pH of 7.0 *not pH =0.0.* Concentrated sulfuric acid or hydrochloric acid pH of 1.0- very strong acids

pH = 0, stronger acid than sulfuric acid

Lakes & aquatic life dead: pH 4-5



Acid Smog a Killer: Who is liable?

Effects of Acid Rain

- ***Materials***- Plants die -Trees die
- ***Visibility*** -Building & Surfaces Corrode Refurbishing costs high
- ***People***-Lung & Eye problems

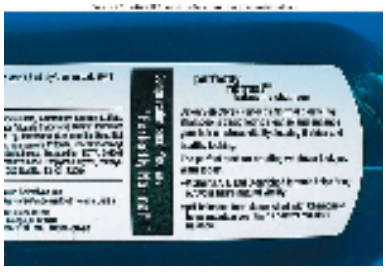
Effects of Acid Rain

- ***Materials***- Plants die -Trees die
- ***Visibility*** -Building & Surfaces Corrode Refurbishing costs high
- ***People***-Lung & Eye problems

Principles of Chemical Safety

- Know the chemicals around you or those involved in your legal case.
- Determine the chemicals dangerous properties; use MSDS etc.
- Determine exposure and risk of the chemicals by testing
- Develop plan to avoid chemical exposure
- Evaluate life threatening chemicals

Safe Chemical: pH Balanced Formula



Safe Chemicals: Candy with Sugar, Acids & water

Safety Objectives & Summary

- **Raise the level of understanding of chemical hygiene and safety**
- Place chemical use in the context of health risk
- **Address misperceptions of risk**
  - **Complacency**
  - **Unduly fearful**
- Review elements of health hazards
- **Explore opportunities for the mitigation of risk**
  - **Exposure control**

Safety Objectives

- The **Material Safety Data sheet** (MSDS) is the foundation of a worker's understanding of the chemical ***risk***
  - The MSDS contains critical information on chemical ***hazards*** and guidelines for safe use of the chemical (***exposure*** reduction)
  - Every chemical in use at Lubrizol has an MSDS readily available
  - ***ALWAYS* consult the most recent MSDS *BEFORE* handling a chemical**

Risk Assessment in Chemical Safety

- **Risk** of working with chemicals is defined by the equation:
  - ***Risk* = *Hazard x Exposure***
- **Risk** = The probability that injury or adverse health effects will occur under a particular set of exposure conditions
- **Hazard** = The innate potential of a substance to cause injury
- **Exposure** = The circumstances associated the contact of an organism with a substance

Perguntas

- **Perguntas, por favor.**
- **Muito obrigado por terem assistido minha palestra.**

Safe vs. hazardous chemical?

- **Few chemicals are without hazards of various kinds and degrees**
- **The Occupational Safety and Health Administration (OSHA) defines a hazardous chemical as any chemical which has a physical hazard or a health hazard**
  - **Physical hazard; combustible liquid, compressed gas, explosive, reactive, pyrophoric**
  - **Health hazard; evidence that acute (immediate) or chronic (delayed) health effects may occur in over-exposed people**

Categories of Toxicity

- **Acute**
  - Sudden onset of symptoms following a single or short-term exposure to a chemical (usually a high concentration)
  - Organ toxicity (irritation/corrosion, CNS depression, asphyxiation)
- **Chronic**
  - Delayed onset of symptoms as a result of repeated exposure to a chemical (normally a low concentration) over the course of weeks-months
  - Organ toxicity (e.g., chronic bronchitis, hepatotoxicity, nephrotoxicity, reproductive toxicity)
  - Carcinogenesis

Adverse Bio-Chem Effects: Key Terms

- **Local** – occur at the site of exposure
  - Irritants, corrosives, asphyxiants
- **Systemic** – effects occur at a site remote from the point of chemical contact
  - Chemical enters the general circulation as a result of dermal, inhalation, or gastrointestinal absorption and exerts a toxic effect on a distant target organ
- **Reversible** – damage can be repaired by the natural processes in the body
- **Transient** - effects disappear rapidly
- **Persistent** – effects continue even after exposure has expired
- **Irreversible** – damage CANNOT be repaired (e.g., dead nerve cells that cannot be replaced)

Acute Toxicity: How is it measured?

- Oral, dermal or inhalation exposure
- Defined as **LD_{50} or LC_{50}**
  - The average dose of a substance that will cause death in **50%** of the test animals after a ***single administration***

Acute Toxicity

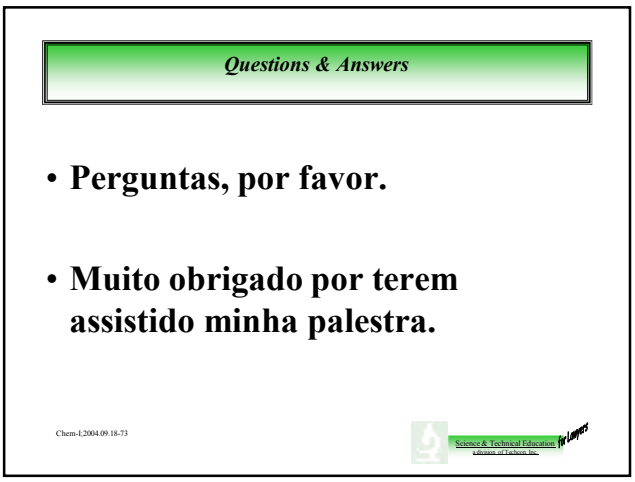
Commonly Used Term	LD_{50} Single Oral Dose for Rats (g/kg)	4-hr Vapor Exposure Causing 2-4 Deaths in 6-rat Groups (pm)	LD_{50} Skin for Rabbits (g/kg)	Probable Lethal Dose for Humans
Extremely toxic	≤0.001	<10	≤0.005	Taste (1 grain)
Highly toxic	0.001-0.05	10-100	0.005-0.043	1 tsp (4 cc)
Moderately toxic	0.05-0.5	100-1,000	0.044-0.340	1 oz (30 cc)
Slightly toxic	0.5-5.0	1,000-10,000	0.35-2.81	1 pint (250 gm)
Practically nontoxic	5.0-15.0	10,000-100,000	2.82-22.6	1 quart
Relatively harmless	>15.0	>100,000	>22.6	>1 quart

Safety Limits of Acute Oral LD_{50}s:

Sample	Safety Limits
Table Sugar	29,700 mg/kg
Ethyl Alcohol	14000 mg/kg 6-9 bottles of wine
Aspirin	1000 mg/kg(280 aspirin)
Caffeine	192 mg/kg: 67cups coffee
Nicotine	53 mg/kg (1800 cigs)
Sodium Cyanide	6 mg/kg

Conclusions

- **Forensic Chemistry is an active career**
- **Forensic Toxicology is a demanding career**
- **Forensic Pharmacy is a field that needs analytical people.**
- **Forensic Science is not at the speed of CSI but slower and truer**


Questions & Answers
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