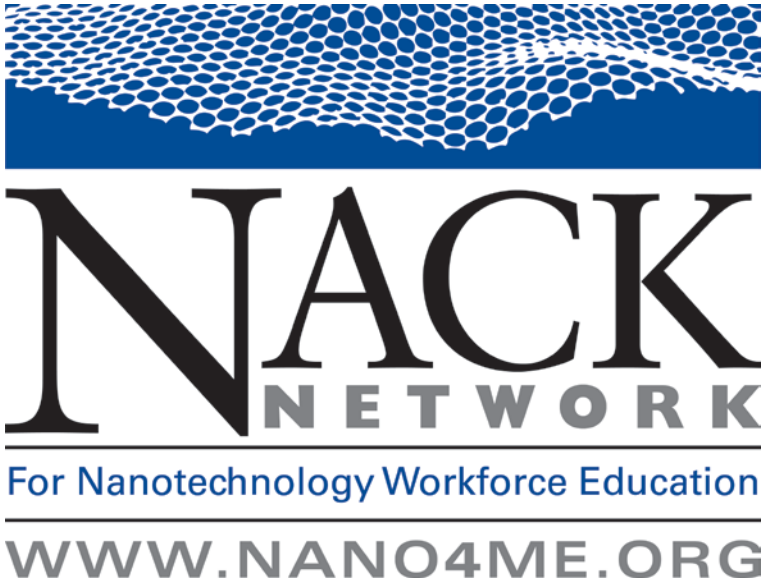


Materials, Safety and Equipment Overview for Nanotechnology

E SC 211

Unit 1
Safety and Environmental Concerns

Lecture 1

General Safety Awareness, Safety and Environmental Concerns

Outline

- General Safety Awareness
- Wet Chemistry Safety
- Gas Safety
- Biological Safety
- Nanomaterial Safety
- Energy Safety
- Environmental Concerns

General Safety Awareness

A safe laboratory environment begins with you!

Personal Safety Basics

- Personal protective equipment including glasses, gloves, aprons, etc. must be readily available
- Training must be undertaken on the use of personal protective equipment, safety devices, and safe work practices

Facility Safety Basics

- At least the following should be found throughout a lab;
  - First aide materials including calcium gluconate gel
  - Fire Extinguishers
  - Safety showers
  - Eye wash stations
  - Chemical spill and cleaning kits
- These items should be located/identified in case of need

Some Facility Safety Basics

Materials

- Many of the chemicals (liquids, gases, solids) used in nanofabrication are hazardous;
  - Toxic
  - Corrosive
  - Irritants
  - Flammable
  - Pyrophoric
  - Explosive
  - Asphyxiates

Right to Know Act

- Material suppliers provide safety information in a document called the Material Safety Data Sheet (MSDS)
  - MSDS sheets are required by law to be in the facility where the materials are used, as a result of the right to know act

MSDS

Common MSDS Content

- Product Identification
  - Name: Common and chemical
  - Composition/Information On Ingredients
- Hazards Identification
  - Health
  - Flammability
  - Reactivity Rating
  - Contact Rating (additional warnings)
- Exposure limits
  - Permissible exposure limits
  - Threshold limit value
- Handling and Storage
- Personal Protection Equipment (PPE)

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10099#1910.1200(g)

Common MSDS Content Continued

- Preventative measures/facility and equipment requirements
- Leaks and spills clean up/exposure control (First Aid)
- Physical and chemical properties
- Stability and reactivity
  - Incompatibles
- Toxicological information
- Ecological information
- Disposal Considerations
- Transportation information
- Regulatory information

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10099#1910.1200(g)

Impact Terminology

- Adverse interactions with materials have been specifically defined. The next few pages will review this vocabulary to aid in understanding safety documentation

Irritant

- A chemical that causes a reversible inflammation of living tissue at the site of contact
- Irritants may affect the skin, eyes, mucus membranes, or respiratory tract
- Exposure to irritants may not result instant inflammation

Mutagen

- Any substance that causes an increase in the rate of change to genes
- Mutations can be passed on as cells reproduce
- Cell lines that contain mutations can turn into tumors or cancers

Teratogen

- Any substance that prevents the proper formation of an embryo
- Viruses, radiation, and chemicals can be teratogens
- Teratogens damage reproductive and endocrine (hormonal) systems

Carcinogens

- A substance that causes uncontrolled cell proliferation
- Some Carcinogens can also be mutagens or teratogens

Sensitizers

- A chemical that causes a person to develop an allergic reaction after repeated exposure, in normal healthy tissue
- *Chemical Hypersensitivity* is the term used to describe the condition of being exposed to a sensitizer

Chemical Storage Cabinets

Chemical Compatibility

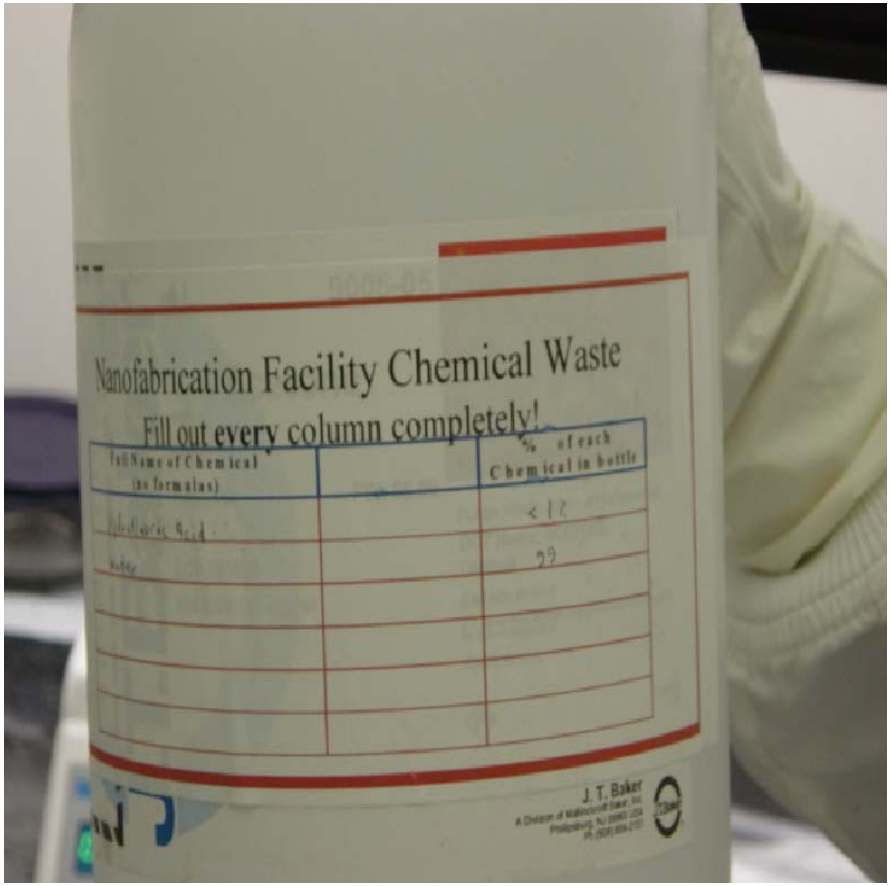
- Though some materials are considered safe, they may be hazardous in combination with other materials, or their respective properties can change with size
- It is important to understand chemical compatibility and what level of material exposure is considered safe

Chemical Waste Disposal

- The full chemical name of each chemical must be written on the label, along with their relative proportions

Chemical Waste Disposal

- The disposal label must be filled out correctly and placed over the plastic disposal bottle's original label, to insure chemical mixing does not occur
- The bottle itself must be rinsed three times with DI water
- The cap on the bottle must be replaced with a vented cap to let any vapor buildup escape, preventing explosion



Chemical Waste Disposal

- The disposal bottle must then be placed in secondary containment
- This is done to prevent serious damage, in the event of a damaged bottle, leading to chemical leakage
- Acids, bases, and solvents have separate secondary containment

Solid Waste Disposal

- Broken glass and other solid materials must be kept in containment.

- Left-over solid materials must be collected, contained, and disposed of properly.

Outline

- General Safety Awareness
- Wet Chemistry Safety
- Gas Safety
- Biological Safety
- Nanomaterial Safety
- Energy Safety
- Environmental Concerns

Safety Guidelines at the Wet Bench

- Use safety glasses at all times.
- Face shield, apron and (protective) nitrile gloves must be worn when working with corrosives.
- Keep acids, bases, and solvents in separate storage areas.

Wet Bench Safety Gear

Safety Guidelines

- Always add a chemical to water, and not the other way around.
- Discard used aqueous chemicals in properly labeled **plastic** waste containers.
- Before using a new waste container, be sure that it has been rinsed at least 3 times with deionized (DI) water.

Corrosive Materials

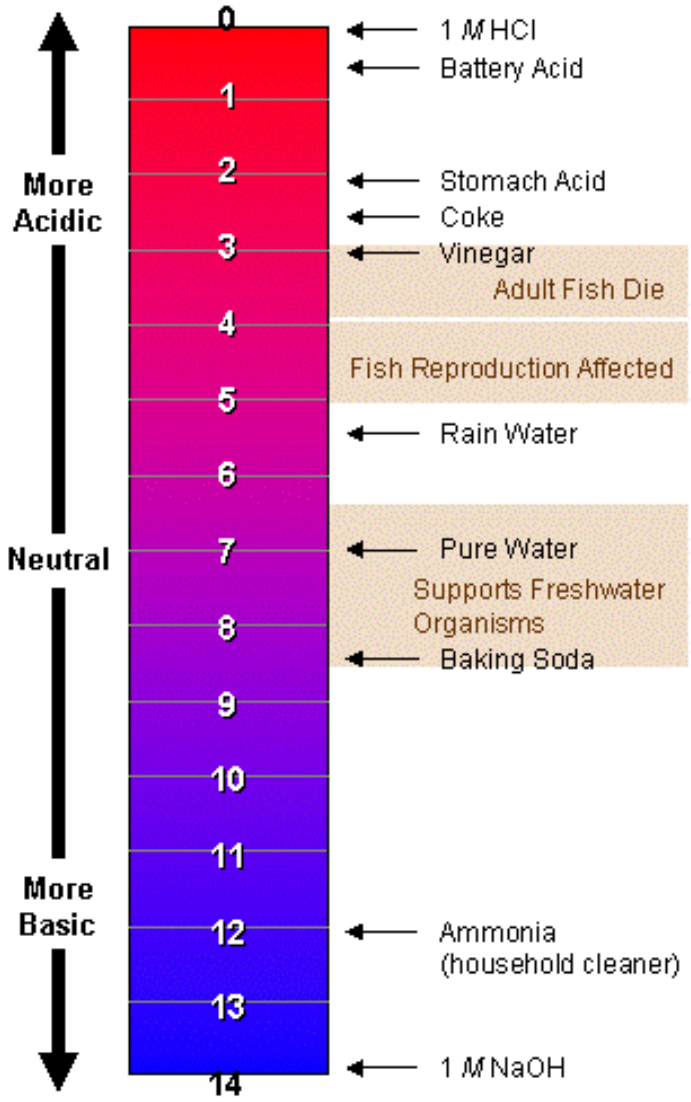
- Strong acids and bases are highly corrosive, potentially causing serious burns and eye injuries.
- Corrosives can be acidic or basic and include, but are not limited to:
  - Hydrofluoric acid (Extremely Dangerous!)
  - Sulfuric acid
  - Nitric acid
  - Hydrochloric acid
  - Sodium hydroxide
  - Ammonium hydroxide

pH

- Measurement of the concentration of H^+ in solution.
- Negative $\log_{10}$ of concentration of H^+
- $pH = -\log [H^+] = \log (1/[H^+])$
- There is an order of magnitude between each whole number on the pH scale.

Brady, T. LeMay, H. *Chemistry The Central Science*. New Jersey 1988

pH Scale



http://www.fst.vt.edu/extension/valueadded/pH.html

Acids

- Compounds that increase the concentrations of H^+ ions in an aqueous solution.
- Any substance with a pH less than 7 is considered to be an acid
- The Brønsted-Lowery definition of an acid is a substance that is capable of donation of a proton.

Brow, T. LeMay, H. *Chemistry The Central Science*. New Jersey 1988

Acids

- When hydrogen chloride (HCl) gas is dissolved in water, the substituent dissociate into H^+ and Cl^-

$$HCl\ (g) \xrightarrow{H_2O} H^+\ (aq) + Cl^-\ (aq)$$

- Some acids like sulfuric acid are liquids. Dissolving H_2SO_4 in water will cause it to dissociate into $2H^+$ and SO_4^{2-}

$$H_2SO_4\ (l) \xrightarrow[H_2O]{} H^+\ (aq) + HSO_4^-\ (aq)$$

$$HSO_4^-\ (aq) \xrightarrow[H_2O]{} H^+\ (aq) + SO_4^-\ (aq)$$

Brow, T. LeMay, H. *Chemistry The Central Science*. New Jersey 1988

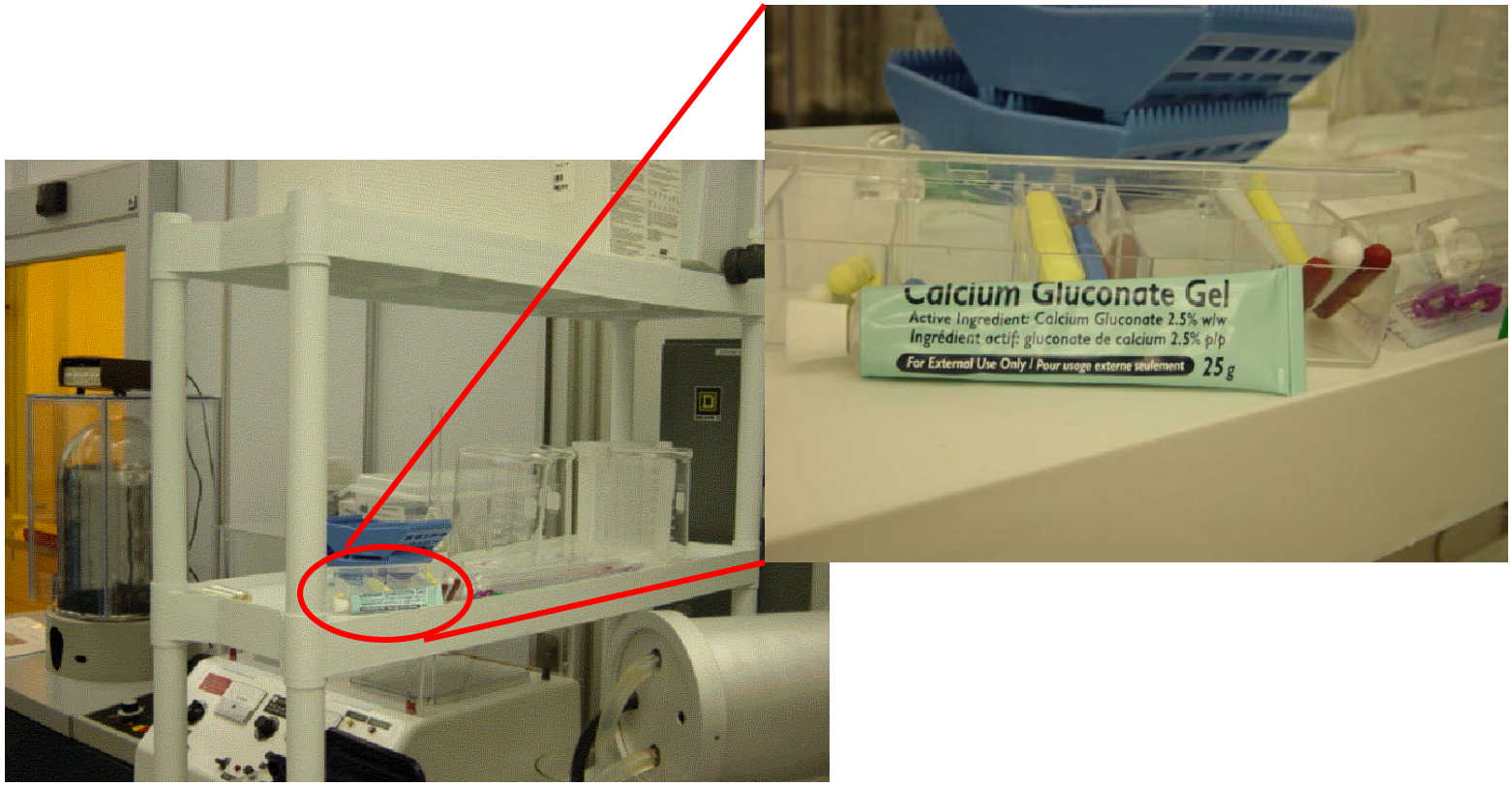
Hydrofluoric Acid (HF)

- HF is commonly used to etch silicon dioxide (e.g., glass) in nanofabrication.
  - It must be stored in and dispensed into plastic containers .
- If exposure occurs, HF attacks calcium in the body and damages nerve endings.

Hydrofluoric Acid Exposure

- In the event of HF exposure, wash the effected area with water and apply calcium gluconate gel, located near the wet bench area
- Exposure requires a visit to the hospital.

Calcium Gluconate Gel



Bases

- Substances that increase the concentration of OH^- ions in an aqueous solution.
- Any substance with a pH greater than 7 is considered to be a base.
- The Brønsted-Lowery definition of a base is a substance that is capable of accepting a proton.

Brow, T. LeMay, H. *Chemistry The Central Science*. New Jersey 1988

Bases

- Many bases consists of ionic compounds such as NaOH, which simply dissociate in water to form Na^+ and OH^-:

$$NaOH\ (s) \xrightarrow{H_2O} Na^+\ (aq) + OH^-\ (aq)$$

- Some bases like ammonia (NH_3) are basic, even if the OH^- is not in its name:

$$NH_3\ (g) + H_2O\ (l) \xrightarrow[H_2O]{} NH_4^+\ (aq) + OH^-\ (aq)$$

- Because ammonia will increase the concentration of OH^- in an aqueous solution, ammonia and water are called ammonium hydroxide (NH_4OH), to remind us that ammonia will form basic solutions.

Brow, T. LeMay, H. *Chemistry The Central Science*. New Jersey 1988

Solvents

- A compound whose phase does not change when combined with other chemistries to make a solution
- i.e., a substance in which a solute dissolves
- Solvents are commonplace and should be handled with care, as most are flammable, can volatilize, and are potentially explosive

Solvents

- Some common solvents
  - Deionized (DI) water
  - Acetone
  - Isopropanol (IPA)
  - Trichloroethylene (TCE)
  - Ethylene Glycol Monomethyl Ether Acetate (EGMEA)

Deionized Water

- DI water is a highly purified water used in nanotechnology
  - A series of specially manufactured ion-exchange resins produce DI water by removing the electrically active salts found in drinking water.
- The water is changed from a conductive medium to a resistive medium with a resistivity of 18 megohm-cm at 25 °C.
- DI water is a universal solvent - many things will dissolve in it.

Deionized Water

- DI water purity is maintained by insuring its resistivity is relatively constant at 18MΩ-cm.
- DI water used in nanotechnology is referred to as **18 mega-ohm** water.
- It is important to remember that DI water is a process chemical and caution should be observed, as with any other cleanroom chemical.
  - If consumed, DI water will leech salts out of the body, which could be potentially fatal!

Acetone

- Chemically classified as a ketone
- General-purpose cleaning solvent
- Organic stripper
- Extremely volatile
- Flammable
- Irritant

Acetone

- If vapors are inhaled, the respiratory tract may become irritated leading to coughing, dizziness, and headache.
- Exposure to high concentrations of vapors can cause narcosis and unconsciousness.
- Prolonged exposure can lead to damage to the central nervous system, liver, and kidneys.

Isopropanol (IPA)

- Chemically classified as an alcohol
- General purpose cleaning solvent
- Organic stripper
- Volatile
- Flammable
- Irritant

Isopropanol (IPA)

- If vapors are inhaled, the respiratory tract may become irritated leading to coughing, dizziness, and headache.
- Exposure to high concentrations of vapors can cause narcosis and unconsciousness.
- Prolonged exposure can lead to damage to the central nervous system.

Trichloroethylene (TCE)

- Chemically classified as a chlorinated hydrocarbon
- General purpose cleaning solvent
- Non-flammable
- Carcinogen

Trichloroethylene (TCE)

- If vapors are inhaled, the respiratory tract becomes irritated and inflamed.
- Exposure to high concentrations can cause damage to the central nervous system, mental confusion, euphoria, and death.
- Prolonged exposure can lead to heart, lung, and kidney problems, as well as cancer.

Ethylene Glycol Monomethyl Ether Acetate (EGMEA)

- Chemically classified as an ether
- Solvent used to dissolve resins
- Flammable
- Irritant
- Teratogen

Ethylene Glycol Monomethyl Ether Acetate (EGMEA)

- Irritant to the respiratory and nervous system.
- Can cause birth defects to developing embryos
  - Mutation of reproductive organs.
- Prolonged exposure can cause liver, kidney, testes, and bone marrow damage.

Wet Chemistry Example

Piranha Etch

- A 70:30 mixture of sulfuric acid and hydrogen peroxide that aggressively strips both organic and inorganic material from the substrate surface
  - Very effective organic stripper
- When mixed at this ratio, an exothermic reaction takes place, quickly raising the temperature into the 110 °C to 130 °C range
- When placed in a very tightly sealed disposal container, vapors can build up, potentially causing the container to explode
- Due to its potential for injury, its use is restricted to the staff only