Active Chemistry for the 21st Century Classroom

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Hot and Cold

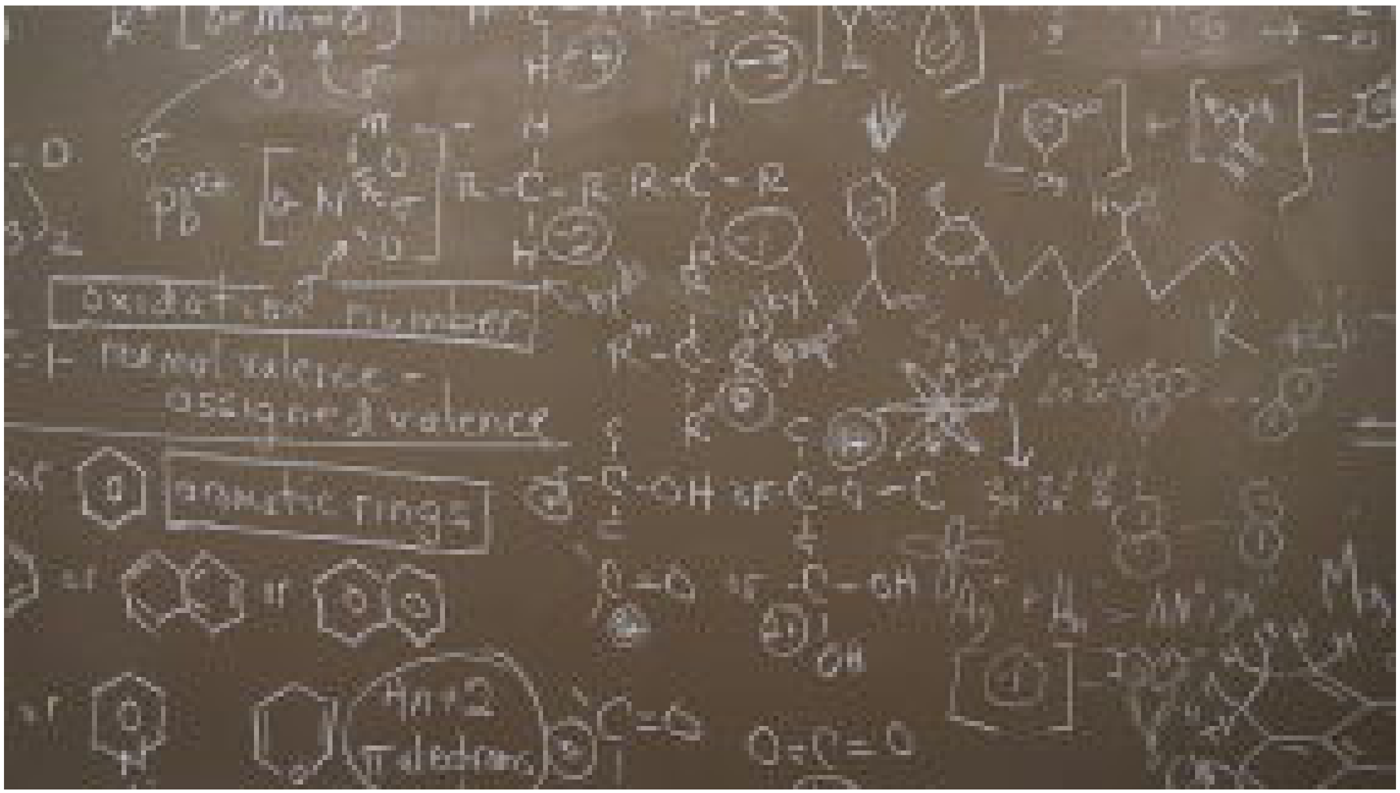
Separate water by density

HOT

COLD

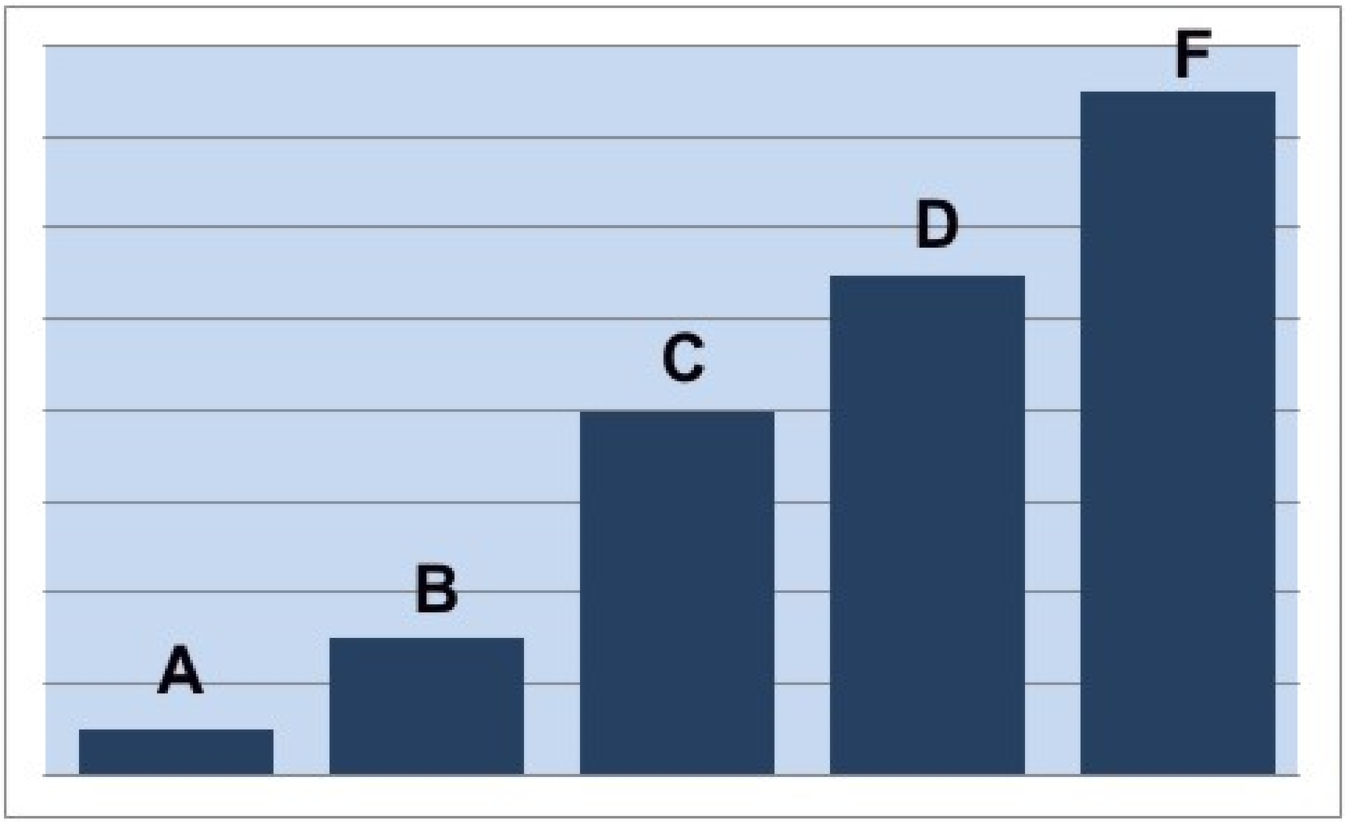
COLD HOT

Do your class notes look like this



DO YOUR STUDENTS LOOK LIKE THIS?

DO YOUR CLASS GRADES LOOK LIKE THIS?

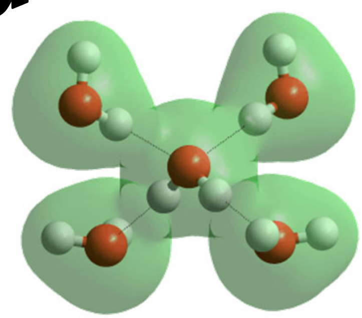


Why is chemistry "hard"?

- Technical vocabulary
- Concepts and abstractions – difficult to relate to everyday
- Difficult to visualize electrons, atoms, molecules, reactions, etc…
- Cannot memorize information – must have some degree of understanding
- Boring lectures ("chalk talks") with a lot of information (information overload)
- Requires math  (Horrors!)

Learning needs to be real.
Learning needs to be multisensory.

Visualize



Touch

Think

Smell

Active learning*

- Topics go beyond the textbook coverage
- Students are participants in the class
- Creates a dialogue
- Provides visualization of concepts
- Allows for discovery
- Presents complex concepts on a concrete level
- Relation to everyday materials and processes
- Students must prepare for class in advance
  - Do not read the textbook to the students

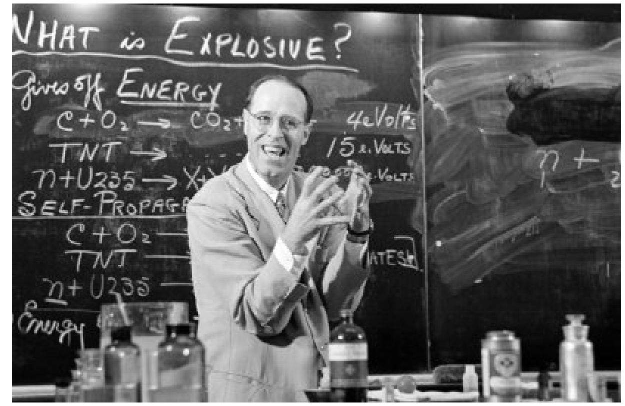
*Scott Freeman and colleagues, Proceedings of the National Academy of Sciences (*Proc. Natl. Acad. Sci. USA* 2014, DOI: 10.1073/pnas.1319030111)

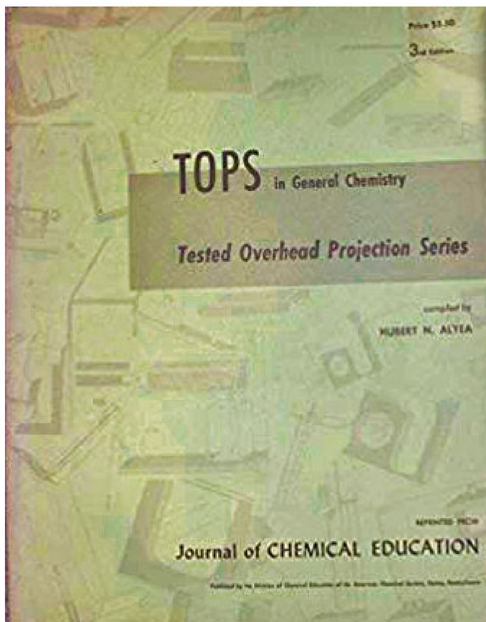
What can we do?

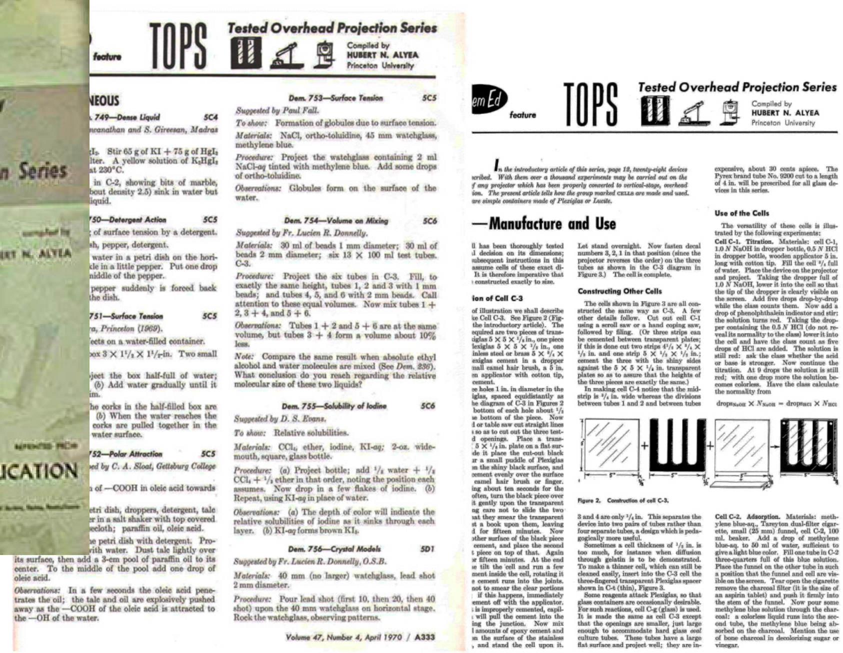
- Go beyond clickers and flipped classrooms
- Classroom instruction:
  - Demonstrations
  - Hands-on class activities
  - Small group activities
- Homework activities
  - Experiments to do at home
- Testing (Active Assessment)
  - Small scale experiments
- Whenever possible, don't walk into your classroom without a demonstration or an activity.

Small scale chemistry experiments:

Hubert Alyea starting in 1961 with his TOPS (Tested Overhead Projection Series) and, later, with his Armchair Chemistry experiments.







Small scale chemistry experiments:

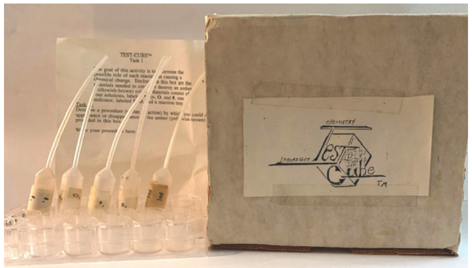
- For his TOPS, Hubert Alyea utilized a number of custom made apparatus.

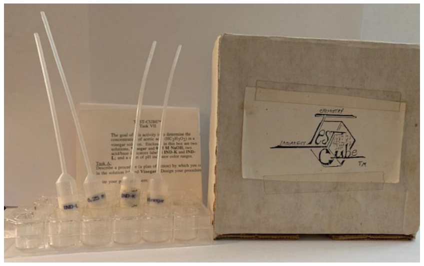
- For his Armchair Chemistry experiments, he used small dropper bottles, small test tubes, watch glasses, and more.

- The availability of inexpensive and readily available materials such as Beral pipettes and well plates made microscale more accessible in the classroom.

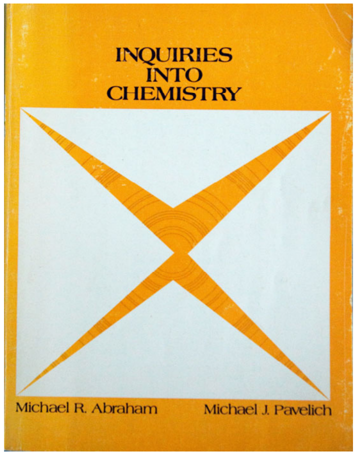
Small scale chemistry experiments:

- Development of suitable questions and techniques by Wilbur Bergquist's "Test Cubes"





- Abraham and Pavelich's open inquiry experiments in their *Inquiries Into Chemistry*



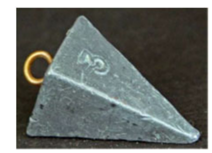
- Bob Silberman's *Small-Scale Laboratory Assessment Activities*

- **The experiments and techniques from classroom activities can be used for**
  - **Hands-on testing in classroom exams**
    - **Initiated in my classes in 1993 through 1998**
    - **Used as part of the 2001 and 2002 New Jersey's Rutgers University Academic Challenge competition**
  - **Laboratory practical exams**
  - **Hands-on sessions at professional conferences and in workshops with teachers, students, and the public**
    - **Participants can rotate between experiment stations**

Elements

How are elements formed?
NOVA: Forging the Elements in "Origins: Back to the Beginning"
https://www.youtube.com/watch?v=621maypRngs (55 minutes in length). The origin of the elements starts at about 34 minutes into the video)
or see The Elements: Forged in Stars at
https://www.youtube.com/watch?v=B-LXUHJmzzc

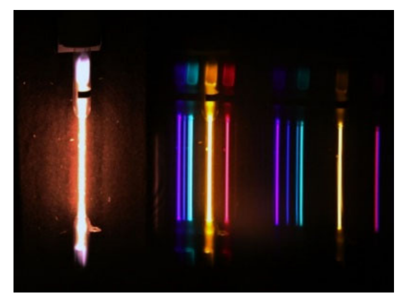
Pass meteorite samples around the classroom



Pass element samples around the classroom

Build a spectroscope

Use Flinn C-Spectra or other holographic diffraction grating.

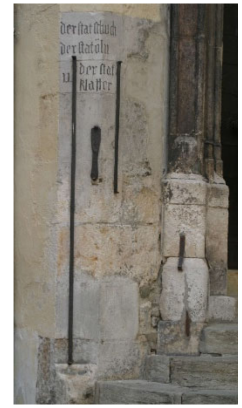


View Spectra using spectrum tubes

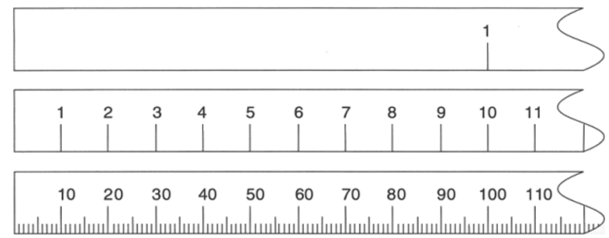
Homework: find spectra of elements in your environment.

Measurement

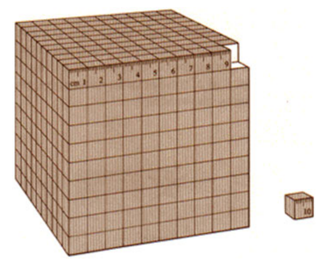
- **Do you waste time teaching measurement?**
- **Don’t define measurement, get the students to measure things**
- **They will get some measurements wrong, but will learn**



Ancient measurement standards in Regensburg, Germany



“Silver” and “gold” pennies (copper coins). Masses are essentially unchanged
http://www.chymist.com/copper%20silver%20gold.pdf



Some references for measurement are:
Powers of Ten https://www.youtube.com/watch?v=0fKBhvDjuy0
Absolute Zero https://www.youtube.com/watch?v=E9U3dh4Capg

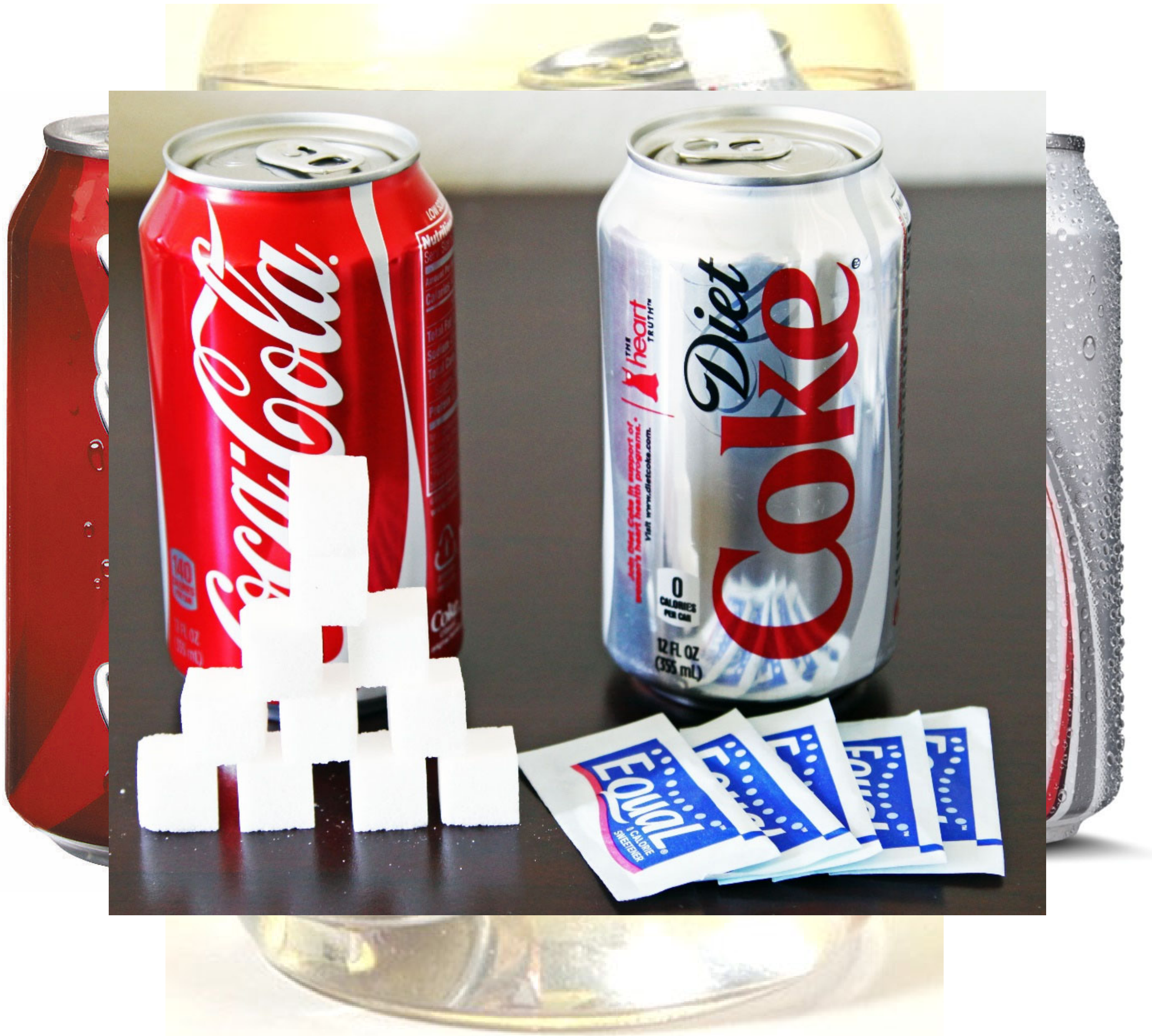
Density

Density-for-the-sake-of-density does not necessarily teach the concept.

Indiana Jones – Raiders of the Lost Ark

and students will explain it to you.

Coke vs. Diet Coke

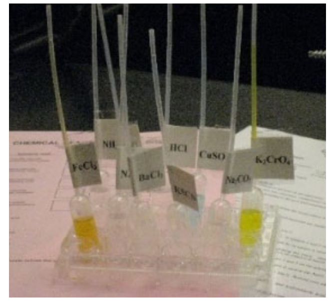


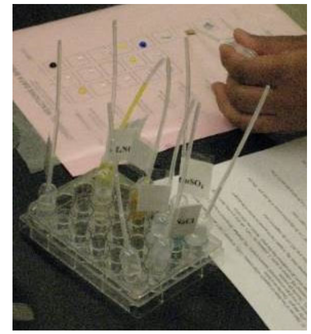
Chemical Reactions

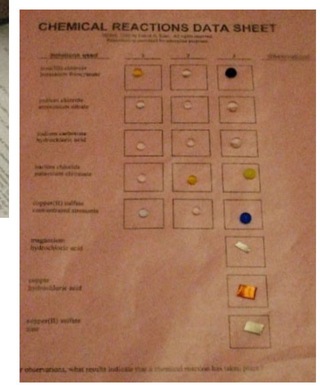
- **Chemical reactions**

  (A lab or classroom activity)

  Instructions at http://www.chymist.com/chemical%20reactions.pdf







- **Synthesis of Zinc Iodide**

  Tracking a chemical reaction in small scale

  Instructions at http://www.chymist.com/zinc%20iodide.pdf

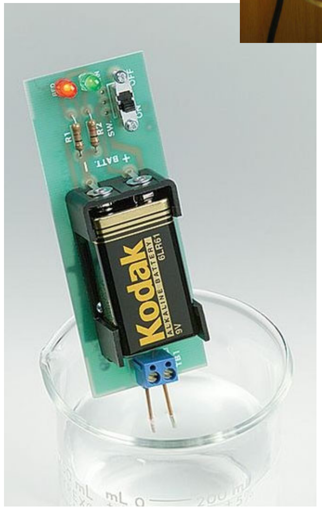
Conductivity Testing

- If household current is used, **fit the apparatus with a momentary switch**.

- Use a battery powered conductivity tester.

Flinn Scientific Conductivity Tester (Cat. No. AP1493) or build your own.

Instructions at http://www.chymist.com/conductivity.pdf



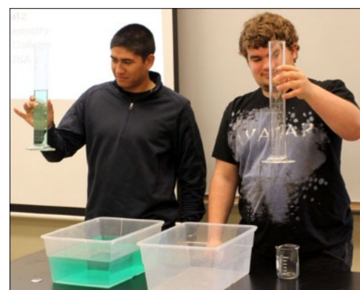
Alka Seltzer: An Intro to kinetics

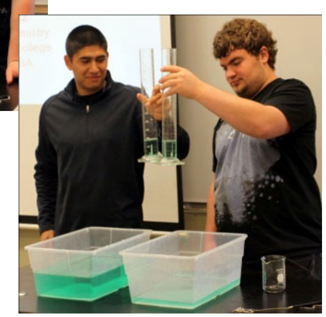
- Vary particle size
- Vary temperature

Alka Seltzer: Limiting reagent

- Note: $NaHCO_3$ is present in excess

http://www.chymist.com/AlkaSeltzer.pdf

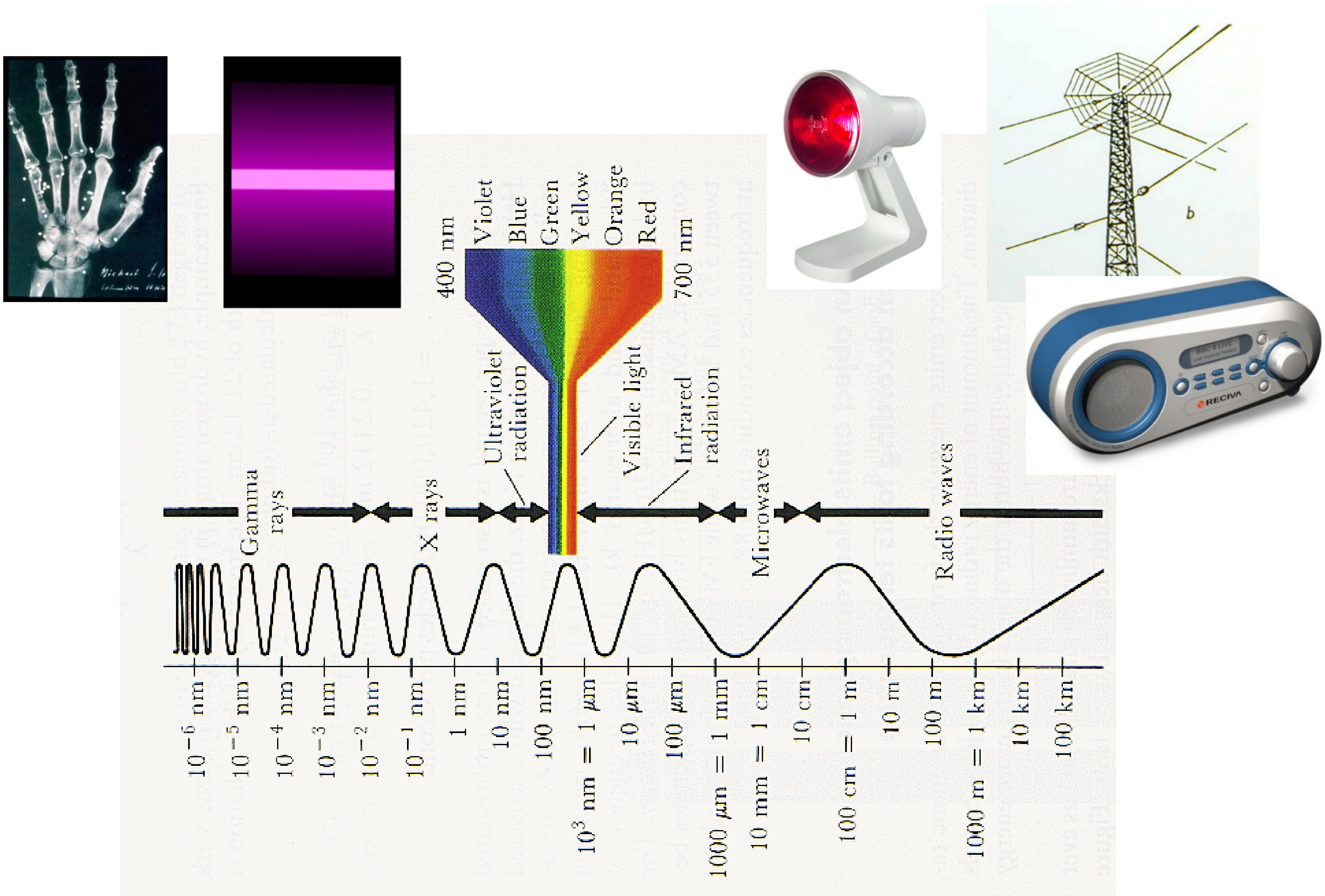




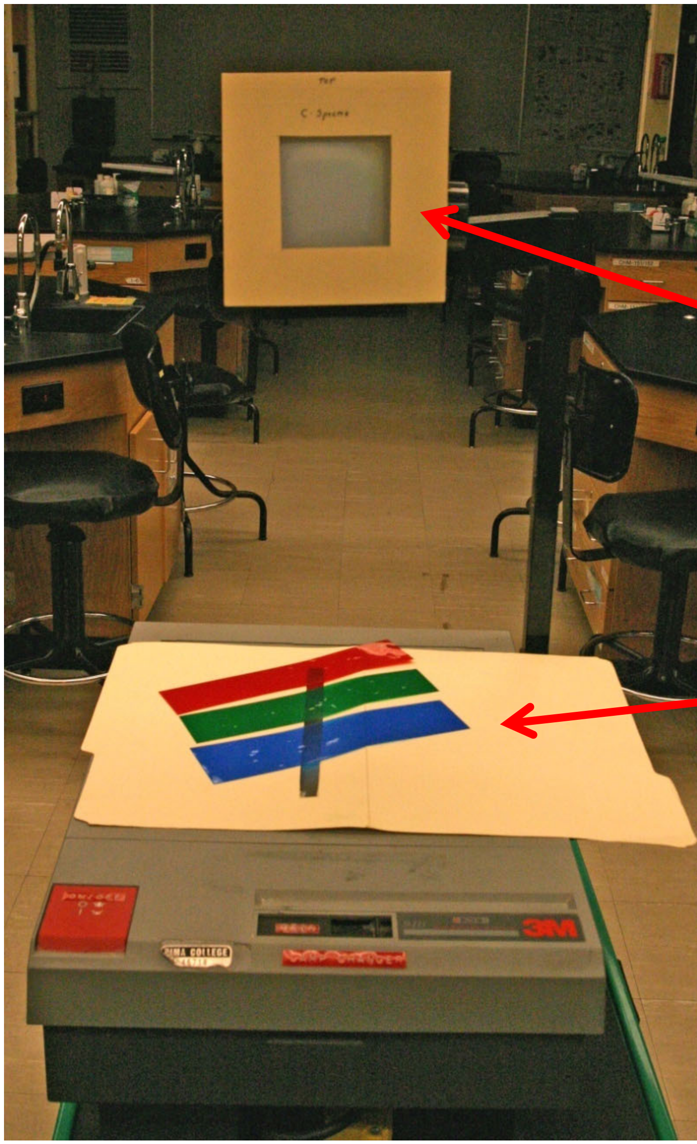
Equilibrium simulation

- Start with 2 beakers equal size (400 mL)
- Repeat with 2 beakers unequal size (100 mL and 400 mL)
- Measure every few cycles
- http://www.chymist.com/Visualizing%20Equilibrium.pdf

The Visual Electromagnetic Spectrum



Visible Light



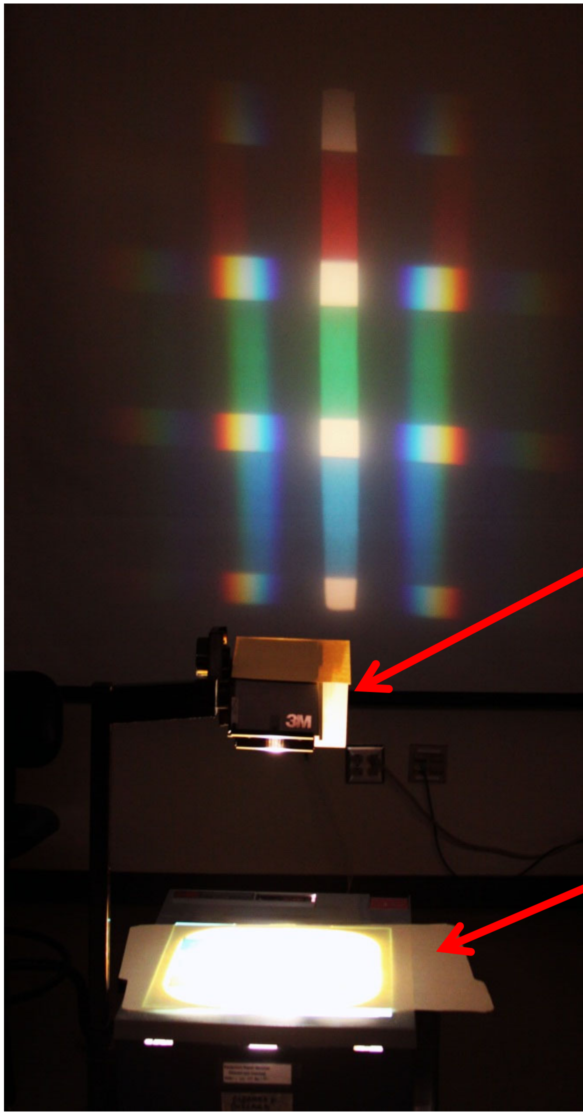
An overhead projector spectroscope

Holographic diffraction grating
(Flinn C-Spectra)

Slit and colored filters

Instructions are available at
http://www.chymist.com/overhead%20spectroscope.pdf

Visible Light



An overhead projector spectroscope

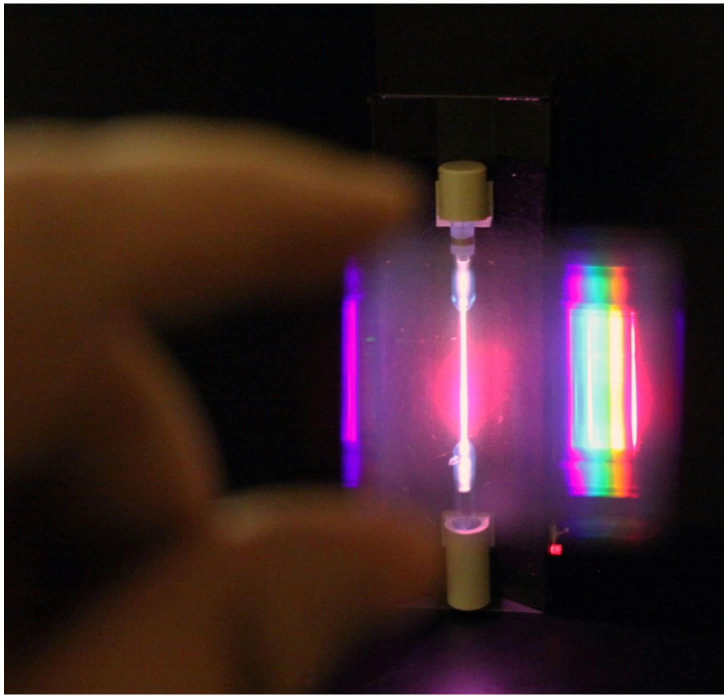
View absorption spectra

Holographic diffraction grating

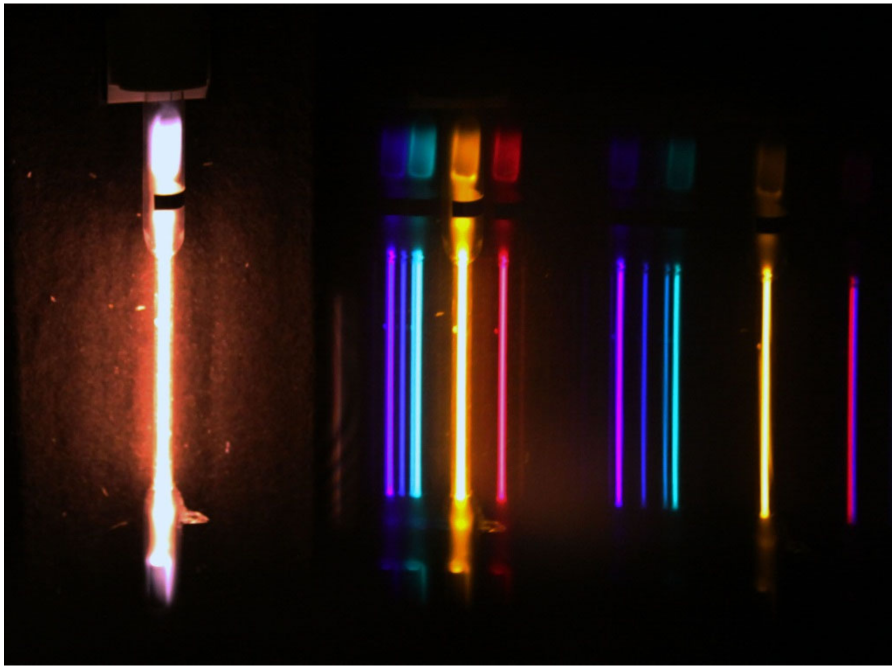
Slit and colored filters

The Electromagnetic Spectrum

Viewing spectra using holographic diffraction grating (Flinn Scientific C-Spectra)



Hydrogen spectrum



Helium spectrum

Colored Flames

Strontium – red

Lithium - red

Calcium – red/orange

Copper – green or blue

Barium – yellow-green

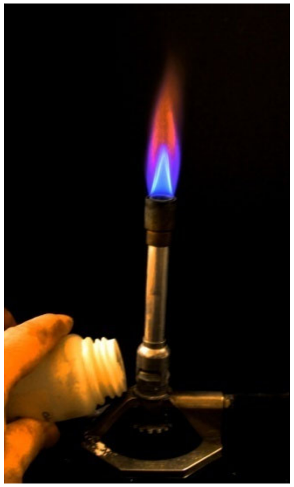
Potassium – violet

Sodium - yellow

Instructions at
http://www.chymist.com/Colored%20flames.pdf

lithium

potassium



calcium

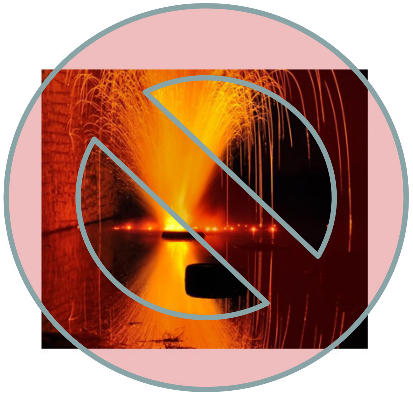
barium

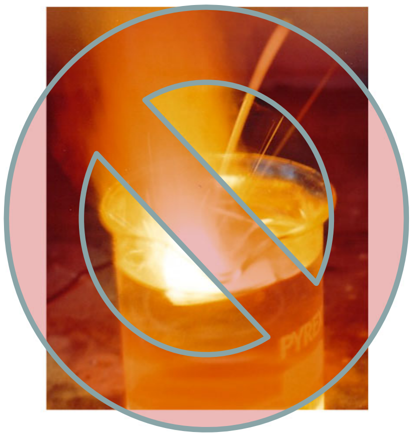
Alkali Metals: Li, Na, and K

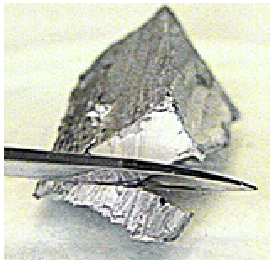
Use small pieces of metals in a 600 or 800-mL beaker.

Cover with a fine wire gauze.

Project the reaction on a large screen.





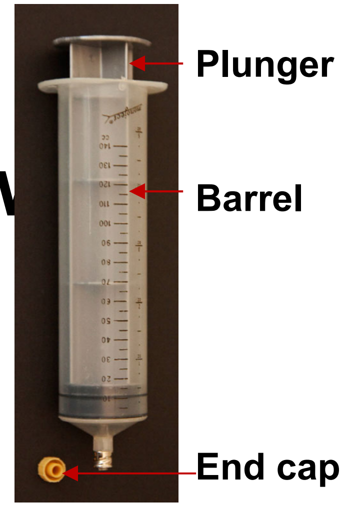


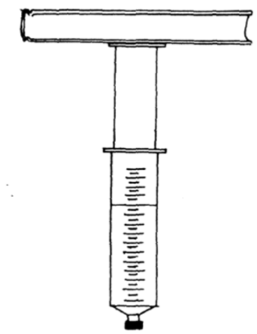
Project the cutting of the metal

Gases:
Experiments with a 140-mL syringe

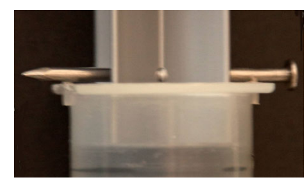
- **Boyle's Law: PV = k**
- **Expand a marshmallow**
- **Boil water at room temperature**
- **Charles' Law: V/T = k**
  - **Need to lubricate barrel and plunger with grease (Vaseline)**
- **Determine mass (density) of a gas**

http://www.chymist.com/Exps%20with%20a%20140%20mL%20syringe.pdf





Use textbooks as weights

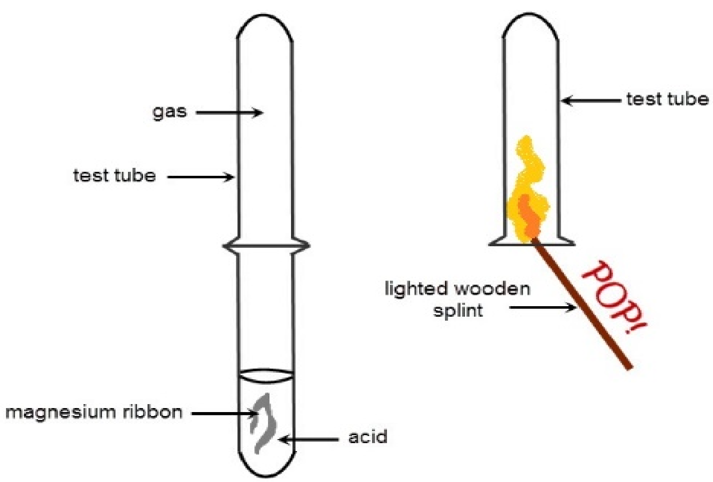


Nail through plunger of syringe at 100 mL and 140 mL

Hydrogen

Igniting a hydrogen filled balloon!

Best teaching moment is using a test tube.



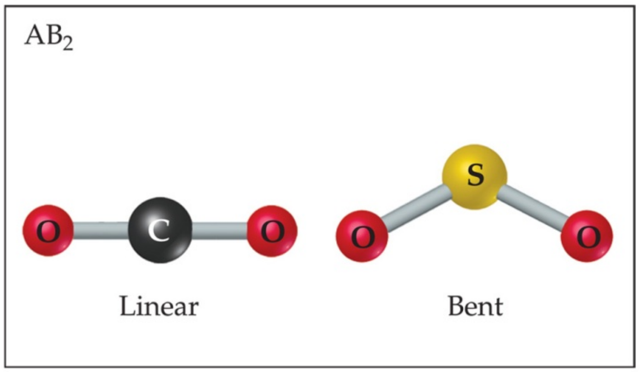
Oxygen

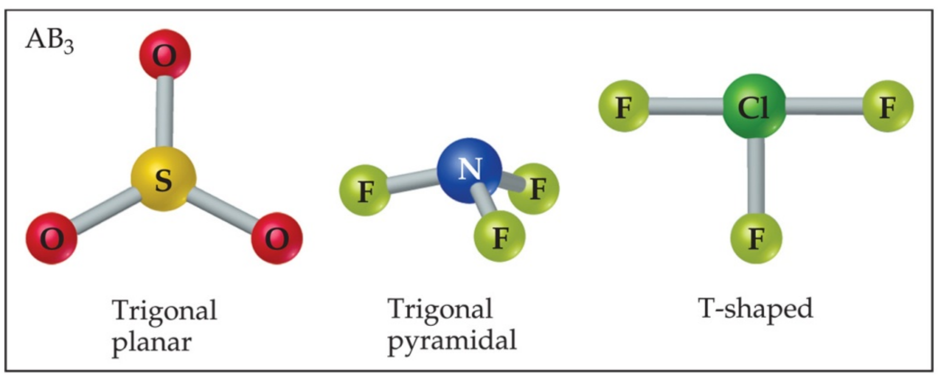
Use hydrogen peroxide and yeast to generate oxygen in a large test tube or a small (50 or 125 mL) flask.

Carbon Dioxide

Use baking soda ($NaHCO_3$) and vinegar to generate CO_2

Molecular Shapes Using Modeling Clay and Toothpicks

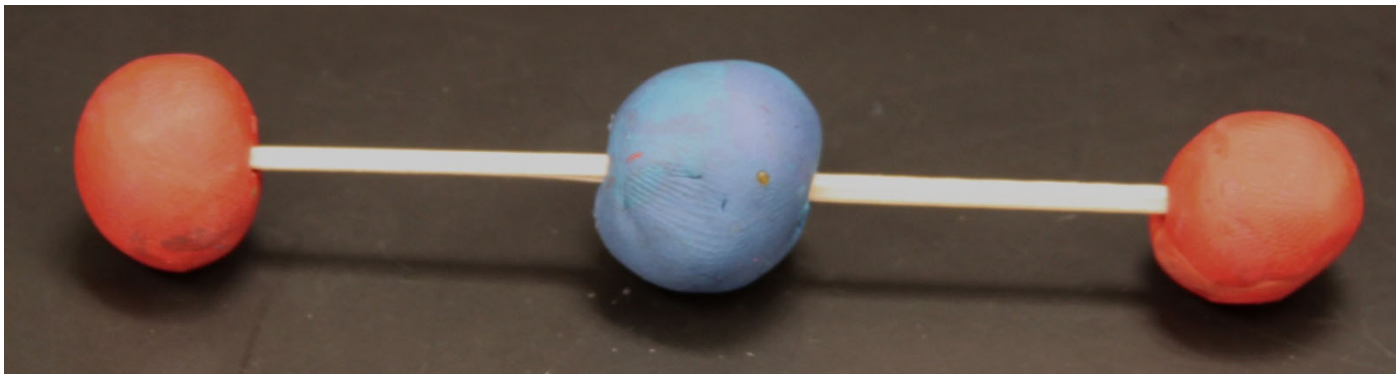




- **The shape of a molecule plays an important role in its reactivity.**
- **Students cannot think in 3-D**
- **Manipulating "atoms" into molecular shapes formalizes VSEPR**
- **Teach shapes BEFORE Lewis dot structures**

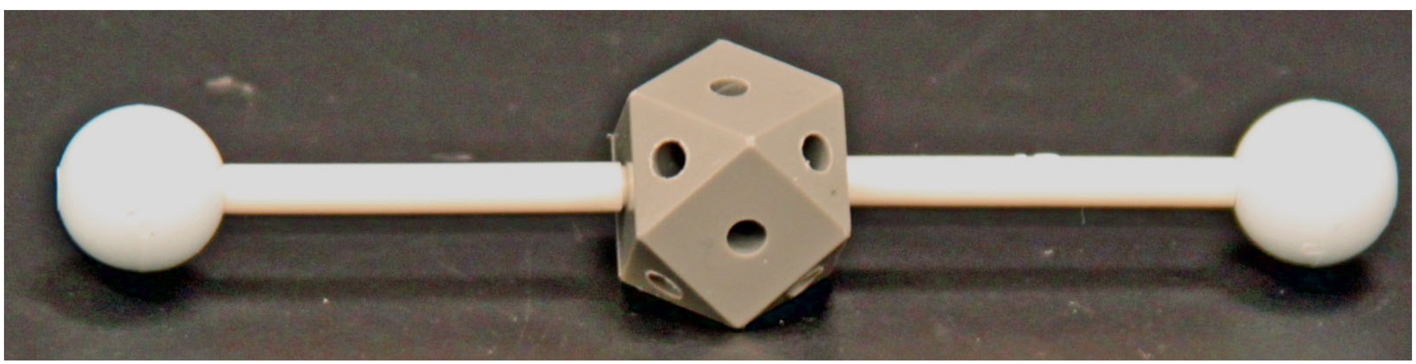
Molecular Shapes

Modeling clay and toothpicks to build shapes

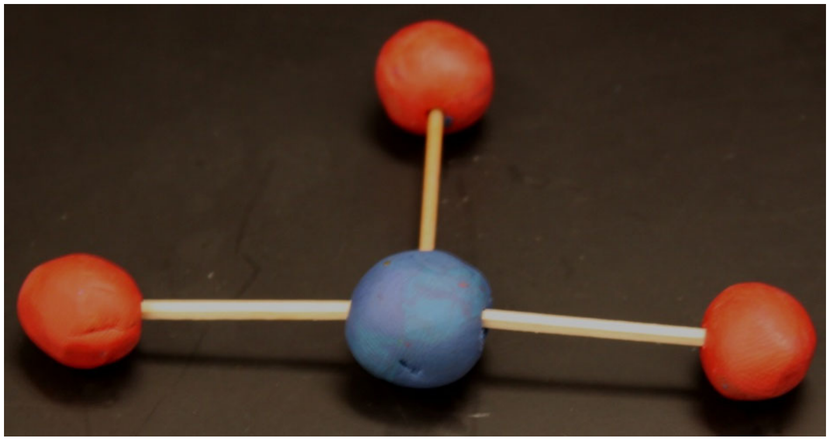


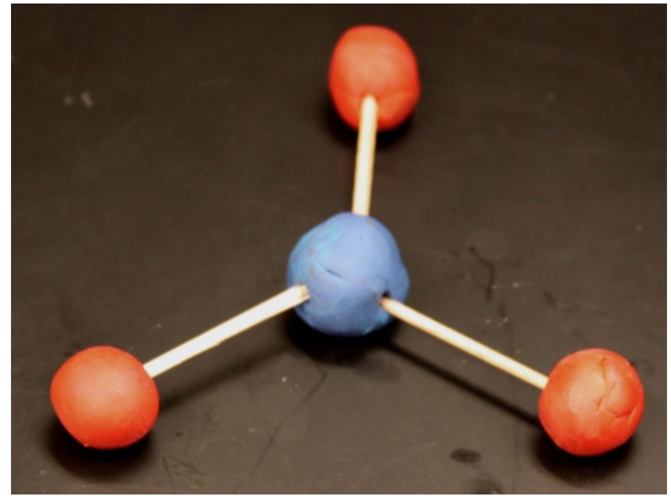
MX_2 – linear, 180° bond angle

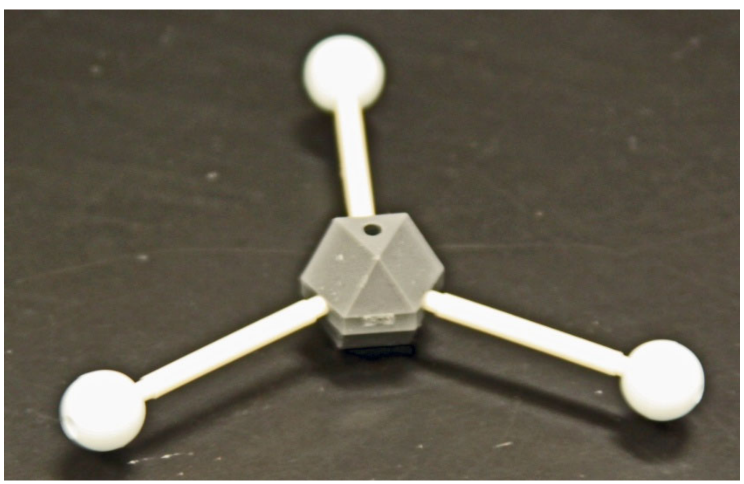
Characteristic of Periodic Table Group IIA



Molecular Shapes

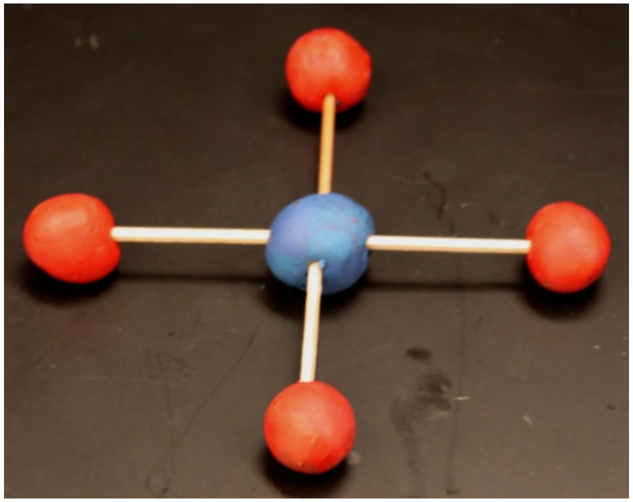


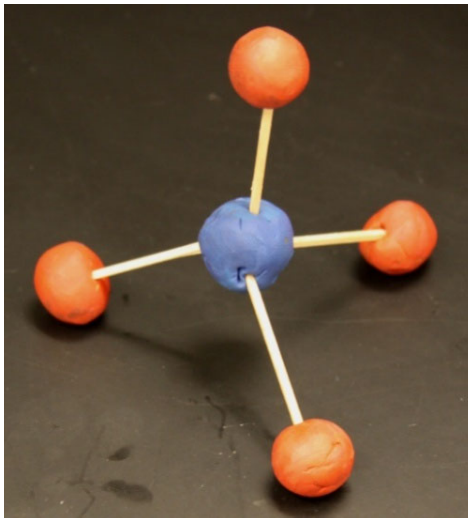


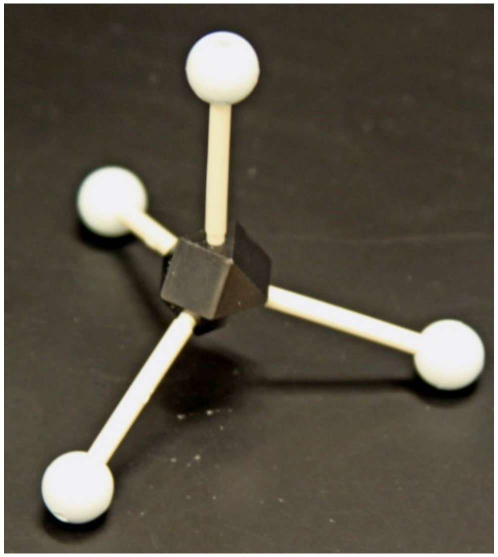


MX_3
triangular planar
(trigonal planar)
120° bond angle
Characteristic of Periodic Table Group IIIA

Molecular Shapes







MX_4

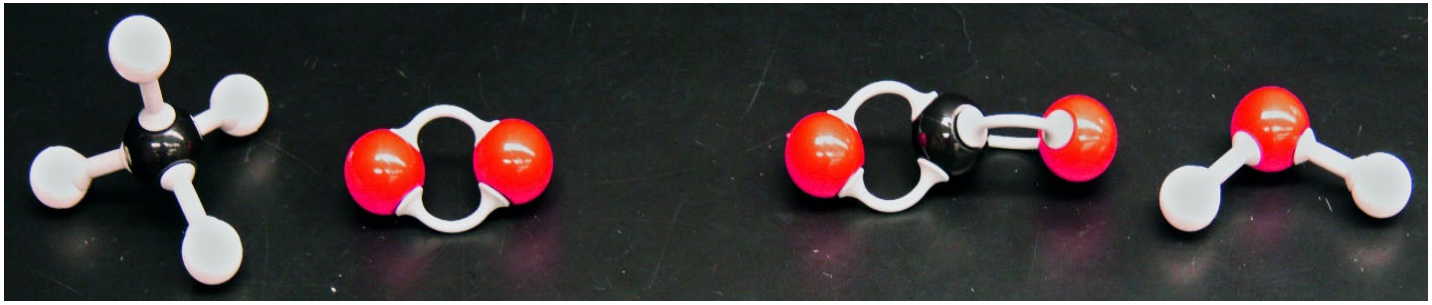
tetrahedral

109.5° bond angle

Characteristic of Periodic Table Group IVA

Students must physically form a 3-D structure

Visual Stoichiometry



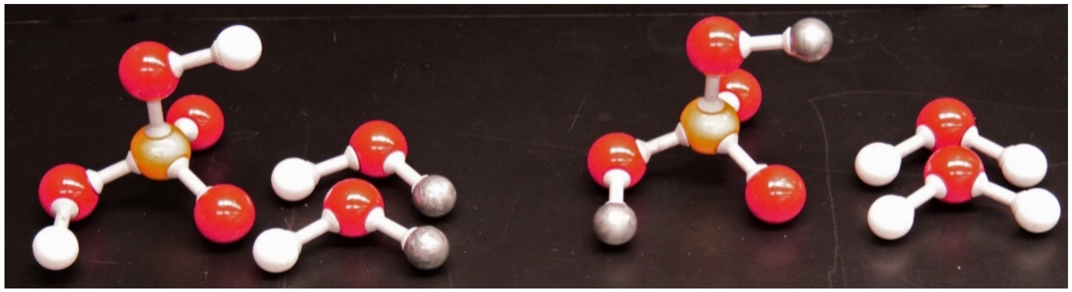
$CH_4 \quad + \quad O_2 \quad \rightarrow \quad CO_2 \quad + \quad H_2O$

(equation not balanced)

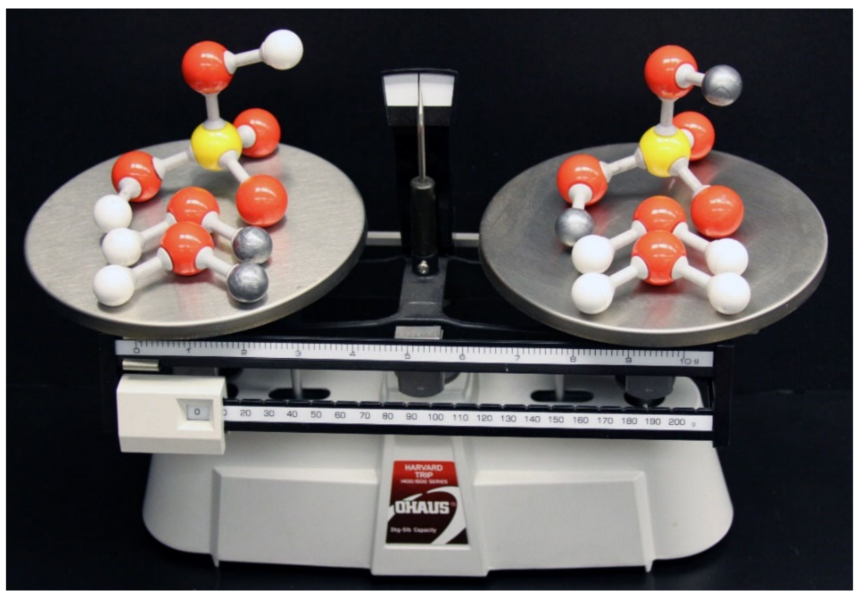
MolyMod Models are injection molded. Same “atoms” and “bonds” have the same mass

Instructions at http://www.chymist.com/Models%20mass%20and%20stoichiometry.pdf

Visual Stoichiometry



$$H_2SO_4 \; + \; 2\,NaOH \;\rightarrow\; Na_2SO_4 \; + \; 2\,H_2O$$

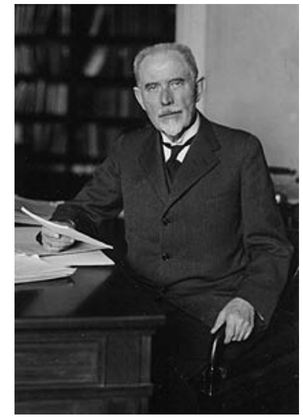


Acids and Bases

- Svante August Arrhenius (1859 – 1927)
  - Acid produces hydrogen ions in water solution.
- Johannes Nicolaus Brønsted (*1879-1947) and* Thomas Martin Lowry (1874-1936)
  - An acid-base reaction consists of the transfer of a proton (or hydrogen ion) from an acid to a base



pH

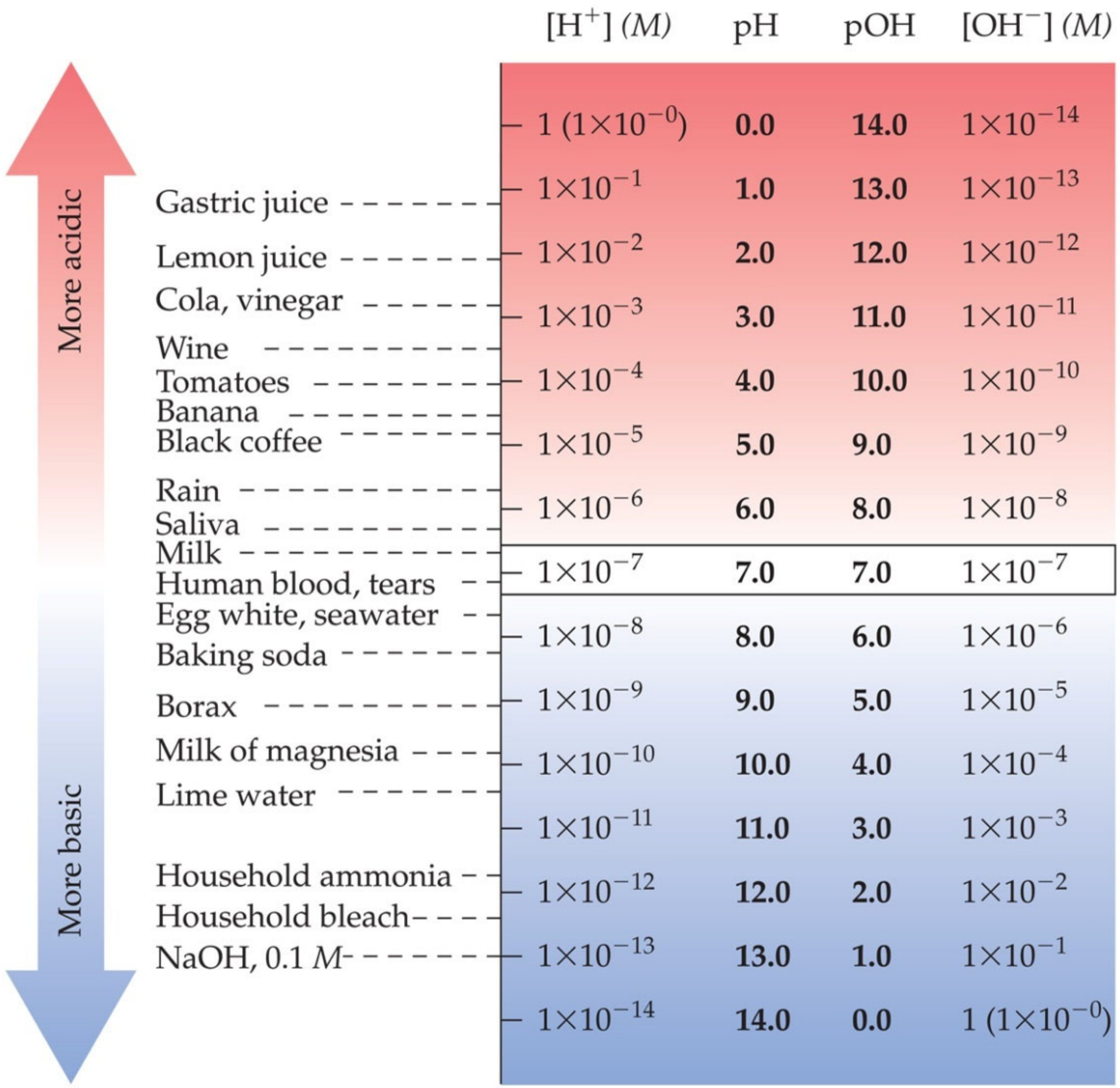


- First introduced by Danish chemist Søren Peder Lauritz Sørensen (1868-1939), the head of the Carlsberg Laboratory's Chemical Department, in 1909
- pH means 'the power of hydrogen'.
- Each value of pH means the H^+ concentration changes by a factor of 10
- As the H^+ concentration decreases, the OH^-

pH 1 strong acid	weak acid	pH 7 neutral	weak base	pH 14 strong base

he pH scale according to the late Dr. Hubert Alyea, Princeton University

pH values for some common substances



Acids, Bases, and pH

- **Acids, bases, and pH using red cabbage paper**
  - **Buffers for reference**
  - **Solutions of household products**

Instructions at
http://www.chymist.com/Visualizing%20pH.pdf

Discuss pH's of various household materials

- **Illustrate indicator colors using serial dilutions to observe color changes**

Phenolphthalein

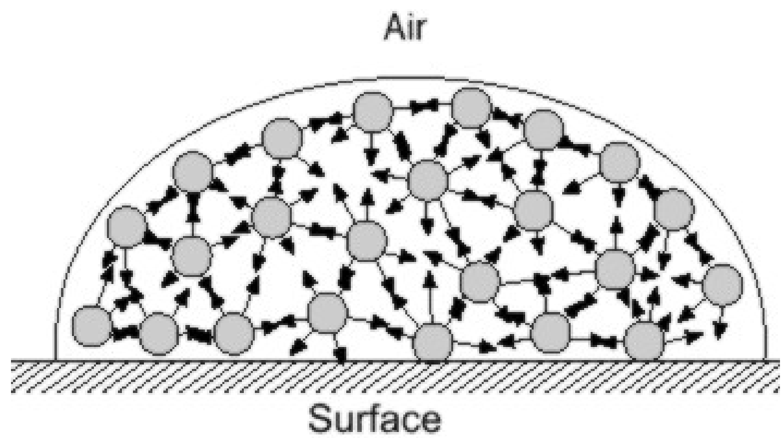
Acid

Base

?

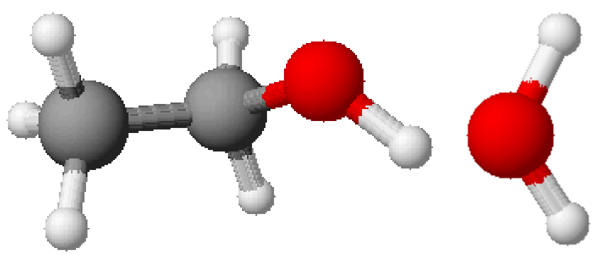
Intermolecular forces
Drops of water on a coin

How many drops of water can you put on a coin? Why?



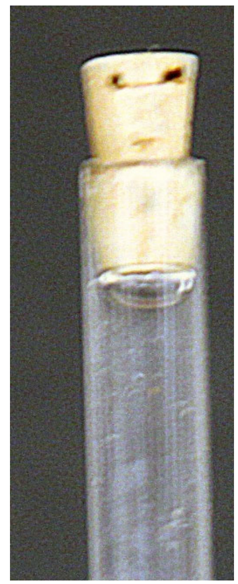
Repeat: Add a drop of dishwashing detergent to the water.
Use ethanol in place of water.

Intermolecular forces: Decrease in Volume



ethanol and water

Instructions at
http://www.chymist.com/Decrease%20in%20volume.pdf



JAMESON
SELECT RESERVE
Single Distillery
BLACK BARREL
1780
JJ&S
JOHN JAMESON & SON
IRISH WHISKEY

Hydrogen Bonding
Increase in Volume

$$HCl + NaOH \rightarrow NaCl + H_2O$$

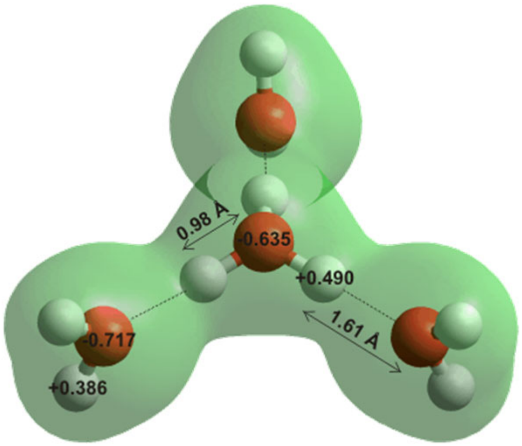
The volume increase is 18.5 mL/mol

Reference: Sam Katz, and Jane E. Miller, *J. Phys. Chem.*, **1971**, *75* (8), pp 1120–1125

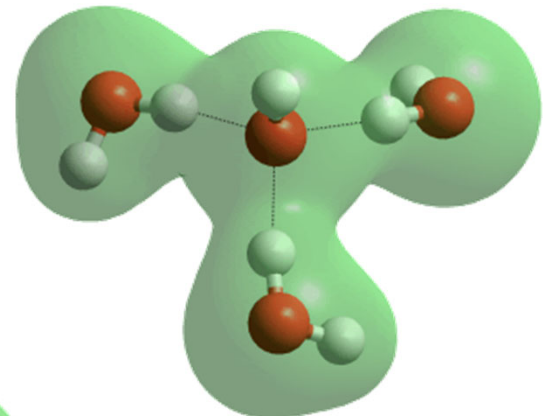
Instructions at http://www.chymist.com/Increase%20in%20Volume%202014.pdf

Hydrogen Bonding

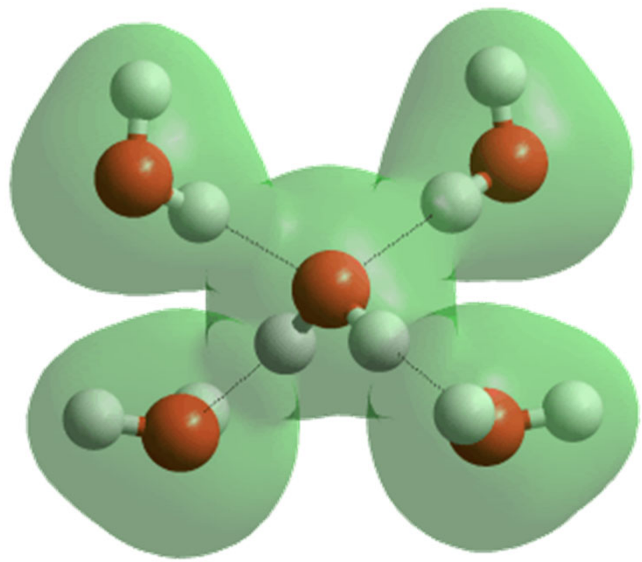
Increase in Volume



Hydrated H_3O^+
O-O distance 2.59 Å



Hydrated OH^-
O-O distance 2.50 Å



H_2O
O-O distance 2.82 Å

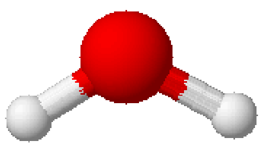
Source: Martin Chaplin,
http://www1.lsbu.ac.uk/water/
index.html

Intermolecular Forces:
Which Will Evaporate First?

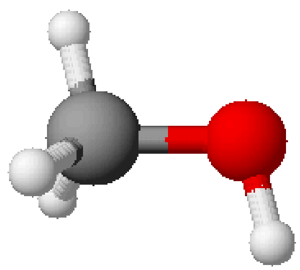
What factors affect evaporation?

Spread these compounds on black slate chalkboards

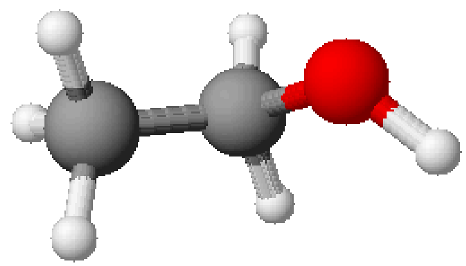
(Available from craft stores or some teacher supply stores.)



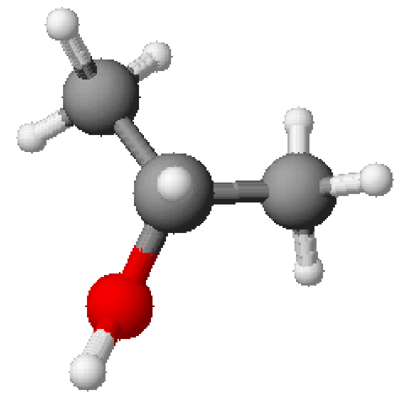
water



methanol



ethanol



2-propanol

Effect of molecular weight:

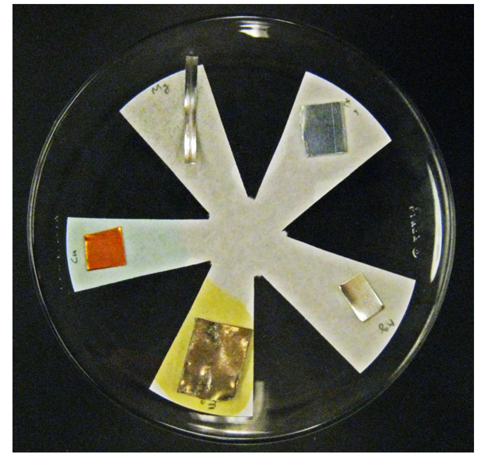
$H_2O = 18$ $CH_3OH = 32$ $C_2H_5OH = 46$ $C_3H_8OH = 60$

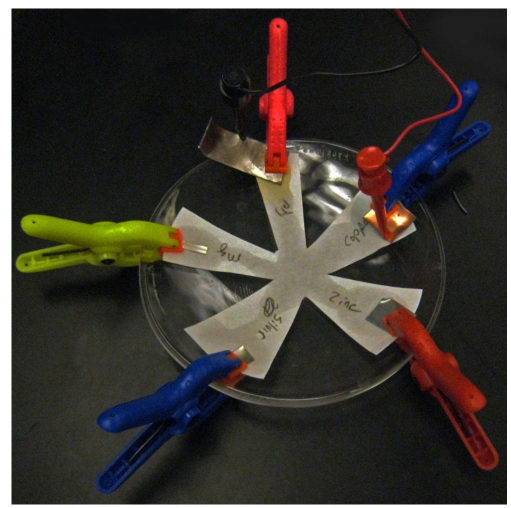
Effect of polarity

Instructions at http://www.chymist.com/evaporate.pdf

Electrochemistry

- Spot each spoke with a drop of metal salt.
- Place piece of metal on spot.
- Moisten paper with $NaNO_3$
- Clamp
- Measure potentials



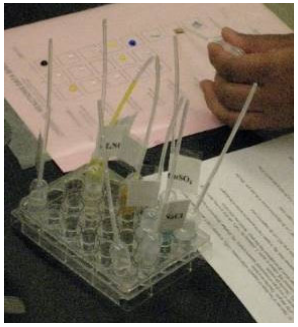


Procedure:
http://www.chymist.com/Investigating%20Electrochemical%20Cells.pdf

Active Assessment

Use microscale experiments as test questions

CHEMICAL REACTION QUESTIONS



The student must physically perform a small-scale reaction. Thus, the old "complete and balance the following reactions" type of questions now have a physical significance.

The materials for the reactions sets are placed in small boxes, plastic drinking cups or beakers, and labeled with an identification number.

More than one set may be needed depending on the size of the class.

Materials can be labeled using names OR formulas of the elements or compounds, but not both.

(Note that both the symbols and the names of the reacting substances are asked for in the problem.)

CHEMICAL REACTIONS

(36 points total - 12 points each)

Directions: Select 3 chemical reactions from the front desk (Please take them one at a time).

Run each reaction on a piece of wax paper using one or two drops of the liquid chemical solutions (or one or two drops of liquid and a piece of solid). Complete the information below for each reaction.

Please return the reaction materials to the front desk. Discard the waste materials by crumpling up the wax paper with the drops of chemical inside and place it in the trash.

Reaction Set No.: _____

a) Symbols of reacting substances:

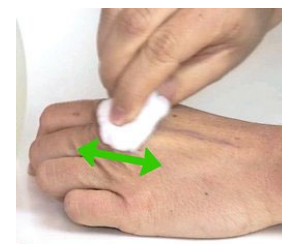
b) Names of reacting substances:

c) Evidence of a chemical reaction:

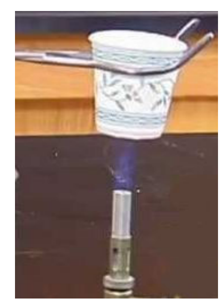
d) Write a balanced chemical equation for the reaction that occurred.

These questions, letters a) through e), involve doing or observing an experiment. The materials are available on the front desk. Select an experiment, take it to your desk and answer the question. You may answer up to two experiment questions. (10 points each)

a) You are given three pennies, pipettes, and three liquids/solutions: water, water-detergent, ethyl alcohol. How many drops of each liquid can you put on a penny? Explain the differences.



b) You are given a cotton ball that is wet with some ethyl rubbing alcohol. Touch the cotton ball to the back of your hand. What sensation do you feel? Explain.



c) On the front desk is a paper cup containing water. It is being heated by a candle. Explain.

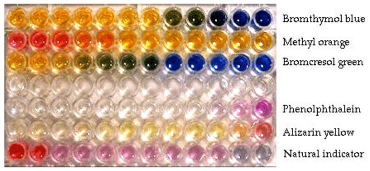
d) You are given a washable marker, a stick of porous chalk, and a cup containing a few mL of water. Draw a line on the chalk, about 1 cm from one end, using the marker. Stand the chalk up in the cup and observe the changes that are taking place (Note: the water is moving through the chalk by a process known as capillary action.):

- i) What changes are occurring?
- ii) Explain your observations using the principles of solutions and intermolecular forces.

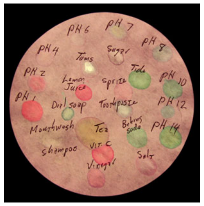
e) The bottles labeled 1, 2 and 3 contain distilled water, a solution of acetic acid, and a solution of sodium chloride. Which is which? Explain how you determined your answer. (Available materials are Na_2CO_3, $AgNO_3$ solution, an indicator, and any other materials as the instructors determine.)

Other experiment problems

- An acid-base indicator problem.

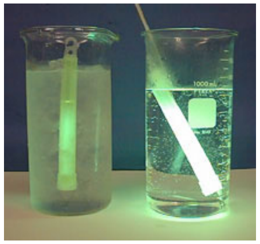


- pH of household products problem.



- A zip-lock bag problem.

- Kinetics problems.

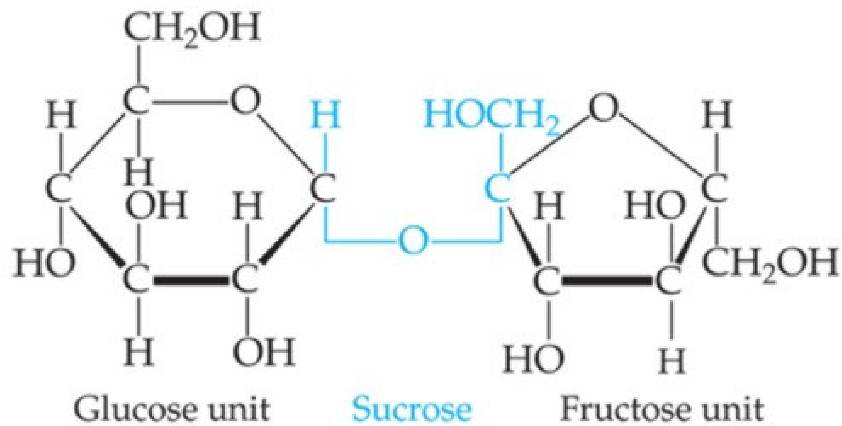


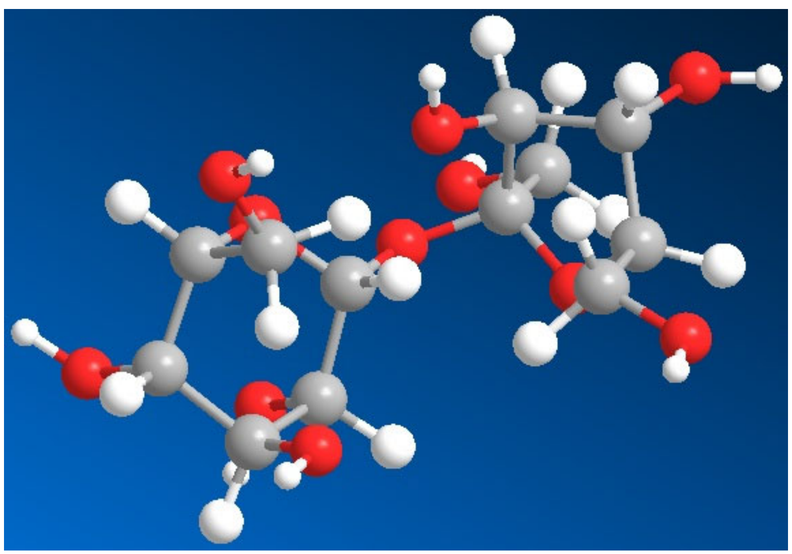
Some things to note

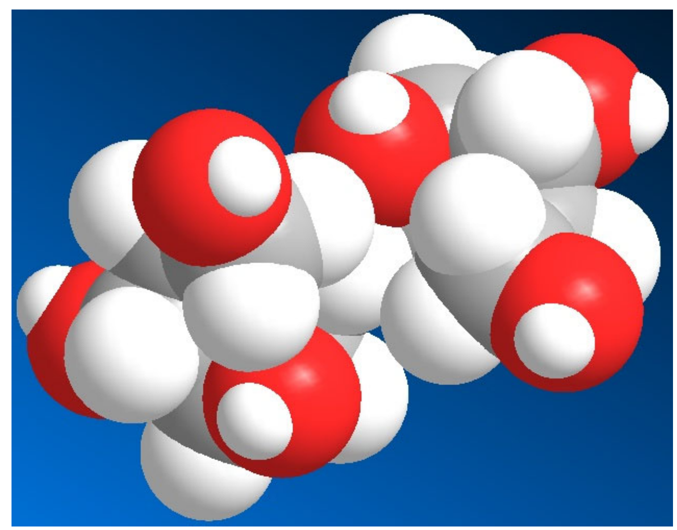
- Works best with small classes – about 40 students or less.
- Students should have had previous experience with hands-on activities in the classroom.
- A negative result:

  Some students start to cut short quizzes about half-way through the semester.

Solutions:
Why does a substance dissolve?







Course syllabi and experiments can be found at

http://www.chymist.com

On the left-hand menu, click on
Compleat Chymical Demonstrator
or
Magic Into Science
or
Active Assessment
or
College Chem Courses
then click on appropriate course link:
Chem 121
Chem 125