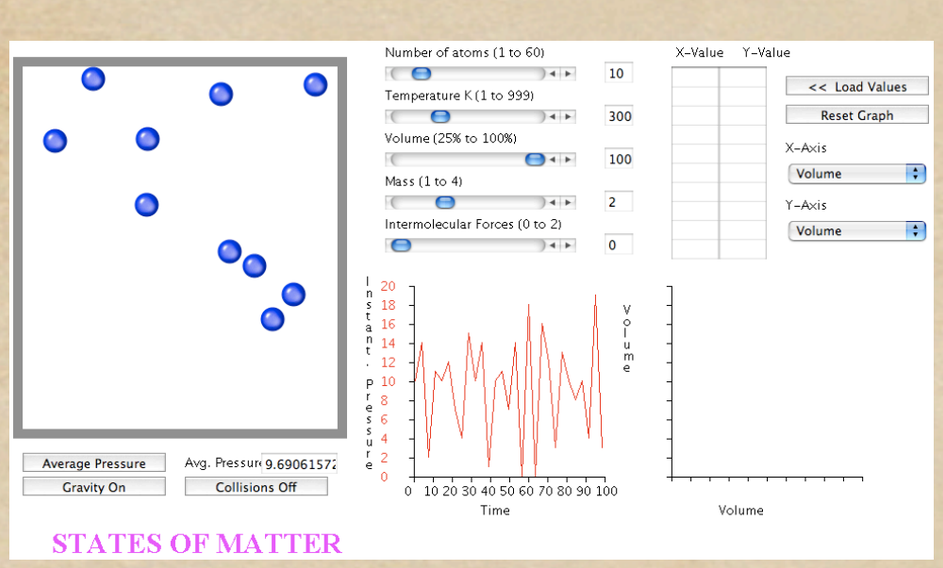
Teaching the Kinetic Theory and Gas Laws Through Computer Simulations and Hands-On Activities



Bryan Marten

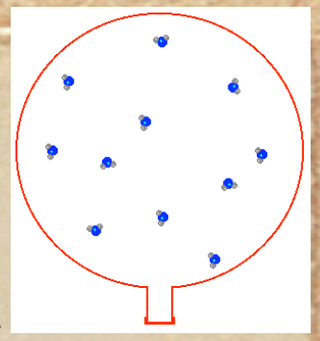
Honors/AP Chemistry Teacher Lowell High School

SFUSD PD Day January 26, 2007

Overview of Today

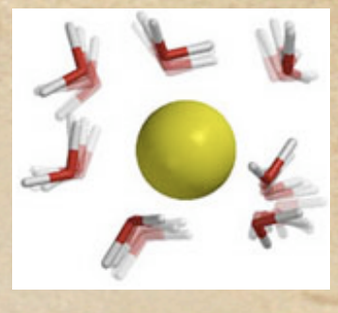
- Standards Addressed
- Simulations - I demo, *you try*
  - Odyssey (expensive, complex, amazing)
  - Sates of Matter (free, simple, good)
- Hands-on Activities - I intro, *you try*
  - Fire Syringe
  - Student Bell Jar
  - Gas Law Demonstrator
  - Absolute Zero Demonstrator
  - Magdeburg Hemishere

Standards Addressed Today



- 4. The kinetic molecular theory describes the motion of atoms and molecules and explains the properties of gases. As a basis for understanding this concept:
  - a. Students know the random motion of molecules and their collisions with a surface create the observable pressure on that surface. (1 Q on CST)
  - b. Students know the random motion of molecules explains the diffusion of gases. (1 Q on CST)
  - c. Students know how to apply the gas laws to relations between the pressure, temperature, and volume of any amount of an ideal gas or any mixture of ideal gases. (2 Q's on CST)
  - f. Students know there is no temperature lower than 0 Kelvin. (1/2 Q on CST)

Odyssey



ODYSSEY
EXPERIMENTS

CHEMICAL MATTER
1 The States of Matter
2 Elements, Compounds, and Mixtures
3 Physical Properties

THERMOCHEMISTRY
4 Chemical Energy
5 Thermal Energy
6 Rotations and Vibrations
7 The Conservation of Energy
8 Heat Capacity

ATOMS AND MOLECULES
9 The Electron Distribution of Atoms
10 Atomic Orbitals
11 d-Orbitals
12 Ionic Radii
13 Isoelectronic Ions
14 Ionic Bonding
15 Covalent Bonding
16 Bond Polarity
17 Resonance
18 The Stability of Benzene
19 Lone Pairs
20 Electron Pair Geometry
21 Molecular Geometry
22 Dipole Moments

GASES
23 The Density of Gases
24 The Motion of the Molecules in a Gas
25 The Forces between Gas Molecules
26 The Temperature of a Gas
27 The Pressure of a Gas
28 The Volume of a Gas
29 The Ability of Gases to Mix
30 Boyle`s Law
31 Charles`s Law
32 Avogadro`s Law
33 The Universality of the Ideal Gas Law
34 Mole Fractions
35 The Molecular Speeds in a Gas
36 The Maxwell-Boltzmann Distribution of Speeds
37 Speed Distribution and Temperature
38 Speed Distribution and Molar Mass
39 The Speed Distribution for Gas Mixtures
40 Effusion
41 Diffusion
42 Gases at High Pressure

LIQUIDS AND SOLIDS
43 The Molecular Characteristics of a Liquid
44 The Molecular Characteristics of a Solid
45 Molecular Motion in Gases, Liquids, and Solids
46 The Energies of Gases, Liquids, and Solids
47 Intermolecular Forces
48 Ion-Dipole Forces
49 Hydrogen Bonding
50 Alcohols
51 Liquid Water
52 Ice
53 The Melting Transition
54 Cubic Crystal Lattices
55 Close Packing in Metals
56 Ionic Solids

SOLUTIONS
57 Molarity and Molality
58 Miscible and Non-Miscible Liquids
59 The Energy of Solutions
60 The Structure of Solutions
61 Hydration Energy and Ionic Size
62 Hydration Energy and Ionic Charge

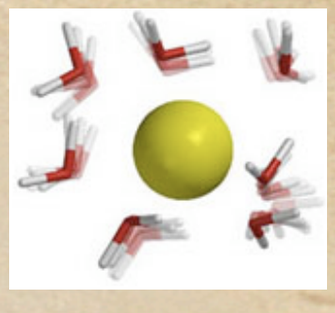
ACIDS AND BASES
63 Molecular Structure and Acid Strength
64 Oxoacids
65 Organic Acids

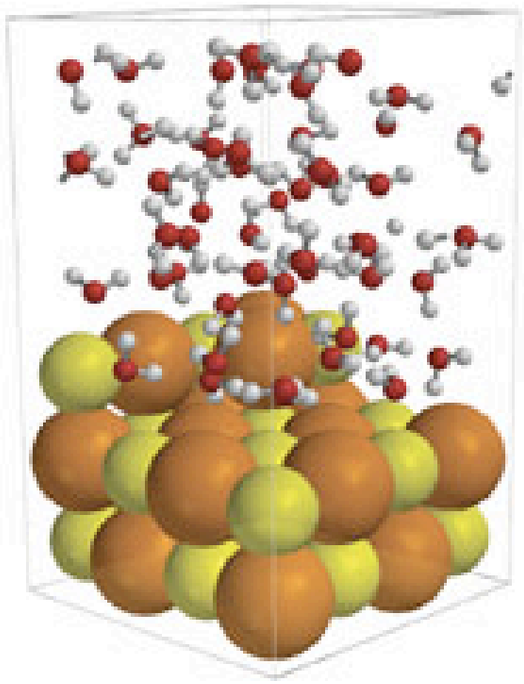
CHEMICAL THERMODYNAMICS
66 Spontaneous Processes
67 Entropy and Phase Changes
68 Entropy and Temperature

TRANSITION METAL COMPLEXES
69 Chelates
70 Structural Isomers
71 Stereoisomers

BIOCHEMISTRY
72 Amino Acids
73 Peptides
74 Proteins
75 Carbohydrates
76 Nucleotides
77 DNA

Odyssey





ODYSSEY Instructor
Molecular Stockroom

***ODYSSEY's* Molecular Stockroom** provides hundreds of pre-constructed samples of matter spanning a wide range of systems. Each entry allows for query of system properties, visualization in multiple model styles, and molecular simulation. The models can be used as the entry to a classroom demonstration or as starting content for new lab activities.

The stockroom can be browsed by individual items or by category. Categories represented include:

Elements	Solutions
Inorganics	Biological
Organics	Polymers

Ready for Discovery?

Open the Molecular Stockroom and explore:

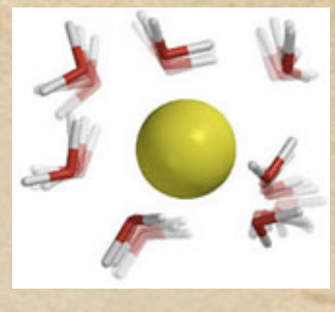
What is the *smallest known protein*?

What are *Freons*?

What does *Teflon* look like?

What *Bases* are associated with DNA and RNA?

Odyssey



Molecule/Ion

- ✔ Molecule/Ion
- Solid
- Organic
- Peptide
- Nucleotide

ODYSSEY Instructor
Model Kit

***ODYSSEY*'s Model Kit** contains a set of builders for Molecules, Solids, Organic Molecules, Peptides, and Nucleotides. These builders are similar to those in Wavefunction's **Spartan**, that is used by tens of thousands of students, instructors, and researchers world-wide.

The **Model Kit** enables the construction of almost any chemical system. This puts an open ended virtual laboratory at your fingertips. All constructed systems are available for simulation and exploration. Instead of having students learn about molecules in 2-D, utilize ***ODYSSEY***'s Model Kit and move into 3-dimentions.

Click on the links below for screen shots of *ODYSSEY*'s Model Kit:

Molecule/Ion Builder

Organic Builder

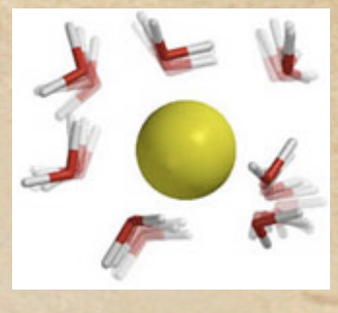
Nucleotide Builder

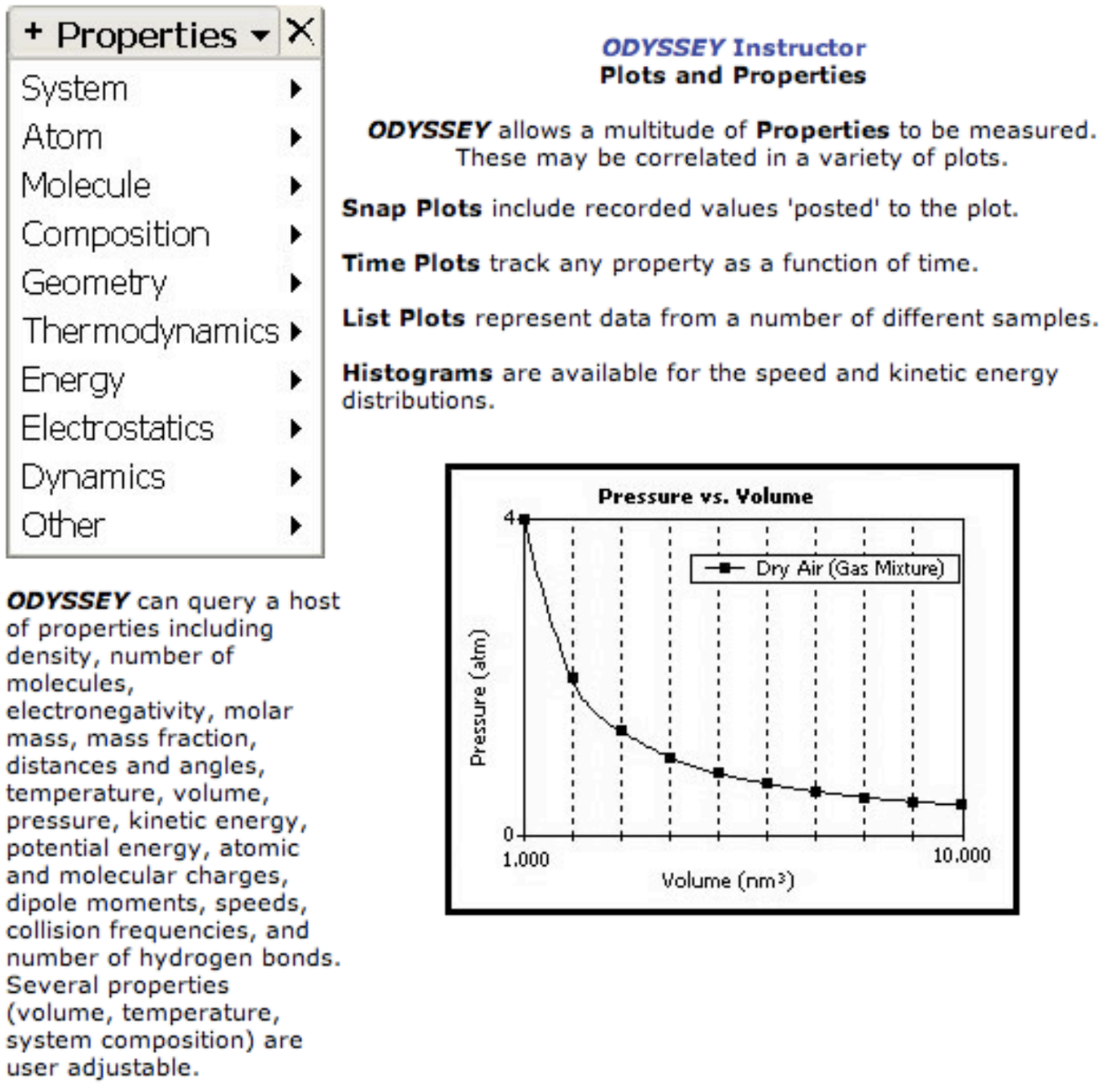
Solids Builder

Peptide Builder

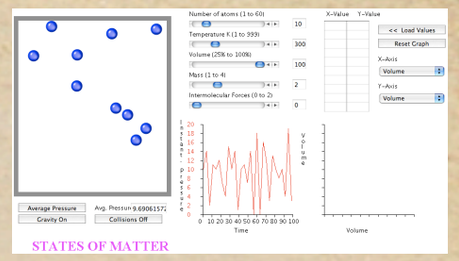
Simulation Cell Panel

Odyssey




+ Properties
System
Atom
Molecule
Composition
Geometry
Thermodynamics
Energy
Electrostatics
Dynamics
Other
ODYSSEY Instructor
Plots and Properties
ODYSSEY allows a multitude of Properties to be measured. These may be correlated in a variety of plots.
Snap Plots include recorded values 'posted' to the plot.
Time Plots track any property as a function of time.
List Plots represent data from a number of different samples.
Histograms are available for the speed and kinetic energy distributions.
Pressure vs. Volume
Dry Air (Gas Mixture)
Pressure (atm)
4
0
1.000
10.000
Volume (nm³)
ODYSSEY can query a host of properties including density, number of molecules, electronegativity, molar mass, mass fraction, distances and angles, temperature, volume, pressure, kinetic energy, potential energy, atomic and molecular charges, dipole moments, speeds, collision frequencies, and number of hydrogen bonds. Several properties (volume, temperature, system composition) are user adjustable.

States of Matter



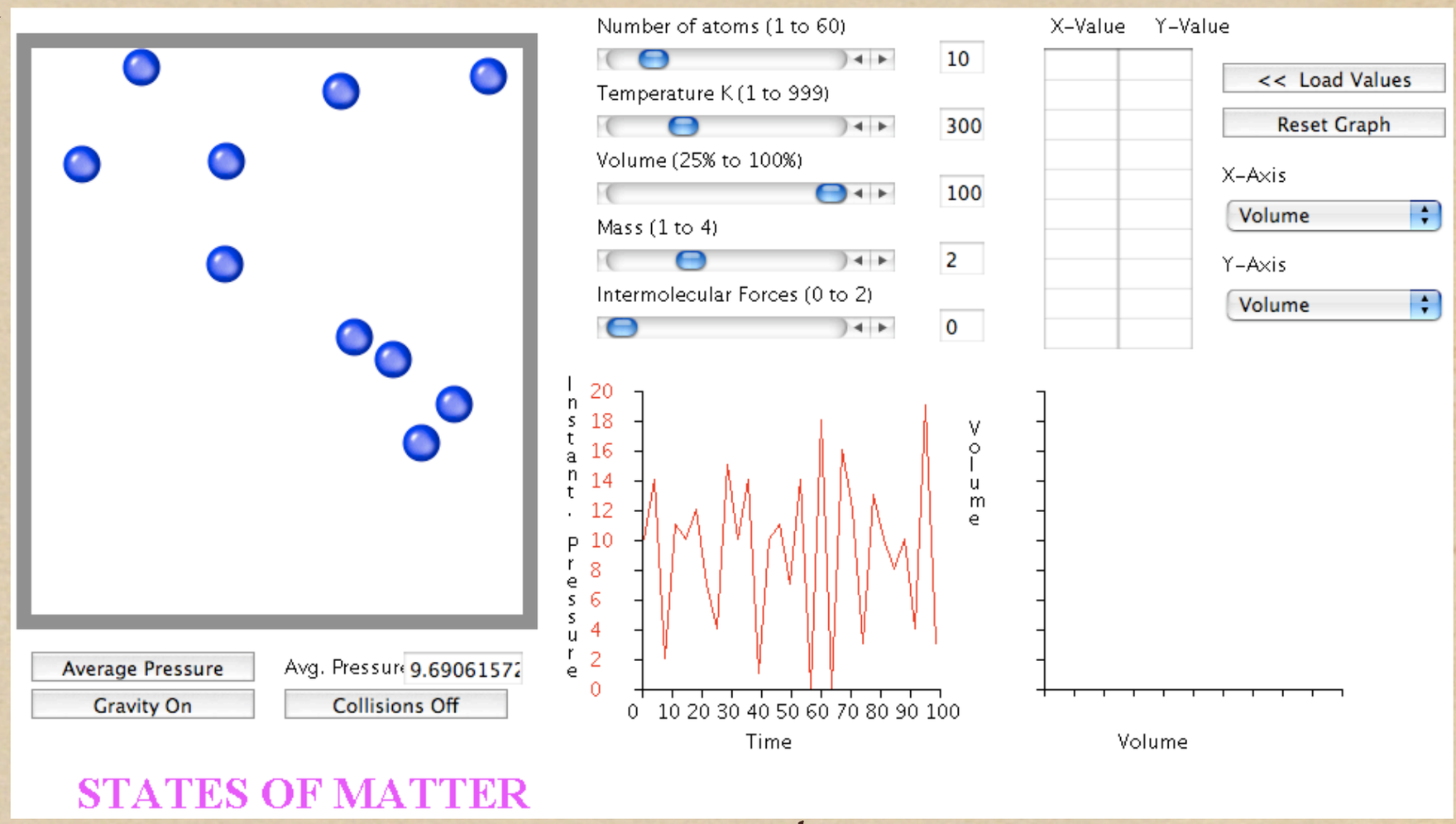
See the affects of changing the following on pressure:

n

T

V

Intermolecular Force Strength



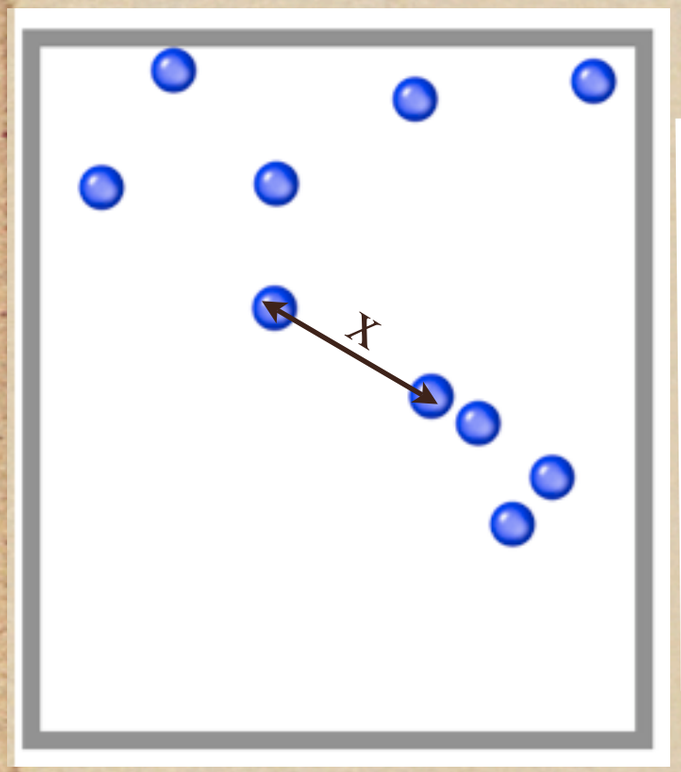
See the affects of changing the mass on KE for a given temp (relates to Graham's Law of Effusion).

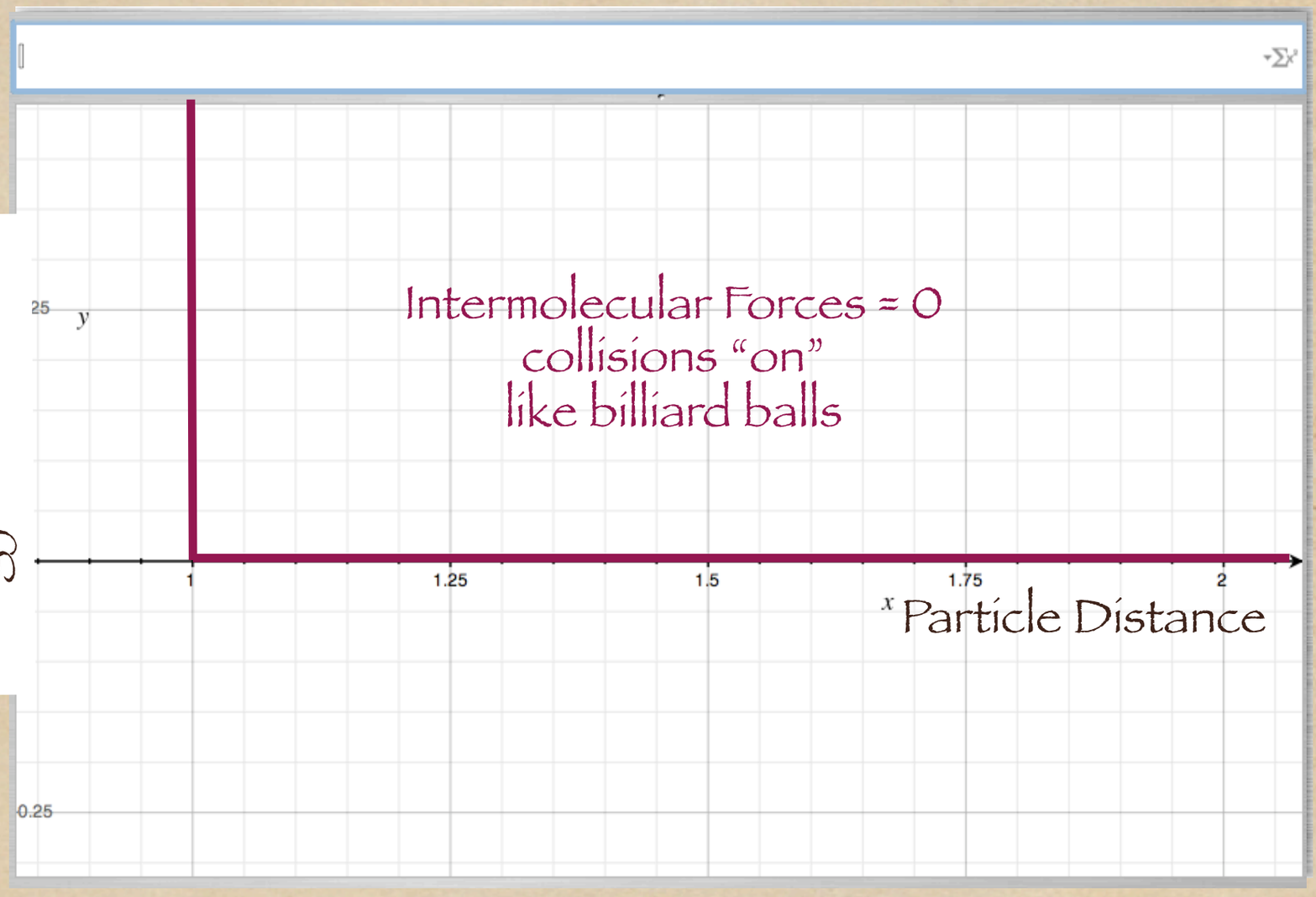
Connect the motion of atoms to physical properties.

Observe a substance's atoms as it changes phases

Make basic plots of the data.

States of Matter



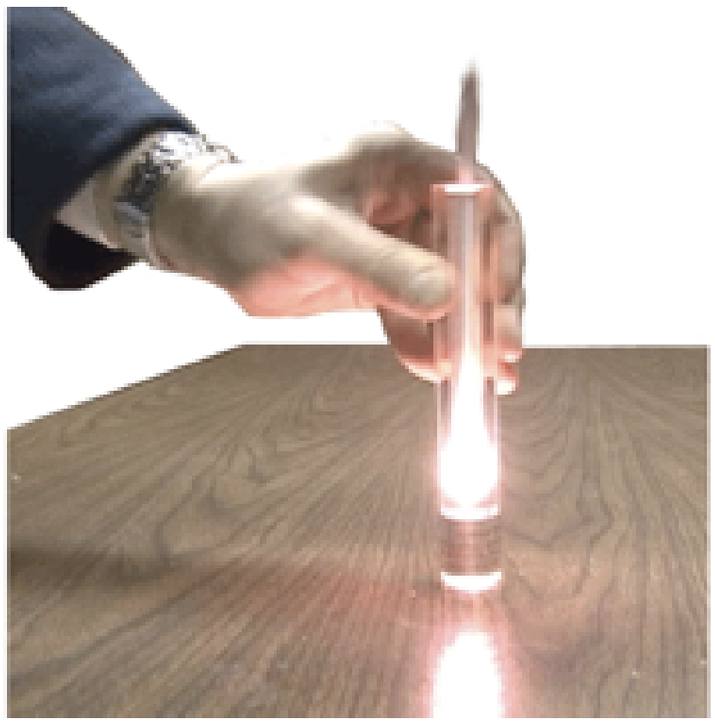


Fire Syringe

Charles' Law

$$\frac{P_1}{T_1} \approx \frac{P_2}{T_2}$$

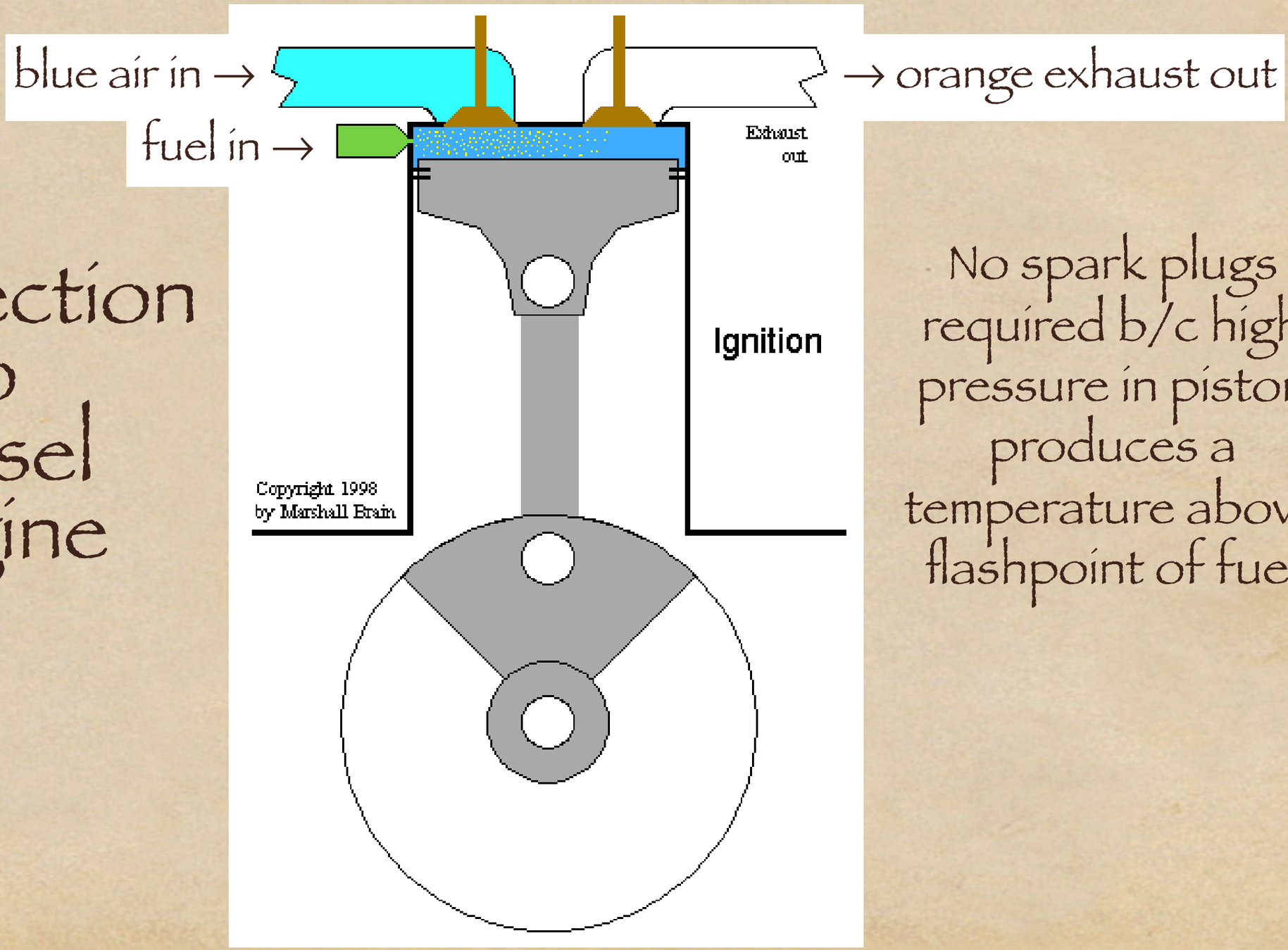
Fire Syringe



Our 15-110 **Science First Fire Syringe** is a classic example of the Ideal Gas Law (PV=nRT). By compressing air into a smaller volume, we are also increasing the temperature. Looking at the formula, a large increase in P, a small decrease in V, with n and R being constant, leads to a large increase in T.

- Kit includes: aluminum piston, lexan piston chamber, and 2 custom made o-rings. You will also need to supply tiny pieces of non-moisturized tissue paper.
- Setup: The setup is quick and easy. Pull out the syringe, drop in 3-4 tiny 5 mm or so tissue pieces. Then re-insert the aluminum piston gently so that it just enters the mouth of the piston chamber. Holding the unit flat on a non-slip surface, push down the aluminum piston with some force and speed. You will see a quick flask of fire, which will last until all available oxygen is used up.
- How it works: Air gets very hot when compressed under high pressure. If you have ever pumped up a bicycle tire, you have noticed the heat generated. When the air in the fire syringe is compressed, it is done so fast and efficiently, so that it can reach a temperature of over 260 degrees C (500 degrees F). As paper burns at 235 dgrees C (454 degrees F), the small pieces of tissue paper ignite.
- Maintenance: Your syringe has been pre-lubricated and should not need any more. After each use, blow out the carbon dust from the small fire you just made and it is good to use again.

Fire Syringe



Connection to Diesel Engine

No spark plugs required b/c high pressure in piston produces a temperature above flashpoint of fuel

Student Bell Jar

Kinetic Theory

Boyle's Law

Vapor Pressure And Boiling

Student Bell Jar

SE-9790

click for larger image

Features & Specifications | **Manuals**

This bell jar provides a vacuum chamber for students to perform many experiments including:

- Watching a balloon expand or warm water boil as air is pumped from the chamber
- Observing that a suction cup no longer sticks when the jar is evacuated.

Tubing is provided so students can connect a pressure sensor for use with DataStudio.

Includes:

- 8 cm x 6 cm dia. clear plastic bell jar with base
- Plastic vial, balloons and suction cup
- 60 cc syringe and valves for evacuating the jar

Be careful of brittle plastic connectors!

Gas Law Demonstrator

Gas Laws Demonstrator

Verify Boyle's and Charles' Laws

Two setups are included in the demonstrator: one to verify Boyle's Law and the other to verify Charles' Law. To demonstrate Boyle's Law, an air-filled syringe is held between two specially drilled 3 1/2" square wood blocks while you exert pressure on the blocks. To demonstrate Charles' Law, you simply suspend the air-filled syringe and a thermometer from a specially drilled 6 1/2" x 2" wood block in a heated water bath. The demonstrator kit includes the syringe, wood blocks, and instructions. A thermometer, beaker, and heat source, required for Charles' Law, are available separately.

Absolute Zero Demonstrator

Large view

Absolute Zero Demonstrator with Stopcock

Charles' Law

$$\frac{P_1}{T_1} \approx \frac{P_2}{T_2}$$

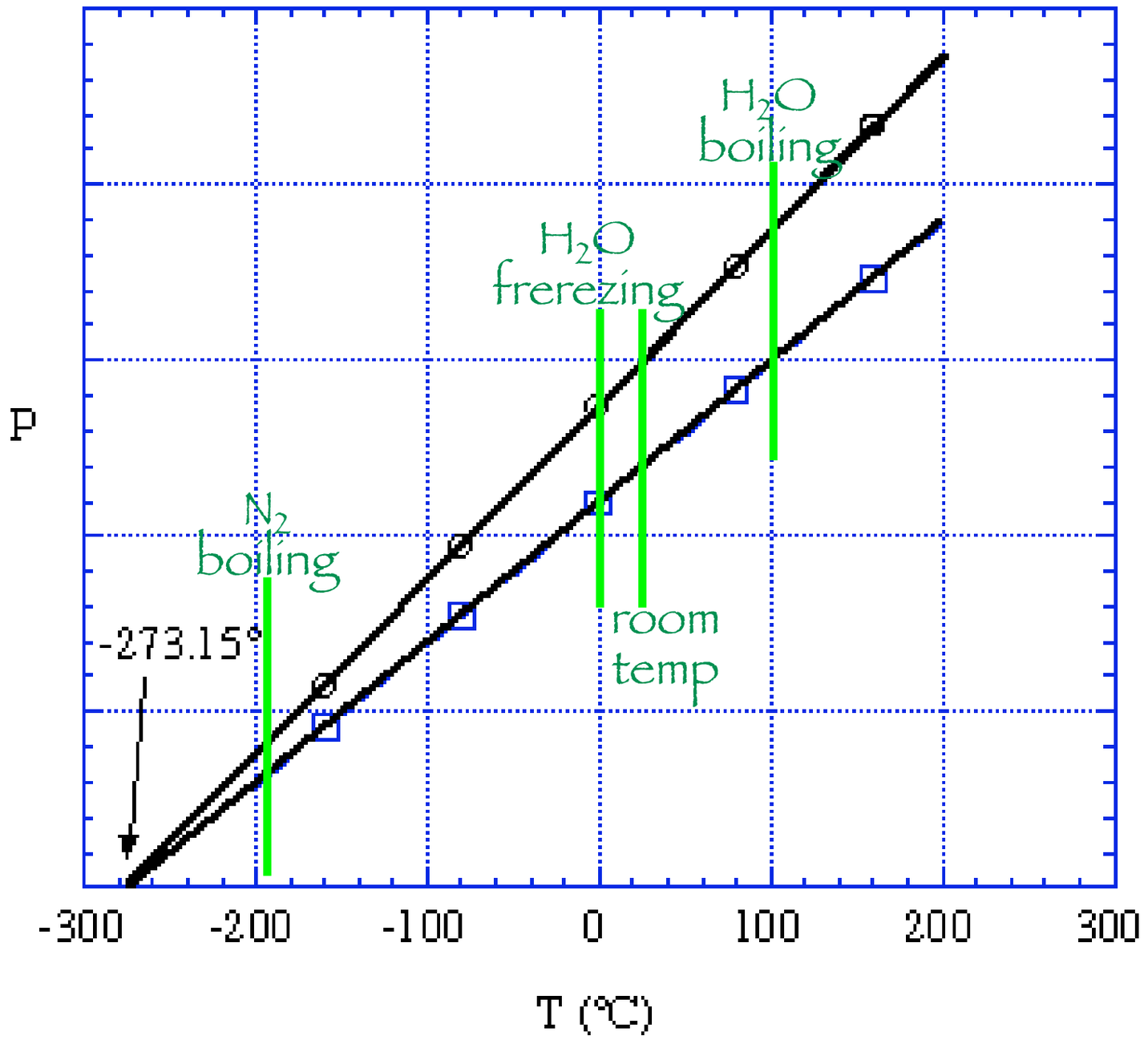
Absolute Zero Demonstrator with Stopcock - Item Details:

In use, the stopcock is opened to equalize the system with ambient pressure. After closing the valve again, the bulb is immersed in a succession of liquids of known temperatures. The pressure and temperature readings are recorded on a typical X-Y graph, with pressure on one axis and temperature on the other axis. By extrapolating the line created by the plotted points on the graph, the point at which pressure would equal zero can be determined. The corresponding temperature at this point is an approximation of absolute zero.

Absolute Zero Demonstrator

different amounts of a

P vs. T for two^ gas at constant volume



Absolute Zero!

Magdeburg Hemisphere

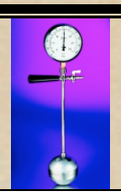
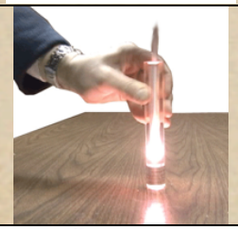
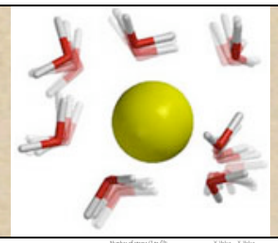
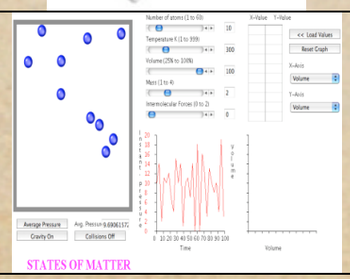
Kinetic Theory

Pumps for a few dollars:

Pumps for a few hundred dollars:

Vacuum Pump (RSVP006)

Von Guericke created a vacuum by attaching two hemispheres and then evacuating the air from the resultant sphere. Von Guericke demonstrated the force of the vacuum before the German emperor Ferdinand III by having two teams of horses attempt to disengage the hemispheres.

	Product Name	Vendor	Web Site Address	Phone Contact	Price
	Absolute Zero Demonstrator	Nasco	www.enasco.com	800-558-9595	$98.70
	Gas Law Demonstrator	Science First or Wards or Cynmar	sciencefirst.com or www.wardsci.com or www.cynmar.com	SciFirst:800-875-3214 Wards:800-962-2660 Cynmar:800-223-3517	$13.75 $13.75 $10.95
	Fire Syringe	Science First or Cynmar	sciencefirst.com or www.cynmar.com	SciFirst:800-875-3214 or Cynmar:800-223-3517	$37.50 $14.95
	Student Bell Jar (SE-9790)	PASCO scientific	store.pasco.com	800-772-8700	$35.00
	Magdeberg Hemisphere	Cynmar	www.cynmar.com	800-223-3517	$16.50
	Odyssey	Wavefunction, Inc.	www.wavefun.com	949-955-2120	$100-$250
	States of Matter Java Simulation	U. of Arizona	States of Matter Simulation: www.chem.arizona.edu/tpp/java/real1.html Other Available Simulations: www.chem.arizona.edu/~jpollard/fido/newconcept.swf	----	FREE

Small thermometers for bell jars: Flinn #AP8713

Acknowledgments

- Lowell colleagues who helped with planning parts of this workshop
  - Katrina Rotter
  - Dacotah Swett (dept head)

Acknowledgments

- SEPAL (Science & Education Partnership) at SFSU
  - Dr. Kimberly Tanner, director and Allison Busch, coordinator
  - Diana Marina - my Masters candidate scientist partner who is at a conference in LA today

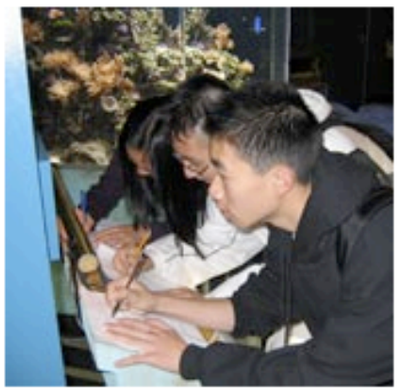
http://www.sfsu.edu/~sepal/

Current SEPAL Programs

SEPAL
The Science Education Partnership & Assessment Laboratory
San Francisco State University

Engaging scientists and teachers in partnership, research and coursework to transform science teaching kindergarten through college.

SEPAL Programs	
GK-12 Partnership Program	Year-long partnership between SFUSD middle or high school teacher and SFSU science graduate student to co-plan and co-teach hands-on, inquiry-based science lessons. visit site>>
Science Education Partners In Biology	Semester-long partnership between SFUSD elementary or middle school teacher and SFSU science graduate/undergraduate students for a variety of potential projects including co-creation of inquiry-based science lessons, co-sponsoring after-school science clubs or science fairs, or other innovative ideas. visit site>>
SEPAL Partnership Program	Less time intensive than the GK-12 Partnership Program, the SEPAL Partnership Program also establishes year-long partnerships between middle or high school science teachers and SFSU science graduate students to co-plan and co-teach hands-on, minds-on science activities to students. visit site>>
Classroom Assessment Research Partnerships (CARP)	Partnership with SFSU graduate/undergraduate students in conducting a science or math education research project about your students understanding or attitudes towards science. May provide support for teachers collecting classroom evidence in preparation for National Board Certification. visit site>>
Summer Laboratory Research Partnerships	Teachers actively participate in a scientific research project in collaboration with an SFSU scientist during the summer. visit site>>



Comments/Ideas

- Things that work better as a demo vs. hands-on
- Ways to engage YOUR students
- Other demos/activities
- Ways to ask questions of the students
- Other ways to do these activities
- Other ways to report & analyze results
- Other other…