PHOTOCHEMICAL BLEACHING OF METHYLENE BLUE: A ZEROTH ORDER REACTION

TOPIC Reaction Kinetics **DEMO #** AP.Kinet.1

REFERENCE A Demo A Day, p. 234

EQUIPMENT Light box or overhead projector
2 – 100 mL beakers

CHEMICALS 1.0 g of iron(II) sulphate, $FeSO_4$
50 mL of 0.1 M sulphuric acid
dropper bottle containing 1% methylene blue

PROCEDURE Dissolve 1.0 g of iron(II) sulphate in 50 mL of 0.1 M sulphuric acid. Add enough methylene blue to give a definite blue colour (3–6 drops). Divide the solution into two 100 mL beakers.

Place one beaker on the light source and irradiate with light for a few seconds. The solution becomes nearly colourless (compare with the second beaker). The colourless solution becomes blue again after being removed from the light for a minute or two. The process can be repeated several times.

What is Happening:

The reaction is shown below.

$$\mathrm{Fe^{2+}} + \underset{\text{(blue)}}{\text{oxidized methylene blue}} + h? \rightleftharpoons \mathrm{Fe^{3+}} + \underset{\text{(colourless)}}{\text{reduced methylene blue}}$$

The rate of the reaction is controlled only by the amount of light and is independent of reactant concentrations. Hence, the reaction is ZEROTH ORDER with respect to reactant concentrations.

THE CHAIN REACTION BETWEEN HYDROGEN AND CHLORINE

TOPIC Reaction Kinetics **DEMO #** AP**.**Kinet**.**2

REFERENCE Chem 13 News, November 1976, p. 7 (modified by Jim Hebden)

EQUIPMENT
thin plastic bag, 1-2 L capacity maximum, with twist-tie
5 x cm piece of aluminum foil
Tesla coil
30-40 cm length of rubber tubing
tubing clamp

CHEMICALS
small lecture bottle of hydrogen gas
small lecture bottle of chlorine gas

PROCEDURE **THIS DEMONSTRATION MUST BE DONE IN AN OPERATING FUME HOOD.** Prior to starting the demonstration, turn on the Tesla coil so that it creates a nice spark when brought near metal and then pull out the electrical plug without changing the setting on the coil. Place the piece of aluminum foil inside the plastic bag, then place the rubber tubing into the mouth of the plastic bag and seal the bag to the tubing with a twist–tie. Press the bag flat to expel air and connect the other end of the rubber tube to the bottle of hydrogen. Inflate the bag about 60% full. Clamp the rubber tube shut with a tubing clamp, remove the tubing from the bottle of hydrogen and attach it to the bottle of chlorine. Fill the bag with chlorine gas. **IMPORTANT:** Do NOT get an exact 50:50 mixture or the mixture will detonate with a massive "BANG" that will possibly deafen students (and yourself) temporarily. When the bag has been filled with the two gases, pull out the rubber tube from the neck of the plastic bag and crimp the twist–tie shut to minimize the loss of gases.

Place the Tesla coil under the plastic bag, such that the tip of the coil is under the aluminum foil. Warn students to stay well back and to the side of the fume hood (in case you accidentally put a 50:50 mixture of gases in the bag, in which case the fume hood will act to "focus" the explosion directly vertical to the mouth of the fume hood). Keeping well out of the way, to the side of the fume hood, plug in the electrical cord of the Tesla coil. BANG!

Point out to students, afterwards, that the reaction has a 6 step mechanism which proceeds as follows. ($H^{\bullet}$ and $Cl^{\bullet}$ are free radicals.)

Cl_2 + energy ? 2 $Cl^{\bullet}$ (chain–initiating step)
$Cl^{\bullet}$ + H_2 ? HCl + $H^{\bullet}$ (chain–propagating step)
$H^{\bullet}$ + Cl_2 ? HCl + $Cl^{\bullet}$ (chain–propagating step)
$H^{\bullet}$ + $H^{\bullet}$? H_2 (chain–terminating step)
$Cl^{\bullet}$ + $Cl^{\bullet}$? Cl_2 (chain–terminating step)
$H^{\bullet}$ + $Cl^{\bullet}$? HCl (chain–terminating step)

Since the reaction is an explosion, each step is very fast. This is not unexpected since free radicals experience little repulsion as they approach a "target" atom and the products of each reaction step are moving at high velocities.

ANTI–BUBBLES

TOPIC	Gas Laws	**DEMO #** AP.Gases.1

REFERENCE A Demo A Day: A Year of Chemical Demonstrations, p. 86

EQUIPMENT
1 L beaker
50 mL beaker (this is critical)
10 mL graduated cylinder

CHEMICALS
30–40 mL of clear dish washing detergent
sodium chloride (alternate variation)
food colouring (alternate variation)

PROCEDURE Note: An “anti–bubble” is a spherical envelope of gas that is bounded on both sides by a liquid.

Fill to near overflowing a 1 L beaker with cold tap water. Let the beaker stand until any bubbles present dissipate. Pour about 1 mL of detergent into the water and stir gently so as to avoid any normal bubbles.

Take 30–40 mL of detergent in the small beaker. With the base of the 50 mL beaker almost touching the surface of the water in the large beaker, “glop” small portions of the detergent into the large beaker with a jerky motion.

Anti–bubbles are easily recognized as they slowly move down and then slowly climb to the surface and stay fully below the surface for 1–2 min.

Alternates:
- Add a little food colouring to the detergent in the 50 mL beaker to prove that the centre of the bubble is liquid.
- Dissolve some sodium chloride to the detergent solution in the 50 mL beaker to increase the density of the anti–bubbles to the point that they SINK to the bottom of the beaker.

DISCREPANT BALLOONS

TOPIC Gas Laws **DEMO** # AP.Gases.2

REFERENCE Twenty Demonstrations Guaranteed to Knock Your Socks Off! Volume II, p. 35

EQUIPMENT
2 balloons
2 – #4 or #5 one–hole stoppers
2 pieces of 5 cm long glass tubing to fit the one–hole stoppers
rubber tubing, 10 cm
pinch clamp for rubber tubing

CHEMICALS —

PROCEDURE Into each one–hole stopper insert a 5 cm piece of glass tubing half way into the narrow end of the stopper. Stretch a balloon over each stopper, wrapping with electrician’s tape if necessary to get a good seal. Connect each piece of glass tubing to either end of a 10 cm length of rubber tubing and put the pinch clamp in the middle of the rubber tubing.

Disconnect one glass tube from the rubber tubing and blow the balloon up to the size of a soccer ball. Pinch off the end of the balloon nearest the stopper and connect the glass tubing back to the rubber tubing. Disconnect the other glass tube from the rubber tubing and inflate the balloon to the size of a softball. Reconnect the glass tube to the rubber tubing. The setup should now look quite lopsided.

Show the setup to the class and ask them to predict what will happen when the pinch clamp is opened. Then open the clamp and observe that the small balloon gets smaller and the larger balloon gets larger!

The reason for this apparent discrepancy is that the total system tends to attain the minimum surface area (SA). Assume that the balloons start out with 1000 mL and 3000 mL. After, the volumes will be 0 mL and 4000 mL, respectively. Examine the table below.

First Balloon			Second Balloon			Combined Surface Area
V (mL)	r (cm)	SA (cm^2)	V (mL)	r (cm)	SA (cm^2)	
0	0	0	4000	9.85	1219	1219
1000	6.20	483	3000	8.95	1006	1489
2000	7.82	768	2000	7.82	768	1536
3000	8.95	1006	1000	6.20	483	1489
4000	9.85	1219	0	0	0	1219

CRUSH THE CAN

TOPIC Gas Laws **DEMO #** AP.Gases.3

REFERENCE A Demo A Day: A Year of Chemical Demonstrations, p. 95

EQUIPMENT
aluminum soda can
hot plate
shallow pan or dish
beaker tongs or Hot Hand

CHEMICALS —

PROCEDURE Fill a shallow dish with water. Put about 10 mL of water in the pop can and heat the can until the water boils. Then, quickly invert the can into the dish in such a way that the can opening is under water. The can will instantly collapse.

HERO’S FOUNTAIN

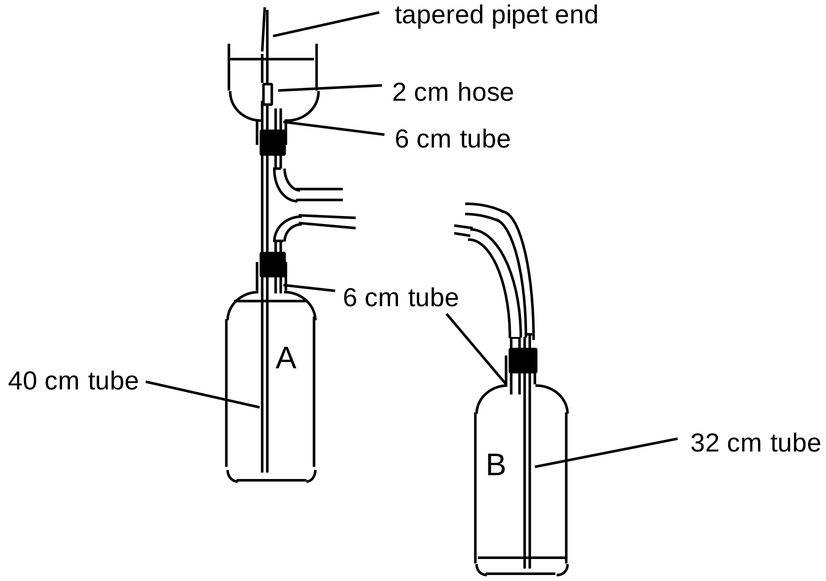
TOPIC Gas Laws **DEMO #** AP**.**Gases**.**4

REFERENCE Twenty Demonstrations Guaranteed to Knock Your Socks Off! Volume II, p. 27

EQUIPMENT
3 – 2 L soda bottles
3 – 2 hole #3 stoppers
100 cm of glass tubing to fit stoppers, cut as follows:
  40 cm length, 32 cm length, 10 cm length and three 6 cm lengths
3–4 m of rubber tubing to fit glass tubing (cut into 2 pieces, each about 1.5–2 m long)
plastic pipet, cut to give a nozzle (as shown in the diagram below)

CHEMICALS —

PROCEDURE Assemble the equipment as shown below.



Fill bottle A with water, put about 2 cm of water in bottle B (just enough to get the water level above the bottom of the long glass tube) and secure all stoppers. To start the fountain, place bottle A on the table and bottle B on the floor, then fill the top funnel with water. Within a few seconds, the fountain will begin spurting up out of the tapered pipet end. To control the rate of flow, adjust the relative heights of the two bottles.

MULTI–COLOURED AMMONIA FOUNTAIN

TOPIC Gas Laws **DEMO #** AP.Gases.5

REFERENCE A Demo A Day: A Year of Chemical Demonstrations, p. 150

EQUIPMENT
3 – 1 L round bottom flasks
3 – two–hole stoppers to fit flasks
separatory funnel
one–hole stopper to fit separatory funnel
2 L beaker
3 – regular stands
1 – tall stand
4 – utility clamps
1 – long piece of glass tubing (see reference)
3 – U-shaped pieces of glass tubing (see reference)

CHEMICALS
source of ammonia gas (lecture bottle)
10 mL of universal indicator
100 mL of 6 M acetic acid

PROCEDURE Assemble the apparatus as shown in the reference.

Fill the apparatus with ammonia gas, from the top down. Fill the beaker with 6.8 mL of 6 M acetic acid for every 1 L of water, add the indicator solution and stir.

Place the open tube at the bottom in the beaker. Fill the drain tube of the separatory funnel with water. Quickly open the stopcock of the separatory funnel to admit a few drops of water and quickly close the stopcock again. Water will be drawn into the flasks and change to different colours as the different flasks fill.

THOUGHT EXPERIMENT : LIFE ON “PLANET V”

TOPIC Gas Laws **DEMO #** AP.Gases.6

REFERENCE Twenty Demonstrations Guaranteed To Knock Your Socks Off II, p. 30

EQUIPMENT Handout sheet (following)

CHEMICALS —

PROCEDURE Have students do the thought experiment in pairs. After they have discussed the experiment among themselves, debrief them by having students understand which of the pieces of equipment rely on air pressure to operate.

AP Chemistry

THOUGHT EXPERIMENT : LIFE ON “PLANET V”

(Adapted from Twenty Demonstrations to Knock Your Socks Off, Volume II)

Imagine you have been relocated to Planet V, a planet just like Earth, but with no atmosphere at all. Which of the items listed below would still work on this planet and which ones would not? For those things that would work, would they work exactly the same? For those things that would not work, can you think of modifications that could enable them to work?

Suction cup

Candle

Match

Alarm Clock

Flashlight

Vacuum cleaner

Paper airplane

Helicopter

Aerosol spray can

Baseball and bat

Nuclear fuel rod

Hour glass

Plant

Syringe

Parachute

Pogo stick

Swing

Balloon

Helium balloon

Automobile

Air bag

Blow dryer

Frisbee

TNT

Light stick

Siphon

Smoke detector

Bow and arrow

Drinking straw

Broom

Rocket

Paint

Shotgun

Bicycle

Bicycle pump

Flag

Golf

Squirt gun

Refrigerator

Magnet

Star

100 watt light bulb

THE EFFECT OF PRESSURE ON BOILING POINT

TOPIC Gas Laws **DEMO #** AP.Gases.7

REFERENCE Chemical Demonstrations: A Sourcebook for Teachers, Volume 1, p. 21

EQUIPMENT
250 mL beaker
50–60 mL syringe with Luer lock
stand with ring and ceramic pad
bunsen burner and flint striker
thermometer

CHEMICALS distilled water

PROCEDURE Heat about 100 mL of distilled water to about 80°C. Draw enough hot water into the syringe to half fill it. Quickly invert the syringe and push in the plunger to expel any air and then close the end with a Luer tip.

Hold the syringe with the plunger up and slowly but forcefully pull up on the plunger. As the plunger is raised, the pressure on the hot water is decreased and the water boils.

BOILING AT REDUCED PRESSURE : BOIL IT COLD

TOPIC Gas Laws **DEMO #** AP.Gases.8

REFERENCE A Demo A Day – A Year of Physical Science Demonstrations, p. 70

EQUIPMENT

- 250 mL side arm vacuum filtration flask
- 2–hole rubber stopper to fit flask
- thermometer
- 15 cm of glass tubing to fit 2–hole stopper
- 5 cm of latex tubing to fit glass tubing
- pinch clamp
- ring and stand
- utility clamp
- vacuum tubing
- aspirator pump (NOT vacuum pump)
- boiling chips

CHEMICALS 100 mL of acetone

PROCEDURE Using glycerine, insert the thermometer into the 2–hole stopper in such a way that the thermometer is just above the bottom of the flask when the stopper is put into the flask. Insert the glass tubing into the second hole of the stopper so as to leave about 10 cm above the stopper. Secure a 5 cm piece of latex tubing to the top of the glass tubing and seal the latex tubing with a pinch clamp. Place 100 mL of acetone in the filter flask, add a few boiling chips, insert the stopper and attach the flask to a water aspirator using the vacuum tubing.

Turn on the aspirator pump. The acetone boils when the pressure inside the flask is equal to the vapour pressure of acetone at room temperature (about 200 mm Hg). Release the pressure using the pinch clamp.

BOILING WATER AT LESS THAN 100^{o}C

TOPIC Gas Laws **DEMO #** AP.Gases.9

REFERENCE Chem 13 News, November 1976, p. 8

EQUIPMENT
500 mL or 1 L thick–walled round bottom flask, free of scratches or hairline cracks
rubber stopper to fit flask (Note: the stopper will be partially sucked into the flask by a vacuum
towel or Hot Hand™
stand and ring, with wire gauze pad
clamp for stand
bunsen burner and flint striker

CHEMICALS 150–200 mL of distilled water

PROCEDURE Set up the bunsen burner, stand, ring and wire gauze pad in preparation for heating the water in the flask. Clamp the flask above the gauze pad and heat the water to boiling. When the water is boiling nicely, place the rubber stopper partially into the neck of the flask, so as to restrict the flow of steam out of the neck but not block it completely. (This partial blockage is make sure any air inside the flask is “flushed” out of the flask.) After a minute of heating with the stopper on top, quickly remove the bunsen burner, stopper the flask securely and loosen the clamp. Holding the neck of the flask in a towel, place the body of the flask sideways under a stream of cold running water from a lab tap. As the water cools, boiling is seen to continue, as evidenced by the continuous “bumping”. After a minute or so of cooling, the water is quite cool but boiling continues.

When finished, removal of the stopper is accompanied by the “hissing” sound of air entering the near–vacuum inside.

What is happening: Water boils when its vapour pressure equals the pressure of the atmosphere pressing down on the water’s surface. When the flask is boiling, all the air is pushed out and the only gas remaining inside is water vapour. When the flask cools, the pressure inside remains more or less equal to the vapour pressure of the water. The stream of cold water on the upper side of the flask condenses the vapour and lowers the vapour pressure to a value lower than that created by the still–hotter liquid below, giving rise to a dramatic “bumping” as the liquid suddenly boils.

HOW ICE SKATES WORK

TOPIC Phase Diagrams **DEMO #** AP.Phases.1

REFERENCE A Demo A Day: A Year of Chemical Demonstrations, p. 84

EQUIPMENT
cylinder of ice, 30 x 5 cm
2 – ring stands
2 – rubber insulated clamps
50 cm of strong thin wire (such as piano or guitar wire)
2 – 1 kg masses

CHEMICALS —

PROCEDURE Prepare a 30 x 3 cm ice cylinder or freeze a water balloon inside a paper towel tube. Clamp the cylinder at both ends using insulated clamps. Attach two 1 kg masses to each end of a strong thin 50 cm wire. Suspend the weighted wire over the cylinder. The weighted masses will pull the wire through the ice in about 5 minutes and will fall with a crash. As the wire moves through the ice the ice will re–freeze in its path.

TRIPLE POINT OF WATER

TOPIC Phase Diagrams **DEMO #** AP.Phases.2

REFERENCE A Demo A Day, Volume 2: Another Year of Chemical Demonstrations, p. 128

EQUIPMENT
500 mL filter flask
one–hole stopper to fit flask
thermometer
25 x 100 mm test tube
vacuum pump
rubber vacuum tubing
safety shield

CHEMICALS
a few chips of ice
5 mL of distilled water

PROCEDURE Place 5 mL of water and a few ice chips in the test tube. Place the test tube inside the flask. Insert the thermometer through the one hole stopper in such a way that the thermometer is immersed in the liquid in the test tube. Place the flask assembly behind a safety shield and connect the flask to the vacuum pump.

Evacuate the flask. After a minute or two, the ice–water mixture will begin to boil, showing that all three phases are present simultaneously. The temperature should be about 0^{o}C and the pressure inside is about 0.6 kPa.

EQUILIBRIUM AND ELASTIC BANDS

TOPIC Thermodynamics **DEMO #** AP.Themo.1

REFERENCE commonly known

EQUIPMENT Large, thick elastic band
stand with ring
large weight (500 g or so)
pieces of wire to secure rubber band to ring and weight to rubber band
bunsen burner and flint striker
electronic balance

CHEMICALS —

PROCEDURE Arrange the apparatus so the weight is suspended from the elastic band, which in turn is suspended from the ring. The weight should partially stretch the band, so the band is midway between its fully stretched and fully elongated states. Rest the weight on the electronic balance pan, so that the pan partly supports the weight.

Ask students to predict what will happen when the elastic band is heated. Gently heat the elastic band with a bunsen burner (CAREFUL: don't burn the elastic, just warm it). The band will contract, pulling the weight up and showing a decreased mass on the balance.

Students should see that the equilibrium is:
(resting, highly random state) $\rightleftharpoons$ (stretched, highly aligned state) + heat

If students take an elastic band and quickly stretch it and hold it against their upper lip while still stretched, the band feels warm.

SUPERHEATED STEAM

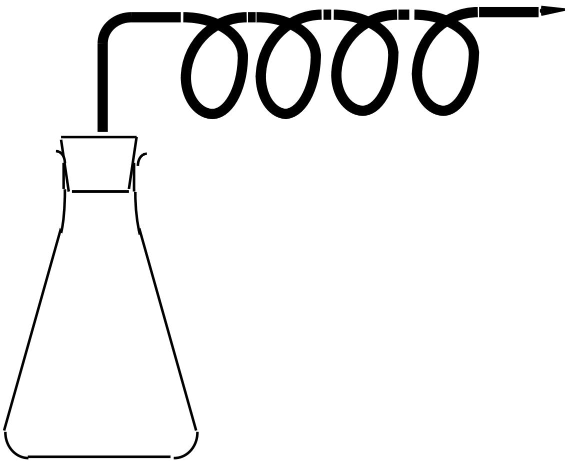
TOPIC Thermodynamics **DEMO #** AP.Themo.2

REFERENCE A Demo A Day, Volume 2: Another Year of Chemical Demonstrations, p. 118

EQUIPMENT
40–50 cm of 3/8 OD copper tubing
250 mL erlenmeyer flask
one–hole stopper to fit flask (hole size to fit tubing)
ring stand
2 – rubber coated utility clamps
Meker burner and flint striker
hot plate
sheet of paper
tongs to hold paper sheet

CHEMICALS —

PROCEDURE Form the copper tubing into a small coil (5 cm diameter) by filling it with sand and wrapping it around a PVC pipe. Leave a 3 cm length at one end and crimp this end to leave a 2–3 mm opening. The other end of the tubing should extend about 15 cm with a right angle bend 5 cm from the end. (See diagram below.) Put 150 mL of water in the flask and clamp the tubing into the stopper, which in turn is fitted into the flask in such a way that the coil extends horizontally past the stand and clamp.



Place a Meker burner under the coil. Heat the flask on the hot plate. Once steam starts to escape the coil, heat the coil with the Meker burner. The superheated steam coming from the coil will be well over 100^{o}C. After a minute of heating, the steam will scorch a piece of paper in the path of the steam and may cause the paper to burst into flame.

MOLARITY VS MOLALITY

TOPIC	Colligative Properties	**DEMO #** AP.Collig.1
REFERENCE	A Demo A Day, Volume 2: Another Year of Chemical Demonstrations, p. 194	
EQUIPMENT	2 – 1 L graduated cylinders 12 large rubber stoppers	
CHEMICALS	—	
PROCEDURE	Tell students that each rubber stopper is a “mole” of solute. Make a “6 molar” solution by adding 6 stoppers to a graduated cylinder and filling to exactly 1 L. Make a “6 molal” solution by adding 6 stoppers to 1 L (1 kg) of water in the other graduated cylinder. Point out that the 6 molar solution contains less than 1 L of water and that the volume of the 1-molal solution is greater than 1 L.	

ACID–WATER PUZZLE

TOPIC Colligative Properties **DEMO #** AP.Collig.2

REFERENCE A Demo A Day: A Year of Chemical Demonstrations, p. 141

EQUIPMENT
2 – 250 mL beakers
2 – thermometers
2 – 100 mL graduated cylinders

CHEMICALS
200 mL of 9 M sulphuric acid (slowly add 100 mL of concentrated sulphuric acid to 100 g of ice — care it gets VERY HOT! Do this in advance so that the acid is at room temperature.)
100 g of ice
100 mL of ice water

PROCEDURE Record the temperature of 100 mL of ice water in a 250 mL beaker. Measure the temperature of the acid solution. Ask what will happen when the acid is added to the ice water. Slowly add 100 mL of 9 M sulphuric acid to 100 mL of ice water. The temperature rises by 18°–20°C.

Record the temperature of 100 g of ice in a second 250 mL beaker. Again, ask what will happen when acid is added. Slowly pour 100 mL of 9 M sulphuric acid on to 100 g of ice. The temperatures drops to about –15°C.

The rise in temperature is due to the exothermic nature of the hydration reaction. The endothermic nature of the reaction when acid is added to ice is due to the freezing point depression by the ionic acid.

GROWTH OF CHEMICAL “CELLS” BY OSMOSIS

TOPIC	Colligative Properties	**DEMO** # AP.Collig.3

REFERENCE A Demo A Day, Volume 2: Another Year of Chemical Demonstrations, p. 195

EQUIPMENT
Light box
250 mL beaker
100 mL graduated cylinder

CHEMICALS
100 mL of 3% potassium ferrocyanide (3.0 g $K_4[Fe(CN)_6]•3H_2O$ dissolved in 97 mL of distilled
6–8 small crystals of copper(II) sulphate (slightly larger than a pinhead)

PROCEDURE Place 100 mL of 3% potassium ferrocyanide in a 250 mL beaker on a light box. Drop 6–8 crystals of copper(II) sulphate in the beaker and observe.

In this demonstration, ferrocyanide ions and copper(II) ions react to form a semi–permeable colloidal membrane around the copper sulphate crystals. Water passes into the membrane of the “cells” as the copper sulphate dissolves, creating an increased osmotic pressure inside and causing the cells to expand.

LEWIS ACID–BASE REACTION

TOPIC Acids and Bases **DEMO #** AP.Acids.1

REFERENCE A Demo A Day, Volume 2: Another Year of Chemical Demonstrations, p. 202

EQUIPMENT
2 – 18 x 150 mL test tubes
1 oz wide mouth bottle with rubber stopper to fit
600 or 1000 mL beaker (heavy duty)
4–6 inch paddle type balloon (heavy duty)
tape or rubber band to secure cut–off balloon around top of beaker
gas bubbler tube

CHEMICALS
20–30 g of FRESH 4 mesh calcium oxide
source of carbon dioxide
dropper bottle of universal indicator

PROCEDURE With the neck of the balloon downward, cut off the lower third of the balloon. Fill the 1 oz bottle with calcium oxide, stopper well and place in the beaker. Fill the beaker with carbon dioxide and stretch the balloon over the top of the beaker. Secure the balloon with tape if necessary.

Bubble some carbon dioxide through distilled water and add a few drops of universal indicator to show that the solution is acidic. Place some calcium oxide in a second test tube containing distilled water and again test to show that the solution is basic.

Turn the beaker upside down and remove the stopper from the bottle by grasping the stopper through the balloon. Empty the bottle into the beaker and turn the beaker right side up. The balloon will be compressed into the beaker and may encapsulate the bottle against the bottom of the beaker. Have students note that the reaction is exothermic (bottom of beaker is warm).

AMPHOTERIC PROPERTIES OF METAL HYDROXIDES

TOPIC Acids and Bases **DEMO #** AP.Acids.2

REFERENCE Chemical Demonstrations: A Sourcebook for Teachers, Volume 2, p. 171

EQUIPMENT
1 L beaker
2 – 400 mL beakers
stirring rod

CHEMICALS
100 mL of 0.5 M zinc chloride (dilute 6.8 g of $ZnCl_2$ to 100 mL)
250 mL of 1.0 M sodium hydroxide (dilute 10.0 g of NaOH to 250 mL)
250 mL of 1.0 M hydrochloric acid (dilute 20.7 mL of concentrated HCl to 250 mL)

PROCEDURE Put 100 mL of zinc chloride solution into a 600 mL beaker. Put 250 mL of each of NaOH and HCl solutions in separate 400 mL beakers.

Slowly add NaOH solution to the $ZnCl_2$ solution and notice the formation of a gelatinous white precipitate. Pour half of the mixture into a separate 600 mL beaker.

The precipitation reaction is: $Zn^{2+} + 2\ OH^{-} \rightarrow Zn(OH)_2(s)$

Continue to pour NaOH solution into one of the beakers containing the precipitate. The precipitate dissolves.

The dissolving reaction is: $Zn(OH)_2(s) + 2\ OH^{-} \rightarrow Zn(OH)_4^{2-}$

Add HCl solution into the other beaker containing precipitate and note that the precipitate dissolves.

OPTICAL ROTATION OF SUGARS

TOPIC	Electronic Structure of Atoms	**DEMO #** AP.Atoms.1

REFERENCE A Demo A Day: A Year of Chemical Demonstrations, p. 122

EQUIPMENT
Overhead projector
250 mL beaker
2 pieces of polaroid film
protractor

CHEMICALS white Karo™ syrup

PROCEDURE Put a piece of polaroid film on the overhead projector stage, place the beaker on the film and put a second sheet of polaroid film on top of the beaker. Rotate the top polaroid to obtain the maximum reduction of light intensity. Record the protractor angle between the sheets.

Pour the syrup into the beaker and notice the increased amount of light coming through. Again, rotate the top polaroid to obtain the maximum reduction of light intensity. Record the protractor angle between the sheets. The change in angle is called the "optical rotation".

POLYMER CRYSTALLINITY

TOPIC Electronic Structure of Atoms **DEMO #** AP.Atoms.2

REFERENCE A Demo A Day, Volume 2: Another Year of Chemical Demonstrations, p. 276

EQUIPMENT
Two pieces of polarizing film
Overhead projector
Scotch tape
samples of different types of plastics: plastic film, “six pack” ring, polyethylene pipet, etc.

CHEMICALS —

PROCEDURE Tape a piece of polaroid film to the lens of the overhead projector. Focus an image of the plastic sample on the screen. Rotate the polarizing film on the overhead until the colour of the image is most brilliant. Observe the changing of colours as the plastic is stretched. The greater the stress, the brighter the colours on the screen.

Also, place a piece of Scotch tape on one piece of film and put a second piece of film over the first and rotate the film.

(Some polymers have small regions of crystallinity which rotate light in an organized manner. Stretching the polymers alters the crystallinity and rotates the light in different directions.)

ELECTROMAGNETIC RADIATION ON THE OVERHEAD

TOPIC Electronic Structure of Atoms **DEMO #** AP**.**Atoms**.**3

REFERENCE Chemistry Demonstration Aids That You Can Build**,** p**.** 9

EQUIPMENT See reference and sheets following

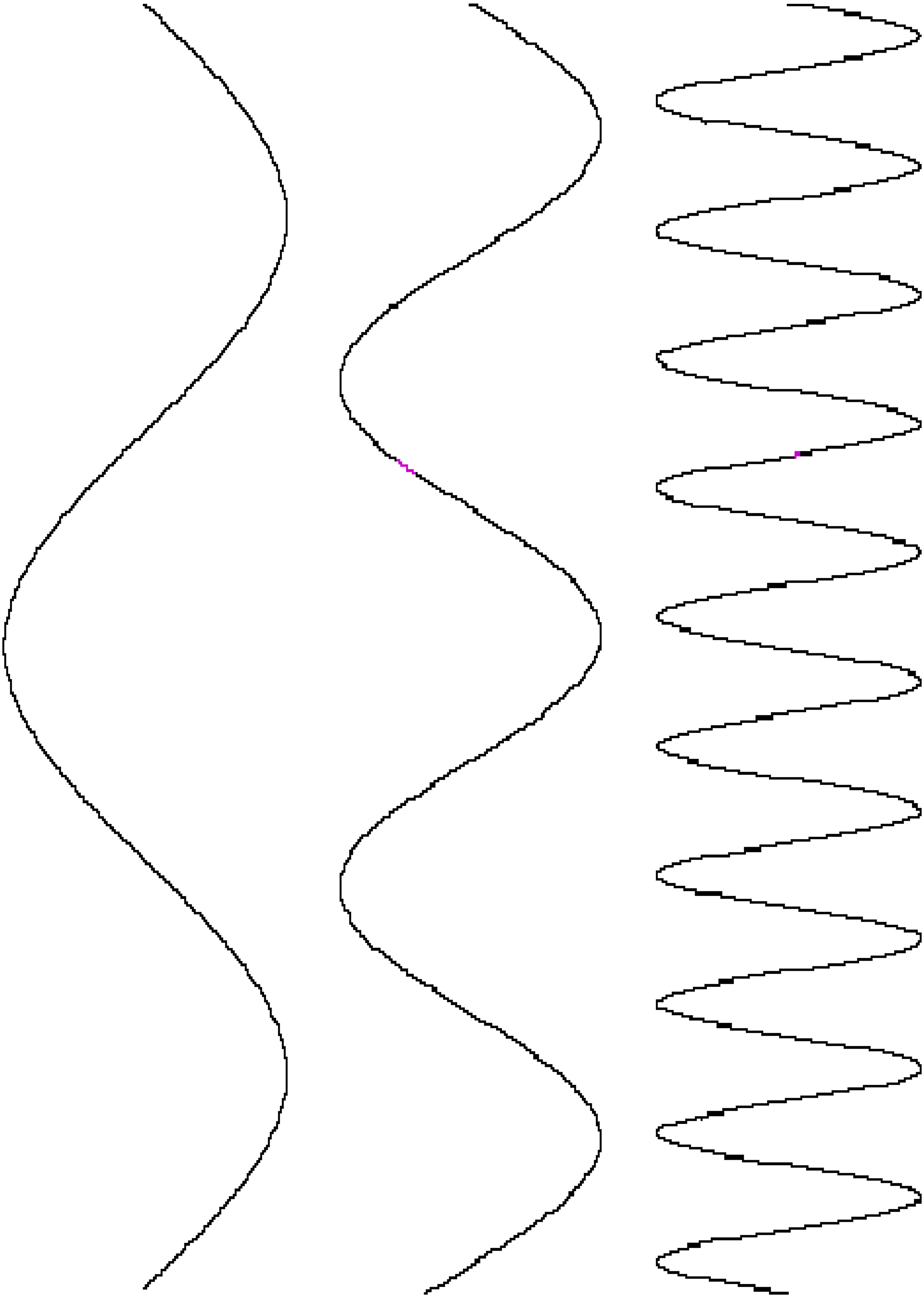
CHEMICALS —

PROCEDURE Place the two sheets on the overhead (either order) and move the top sheet slowly across the bottom one**.** The projected image is that of a moving wave**.** Use the equations below to discuss the relationship between wavelength and frequency**.**

$\lambda \nu = c$ and $E = h\nu = \frac{hc}{\lambda}$

[redacted]

[redacted]



PARAMAGNETIC COMPOUNDS : SWINGING ELECTRONS

TOPIC Electronic Structure of Atoms **DEMO #** AP.Atoms.4

REFERENCE A Demo A Day: A Year of Chemical Demonstrations, p. 124

EQUIPMENT
very strong magnet
8 – 18 x 150 mm test tubes
2 – ring stands with clamps
horizontal bar (extra rod from ring stand)
thread

CHEMICALS
calcium sulphate, $CaSO_4$ (any hydrate)
manganese(II) sulphate, $MnSO_4$ (any hydrate)
copper(II) sulphate, $CuSO_4 \bullet 5H_2O$
zinc sulphate, $ZnSO_4$ (any hydrate)
100 mL of saturated calcium sulphate
100 mL of saturated manganese(II) sulphate
100 mL of saturated copper(II) sulphate
100 mL of saturated zinc sulphate

PROCEDURE Fill each of four test tubes about half full of each compound and label. Fill another four test tubes about half full of the saturated solutions and label. Stopper and seal with wax for use as a permanent demonstration. Suspend the metal rod as a horizontal bar clamped between two stands. The bar should be as high as possible. Suspend each test tube from the bar using thread.

Bring the magnet near each test tube in succession. The tubes containing manganese and copper will be attracted to the magnet; the solid samples more than the saturated solutions.

QUANTIZED PHOSPHORESCENCE

TOPIC Electronic Structure of Atoms **DEMO #** AP**.**Atoms**.**5

REFERENCE A Demo A Day**,** Volume 2**:** Another Year of Chemical Demonstrations**,** p**.** 65

EQUIPMENT
100 mL graduated cylinder
one sheet of each of red**,** blue and green cellophane**,** in cardboard frames
scotch tape
flashlight

CHEMICALS 10 g of sodium fluorescein dissolved and diluted to 100 mL

PROCEDURE Pour the fluorescein solution into the 100 mL graduated cylinder**.** Darken the room**.** Place the red piece of cellophane on top of the graduated cylinder and shine the flashlight down the cylinder**.** Turn off the flashlight to see if the solution glows (it should not)**.**

Repeat using the green and blue cellophane filters**.** The solution fluoresces with these filters**.**

POLAROID

TOPIC Electronic Structure of Atoms **DEMO #** AP.Atoms.6

REFERENCE commonly known

EQUIPMENT 4 pieces of polaroid film, preferably as large as possible

CHEMICALS —

PROCEDURE Hold 2 pieces of polaroid film on top of each other, with a light source behind them (an overhead projector or a window). As the top piece is rotated relative to the bottom piece, the light is extinguished at one position; full amounts of light pass through when the pieces are aligned 90° to the extinguished position.

With the sheets in the extinguished position, insert between them a third sheet at a 45° angle to the other two. Light now passes through all 3 sheets in the centre zone. Finally, insert a 4th sheet between the top and middle sheets, 90° to the middle piece (and 45° to the top and bottom pieces). An interesting arrangement of extinguished versus non-extinguished zones emerges.

What is Happening:

The polaroid plastic can be thought of as a picket fence. A skip rope can be waved up and down and the wave will pass through the pickets. If the wave were to go side to side, the sideways wave would be stopped at the up and down pickets.

Aligning the polaroid pieces parallel to each other, allowing light to pass through, is equivalent to having two fences one behind each other. A wave that passes through one fence can pass through the next one. If the two fences are aligned so that the pickets are up-down on one and sideways on the next, no wave can get through. Similarly, when the polaroid is aligned 90° to each other, no light passes through.

Strictly speaking, the light passing through the first piece of polaroid is said to become “plane polarized” and now vibrates up and down, say, only. If the light passing through one piece of polaroid is passed through a second piece of polaroid, the amount of light passing through the second piece is proportional to the cosine of the angle between them. For example, when the pieces are parallel (0° angle between them), 100% of the light gets through; when the pieces are at 90°, 0% of the light gets through.

If you have two pieces at 90° to each other, inserting a third piece of polaroid at 45° to the other two causes an interesting effect. When light is plane polarized by passing through the first sheet, about 71% of the light passes through a second polaroid at 45° to the first sheet. But the light passing through the second sheet is now plane polarized by the second sheet, 45° to the first sheet. Passing the light from the second sheet through a third sheet 45° to the second (and 90° to the first) again allows 71% of the light from the second sheet to pass through the third. Hence, where previously 0% of the light passed through two pieces at 90° to each other, the presence of the third sheet at 45° allows 50% (71% of 71%) to pass through now.

CRYSTAL COLOUR CENTRES : COLOURFUL ELECTRONS

TOPIC Electronic Structure of Atoms **DEMO #** AP.Atoms.7

REFERENCE A Demo A Day, Volume 2: Another Year of Chemical Demonstrations, p. 152

EQUIPMENT
2 – heavy walled ignition tubes
ring stand and clamp
one hole stopper to fit ignition tube
5 cm length of glass tubing to fit stopper
vacuum pump
rubber vacuum tubing to connect to 5 cm glass tube
tesla coil
250 mL beaker
stirring rod

CHEMICALS 2 g of potassium chloride crystals, KCl

PROCEDURE Place 1 g of potassium chloride crystals in each of the ignition tubes. One tube of crystals will be a control. Clamp the other tube containing crystals vertically. Use the one hole stopper, glass tube and vacuum tubing to connect the test tube to the vacuum pump. Start the vacuum pump and then discharge the tesla coil near the crystals so as to form an electric arc from the tesla coil to the crystals. After a few minutes, the crystals become violet in colour due to the formation of “colour centres”. The control tube remains colourless / white.

When the violet crystals are dissolved in water, the solution is colourless due to the destruction of the colour centres.

THERMCELLS ARE SIMPLE BATTERIES (THE BECQUEREL EFFECT)

TOPIC Electrochemistry: **DEMO** # AP.Electro.1

REFERENCE A Demo A Day, Volume 2: Another Year of Chemical Demonstrations, p. 264

EQUIPMENT
10 mm OD glass tubing, 1 m long
2 – rubber stoppers to fit glass tubing
2 – 50 cm pieces of bare copper wire
voltmeter with alligator leads
large ring stand and 2 clamps
heat gun or blow dryer
small drill (1/16" or smaller) or dissecting needle

CHEMICALS 150 mL of 0.0050 M copper (II) sulphate, $CuSO_4$

PROCEDURE Make two identical electrodes by coiling the 50 cm pieces of copper wire around a pencil. Drill a rubber stopper or pierce it with a dissecting needle so as to be able to pass the copper wire through the stopper. Have about 20 cm of straight wire extending out of the top of the stopper and a 5 cm long coil of wire inside. Repeat the procedure for the other stopper. Clamp the glass tube vertically and place one stopper at the lower end. Fill the tube with 0.0050 M copper (II) sulphate and secure the other end with the second stopper.

Attach the leads of the voltmeter to the copper leads of the thermcell. The initial reading will probably be in the range 0–25 mV. Begin heating the top end of the glass tubing with a heat source. After about 3 minutes, the voltage should be in excess of 100 mV. Ask students to suggest possible uses for this cell.

The half–cell potential is a function of the temperature.

$$E = E^o - \frac{RT}{nF} \ln Q$$

The greater the temperature, the smaller the half–cell potential. In the above cell, the anode and cathode initially involve the same half cells. When one "half cell" is heated, the half cells now differ in potential and a potential difference is created.

COLOUR EFFECTS DUE TO LIGAND EXCHANGE IN NICKEL COMPLEXES

TOPIC VB and MO Theory **DEMO #** AP.VB/MO.1

REFERENCE Chemical Curiosities: Spectacular Experiments and Inspired Quotes, p. 105

EQUIPMENT 6 – 18 x 150 mm test tubes
dropping pipet

CHEMICALS nickel(II) chloride, $NiCl_2 \cdot 6H_2O$
concentrated ammonia
10 mL of ethanol

PROCEDURE Dry about 10 g of nickel chloride at 120°C until it turns yellow. Quickly transfer about 3/4 of the dried chemical to an 18 x 150 mm test tube and seal in a flame. Put the remaining dried chemical in a separate test tube and quickly seal with a stopper.

Tube 1: $NiCl_2$ (anhydrous). Yellow colour. Crystallizes in a layered lattice in which the chloride ion has a cubic closest packing.

Dissolve 24 g of nickel chloride in 20 mL of distilled water. Divide this solution among four 18 x 150 mm test tubes.

Tube 1: normal green colour of nickel(II) ion — $[Ni(H_2O)_6]^{2+}$
Tube 2: add a few drops of concentrated ammonia to get a turquoise colour – $[Ni(H_2O)_m(NH_3)_n]^{2+}$
Tube 3: add a few more drops of ammonia to get a dark blue colour — $[Ni(H_2O)_m(NH_3)_n]^{2+}$
Tube 4: add an excess of ammonia to get a violet colour — $[Ni(NH_3)_6]^{2+}$
Tube 5: add some alcohol to the stoppered test tube containing dehydrated nickel(II) chloride. Then allow to contact moisture from the air to get a lime green colour.

COLOUR EFFECTS IN AQUEOUS SYSTEMS CONTAINING DIVALENT METAL IONS DERIVED FROM SELECTED 3d ELEMENTS

TOPIC VB and MO Theory **DEMO** # AP.VB/MO.2

REFERENCE Chemical Curiosities: Spectacular Experiments and Inspired Quotes, p. 114

EQUIPMENT
8 – 18 X 150 mm test tubes
test tube rack
25 mL graduated cylinder
10 mL graduated cylinder

CHEMICALS
1.5 g of solid manganese(II) sulphate
1.5 g of solid iron(II) sulphate
1.5 g of solid cobalt(II) sulphate
1.5 g of solid nickel(II) sulphate
1.5 g of solid copper(II) sulphate
1.5 g of solid zinc sulphate
1.5 g of solid ammonium metavanadate
1.**8** g of solid chromium(III) sulphate
a scoopful of zinc granules
10 mL of concentrated sulphuric acid
50 mL of 20% sulphuric acid (CARE: slowly add 10 mL of concentrated H_2SO_4 to 40 mL of cold water)
20 mL of n–hexane

PROCEDURE

Test tube 1: 1.5 g of ammonium metavanadate are added to 15 mL of 20% sulphuric acid and a few granules of zinc are added. When hydrogen production ceases, 5 mL of n–hexane is carefully poured on the top. (Colour = **LILAC**) If necessary, add more zinc or sulphuric acid if the colour is not correct.

Test tube 2: 1.8 g of chromium(III) sulphate are added to 15 mL of 20% sulphuric acid and a few zinc granules are added. When hydrogen production ceases, 5 mL of n–hexane is carefully poured on the top. (Colour = **LIGHT BLUE**) If necessary, add more zinc or sulphuric acid if the colour is not correct.

Test tube 3: 1.5 g of manganese(II) sulphate are dissolved in 10 mL of water and 1 mL of concentrated sulphuric acid is added. (Colour = **PALE PINK**)

Test tube 4: 1.5 g of iron(II) sulphate are dissolved in 10 mL of water and 1 mL of concentrated sulphuric acid is added. (Colour = **LIGHT GREEN**)

Test tube 5: 1.5 g of cobalt(II) sulphate are dissolved in 10 mL of water and 1 mL of concentrated sulphuric acid is added. (Colour = **PINK**)

Test tube 6: 1.5 g of nickel(II) sulphate are dissolved in 10 mL of water and 1 mL of concentrated sulphuric acid is added. (Colour = **EMERALD GREEN**)

Test tube 7: 1.5 g of copper(II) sulphate are dissolved in 10 mL of water and 1 mL of concentrated sulphuric acid is added. (Colour = **LAPIS LAZULI**)

Test tube 8: 1.5 g of zinc sulphate are dissolved in 10 mL of water and 1 mL of concentrated sulphuric acid is added. (Colour = **COLOURLESS**)

PARAMAGNETIC OXYGEN GAS

TOPIC VB and MO Theory **DEMO #** AP.VB/MO.3

REFERENCE Journal of Chemical Education, Vol. 67, p. 63 (1990)

EQUIPMENT
small Petri plate
very strong magnet (example: neodymium)
rubber tubing (to lead from oxygen source to demonstration)
pipette to fit tubing, with thin end

CHEMICALS
Source of oxygen
Soap bubble solution

PROCEDURE Completely fill the Petri plate with bubble solution, such that the soap solution is higher than the top of the Petri plate and forms a convex curve at the top. Use the pipette tip to inject a bubble of oxygen about 3–10 mm across into the bubble solution. Bring a strong magnet close to the bubble at an angle of about 45^{o} to the surface of the liquid. When the magnet is about 1 cm from the bubble, the bubble moves toward the magnet as a result of the paramagnetism arising from the two unpaired electrons on each oxygen molecule. Note: do not bring your hand close to the bubble, so as to avoid movement due to local heating of the air.