



Determination of the Charge on an Electron

Topical Unit of Instruction: Atomic Structure

Teacher's Edition

Rehab
the
LAB

Introduction

There are no chemical consumables in this lab. The ZnSO_4 can be reused from year to year indefinitely. After several years, it may no longer appear very pure, but it will still yield excellent results. The electrodes are also good for many years. To prolong battery life up to several years, they can be kept in the refrigerator or freezer. Recharging or recycling batteries will help keep batteries out of the landfills.

Time

50 minutes for data collection

50 minutes for final balance readings and processing data

Objectives

1. To determine the charge on an electron.
2. To gain experience setting up a circuit.

Preparation

1. Use tin snips to cut electrodes from zinc sheet.
2. Place 228 g $\text{ZnSO}_4 \cdot 7 \text{H}_2\text{O}$ in one-liter volumetric flask. Dissolve in about $\frac{3}{4}$ L distilled H_2O . Dilute to volume. Solution will not be clear.

Typical Results

1. a. $\sim .70$ amperes
b. 25 min. $\times 60$ sec/min = 1500 sec
c. 0.70 amp $\times 1500$ sec = 1.050×10^3 amp-sec
2. $\sim .35$ g each, "+" electrode should lose mass and "-" electrode should gain mass
3. $\sim [0.35\text{g} / (1.09 \times 10^{-22} \text{ g/Zn atom})] = 3.2 \times 10^{21}$ Zn atoms
You will have to give students the mass of a Zn atom if you have not yet taught Avagadro's Number and moles!
4. $\sim [(1.05 \times 10^3 \text{ amp-sec}) / (3.2 \times 10^{21} \text{ Zn atoms})] = 3.3 \times 10^{-19}$ [(amp-sec)/Zn atom]
5. $\sim [(3.3 \times 10^{-19} \text{ [(amp-sec)/Zn atom]} / 2(\text{electrons/Zn atom}))] = 1.7 \times 10^{-19}$ (amp-sec)/electron = 1.7×10^{-19} (coulomb/electron)
6. % error = $1(1.60 \times 10^{-19}) - (1.7 \times 10^{-19}) / (1.6 \times 10^{-19}) = 6.3\%$

Materials

(For a class of 32 students working in pairs)

- 32 zinc electrodes ($\sim 3 \times 10$ cm)
- 1 package steel wool (from hardware store)
- balances (sensitive to 0.01 g)
- 16 250 mL beakers
- ~ 3.5 L of 1.0 M ZnSO_4
- 48 wire leads with alligator clips
- 16 battery holders – Frey (vendor) has great ones!
- 64 "D" batteries
- 16 ammeters (borrow from physics teacher)
- 8 squirt bottles with distilled H_2O
- clock with second hand



Determination of the Charge on an Electron

Hints

1. It is imperative that you do this experiment before you have students do it! Although this should be standard practice for all science teachers introducing new labs into their curriculum, it is especially important for this activity.
2. Maintaining the current at 0.70 amps is not always an easy task. If it is too high, try bypassing a battery by placing the alligator clip on the aluminum post between the last two batteries on one end. If it is too low, try toggling the aluminum posts between the batteries or moving the electrodes in the beaker a little closer together. If your batteries are more than a couple of years old, check to make sure they still work the day before you intend to have students do the lab.
3. If your ammeters have more than one positive terminal, remind students to use the one that will allow them to read 0.70 amperes. Also, remind them to not let the electrodes touch each other. This may include some “fiddling” around with alligator clips during set-up.
4. Make sure you check each set-up before students add ZnSO_4 . If you disconnect the “-“ terminal on the ammeter, they can pour the ZnSO_4 in the beaker and easily reconnect the “-“ terminal without disrupting the rest of the circuit.
5. Although the mass change in the 2 electrodes should be similar (the amount lost by the “+” should be about the same as the mass gained by the “-“), the data from the “-“ electrode is usually more reliable. The Zn plated onto the “-“ electrode is usually fairly pure, whereas the mass lost from the “+” electrode may contain some impurities.
6. Students must use the same balance for all mass measurements. You may wish to number or label your balances to ensure that this happens.
7. If ammeters are in short supply, have students work in groups of three instead of pairs.
8. The calculations for this lab are not easy for some students, particularly if you choose to teach atomic structure before you teach moles. Working on the calculations together as a class will lower the anxiety of the less math-able students.





Determination of Moles of Copper and Iron in Reaction

Teacher's Edition

Rehab
the
LAB

Topical Unit of Instruction: Moles or Stoichiometry

Introduction

This is the classic iron nails in CuCl_2 activity with a slightly different twist. Instead of using excess CuCl_2 which produces large quantities of toxic Cu^{+2} ions, CuCl_2 is the limiting reactant. If the iron nails are allowed to sit in the small amount (2.0 g) of CuCl_2 overnight, the reaction will go to completion, yielding Fe^{+2} in excess, which can be flushed down the sink with excess water. Fe^{+2} is the ion that is incorporated into the hemoglobin molecule and is frequently prescribed (as ferrous sulfate or ferrous gluconate, for example) for patients who are anemic.

Time

Day 1: 30 minutes

Day 2: 30 minutes

Day 3: 40 minutes, including calculations

Objectives

1. To determine moles of iron used and copper produced in a single replacement reaction.
2. To determine the ratio of moles of iron to moles of copper in order to generate a balanced equation for the reaction.

Preparation

To make 500 mL 1 M HCl: Fill a 500 mL volumetric flask about $\frac{3}{4}$ full of distilled H_2O . Working in a fume hood and wearing goggles, carefully measure 42 mL concentrated HCl in graduated cylinder and slowly add to volumetric flask. Swirl to mix and allow to come to room temperature. Dilute to volume. It will take a few hours for the diluted acid to cool, so make this at least the day before students will use it.

Typical Results

1. Data (A)-(D)= .61g of iron used
2. Data (E)-(B)= .69 g of copper produced
3. $(.61 \text{ g} / 55.8 \text{ g/mole}) = 0.011 \text{ mole Fe}$
4. $(.69 \text{ g} / 63.6 \text{ g/mole}) = 0.011 \text{ mole Cu}$
5. $(.011 / .011) = 1:1$
6. $\text{CuCl}_2(\text{aq}) + \text{Fe}(\text{s}) \rightarrow \text{Cu}(\text{s}) + \text{FeCl}_2(\text{aq})$

Materials

(For a class of 32 students working in pairs)

- 32 iron nails (length slightly less than inside diameter of 250 mL beaker)
- 8 sheets of fine sand paper cut into quarters
- balances (sensitive to 0.01g)
- 16 250 mL beakers
- several wax pencils
- 32 g $\text{CuCl}_2 \cdot 2 \text{H}_2\text{O}$
- several liters distilled H_2O
- 16 pairs of crucible tongs
- 8 squirt bottles with distilled H_2O
- 16 stirring rods
- 16 large beakers for decanting
- ~500 mL of 1 M HCl
- drying oven



Determination of Moles of Copper and Iron in Reaction

Disposal

1. Have students dump decanted HCl into a large container. Neutralize with base to a pH between 6 and 9 before flushing down sink with water.
2. Collect used nails. They can be used for several years until they are about $\frac{1}{2}$ mm in thickness.
3. Solid copper produced can be saved for later use or put in garbage.

Hints

1. Make sure you purchase iron nails that will lie flat on the bottom of 250 mL beakers.
2. If your drying oven is small and you have several classes, you may have to dry beakers in class shifts for a couple of hours per shift.
3. If you have a little iron residue in your beakers, you may have to scrub them with a steel wool soap pad such as SOS[®] or Brillo[®].





Determination of Density

Topical Unit of Instruction: Properties of Matter

Introduction

Only one potentially toxic liquid is used in this lab and it happens to be a common household toxin. The chemicals can also be reused from class to class.

Time

50 minutes for data collection

Objectives

1. To determine density of three unknown liquids.
2. To practice correct use of volumetric pipet.
3. To generate "best fit" lines from plotted points.

Preparation

Liquid A

Liquid A is saturated salt water. About a week before the lab is scheduled, put about 200 mL of distilled H₂O in a large beaker. Add NaCl until a fair amount is sitting on the bottom of the beaker. Mix well. Continue to add NaCl and mix for several days as solution continues to dissolve more salt. On the morning of the lab, mix in a few drops of food coloring and pour the supernatant from the saturated saltwater into 3-4 dispensing containers that have been clearly labeled as "A". Accepted density is 1.2 g/mL.

Liquid B

Liquid B can be either methanol, ethanol, or isopropanol. If you choose isopropanol, purchase it from a chemical supplier. The isopropanol sold in drug stores as rubbing alcohol is actually a 70% solution in H₂O and will not give the appropriate results. Add a few drops of another food color to about 200 mL of the alcohol and dispense into 3-4 containers labeled as "B". Accepted density is 0.8 g/mL.

Liquid C

Liquid C needs no preparation. Dispense 200 mL of distilled H₂O between 3-4 containers labeled as "C". Accepted density is 1.0 g/mL.

Materials

(For a class of 32 students working in pairs)

- 16 small beakers (25 or 50 mL)
- 16 centigram balances
- 16 assorted pipets (including the following sizes: 0.5, 1, 2, 3, 4, 5, 7, 10, 15, and 25 mL)
- 16 pipet fillers
- 200 mL each of liquid A (saturated salt water), liquid B (methanol, ethanol, or isopropanol), and liquid C (distilled water)
- 32 sheets of graph paper



Determination of Density

Safety Reminders

1. Students should never taste any chemical, but emphasize that liquid B is particularly toxic.
2. Presenting the liquids as different colors eliminates the potential for students to pour the chemicals back into the wrong dispensing container and thereby contaminate a large quantity. Tell them that all of the liquids are actually colorless, that you have added the color for safety and that the color has no effect on the results of the lab.
3. Volumetric pipet tips are especially fragile. They can easily be chipped if students are not careful about shaking them dry. In addition to the chipped glass being a safety issue, the pipet will probably not deliver its appropriate volume.
4. Remind students to never mouth pipet.

Typical Results

When best fit lines are drawn from class data, the slopes of the lines are very close to the accepted densities.

Disposal

Liquids A and C can be poured down the drain. Liquid B could be saved for cleaning purposes (where very pure alcohol is not necessary) or allowed to evaporate over the course of several weeks.

Hints

1. Assign a pipet size to each pair of students to ensure a wide range of class data. Make sure students are comfortable using pipets before they start the data collection.
2. After students have completed their graphing, ask them if they can identify any of the liquids. They will often correctly identify liquid C as water. Tell them what the liquids are at this point.





Determination of the Molar Volume of Gas

Topical Unit of Instruction: Gases or Moles

Teacher's Edition

Rehab
the LAB

Introduction

The only harmful product of this lab is the excess HCl which can be neutralized and then disposed of down the sink. The Cu wire does not react and can be reused indefinitely.

Time

50 minutes for data collection

50 minutes for calculations

Objectives

1. To collect a gas by displacement of H_2O .
2. To calculate the molar volume of a gas at standard temperature and pressure.

Preparation

1. Measure 1.00 m of Mg ribbon and find its mass. If you have a balance sensitive to at least 0.001 g, use it. Give this mass to students before you start the lab.
2. Since the thickness of Mg ribbon varies from vendor to vendor, you will have to determine the approximate length needed to yield pieces of about 0.040 g. The pieces don't have to be pre-cut real perfectly—a little variation is good!
3. Cut the Cu wire into ~ 25 cm lengths.
4. To make 200 mL of 6.0 M HCl, fill a 200 mL volumetric flask about 1/3 full of distilled H_2O . Working in a fume hood with goggles on, measure 100.0 mL concentrated HCl and slowly pour into flask. Swirl. Allow to cool to room temperature and dilute to volume. You may want to add a few drops of food color so students can watch it sink through the H_2O .
5. Do this lab yourself before you do it with the students. Personal experience is so helpful on this one. Also, you may need to adjust the Mg ribbon lengths. It is preferable to produce as much H_2 as possible, but if the gas volume produced goes beyond the measurements on the gas measuring tube, you will have a disaster.

Typical Results

Data Table:

Mass of 1.00 m of Mg ribbon:	~ 0.980 g
Length of Mg ribbon:	~ 4.2 cm
Room Temperature:	~ 22° C
Barometric Pressure:	759 mm Hg
Volume of Collected Gas:	42.1 mL

Materials

(For a class of 32 students working in pairs)

- 16 gas measuring tubes (50 mL)
- 16 ring stands
- 16 utility clamps
- 16 large beakers (400 or 600 mL)
- 16 graduated cylinders (10 mL)
- 16 thermometers
- classroom barometer
- 16 1-hole rubber stoppers (to fit gas measuring tubes)
- 1 large deep container of H_2O (2 L graduated cylinder, battery jar or deep bucket will work)
- 16 rulers
- 16 pre-cut pieces of Mg ribbon ~ 0.040 g
- 16 pieces of fine Cu wire ~ 25 cm
- 200 mL 6.0 M HCl



Determination of the Molar Volume of Gas

Analysis and Calculations

- $\text{Mg(s)} + 2\text{HCl(aq)} \rightarrow \text{MgCl}_2\text{(aq)} + \text{H}_2\text{(g)}$
- $100.0 \text{ cm} = 4.2 \text{ cm}$ $X = 0.041 \text{ g Mg used}$
 0.980 g $X \text{ g}$
- $0.041 \text{ g} = 0.0017 \text{ moles of Mg}$
 24.3 g/mole
- 1 mole of Mg produces 1 mole of H_2 , so 0.0017 moles of H_2 should have been produced.
- $759 \text{ mm Hg} \times 101.3 \text{ kPa/atm} = 101.2 \text{ kPa}$
 760 mm Hg/atm
- $P_t = P_{\text{H}_2} + P_{\text{H}_2\text{O}}$
 $101.2 \text{ kPa} = P_{\text{H}_2} + 2.6 \text{ kPa}$
 $98.6 \text{ kPa} = P_{\text{H}_2}$
- $P_1 V_1 = P_2 V_2$ $P_1 = 98.6 \text{ kPa}$ $P_2 = 101.3 \text{ kPa}$
 T_1 T_2 $V_1 = 42.1 \text{ mL}$ $V_2 = ?$
 $T_1 = 22^\circ = 295 \text{ K}$ $T_2 = 273 \text{ K}$
 $(98.6 \text{ kPa})(42.1 \text{ mL}) = (101.3 \text{ kPa})V_2$
 295 K 273 K
 $37.9 \text{ mL} = V_2$
- $37.9 \text{ mL} = 0.0379 \text{ L}$
 $1,000 \text{ mL/L}$
- $0.0379 \text{ L} = X \text{ L}$
 0.0017 moles 1 mole
 $X = 22.3 \text{ moles/L}$

Disposal

- Have students pour excess HCl (with $\text{MgCl}_2\text{(aq)}$) from gas measuring tubes into a large container. Neutralize with base to a pH between 6 and 9, and pour down drain with lots of H_2O .
- Collect Cu wire, rinse, and reuse.

Hints

- You'll have to look up the vapor pressure of H_2O at your room temperature in a handbook to give to students.
- Remind students to be especially careful of the 6.0 M HCl. It is nasty!
- Remind students to be careful with gas measuring tubes. To clean them, suggest students rinse the beaker, repeatedly fill the tube with clean H_2O from the beaker, and then dump. It is likely that the tubes will NOT fit in the sink under the faucet, and students could easily break one if they attempt to clean it directly under the faucet.
- Check Mg ribbon for oxidation. Do not measure or use any Mg segment that has oxidized.





Formula of a Hydrate

Topical Unit of Instruction: Chemical Formulas or Liquids and Solids

Introduction

No toxic materials are used in this lab. Both chemicals, alum and Epsom salts, are available in your local drug store. Alum is commonly used in home pickling (Check out the ingredients on your pickle relish jar in your refrigerator at home!) and Epsom salts are frequently used in solution to soak sprained ankles or wrists. Perhaps some of your students will be familiar with Epsom salts. Both alum and Epsom salts can be ordered from a science supply vendor as well.

Time

50 minutes to collect data

30 minutes to process data

Objectives

1. To determine the formula of a hydrate.
2. To calculate the percent H₂O in a hydrate.

Preparation

Assign each lab pair one of the hydrates. If you have plenty of evaporating dishes and crucibles with covers, you may just want to assign alum to half the class and Epsom salts to the other half.

Safety Reminders

1. Porcelain retains heat for a prolonged period of time so cooling requires many minutes. Remind students to be very careful not to burn themselves.
2. Remind students never to set hot porcelain on the lab countertop.
3. Students should not peer over "cooking" hydrates to avoid steam burns as water is released.

Typical Results and Calculation Tips

1. Subtract mass of empty dish (a) from mass of dish and anhydrous salt (c).

2. Molar masses:



$$\text{Al: } 1 \times 27.0 = 27.0$$

$$\text{K: } 1 \times 39.1 = 39.1$$

$$\text{S: } 2 \times 32.1 = 64.2$$

$$\text{O: } 8 \times 16.0 = 128.0$$

$$258.3$$



$$\text{Mg: } 1 \times 24.3 = 24.3$$

$$\text{S: } 1 \times 32.1 = 32.1$$

$$\text{O: } 4 \times 16.0 = 64.0$$

$$120.4$$

3. Divide g (#1 above) by molar mass (#2 above).

Materials

(For a class of 32 students working in pairs)

- 16 porcelain containers-mixture of evaporating dishes and crucibles with covers
- 16 wire gauze or pipe stem triangles to accommodate evaporating dish/crucible assortment
- alum
- Epsom salts
- 16 crucible tongs
- balances
- 16 ring stands
- 16 iron rings
- 16 laboratory burners
- 16 burner lighters



Formula of a Hydrate

(continued from front side)

4. Subtract mass of dish and anhydrous salt (c) from mass of dish and hydrate (b).

5. Molar mass H₂O:

$$\begin{array}{r} \text{H: } 2 \times 1.0 = 2.0 \\ \text{O: } 1 \times 16.0 = 16.0 \\ \hline 18.0 \end{array}$$

6. Divide g of H₂O (#4 above) by molar mass of H₂O (#5 above).

7. Alum should be 12; epsom salts should be 7.

8. Alum is AlK(SO₄)₂ • 12 H₂O
Epsom salts is MgSO₄ • 7 H₂O

9. Alum:

$$\begin{array}{r} \text{Al: } 1 \times 27.0 = 27.0 \\ \text{K: } 1 \times 39.1 = 39.1 \\ \text{S: } 2 \times 32.1 = 64.2 \\ \text{O: } 8 \times 16.0 = 128.0 \\ \text{H}_2\text{O: } 12 \times 18.0 = 216.0 \\ \hline 474.3 \end{array}$$

Epsom Salts:

$$\begin{array}{r} \text{Mg: } 1 \times 24.3 = 24.3 \\ \text{S: } 1 \times 32.1 = 32.1 \\ \text{O: } 4 \times 16.0 = 64.0 \\ \text{H}_2\text{O: } 7 \times 18.0 = 126.0 \\ \hline 246.4 \end{array}$$

% H₂O = (216.0/474.3) X 100% = 45.5% (almost half!) % H₂O = (126.0/246.4) X 100% = 51.1% (over half!)

Disposal

Wrap anhydrous salts in paper towels and place in garbage. You could also collect the dehydrated alum and Epsom salts in separate containers and rehydrate them with very large amounts of distilled H₂O. It will take several months for the excess H₂O to evaporate, and the student results may not be quite as good as with “new” hydrates if you attempt to use the “rehydrates” the following year.

Hints

1. If time is a factor in data collection, students may wish to carefully set the hot porcelain container on the iron base of the ring stand (not the countertop!) with tongs. It will cool more quickly.
2. The iron rings will remain hot for many minutes. Rather than risk the students burning themselves, it may be easier for you to put the rings and stands away several hours after students have completed the lab.





Heating and Cooling Curves

Topical Unit of Instruction: Liquids and Solids

Introduction

This lab uses lauric acid, a non-toxic chemical, as a substitute for the commonly used para-dichlorobenzene, which is toxic as well as a possible carcinogen. The lauric acid can be saved and reused from year to year.

Time

50 minutes for data collection

30 minutes for graphing

Objectives

1. To generate heating and cooling curves for a pure substance.
2. To determine the freezing/melting point of lauric acid from the cooling/heating curves.

Preparation

1. Pre-measure the lauric acid in test tubes and Parafilm® until ready to use. It is wise to set up an extra test tube just in case students accidentally stir through the bottom of a test tube with the thermometer.
2. Using a piece of laboratory tape, label 16 thermometers with letter or number codes for use in the lauric acid. If you are planning to have students do the freezing point depression lab using the benzoic acid/lauric acid solution, each pair must use the same thermometer they used in the pure lauric acid.

Safety Reminders

1. Students need to stir the melted lauric acid with the thermometers very carefully, or they will stir the bottoms out of the test tubes.
2. Students need to be reminded not to touch anything hot with their skin.

Typical Results

Graphs usually produce obvious plateaus at about 41- 44° C. Accepted melting point is 44° C.

Disposal

Test tubes can be Parafilmed® and reused indefinitely.

Hint

This lab could easily be adapted to computer or graphing calculator temperature probes.

Materials

(For a class of 32 students working in pairs)

- 16 large test tubes (25 x 150 mm work well) each containing 15 g lauric acid
- 16 test tube holders
- 32 large (400-600 mL) beakers
- 16 hot plates (8 will do if 2 pairs share)
- 32 thermometers
- clock (or watches) with second hand
- 32 sheets of graph paper





I Scream, You Scream, We All Scream For Ice Cream!

Topical Unit of Instruction: Solutions-Colligative Properties

Teacher's Edition

Rehab
the LAB

Introduction

No harmful chemicals are used in this lab and it's a lot of fun!

Time

50 Minutes for data collection

15 minutes for analysis and calculations

Objectives

Preparation

1. Cut tops off pop bottles leaving bottoms that are about 5 inches deep.
This is not easy to do, but using large sharp scissors helps. Do not have students do this.
2. Make ice cream mix. If you have a favorite old family recipe, use it as long as it does not call for raw eggs. It may be easier to make the mix at home and transport to school in clean gallon milk jugs. This is a great recipe if you need one:
Ice Cream Mix
 - 6 c. whole milk
 - 1 T. vanilla
 - 1 t. salt
 - 1 c. sugar
3. Collect dishpans of ice a couple of days beforehand and store in freezers around school.

Materials

(For a class of 32 students working alone)

- 32 - 2L pop bottle bottoms
- 32 - 8 or 12 oz. clear plastic disposable cups
- 32 plastic spoons
- 1 - 2 clean dishpans of ice
- 5 lbs. rock salt
- 1 gallon ice cream mix
- 32 thermometers



I Scream, You Scream, We
All Scream For Ice Cream!

Typical Results

Data Table:

Temperature of Ice/Rock Salt Mixture: -12°C

Analysis and Calculations

1. $\Delta T_f = K_f \cdot m$

$$12^{\circ}\text{C} = 1.86 \cdot m$$

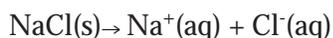
$$m = 6.5 \text{ moles/kg}$$

$$500 \text{ g}/1000 \text{ g/kg} = .50 \text{ kg}$$

$$m = \text{moles/kg}$$

$$6.5 = \text{moles}/.50 \text{ kg}$$

$$\text{moles} = 3.25 = \text{moles of particles}$$



Therefore, every mole of salt produces 2 moles of dissolved ions.

$$\text{Moles of NaCl} = 3.25/2 = 1.6 \text{ moles NaCl}$$

$$\text{Moles} = \text{g/molar mass}$$

$$\text{Molar Mass} = \text{Na: } 1 \times 23.0 = 23.0$$

$$\text{Cl: } 1 \times 35.5 = 35.5$$

$$58.5$$

$$1.6 \text{ moles NaCl} = \text{g}/58.5$$

$$\text{g NaCl} = 94$$

- Adding salt to ice on sidewalks or roads lowers the freezing point below 0°C . This will allow the ice to melt even when the ambient air temperature is considerably below freezing.
- The canister is filled with a solution. The normal freezing point of the solvent is depressed by adding solute. Before use, the canister must be subjected to the very cold temperature of the freezer for a day or so.

Disposal

- Ice and rock salt can be washed down the drain.
- Rinse pop bottles and reuse – do not run through dishwasher.
- Plastic cups and spoons can be run through the dishwasher and reused for years.

Hints

- Make sure lab area is scrupulously clean. Perhaps you can use the cooking classroom if it is available.
- Try to find pop bottles with the extra black or dark green bases. They seem to work better, probably because they insulate somewhat from warm room air. If you cannot find these, try using two pop bottle bottoms, one inside the other, for each student.





Investigating Le Chatelier's Principle

Topical Unit of Instruction: Equilibrium

Teacher's Edition

Rehab
the LAB

Introduction

This is the classic FeSCN^{2+} equilibrium activity. Instead of using several milliliters of chemicals, students use drops of mostly dilute solutions.

Time

50 minutes or less

Objectives

1. To observe equilibrium shifts as stresses are applied to a chemical system.
2. To use Le Chatelier's principle to explain equilibrium shifts in a chemical system.

Preparation

To make 100 mL of each chemical use:

0.2 M FeCl_3 : 5.40 g of $\text{FeCl}_3 \cdot 6 \text{H}_2\text{O}$

0.2 M KSCN : 1.94 g of KSCN

0.2 M $\text{Fe}(\text{NO}_3)_3$: 8.08 g of $\text{Fe}(\text{NO}_3)_3 \cdot 9 \text{H}_2\text{O}$

0.2 M KCl : 1.48 g of KCl

6.0 M NaOH : 24.00 g of NaOH

Fill 100 mL volumetric flasks about $\frac{3}{4}$ full of distilled H_2O . Add appropriate amount of chemical. Swirl to dissolve. This may take several minutes for the iron compounds. Dilute to volume and divide among labeled dropper bottles. NOTE: Dissolving NaOH is very exothermic. Allow to come to room temperature before diluting to volume.

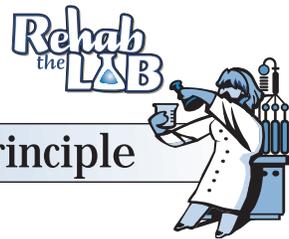
Typical Results

Chemical Added	Observations/ Description	Stress Ion	Spectator Ion	Direction of Equilibrium Shift
B: $\text{Fe}(\text{NO}_3)_3$	darker orange	Fe^{3+}	NO_3^-	\rightarrow
C: KCl	no change	none	K^+ and Cl^-	no shift
D: KSCN	darker orange	SCN^-	K^+	\rightarrow
E: NaOH	pale yellow haziness	OH^-	Na^+	\leftarrow

Materials

(For a class of 32 students working in pairs)

- 4 sets of dropper bottles of:
 - 0.2 M FeCl_3
 - 0.2 M KSCN
 - 0.2 M $\text{Fe}(\text{NO}_3)_3$
 - 0.2 M KCl
 - 6.0 M NaOH
- several liters distilled H_2O
- 16-250 mL beakers
- 80 test tubes (13 X 100 mm work well)
- 16 test tube racks
- wax pencils



Investigating Le Chatelier's Principle

Typical Results

When NaOH is added, OH^- reacts with Fe^{3+} to form insoluble $\text{Fe}(\text{OH})_3$ which precipitates out of solution to cause the haziness. In essence, adding OH^- as a stress decreases the amount of Fe^{3+} in test tube E. This decreases FeSCN^{2+} causing the equilibrium to shift left producing more colorless SCN^- . Hence, the color becomes pale.

Disposal

1. Contents of test tubes A,B,C, and D can be poured down the drain with lots of H_2O .
2. Have students pour contents of test tube E in a large beaker. Neutralize with acid to a pH between 6 and 9, and pour down sink with lots of H_2O .

Hints

You may want to add the 6.0 M NaOH to test tube E for each pair of students. This will help minimize drips of this dangerous, caustic chemical on counter tops and outside of test tubes. Students may need help recognizing the haziness after the NaOH is added.





Least-Toxic Chem Labs

Teacher's Edition



Building a Hazard-Free Classroom

Safe labs that don't pollute

High school chemistry experiments often use hazardous materials and generate hazardous waste. It is also not uncommon for some school labs to end up as holding areas for toxins like liquid mercury, and potential explosives like picric acid. This packet of experiments represents one step that teachers can take to create less hazardous waste, improve lab safety and help reduce students' exposure to hazardous chemicals. It includes some of the most popular labs taught in high school chemistry classes, revised to include improved microscale techniques and substitute least-toxic chemicals for hazardous ones. This collection of labs is a valuable tool for reducing your classroom's impact on the environment.

The experiments were written and reviewed by high school chemistry teachers in King County, Washington. They are not intended to replace your entire curriculum. Use what you can; the adoption of even one lab will go a long way toward reducing the amount of hazardous waste generated in your classroom.

Free help for King County teachers

These labs were developed as part of a larger program called Rehab the Lab. Rehab the Lab is a progressive effort of the Local Hazardous Waste Management Program in King County to eliminate the risks from hazardous waste in schools. This program offers teachers a vital and free service through December 2001. With your pledge to help reduce hazardous waste in your classroom and school, the County will identify chemicals that need disposal, pay 100 percent of the costs to have them safely hauled away, and help create a compatible chemical storage system in your lab. Use the e-mail address below to schedule a visit from one of our technical field representatives.

Contact us

We welcome any feedback you might have, or information on any other experiments that you'd like us to "rehab."

Just e-mail us at dave.waddell@metrokc.gov.

Good luck!

Safety Suggestions

These laboratory activities are intended for use by high school chemistry teachers who:

- have appropriate university level chemistry coursework;
- are endorsed to teach high school chemistry; and
- have a good understanding of safety hazards and regularly update their knowledge of safety issues.

We recommend that before high school students perform these experiments, they:

- have first been taught safe lab practices; and
- have read and understand a safety contract which has been signed by them and by their parents.

Two copies of the safety contract should be issued to each student to be signed. One should be kept on file by the teacher, and one should be kept by the student in his/her science notebook. Most major publishers include appropriate safety contracts in their lab manuals, and chemical supply companies offer them as well.

By providing these chemistry lab lessons, King County shall not be deemed to, or construed to have assessed all the risks that may be applicable to the school or school district using them. Responsibility for proper handling of chemicals and materials used in these laboratory lessons, and responsibility for proper disposal of waste generated in these lessons, lies with the school and school district.



Molar Mass Determination From Freezing Point Depression

Topical Unit of Instruction: Solutions-Colligative Properties

Teacher's Edition

Rehab
the LAB

Introduction

This lab uses mostly non-toxic lauric acid combined with a small amount of benzoic acid which is only slightly toxic. The chemicals can be reused from year to year.

Time

50 minutes for data collection
50 minutes for processing data

Objective

1. To calculate molar mass of a solute from freezing point depression.
2. To generate a cooling curve for a typical solution.

Preparation

1. Carefully pre-measure 2.00 g benzoic acid and 16.00 g of lauric acid for each test tube. Parafilm[®] until ready to use. It is wise to set up an extra test tube just in case students accidentally stir through a test tube with the thermometer. Check thermometer labels. It is imperative that each lab pair use the same thermometer for the benzoic/lauric acid mixture in this lab that they used in the pure lauric acid for "Heating and Cooling Curves."

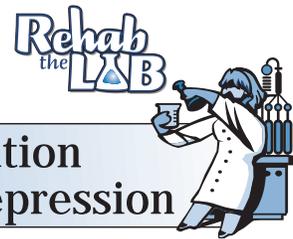
Safety Reminders

1. Students need to stir the melted solution with the thermometer very carefully, or they will stir the bottoms out of the test tubes.
2. Students need to be reminded not to touch anything hot with their skin.

Materials

(For a class of 32 students working in pairs)

- 16 large test tubes (25 x 150 mm work well) containing 2.00 g benzoic acid plus 16.00 g lauric acid
- 16 test tube holders
- 32 large (400-600 mL) beakers
- 16 hot plates (8 will do if two pairs share!)
- 32 thermometers (16 labeled from "Heating and Cooling Curves" lab)
- clock (or watches) with second hand
- 32 sheets of graph paper



Molar Mass Determination From Freezing Point Depression

Typical Results:

1. $\Delta T_f = 4.0^\circ\text{C}$
2. $\Delta T_f / K_f = m = 1.03 \text{ moles/kg}$
3. $\text{g} / (1,000 \text{ g/kg}) = 0.01600 \text{ kg lauric acid}$
4. $m \cdot \text{kg} = (1.03 \text{ moles/kg}) (0.01600 \text{ kg}) = 0.0165 \text{ moles benzoic acid}$
5. $(\text{g/moles}) = (2.00\text{g}/0.0165 \text{ moles}) = 121 \text{ g/mole}$
6. C: $7 \times 12.0 = 84.0$
H: $6 \times 1.0 = 6.0$
O: $2 \times 16.0 = 32.0$
122 g/moles
7. $122 - 121 / 122 \cdot 100 = 1\%$

Disposal

Test tubes can be Parafilmed[®] and reused indefinitely.

Hint

This lab could be easily adapted to computer or graphing calculator temperature probes. However, as with thermometers, each pair of students must use the same probe that they used in the pure lauric acid in the "Heating and Cooling Curves" lab.





Percent Composition of an Egg

Topical Unit of Instruction: The Mole-Percent Composition

Teacher's Edition

Rehab
the
L&B

Introduction

No toxic chemicals are used in this lab.

Time

50 minutes

Objectives

1. To determine the % composition of an egg.
2. To use previously learned math concept in science.
3. To figure out lab procedure with minimal teacher input.

Preparation

None necessary!!!

Safety Reminders

Most students will probably choose to do the lab with the raw egg. Remind them about Salmonella risk and insist on thorough hand washing when they are finished, preferably with an anti-bacterial soap. Also, ask them to keep their hands away from their faces as they perform the lab.

Disposal

Set out large containers for collection of egg parts (shells too!). Put everything down the garbage disposal in the home and family department. If your science department has a dishwasher, run all containers used by students through dishwasher. If no dishwasher is available, carefully and thoroughly wash containers by hand.

Hint

Encourage students to separate yolk from white with great caution if they choose to use a raw egg. Purchase a few extra eggs, just in case student inexperience results in some broken yolks.

Special thanks to Kathee Terry, Science Curriculum Developer K-12, Bellevue School District, for suggesting this lab idea.

Materials

(For a class of 32 students working in pairs)

- 16 eggs
- 16 balances
- 50 (or so) containers (some beakers)
- hot plates





Rehab the Bio Lab

Teacher's Edition



Stains and Indicators

One very effective practice for reducing stockpiles of chemical solutions is to purchase stains and indicators as dry solids. Mixing solutions from the dry solids eliminates having to store many bottles of premixed solutions for several months or years. Preparing small volumes as needed and dispensing them in dropper bottles is often sufficient for several classes.

Examples of Commonly Used Stains and Indicators

Bromthymol Blue, 0.04% aqueous: Dissolve 0.040 g of bromthymol blue in about 50 mL of distilled H₂O in a 100 mL volumetric flask. Dilute to volume.

Phenolphthalein, 1% alcoholic: Dissolve 1.00 g of phenolphthalein in about 50 mL of 95% ethanol in a 100 mL volumetric flask. Dilute to volume with ethanol.

Methylene Blue, 1% aqueous: Dissolve 1.00 g of methylene blue in about 75 mL of distilled H₂O in a 100 mL volumetric flask. Dilute to volume.

Biological Specimen Storage

Many science supply companies sell alcohol-based alternatives to formaldehyde or formalin for storage of biological specimens. For example, Carolina Biological sells Carosafe and Flinn markets Formalternate. If you must use formaldehyde and/or formalin, it can be disposed of after neutralizing waste with a commercially available deactivation compound. Call or e-mail the numbers listed below for more information on this process and vendors who can supply the deactivator.

Resources

- *Flinn Chemical and Biological Catalog Reference Manual* (Laboratory Solution Preparation Section)
- *A Sourcebook for the Biological Sciences*, Evelyn Morholt and Paul F. Brandwein, Harcourt Brace Jovanovich Publishers (any edition will work)





Solubility and Precipitation

Topical Unit of Instruction: Solutions and Solubility

Introduction

This microscale lab uses extremely small quantities of dilute solutions of mostly non-toxic chemicals. It generates two drops for each of the fifteen combinations, only 30 drops of waste in all!

Time

30 minutes for data collection

50 minutes for analysis and conclusions

Objectives

1. To observe precipitate formation in double replacement reactions.
2. To predict products of double replacement reactions using a solubility chart and to write balanced equations for those reactions.

Preparation

1. To make 100 mL of each solution, put ~50 mL distilled H₂O in each of six 100 mL volumetric flasks. Add the solutes as follows:

AgNO₃ : 1.70 g

NaNO₃ : 0.85 g

Na₃PO₄ • 12 H₂O : 3.80 g

K₂CO₃ : 1.38 g

FeCl₃ • 6H₂O : 2.70 g

CuSO₄ • 5H₂O : 2.50 g

Swirl until dissolved and dilute to volume with distilled H₂O.

2. Dispense the solutions in 4 sets of labeled Beral pipets.

Materials

(For a class of 32 students working in pairs)

- 10 mL of each of the following 0.1 M solutions: AgNO₃, NaNO₃, Na₃PO₄, K₂CO₃, FeCl₃, and CuSO₄.
- 16 well plates
- 24 Beral pipets

Typical Results

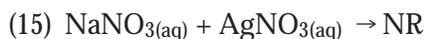
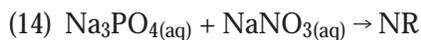
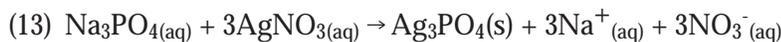
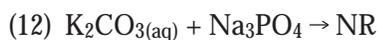
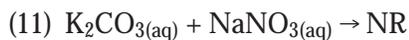
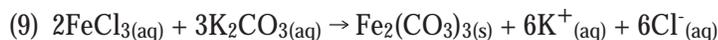
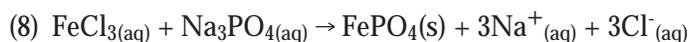
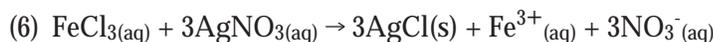
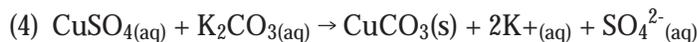
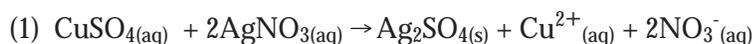
	AgNO ₃	NaNO ₃	Na ₃ PO ₄	K ₂ CO ₃	FeCl ₃
CuSO ₄	White PPT (1)	NR (2)	Turquoise PPT (3)	Turquoise PPT (4)	Yellow PPT (5)
FeCl ₃	White PPT (6)	NR (7)	White PPT (8)	Orange PPT (9)	
K ₂ CO ₃	White PPT (10)	NR (11)	NR (12)		
Na ₃ PO ₄	Yellow PPT (13)	NR (14)			
NaNO ₃	NR (15)				



Solubility and Precipitation

Analysis and Conclusions

1.



2.

(A) NO_3^-

(B) Na^+ and K^+

(C) SO_4^{2-} , CO_3^{2-} , and PO_4^{3-}

(D) Ag^+

Disposal

Wash well plates down sink with excess H_2O . Save labeled pipets from year to year.

Hint

Although 96 well plates work fine, students find it easier to make observations in 24 well plates.

