Solution Manual for Experiments in General Chemistry 6thEdition by Murov

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INSTRUCTOR'S GUIDE for *EXPERIMENTS IN GENERAL CHEMISTRY*

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C indicates that a centigram balance will suffice for this experiment.
M indicates that a milligram balance is recommended for this experiment.

Instructor's Guide

Labs should be equipped with:

Aspirators
Balances
Beaker Tongs
Buret Clamps
Burners Hoods
Hot Plates/Stirrers
Rings
Ring Supports Test Tube
Clamps Three-Pronged
Clamps
Spectronic 20's or alternative

Recommended Locker Equipment:

5 Beakers 100, 150, 250, 400, 600 ml.
1 Clay Triangle
1 Crucible
1 Crucible Cover 1
Crucible Tongs
1 Evaporating Dish
1 Flame Spreader
3 Flasks, Erlenmeyer 125, 250, 500 ml.
1 Flask, Florence 500 ml.
1 Funnel, long stem
2 Graduated Cylinders 10, 50 ml. 1 Medicine Dropper
1 Piece of Rubber Tubing 50 cm.
1 Pinch Clamp 1
Pipet, 10 ml.
6 Test Tubes 13 X 100 mm. 6
Test Tubes 18 X 150 mm.
1 Test Tube Brush
1 Test Tube Clamp
1 Test Tube Rack
1 Thermometer 110^{o} C
1 Wash Bottle
2 Watch Glasses
1 Wire Gauze

Chemicals Required:

* means that this solution requires special preperation instructions, given in this manual.

Chemical Or Supply	**Description Or Concentration**	**Exp #**	**Qty/Student**
Acetic Acid	0.1M	8	50 ml
Acetic Acid	0.2M	5	10 mL
Acetic Acid	0.2M	23	25 ml
*Acetic Acid/Sodium Acetate 0.1M in each		23	20 ml
Acetone	100%	16	25 ml
		28	10 ml
		34	100 ml
Acetophenone	100%	4	6 ml
*Adipoyl Chloride in Cyclohexane	0.25M	34	4 ml
Aluminum foil		8	50 cm^2
		21	50 cm^2
Aluminum Shot		1	Zero
		12	Zero
Aluminum Nitrate	0.1M	1	Zero
*Ammonia -Ammonium chloride buffer		19	40 Drops
Ammonium Chloride	0.1M	23	25 ml
Ammonium Chloride	100%	12	3 g
		6	3 g
		24	3 g
Ammonium Hydroxide	0.1M	8	50 ml
		23	25 ml
Ammonium Hydroxide	3.0M	26	10 ml
Ammonium Hydroxide	6.0M	9	10 ml
Ammonium Hydroxide	Conc.	16	?
Ammonium Oxalate	1.0M	9	?

Ammonium Thiocyanate	100%	5	4 g
		24	4 g
Antacid Tablet		23	1
Aspirin Tablet		33	1
Barium Chloride	0.1M	1	Zero
Benzoic Acid	100%	18	
Beral pipets		6, 28	2, 3
Bleach		30	20 ml
Boiling Chips		19	2
Borax	4%	34	5 ml
Boric Acid	100%	5	1 g
*Bromophenol Blue Indicator		35	3 Drops
*Bromothymol Blue Indicatior		21	10 Drops
*1:1:1 Butanol: Ethanol:Ammonia		16	40 ml
Calcium Acetate	Saturated	5	2 ml
Calcium Chloride	0.1M	1	4 ml
Calcium Chloride	1.0M	2	10 ml
Calgon		19	15 g
Candle		1	1
		6	1

Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
Capillary Tube (Sealed End)		3	3
Carbon		1	Zero
Ceric Ammonium Nitrate	0.1M	31	2 ml
Cerium(III) Nitrate	0.1M	1	Zero
Cerium(IV) Sulfate		1	Zero
*Chromatography Paper Whatman #1		16	2
Chromium(III) Chloride	0.1M	1	Zero
Cobalt(II) Chloride	0.1M	1	Zero
Cobalt(II) Chloride	1.0M	16	1 ml
*Cobalt Chloride Test Papter		7	2 Pieces
Cobalt Nitrate Hexahydrate		14	2.18 g
Copper Foil Squares	1 cm^2	10	5
		31	2
Copper Foil Strips	1 cm X 10 cm	30	3
Copper Shot		1	Zero
Copper Shot		12	Zero
Copper Wire		7	1 Inch
		8	2 cm
		32	50 cm
		34	10 cm
Copper(II) Acetate Monohydrate		28	1.6 g
Copper(II) Chloride	0.1M	1	Zero
Copper(II) Hydroxide	100%	6	0.5 g
Copper(II) Nitrate	0.1M	1	Zero
Copper(II) Salts		7	1.2 g

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
Copper(II) Sulfate	0.1M	1	Zero
		6	3 ml
		10	10 ml
		26	20 ml
		31	4 ml
Copper(II) Sulfate	1.0M	16	1 ml
		27	1 Drop
		32	140 ml
Copper(II) Sulfate Pentahydrate		6	2 g
		7	1.2 g
		5	1 g
Copper(II) Sulfate Anhydrous		6	0.5 g
*1,6 Diaminohexane in 0.5M NaOH		34	4 ml
*Diphenylamine in Conc. H2SO4	1%	11	4 Drops
*EDTA, Disodium	0.00500M	19	25 ml
Elmers Glue		34	20 g
*Eriochrome Black T		19	4 drops
Ethanol	0.1M	8	25 ml
Ethanol, Denatured	95%	6	15 ml
		16	27 ml
Fabrics		16	
Felt Tip Pens		16	
Filter Paper	5.5 cm	28	1

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
Filter Paper	12.5 cm	2	1
		6	2
		19	2
		32	1
Food Coloring		1	1 Drop
Glass Rod		8	1
Glass Tubing	6 mm	1	1 meter
Glass Wool		5	1 g
Glucose	0.1M	8	25 ml
Glucose	80 g/liter	1	15 ml
Glycine	100%	28	1.3 g
Green Grass		16	10 g
Guar Gum		34	1 g
Hydrochloric Acid	0.001M	23	50 ml
Hydrochloric Acid	0.01M	23	25 ml
Hydrochloric Acid	0.1M	23	25 ml
		30	150 ml
Hydrochloric Acid	0.1M Or 0.2M Unknown Standard	23	50 ml
Hydrochloric Acid	0.5M Standard	35	15 ml
Hydrochloric Acid	1.0M	8	25 ml
Hydrochloric Acid	2.0M	12	50 mL
Hydrochloric Acid	3.0M	1	6 ml
		6	2 ml
		21	6 ml
		29	4 ml
Hydrochloric Acid	6.0M	2	10 Drops

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
		6	5 ml
		5	10 ml
		17	25 ml
		16	7 ml
		29	3 ml
		30	20 ml
		19	10 ml
Hydrochloric Acid	6.0M	21	5 ml
		26	40 Drops
		31	1 Drop
Hydrogen Peroxide	3%	5	50 ml
		31	4 ml
Ice			2
			4
			18
			29
Iodine	100%	1	Zero
	100%	5	1.2
	$1x10^{-4}$ M	25	25 ml
Iodine Water Saturated			5 ml
		16	2 ml
		31	15 g
Ion Exchange Resin H^+ Form		19	
Iron Filings		1	Zero
Iron (Steel Wool)		10	5 g
*Iron(III) Chloride	0.05M HCL	33	600 ml

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
*Iron(III) Chloride	0.1M	1	2 ml
Iron(III) Chloride	0.5M	16	1 ml
Iron(III) Chloride	100%	1	Zero
Iron(III) Nitrate	0.1M	10	10 ml
Iron(II) Sulfide	100%	26	Zero
Kerosene	100%	17	30 ml
Lauric Acid	100%	21	4 g
Lead Shot		1	Zero
		12	Zero
Lead Chromate	100%	1	Zero
Lead Iodide	100%	1	Zero
Lead Nitrate	100%	1	Zero
Lithium Chloride	0.1M	1	Zero
		9	5 ml
Lithium Chloride	100%	12	3 g
Lithium Sulfate	0.5M	9	10 ml
Magnesium	Ribbon	1	Zero
		5	2 cm
		10	10 cm
		31	2 cm
Magnesium Chloride	0.1M	1	Zero
Magnesium Chloride	0.1M	26	20 ml
Magnesium Nitrate	0.1M	9	10 ml
Magnesium Sulfate	0.1M	5	5 ml
		10	10 ml
Magnesium Sulfate Heptahydrate		5	4 g
		9	10 ml

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
Maleic Acid	0.1M Or 0.2M	23	20 ml
Manganese	100%	6	7 g
Manganese(II) Chloride	0.1M	1	Zero
Manganese(II) Chloride	1.0M	16	1 ml
Manganese Dioxide	100%	6	0.1 g
*Mercury(I) Nitrate	0.1M	1	Zero
*Mercury(II) Nitrate	0.1M	1	Zero
Methylene Blue	0.4 g/L	1	10 Drops
Methylene Blue	0.4 g/L	16	10 Drops
*Methyl Orange	Indicator	21	10 Drops
		35	3 Drops
Nickel	Shot	12	Zero
Nickel(II) Chloride	0.1M	1	Zero
Nitric Acid	2.0M	12	50 ml
Pencils		8	1
		16	1
*pH 4 Buffer		23	25 ml
*pH 7 Buffer		23	25 ml
*Phenolphthalein Indicator		21	19 Drops
		23	18 Drops
Phenylcarbonate	100%	3	
Phosphorous, Red	100%	1	Zero
Plastic Strips		8	1
*Polyvinyl Alcohol	4%	34	5 ml
Potassium Acetate	100%	5	1 g

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
Potassium Biphthalate	100%	21	3.6 g
Potassium Bitartrate	100%	24	1 g
Potassium Bromide	0.1M	31	2 ml
Potassium Chloride	0.1M	1	Zero
Potassium Chloride	0.2M	27	30 ml
Potassium Chloride	100%	24	1 g
Potassium Chromate	100%	1	Zero
Potassium Ferricyanide	0.1M	1	Zero
		31	2 ml
Potassium Ferricyanide	1%	11	6 Drops
Potassium Ferrocyanide	0.1M	1	Zero
		26	8 ml
Potassium Ferrocyanide Trihydrate		11	1.1 g
Potassium Hydroxide	64 g/L	1	15 ml
Potassium Hydroxide	3.0M	12	6 ml
Potassium Iodate	0.1M	31	2 ml
Potassium Iodide	2.00×10^{-3} M	25	15 ml
Potassium Iodide	0.1M	31	8 ml
Potassium Iodide	0.2M	27	230 ml
Potassium Iodide	0.5 M	25	10 ml
Potassium Iodide	100%	29	4.5 g
		30	6 g
Potassium Nitrate	0.1M	1	2 ml
Potassium Nitrate	1.0M	32	20 ml
Potassium Permanganate	0.1M	1	Zero
*Potassium Persulfate	0.10M	24	230 ml
Potassium Phosphate	1.0M	9	10 ml

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
Potassium Sulfate	0.1M	27	30 ml
Potassium Thiocyanate	0.1M	1	2 ml
Potassium Thiocyanate	1.0M	26	15 ml
1 Propanol	100%	28	20 ml
*Rubber Rings		3	3
Sand		16	1 g
Silicon	100%	1	Zero
Silver Nitrate	0.1M	1	Zero
		19	10 Drops
Sodium Acetate	0.1M	1	Zero
		23	25 ml
Sodium Bicarbonate	0.1M	23	25 ml
Sodium Bromide	0.1M	1	Zero
Sodium Carbonate	0.1M	1	Zero
		19	20 Drops
		23	25 ml
Sodium Carbonate	1.0M	1	2 ml
		2	10 ml
		7	4 ml
		9	10 ml
		21	9 ml
Sodium Chlorate	0.1M	1	Zero
Sodium Chloride	1×10^{-5}M	8	25 ml
Sodium Chloride	1×10^{-3}M	8	25 ml
Sodium Chloride	0.1M	1	Zero

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
Sodium Chloride	0.1M	8	25 ml
		9	5 ml
		19	20 Drops
		23	25 ml
Sodium Chloride	5%	4	Unknown
Sodium Chloride	10%	4	Unknown
Sodium Chloride	15%	4	Unknown
Sodium Chloride	20%	4	Unknown
Sodium Chloride	Saturated	2	6 ml
Sodium Chromate	0.1M	1	Zero
Sodium Dichromate	0.1M	1	Zero
Sodium Hydroxide	0.1M	1	Zero
		21	9 ml
		23	25 ml
Sodium Hydroxide	0.2M Standard	22	100 ml from Exp21
		23	100 ml from Exp21
		35	100 ml from Exp21
Sodium Hydroxide	1.0M	12	50 mL
		21	50 Drops
		33	10 ml
Sodium Hydroxide	2.0M	12	100 mL
Sodium Hydroxide	3.0M	1	2 ml
		7	7 ml
		9	10 ml
		21	6 ml
		26	15 ml

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
Sodium Hydroxide	6.0M	7	10 ml
		12	6 ml
Sodium Hydroxide	Pellets	21	8 g
Sodium Iodate	0.1M	1	Zero
Sodium Iodide	0.1M	1	Zero
Sodium Nitrate	0.1M	1	Zero
		7	2 ml
Sodium Oxalate	0.1M	1	Zero
Sodium Phosphate	0.1M	1	Zero
		7	2 ml
		26	12 ml
Sodium Salicylate	100%	33	0.4 g
Sodium Sulfate	0.01M	32	250 ml
Sodium Sulfate	0.1M	1	Zero
		10	10 ml
Sodium Sulfate	1.0M	9	10 ml?
		16	0.5 ml
Sodium Sulfate	Decahydrate	5	1 g
Sodium Sulfite	0.1M	1	Zero
Sodium Thiocyanate	0.1M	1	Zero
Sodium Thiosulfate	0.1M	1	Zero
Sodium Thiosulfate	1.0M	31	4 ml
Sodium Thiosulfate	Pentahydrate	29	8.2 g
*Sodium Thiosulfate/Starch	0.005M/0.4%	27	130 ml
*Solution 0.1M in Mg, Na, Li, Sr		9	1 ml
*Solution A		21	20 ml

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
*Solution B		21	10 ml
*Solution C		21	10 ml
*Solution A		34	10 ml
*Solution B		34	10 ml
*Solution C		34	10 ml
*Starch Indicator	0.4%	29	6 ml
		30	12 ml
Steel Ball Bearings		12	10 g
Steel Wool		10	5 g
		32	1 g
Strontium Chloride	0.1M	1	Zero
		5	1 ml
		9	10 ml
Strontium Chloride	Hexahydrate	5	4 g
Strontium Hydroxide	Octahydrate	6	7 g
Strontium Hydroxide	Octahydrate	24	7 g
Sulfur	100%	1	Zero

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Chemical Or Supply	Description Or Concentration	Exp #	Qty/Student
Sulfuric Acid	0.05M	30	70 ml
Sulfuric Acid	0.1M	8	50 ml
Sulfuric Acid	1.5M	9	15 ml
Sulfuric Acid	3.0M	7	2 ml
		11	20 ml
Sulfuric Acid	3.0M	16	2 Drops
*Tin(II) Chloride	0.1M	1	Zero
*Tin(IV) Chloride	0.1M	1	Zero
*Vanillin	Crude	2	2 g
*Vinegar	Unknown	22	15 ml
White Paper		11	1 Piece
Wood Splints		1	1
		8	1
		21	3
Zinc	Shot	1	Zero
		7	6 g
		12	Zero
Zinc	Ribbon 1 cm^2	6	2
		10	5
		17	1 g
		31	2
Zinc	Ribbon 1X10 cm	32	1
Zinc	20 mesh granular	5	1.2
Zinc Nitrate	0.1M	1	Zero
		26	20 ml
Zinc Sulfate	0.1M	7	3 ml

		5	5 ml
		10	10 ml
		31	4 ml
Zinc Sulfate	1.0M	29	36 ml
		32	80 ml
Zinc Sulfate Heptahydrate		5	4 g
Zinc tablets (50 mg)		11	1

* means that this solution requires special preperation instructions, given in this manual.

Experiment 1 - Early Explorations and Terminology

Chemicals And Supplies:

0.1M aluminum nitrate (demo), 0.1M barium chloride (demo), 0.1M calcium chloride (4 ml and demo), candle (1), 0.1M cerium (III) nitrate (demo), cerium(IV) sulfate (demo), 0.1M chromium (III) chloride (demo), 0.1M cobalt (II) chloride (demo), cobalt(II) nitrate (demo), cobalt(II) sulfate (demo), 0.1M copper (II) chloride (demo), food coloring (1 drop), 6 mm glass tubing (1 meter), 80 g/L glucose (15 ml), 3.0M hydrochloric acid (6 ml), iodine (demo), 0.1M iron (III) chloride (2 ml and demo), 0.1M lead (II) nitrate (demo), 0.1M lithium chloride (demo), magnesium ribbon (demo), 0.1M magnesium chloride (demo), 0.1M manganese (II) chloride (demo), match (1), 0.1M mercury (I) nitrate * (demo), 0.1M mercury (II) nitrate *(demo), 0.4 g/L methylene blue(10
drops), paper (preferably newspaper (1 sheet/student), 0.1M nickel (II) chloride (demo), 0.1M potassium chloride (demo), 0.1M potassium ferricyanide (demo), 0.1M potassium ferrocyanide (demo), 64 g/L potassium hydroxide (15 ml), 0.1M potassium nitrate (2 ml), 0.1M potassium permanganate (demo), 0.1M potassium thiocyanate (2 ml), 0.1M silver nitrate (demo), 0.1M sodium acetate (demo) 0.1M sodium bromide (demo), 0.1M sodium carbonate (2 ml and demo),
1.0M sodium carbonate (2 ml), 0.1M sodium chlorate (demo), 0.1M sodium chloride (demo),
0.1M sodium chromate (demo), solid sodium chromate (demo), 0.1M sodium dichromate
(demo),
0.1M sodium hydroxide (demo), 3.0M sodium hydroxide (2 ml), 0.1M sodium iodate (demo),
0.1M sodium iodide (demo), 0.1M sodium nitrate (demo), 0.1M sodium oxalate (demo), 0.1M

sodium phosphate (demo), 0.1M sodium sulfate (demo), 0.1M sodium sulfite (demo), sodium tetraborate (2.1 g), 0.1M sodium thiocyanate (demo), 0.1M sodium thiosulfate (demo), 0.1M strontium chloride (demo), 0.1M tin (II) chloride (demo), 0.1M tin (IV) chloride (demo), wood splints (1), 0.1M zinc nitrate (demo).

Equipment:

100 ml beaker, 150 ml beaker, 250 ml Erlenmeyer flask, flame spreader, 1 gas bottle, 100x20 mm Petri dish, 50 ml graduated cylinder, molecular models, stir rod, 5-18 X 150 mm test tubes, wire gauze.

General Instructions:

1 . Time: 4 hours

2 . Safety precautions

a. Burning wooden splints should be placed in fireproof recepticles.

b. Students should be warned that hot glass looks like cold glass. A student can detect if a glass piece is still hot by holding his hand over it. Hot glass produces warm convection currents. Students should place hot glass pieces on a wire gauze to protect the lab bench.

c. There are several very toxic compounds students will be observing in this experiment. These chemicals should be in sealed containers and labeled "poison".

d. Thiocyanate ion reacts with oxidizing agents to produce a foul smelling volatile compound (possibly thiocyanogen). Be certain that waste thiocyanate is not disposed of in a sink or container where it might come into contact with oxidizing agents. Thiocyanate ion is also supposed to decompose with heat or in the presence of strong concentrated acids to produce poisonous hydrogen cyanide. Precautions should also be taken against these possibilities.

e. 3M hydrochloric acid and 3M sodium hydroxide are somewhat corrosive.

f. Some demonstration chemicals used in this experiment (e.g. Ba, Hg) present disposal problems. They should be stored from semester to semester (or quarter to quarter) rather than disposed of.

3. Special chemicals and unknowns: (the mercury solutions are for demonstration purposes only and should be stored for repeated use in sealed vials)

a. 0.1M mercury (I) nitrate is prepared by dissolving 56.2 grams of $Hg_2(NO_3)_2 \cdot 2H_2O$ in 200 ml of 6M nitric acid and diluting to a liter.

b. 0.1M mercury (II) nitrate is prepared by dissolving 32.4 grams of $Hg(NO_3)_2$ in 50 ml of 6M nitric acid and diluting to a liter.

c. There are no unknowns in this experiment.

4. Comments:

a. Chemicals for part I should be put in small sealed vials. They may be stored and used again the following semester or quarter.

b. The blue color of the solution in the "mystery flask" (part J) slowly fades as the glucose reduces the methylene blue to a colorless compound. When the mixture is swirled, oxygen from the air reoxidizes the methylene blue and the blue color returns. It may take several minutes for the color to fade initially. The potassium hydroxide solution is necessary because the reaction takes place only in base.

Prelaboratory Problems Solutions are in the ***Appendix***.

Experiment 1 - Results and Discussion

A. The meniscus.

1. The meniscus between water and glass should be concave upward.

3. ***Why is water level higher near the glass than in the middle?***

B. The candle flame.

3. Further observations:

a. beaker partially over burning candle - ***condensation of water on inside b.***

stirring rod next to extinguished wick - ***slight deposit of wax***

c. burning match approaching extinguished wick - ***candle reignites before match reaches wick***

4. Was your first explanation (question 2) correct or do you want to modify it or suggest a new one? Explain your answer.

The paraffin vapor is burning. When the beaker is held over a burning candle, water vapor collects on the inside. Paraffin collects on a stir rod held above the candle just after it has been extinguished and the match reignites before the match reaches it..

D. Rate Of Mixing

1. Initial observations:

Initially in the cold water, the food color will fall to the bottom of the beaker leaving a color trail. In the hot water mixing occurs very rapidly.

2. Observations about 1/2 hour later:

After 1/2 hour even the cold water solution should be approaching homogeneity.

3. When two aqueous solutions are introduced into the same container, is stirring needed to achieve a homogeneous system? Explain your answer.

Yes, at low temperatures the mixing process is slow and if one solution is denser than the other there is a tendency to form layesr.

4. How would you stir a solution freshly prepared in a volumetric flask?

By stoppering, inverting and swirling the flask several times.

E. Tearing Paper

The paper should tear rather straight in one direction and curve rapidly toward the favored direction when the paper is torn at right angles. Apparently industrial preparation of the paper leads to preferential alignment of the fibers or cellulose polymers in one direction. Tearing it one direction then requires breaking of weaker intermolecular forces while tearing in the other direction involves an attempt to break intramolecular bonds.

F. Chemistry reference.

acetic acid formula *$C_2H_3O_2$ or $HC_2H_3O_2$*
b.p. *117.9 °C* m.p. *16.6 °C*
TD_{Lo} *1.47 mg/kg* LD_{50} *3310 mg/kg*

Meaning of TD_{Lo} *lowest published toxic dose*
Meaning of LD_{50} *lethal dose to kill half the population*
Household product(s) that contain acetic acid *vinegar (about 5% acetic acid), cleaning agents, pickle preservative*

H. Solutions.

1 –6. Both of the 0.05 g portions of sodium tetraborate decahydrate should dissolve fairly readily. The additional 2 g will result in a saturated solution and most will not dissolve until the solution is heated. The solid will dissolve upon heating and slow cooling results in the formation of neat looking crystals.

I. Colors.

1 List the colored cations and their colors.

Ce^{3+}	***yellow***
Cr^{3+}	***green***
Co^{2+}	***red or pink***
Cu^{2+}	***blue***
Fe^{3+}	***yellow***
Ni^{2+}	***green***

2 Can you make any generalizations about color versus position in the periodic chart?

Apparently color is only common among the transition metal ions.

3 List the colored anions and their colors.

CrO_4^{2-}	***Yellow***
$Cr_2O_7^{2-}$	***Orange***
$Fe(CN)_6^{3-}$	***Yellow to orange***
$Fe(CN)_6^{4-}$	***Light Yellow***
MnO_4^-	***Magenta***

J. Chemical Reactions

A. ***white precipitate***
B. ***heat***
C. ***no apparent reaction***
D. ***bubbles or evolution of a gas***
E. ***formation of a deep red color***

K. Mystery flask (see Anderson, L.; Wittkopp,S. M.; Painter, C. J.; Liegel, J.J.; Schreiner, R.; Bell, J. A.; Shakhashiri, B. Z. *J. Chem. Educ.*, **2012**, *89* (11), pp 1425–1431 for recent article on blue bottle reaction)

1. Observations upon standing:

The solution should turn colorless (note that clear is not an adequate answer). A very important observation that is a valuable clue concerning the cause of the color change is that the top surface of the solution has a tinge of blue.

2. Observations upon swirling:

The blue color returns.

3. Suggest an explanation for the change that occurs upon swirling.

Oxygen oxidizes the reduced colorless form of methylene blue back to the original blue compound.

4. How could you test your explanation (it might be possible with your instructor's approval to actually perform the test).

Exclude oxygen by bubbling N2 through the solution before swirling. Also test with a pure oxygen atmosphere by bubbling O2 through the solution.

L. Classic Burning Candle Experiment.

The results are not very reproducible indicating that the oxygen consumption explanation is unlikely and some of the oxygen is replaced by carbon dioxide anyway. Actually, about 11% oxygen is needed to sustain the flame so there is still about half of the original amount of oxygen present when the flame goes out. The heat from the wax vapor combustion heats the air in the bottle causing it to expand and some heated air leaves the bottle. After the flame goes out, the air cools and the water rises to replace the space previously occupied by the air that has exited. In addition to checking for reproducibility, students could try other experiments such as replacing all of the air in the bottle with oxygen.