CHEMISTRY EXPERIMENTS

for High School at Home

Christina H. Swan • John D. Mays

Chemistry Experiments for High School *at Home*

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Welcome

W

How Important Are Chemistry Experiments?

A laboratory practicum incorporating a series of quantitative experiments is an essential component of any high school or college chemistry course. It is one thing to read about precipitations; it is another thing to see the precipitates form with your own eyes. Again, it is one thing to talk about the dramatic change in solution pH near the equivalence point of a titration; it is another to see how quickly the pH changes and to see the change in indicator color that occurs at the same time.

In addition to seeing the reactions first hand, laboratory experience provides students with practice using standard laboratory apparatus and methods. Modern chemistry is a discipline born in the laboratory, and the test tubes, graduated cylinders, and Bunsen burners used in a chemistry lab are familiar to nearly everyone who has completed a formal education. We remember an occasion when our head of school nearly lost his cool upon his discovery that some juniors in the Rhetoric class he was teaching did not know what a test tube was. The topic at hand was *in vitro* fertilization, and our head of school had used the phrase "test-tube baby," only to find that several students did not know what he meant. He raced down to the lab, grabbed a few test tubes, and stormed back to his classroom to inform the students of what their science education had apparently failed to inform them. These days, the experience gained in a chemistry lab can make a difference in a person's ability simply to follow an article in a newspaper!

Finally, there is nothing like laboratory practice to give students a feel for how the stoichiometric calculations learned in the classroom relate to the predictions and results of an actual experiment. Experienced teachers all know that when a student encounters a subject in several different ways and through various means, the learning outcomes are far superior to those that result when a student encounters a subject in only one way or through a limited number of means. Accordingly, students *learn* chemistry at a deeper level and *remember* chemical principles longer if they experience the subject through both the classroom and the laboratory.

The 19 experiments in this volume expose students to the practical aspects associated with the broad array of topics that occur in a first-year chemistry course. We encourage you to incorporate as many of these experiments as possible into your own students' experience of the subject.

Chemistry Texts

This manual has been designed to accompany these chemistry texts written by John D. Mays:

- Published by Novare Science & Math:

  General Chemistry
  Chemistry for Accelerated Students

- Published by Centripetal Press:

  Principles of Chemistry
  Accelerated Chemistry

At the beginning of each experiment in this book are references to content in these texts pertaining to the experiment. Exceptions are Experiments 13 and 14, which address topics covered only in the accelerated texts.

Introduction Part 1
Costs and Materials

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Performing a sequence of legitimate, quantitative experiments for a course in chemistry cannot be done without significant expenses for apparatus and chemicals. In this section, we describe why this is so, what your options are, what you are getting for your money, and options for controlling costs. We also present complete details about the items needed to perform the experiments in this book. In Parts 2, 3, and 4 of the Introduction, we treat topics of the utmost importance for those who would conduct chemistry experiments outside of a formal chemistry laboratory—topics such as safety, storage, and disposal. *Please read the entire introduction carefully before proceeding with any purchases or experiments.*

Experiments Versus Demonstrations

A quick internet search for "home chemistry experiments" will turn up scores of sites purporting to describe "experiments" that can be done at home with common materials. Many of these activities are very interesting; some are quite astonishing. However, what one inevitably finds is that these activities are *not* the kinds of experiments students need to accompany a high school course in chemistry. In fact, a better term for these so-called experiments is *demonstrations*. There are some key differences between experiments and demonstrations.

A demonstration can be performed without much in the way of quantitative analysis. One prepares a few chemicals, mixes them together under certain conditions, and then watches the amazing result. Afterward, the demonstrator might lead the viewer through the chemical reaction that occurred, using the chemical equation to show how the reactants were transformed into the products. Such demonstrations do not get very technical. The only real technical content is the chemical equation. Stoichiometry and quantitative analysis are almost never involved.

By contrast, experiments supporting the formal study of chemistry are *quantitative*—they involve measurements, predictions, and more measurements. Specific quantities or concentrations of reactants must be prepared before the reaction. After the reaction, careful measurements of the reaction products must be made in order to compare the results to the stoichiometric predictions. Making measurements of volumes, masses, and temperatures requires apparatus—graduated cylinders, burets, mass balances, thermometers and a host of odds and ends. And for the measurements to be useful in the study of chemistry, the instruments used to make the measurements must be reasonably accurate and fairly precise.

This is a book of experiments, not demonstrations. A book about chemistry demonstrations isn't really needed—you can easily find plenty of them online. If you are not up for the costs and complexities of quantitative experiments, you should focus on the informal demonstrations instead.

This book has been designed for those seeking quantitative experiments to support a formal study of chemistry, who desire a full spectrum of experiments at the lowest possible cost. Moreover, the experiments were designed with two additional assumptions:

1. Lab apparatus such as Bunsen burners, vacuum systems, and a wide variety of glassware are not available.
2. Those performing the experiments are a single small student team at a school, or a single student or group of students at home working under the supervision of parents or a tutor.

The first of these assumptions affects the apparatus we have specified; we have attempted to use the narrowest possible assortment to minimize cost. The second assumption directly affects the quantities of chemicals purchased. We have specified the smallest quantities available so that costs are minimized and disposal of leftover chemicals is as simple as possible. Schools please note: If you have more than one student group working, or if you can order chemicals in larger quantities now to lower long-term costs over several years of your program, you should order larger quantities of chemicals than those specified in the charts on the following pages. A good supplier of larger quantities of chemicals is Flinn Scientific, at flinnsci.com.

If you intend to perform the quantitative experiments that should accompany the formal study of high-school level chemistry, you must procure a basic assortment of quantitative chemistry apparatus and quite a few chemicals. Moreover, you must use personal protective items such as gloves and goggles and provide for proper storage and disposal of all the compounds purchased for or produced by the reactions you study. This requires an investment of several hundred dollars. For schools, this investment is not much of a problem because the cost can be spread out over the tuition payments of many students and the apparatus can be used year after year. But for an individual home school family, the cost can be a much larger issue. There is no way around this except to dispense with real experiments and stick to fun demonstrations. These are readily available online, so again, this book is not designed to support those who decide to go that route.

Planning and Managing Costs

Supplies Kits

The cost and materials descriptions below were written for those procuring all their own apparatus and supplies. Since the first printing of this book, Novare Science & Math has teamed up with Home Science Tools (homesciencetools.com) to make kits available containing the supplies needed. As of January, 2019, kits are available for the Economy Core Experiments for both our chemistry courses (see below). These kits are available at the Home Science Tools website. Look for Novare under the Homeschool Curriculum & Kits tab.

Which Experiments Apply to Which Students

To assist with the cost discussion below, note the following:

- The full slate of 19 experiments in this book applies only to students using *Chemistry for Accelerated Students* (CAS) or *Accelerated Chemistry* (AC) at a school with a physical building.
- For students using *General Chemistry* (GC) or *Principles of Chemistry* (PC) at a school with a physical building, Experiments 13 and 14 do not apply, leaving 17 possible experiments.
- For students performing the experiments in a home environment, Experiment 18 does not apply (as explained in the Chemical Notes section of the Introduction Part 2). This means there are 18 possible experiments for students using CAS or AC and 16 possible experiments for students using GC or PC.

Costs vs. Experiments

Obviously, the costs to perform the experiments depend on which experiments are performed and the number of students involved. In the analysis below, we have assumed a single experimental team, which could be any of the following:

- A small classroom of 3–5 students working in a single team

- A home school coop with 3–5 students working in a single team
- A single student studying at home as part of an online course
- A single student studying at home in a home school environment

Chemical quantities and costs discussed below assume one of these "single-team" scenarios. As previously mentioned, at schools with more students than this the instructor should source chemicals in larger quantities than the "single-serving" sizes listed in our chemical tables. This increases initial costs but reduces costs over time and reduces the amount of time the instructor must spend ordering supplies each year.

For many families in which a single student is performing the experiments, costs are a major factor. This situation also typically applies to individual home school students and to students taking chemistry as part of an online course. For those whose primary consideration is holding down costs, we have designated an "Economy Core" of 8 or 6 experiments. These Economy Core experiments are as follows:

- For students studying in the CAS text, Experiments 2, 4, 9, 11, 12, 13, 14, and 15.
- For students studying in the GC text, Experiments 2, 4, 9, 11, 12, and 15.

Again, kits are available for these experiments at the Home Science Tools website.

Cost Categories

For a realistic assessment of the total cost, those planning the experiments should expect costs in each of the following expense categories:

- *Common Items*: The Common Items are listed in one of the tables below. We assume these items are already available in the home or can be purchased at a local store at minimal expense. Costs for Common Items are not included in the cost figures tabulated below.
- *Personal Protective Gear*: This gear includes the goggles, nitrile gloves, and laboratory apron that should be worn by every person present at every experiment. There are many sources, but items from sciencecompany.com are as follows:

Item	Catalog Number	Price
goggles	NC-11005	$3.95
nitrile gloves	NC-7026	$12.95 (pack of 100)
laboratory apron	NC-4780 (medium/junior) NC-4215 (large/adult)	$7.95 $9.50

  Additionally, we recommend that a face shield be worn by each person present when concentrated acids are being handled. You will find these at homedepot.com for $13.97. Finally, you need to have one pair of gloves on hand for handling hot items. Laboratory-grade heat-resistant gloves are quite expensive (around $100), but a good alternative is the long-cuffed gloves sold for barbecuing. These "BBQ and fireplace gloves" can be purchased at homedepot.com for $20.97.
- *Apparatus*: This category includes all the laboratory equipment needed. Students studying at home may wish to substitute readily available items from the home where possible to hold down costs. The cost figures tabulated below do not include shipping. Shipping costs may be minimized by ordering as much apparatus as possible at one time from each single supplier.
- *Plastic Bottles*: For preparing the solutions (see Introduction Part 3) and collecting chemical waste, a number of plastic bottles with plastic lids (both medium-sized and small) are required. How many you need depends on which experiments you perform and whether you plan to reuse bottles by discarding leftover chemicals after each experiment. For the

Item	Experiment(s)	Notes
iron supplements	16	Experiment with three or four different name-brand or generic supplements, or as many as time and budget allow.
paper towel	18	Also used generally for clean up.
pencil	17	
plastic spoons		For general use transferring solid chemical compounds.
polystyrene (Styrofoam) cups with lids	13	These are only needed for students using the CAS or AC texts.
pure cornstarch	14	Available at grocery stores. This is only needed for students using the CAS or AC texts.
rubber bands, small	1	
sand	2	Use fine-grained sand, such as "Play Sand" available from building supply stores.
scissors	17	
soda can	19	Clean, empty.
sodium bicarbonate	9	This is baking soda.
spatula, small	2, 18	
stopwatch	7, 14	The stopwatch on a smart phone is fine.
straight pin	19	
table salt, non-iodized	2, 3, 10	Pure sodium chloride. Buy the kind without iodine added.
tape, masking		For general use in labeling.
toothpicks	14	

Apparatus List

The needed items of apparatus are listed in the tables on the next five pages. The general items on the first two pages are required for performing many of the experiments, including the Economy Core experiments referred to earlier. Again, kits are available for these experiments at the Home Science Tools website.

General Items Needed Throughout the Experiments						
Item	Source	Model	Cost	Quan.	Notes	Acceptable Substitutes
alcohol burner	sciencecompany.com	NC-3787	5.95	1	In the absence of a natural gas Bunsen burner, this is the best substitute for general purpose heating. Experiment 3 will need to use a natural gas or propane stove or burner.	None.
balance	homesciencetools.com	BS-DB0200	49.95	1	200 g capacity, 0.01 g resolution. If you can afford a 0.001 g scale, get one. If not, this is the best deal on a 0.01 g scale.	None.
beaker, 50 mL	sciencecompany.com	NC-5584	3.20	2	Lab beakers are needed for heating. Heating items in regular jars or glass can cause the glass to crack.	Pyrex measuring cup.
beaker, 100 mL	sciencecompany.com	NC-7865	3.75	1	Lab beakers are needed for heating. Heating items in regular jars or glass can cause the glass to crack.	Pyrex measuring cup.
beaker, 250 mL	sciencecompany.com	NC-5583	4.50	4	Lab beakers are needed for heating. Heating items in regular jars or glass can cause the glass to crack.	Pyrex glass.
beaker, 400 mL	sciencecompany.com	NC-7866	4.95	1	Lab beakers are needed for heating. Heating items in regular jars or glass can cause the glass to crack.	Pyrex glass.
buret, 25 mL	sciencecompany.com	NC-9825	31.95	1	Purchasing 2 will expedite Experiment 11.	None.
buret clamp	amazon.com		8.00	1	Schools may wish to purchase the American Educational double buret clamp instead for $15.61.	None.
clamp, 3-finger, with ring stand clamp	amazon.com	Clamp Retort	9.00	1		None.
dropper, glass	sciencecompany.com	NC-0363-PK	2.35	1 pk	Pack contains 4 glass droppers.	Eye dropper.
dropper bottle	sciencecompany.com	NC-0343	1.95	10		Small jars or bottles with non-metallic screw-on lids.
Erlenmeyer flask, 125 mL	sciencecompany.com	NC-9166	3.95	3	For school classrooms, 6 flasks per student group are recommended.	None.
filter funnel, glass, 50 mm	sciencecompany.com	NC-0472	3.75	1	If possible, purchase 2 to expedite Experiments 8 and 11.	None.
filter paper, 9 cm	sciencecompany.com	NC-12142	6.95	1 pk		Coffee filters.
funnel support ring, 2 inch iron ring	onlinesciencemall.com		6.25	1	Search under "cast iron support ring"	None.

General Items Needed Throughout the Experiments						
Item	Source	Model	Cost	Quan.	Notes	Acceptable Substitutes
glass stirring rod, 10 inch	sciencecompany.com	NC-5604	1.35	1		None.
graduated cylinder, 10 mL	sciencecompany.com	NC-7874	2.50	2	If possible, purchase 4.	None.
graduated cylinder, 100 mL	sciencecompany.com	NC-7832	5.50	2	Recommend that schools purchase six of these per student team.	None.
iron burner ring, 3 inch	sciencecompany.com	NC-11223	5.95	1		None.
ring stand	amazon.com	American Educational	12.91	1		None.
test tube set	sciencecompany.com	Z0039	15.95	1 or 2	Purchasing 2 will be convenient, but experiments can be performed with one. Includes 6 test tubes, test tube rack, test tube clamp holder, and test tube brush.	Small jars or bottles with non-metallic screw-on lids.
thermometer	sciencecompany.com	NC-1005	4.15	1	Celsius, 12-inch, alcohol, glass thermometer.	Any thermometer that reads in °C from 0 to 100°C. Glass thermometers will fit better in the two-hole rubber stopper.
tongs	sciencecompany.com	NC-7038	5.95	1	These are general purpose beaker tongs.	None.
volumetric flask, 50 mL	sciencecompany.com	NC-13090	4.95	1	Used repeatedly for preparing the solutions needed for various experiments.	None.
volumetric flask, 250 mL	sciencecompany.com	NC-10977	10.95	1	Used repeatedly for preparing the solutions needed for various experiments.	None.
wash bottle	sciencecompany.com	NC-9129	4.90	1 (or 3, see note)	Schools performing Experiment 18 should purchase 3 wash bottles per student group. (We recommend that students studying at home skip Experiment 18.)	
watch glass, 4 inch	sciencecompany.com	NC-11087	1.95	1	If possible, purchase 2 to expedite the experiments.	Small dish or plate.
weigh boat, medium, approx 3"	sale-fire.com		7.50	1 pk	Weigh boats are also called *weighing dishes* and *pour boat weighing dishes.*	Coffee filters.
wire gauze	sciencecompany.com	NC-7859	1.85	1		None.

Apparatus Needed for Specific Experiments							
Item	Exp. Needed	Source	Model	Cost	Quan.	Notes	Acceptable Substitutes
boiling chips	1, 7	amazon.com	—	0.25	(1) 1 g	Aluminum oxide boiling chips. These make boiling smoother.	None.
capillary tubes	1	amazon.com	Dynalon SMP10/1	9.85	(1) 100 pk	Capillary tubes for melting point device, closed on one end.	None.
glass tubing, 6 mm OD	1, 7, 9	sciencecompany.com	NC-10889	6.00	(1) 2 pk	To bend this tubing as required in the experiments requires a propane burner or Bunsen burner. The alcohol burner does not produce a hot enough flame.	None.
rubber stopper, size 4, two-hole	1, 7	sciencecompany.com	NC-0973	1.25	1	If possible, purchase 2 to expedite the experiment.	None.
test tube, 25 mm × 150 mm	1, 7	sciencecompany.com	NC-2592	1.50	1	If possible, purchase 2 to expedite the experiment.	None.
test tube stopper, #000	1, 18	sciencecompany.com	NC-0969	0.35	6	If you have 12 test tubes, purchase 12.	None.
latex tubing, 3/16" ID	1, 7, 9	sciencecompany.com	NC-1243-PK5	7.25	1	This is one 5-ft section of tubing.	None.
evaporating dish, 100 mL	2, 18	amazon.com	SEOH brand	6.75	1		None.
propane stove	3	amazon.com	Coleman PerfectFlow	23.88	1	This stove is not needed if a natural gas stove or other natural gas or propane stove is available.	Natural gas cook stove.
24-well plate	5, 10	onlinesciencemall.com	"polystyrene well plate"	2.95	2		Plastic artist's paint palette.

Apparatus Needed for Specific Experiments							
Item	Exp. Needed	Source	Model	Cost	Quan.	Notes	Acceptable Substitutes
weigh boat, small	9, 13	onlinesciencemall.com		6.95	1 pk	This is a pack of 100, and we only need 1 for Experiment 9. These small weigh boats may also be used for Experiment 13. Weigh boats are also called *weighing dishes* and *pour boat weighing dishes.*	Any small, open plastic dish or container small enough to fit through the neck of the Erlenmeyer flask.
graduated cylinder, 500 mL	9	sciencecompany.com	NC-8069	7.50	1	This model is polypropylene for light weight and low cost.	None.
barometer	9	amazon.com	ETA brand	11.18	1	If a barometer is not available, the local barometric pressure in any city is easy to obtain online. However, if the weather is changing at the moment the experiment is performed, online data will probably not accurately reflect laboratory conditions.	Online data.
rubber stopper, #5, 1-hole	9	sciencecompany.com	NC-0974	1.45	1		None.
rubber stopper, #5, solid	11	sciencecompany.com	NC-0960	0.80	1	The solid stopper is used in the preparation of the low-CO_2 NaOH. See Notes for Experimenters for details.	
12-well plate	14	labdepotinc.com	JSC012	6.29	1		The 24-well plate from Experiment 5, or a plastic artist's paint palette.
digital pH meter	15	amazon.com	Etekcity PH-009	11.81	1	There are many different models of inexpensive pH meters.	None.
magnetic stir plate	15	labdepotinc.com	86152003	110.50	1	This item is completely optional. Schools may wish to consider hot plate stirrers, which are much more expensive but combine heat with stirring functions.	None, but this item is optional.
Erlenmeyer flask, 250 mL	16	sciencecompany.com	NC-7884	4.85	1	Schools should consider providing at least three of these per student lab group.	None.
forceps	17	sciencecompany.com	NC-7830	3.50	1		Large tweezers.
voltmeter	17	frys.com	5427439	11.99	1		Any DC voltmeter that will read to 0.01 VDC.
Petri dish	17	sciencecompany.com	NC-12131	2.95	1		Flat-bottomed plate or dish.

Apparatus Needed for Specific Experiments

Item	Exp. Needed	Source	Model	Cost	Quan.	Notes	Acceptable Substitutes
filter paper, 12.5 cm	17, 18	sciencecompany.com	NC-12168	8.85	1 pk		Coffee filters.
beaker, 600 mL	18	sciencecompany.com	NC-5582	5.95	2		None.
filter funnel, glass, 75 mm	18	sciencecompany.com	NC-0473	4.50	1	Search under "glass funnel."	Medium-sized plastic funnel.
iron burner ring, 4 inch	18	sciencecompany.com	NC-11222	7.95	1	Search under "ring clamp."	None.
thermometer clamp	19	onlinesciencemall.com	—	9.95	1		Clamp, 3-finger, with ring stand clamp.
cork stopper, #16	19	craft store		2.99	1	Price shown is for a pack of 2 #16 cork stoppers from hobbylobby.com.	Any other cork, such as from a wine bottle. However, do not use synthetic wine bottle corks.

Chemicals List

The chemicals needed are listed in the tables on the next five pages. General notices regarding toxicity and flammability are also indicated.

Note that since the first printing of this book, the supplier hms-beagle.com listed for many chemicals has gone out of business. You can try homesciencetools.com or search for other online suppliers. And once again, we mention that kits are now available from homesciencetools.com for the Economy Core experiments.

Chemicals Needed for Specific Experiments

Item	Use (Exp. No.)	Source	Cat. No.	Cost	Quan.	Toxicity*	Flammability	Notes
ethanol, C_2H_5OH (denatured)	1, 7	sciencecompany.com	NC-0026	12.95	1 L	medium	high	This ethanol may also be used in the alcohol burner. See Chemical Notes for info on ethanol.
acetone, CH_3CH_3CO	1, 7, 14	sciencecompany.com	NC-0007	14.95	16 oz	low	high	Primary ingredient in old-fashioned fingernail polish remover; quantity adequate for Experiments 1, 7, and 14.
hexane, C_6H_{12}	1, 7	amazon.com	—	25.00	1 L	low	high	Buy high purity solvent from Univar or Consolidated Chemical and Solvents.
lauric acid, $C_{12}H_{24}O_2$	1	goodearthspa.com	—	5.05	4 oz.	low	low	A common fatty acid found naturally in oils such as coconut oil.
toluene, C_7H_8	1	hms-beagle.com	9552	2.00	25 mL	med (1)	high	Common solvent.
naphthalene, $C_{10}H_8$	1	hms-beagle.com	4169	2.15	15 g	low	med	Primary ingredient in old-fashioned moth balls.
benzoic acid, $C_7H_6O_2$	2	hms-beagle.com	1317	3.00	15 g	low	low	
lithium chloride, LiCl	3	sale-fire.com	—	5.50	30 g	low	none	
magnesium chloride, $MgCl_2$	3, 6	labdepotinc.com	BDH9244-500G-EA	38.91	500 g	low	none	Because small quantity not available, this compound is expensive but needed for two experiments.
potassium chloride, KCl	3	hms-beagle.com	1303	2.00	15 g	low	none	
calcium chloride, $CaCl_2$	3	hms-beagle.com	9878	2.25	25 g	low	none	
strontium chloride hexahydrate, $SrCl_2 \cdot 6H_2O$	3	hms-beagle.com	1179	5.00	15 g	low	none	Informational note: Throughout this chemicals list, "hydrate" means there are water molecules in the compound. Since the compounds are dissolved in water anyway for the experiment, this is fine.
copper chloride dihydrate, $CuCl_2 \cdot 2H_2O$	3, 4	sale-fire.com	—	4.80	100 g	low	none	
zinc chloride	3	hms-beagle.com	4267	4.00	30 g	low	none	

*Refers to general hazard from skin contact or vapors, not to ingestion or hazard to eyes.

Notes:

(1) Avoid breathing vapors. Use in well-ventilated area. (2) Highly corrosive. (3) Can cause severe skin burns. (4) can cause skin irritation (5) hazardous to environment

Chemicals Needed for Specific Experiments								
Item	Use (Exp. No.)	Source	Cat. No.	Cost	Quan.	Toxicity*	Flammability	Notes
hydrochloric acid, concentrated, HCl, 11.6 *M*	4, 5, 9, 11, 12, 13, 14	sciencecompany.com	NC-1193	34.95	1 L	high (1, 2)	none	This concentrated acid is used to prepare the HCl solutions for all experiments requiring HCl. The product is labeled 36–37% strength, which translates to 11.6 *M*.
zinc, mossy, Zn	4, 5	sciencecompany.com	NC-9848	9.95	100 g	none	none	
calcium metal, Ca	5	sale-fire.com	—	11.12	50 g	none	low	
magnesium, Mg	5, 17	hms-beagle.com	2439	4.10	0.9 g	none	med	Keep this material away from flames.
tin, Sn	5	hms-beagle.com	3905	9.39	2 oz	none	none	
calcium nitrate, $Ca(NO_3)_2$	5	amazon.com or ebay	—	7.99	5 lb	low	none	Fertilizer; some lower prices found on eBay.
copper sulfate pentahydrate, $CuSO_4 \cdot 5H_2O$	5	hms-beagle.com	1144	4.60	25 g	low	none	
magnesium nitrate hexahydrate, $Mg(NO_3)_2 \cdot 6H_2O$	5	hms-beagle.com	9102	6.00	20 g	low	none	
iron(III) nitrate nonahydrate, $Fe(NO_3)_3 \cdot 9H_2O$	5, 17	hms-beagle.com	1331	2.50	10 g	high (1, 3)	see note	Not flammable itself, but a strong oxidizer. Keep away from flame and organic materials.
iron(II) sulfate heptahydrate, $FeSO_4 \cdot 7H_2O$	5, 8	hms-beagle.com	1236	2.45	15 g	low	none	
tin(IV) chloride pentahydrate, $SnCl_4 \cdot 5H_2O$	5	hms-beagle.com	5762	5.50	15 g	high (1, 3)	none	
zinc nitrate hexahydrate $Zn(NO_3)_2 \cdot 6H_2O$	5	sale-fire.com		4.85	30 g	high (1, 3)	see note	Not flammable itself, but a strong oxidizer. Keep away from flame and organic materials. Do not subject to shock.
silver nitrate, $AgNO_3$	5, 6, 8, 10, 17	hms-beagle.com	1204	30.40	10 g	high (1, 3, 5)	see note	Not flammable itself, but a strong oxidizer. Keep away from flame and organic materials.

*Refers to general hazard from skin contact or vapors, not to ingestion or hazard to eyes.
Notes:
(1) Avoid breathing vapors. Use in well-ventilated area. (2) Highly corrosive. (3) Can cause severe skin burns. (4) can cause skin irritation (5) hazardous to environment

Chemicals Needed for Specific Experiments								
Item	Use (Exp. No.)	Source	Cat. No.	Cost	Quan.	Toxicity*	Flammability	Notes
glycerol	7	high end drug store		10.59	177 mL	low	low	
mineral oil	7	grocery store		3.49	473 mL	low	low	
potassium permanganate, $KMnO_4$	8, 16	sciencecompany.com	NC-0744	10.95	100 g	medium	see note	Not flammable itself, but a strong oxidizer. Keep away from flame and other materials.
sodium carbonate, Na_2CO_3	8, 10	hms-beagle.com	1174	4.00	60 g	medium	none	
sulfuric acid, H_2SO_4, 18 *M*	8, 16, 18	hms-beagle.com	4047	4.00	25 mL	high (1, 2, 3)	none	This concentrated acid (95–98%) will be used to prepare the acid for all experiments requiring H_2SO_4.
acetic acid, CH_3COOH	9, 15	hms-beagle.com	4503	4.00	25 mL	high (1, 2, 3)	medium	This glacial (pure) acetic acid is 17.4 *M* and is used to prepare the solutions in Experiments 9 and 15.
sodium iodide, NaI	10	hms-beagle.com	11279	2.75	25 mL	low	none	This 1.0 *M* solution is used to prepare the 0.1 *M* solution required.
sodium sulfate, Na_2SO_4	10	hms-beagle.com	3258	2.00	15 g	low	none	
barium nitrate, $Ba(NO_3)_2$	10	hms-beagle.com	1201	3.20	25 g	high (1, 5)	see note	Not flammable itself, but a strong oxidizer. Keep away from flame and organic materials.
lead nitrate, $PB(NO_3)_2$	10	hms-beagle.com	8404	3.00	25 mL	high (1, 5)	see note	Not flammable itself, but a strong oxidizer. Keep away from flame and organic materials. This is a 0.1 *M* solution and can be used in Experiment 11 as is.
copper(II) nitrate hemipentahydrate, $Cu(NO_3)_2{\cdot}2.5H_2O$	10, 17	hms-beagle.com	1329	2.50	10 g	high (1)	see note	Not flammable itself, but a strong oxidizer. Keep away from flame and organic materials.
nitric acid, HNO_3	10	hms-beagle.com	1186	3.00	25 mL	high (1, 2, 3)	see note	Not flammable itself, but a strong oxidizer. Keep away from flame and organic materials. This is a 1.0 *M* solution for use in Experiment 10 as is.

*Refers to general hazard from skin contact or vapors, not to ingestion or hazard to eyes.

Notes:

(1) Avoid breathing vapors. Use in well-ventilated area. (2) Highly corrosive. (3) Can cause severe skin burns. (4) can cause skin irritation (5) hazardous to environment

Chemicals Needed for Specific Experiments

Item	Use (Exp. No.)	Source	Cat. No.	Cost	Quan.	Toxicity*	Flammability	Notes
potassium hydrogen phthalate (KHP)	11	onlinesciencemall.com	—	4.75	10 g	low	none	
sodium hydroxide, NaOH	11, 12, 13, 15	sale-fire.com	—	7.99	8 oz (226 g)	high (1, 2, 3)	none	This quantity of pellets adequate for 4 experiments. Also known as lye.
bromothymol blue solution	11	hms-beagle.com	4386	4.00	30 mL	medium	low	
litmus solution, 0.5%	12	amazon.com		10.00	60 mL	none	none	Search under "litmus 0.5% aqueous solution."
iodine, pure elemental	14	sale-fire.com		7.86	0.5 oz	medium (4, 5)	none	
oxalic acid, $H_2C_2O_4$	15	hms-beagle.com	5022	3.50	15 g	high (1, 2, 3, 5)	low	
phosphoric acid, H_3PO_4, 1 *M*	16	hms-beagle.com	4178	4@3.00	25 mL	high (1, 2, 3)	none	The 25 mL quantity is enough to perform three test trials on one iron supplement. To test four supplements you will need four of these.
aluminum metal	17	hms-beagle.com	3115	1.35	1 strip	none	none	Any piece of aluminum metal or wire (readily available at hardware stores) will do. Item shown here is an inexpensive source.
nickel metal	17	sale-fire.com		6.99		none	none	Any small strips or pieces of nickel metal will do. At sale-fire.com there are nickel cubes and balls for various prices.
silver metal	17	goldleafproducts.com		9.00	1 book	none	none	This is for a book of 25 small sheets of real silver leaf.
aluminum nitrate nonahydrate	17	hms-beagle.com	11449	10.00	25 g	medium	see note	Not flammable itself, but an oxidizer. Keep away from flame and organic materials.
nickel nitrate	17	sale-fire.com		7.20	50 g	medium	see note	Not flammable itself, but an oxidizer. Keep away from flame and organic materials.

*Refers to general hazard from skin contact or vapors, not to ingestion or hazard to eyes.

Notes:

(1) Avoid breathing vapors. Use in well-ventilated area. (2) Highly corrosive. (3) Can cause severe skin burns. (4) can cause skin irritation (5) hazardous to environment

Chemicals Needed for Specific Experiments								
Item	Use (Exp. No.)	Source	Cat. No.	Cost	Quan.	Toxicity*	Flammability	Notes
acetic anhydride	18	sale-fire.com		27.00	30 mL	high (1, 4)	high	Reacts with water; keep separate.
absolute ethanol, C_2H_5OH	18	amazon.com		23.95	16 oz	medium	high	This ethanol may also be used in the alcohol burner. See Chemical Notes for info on ethanol.
salicylic acid	18	hms-beagle.com	1192	4.85	15 g	medium (4)	low	
iron chloride hexahydrate, $FeCl_3 \cdot 6H_2O$	18	hms-beagle.com	7974	3.50	15 g	low	none	

*Refers to general hazard from skin contact or vapors, not to ingestion or hazard to eyes.

Notes:

(1) Avoid breathing vapors. Use in well-ventilated area. (2) Highly corrosive. (3) Can cause severe skin burns. (4) can cause skin irritation (5) hazardous to environment

Introduction Part 2
Safety, Storage, and Disposal

I·2

Storage

It is important to plan out and arrange for your storage requirements prior to ordering chemicals. Otherwise, chemicals could be placed in inappropriate locations where there is the danger of fire or of harm to unknowing children or pets. For the chemicals used in the experiments in this book, the most important aspects of proper storage are the following:

- Chemicals are secured from children, pets, or anyone else who could come to harm by improper use or handling of the chemicals.
- Solvents are separated from sources of flame such as hot water heaters, sparking equipment, cook stoves, people smoking, and the like.
- Nitrate compounds, which are not flammable but which accelerate the burning of other compounds (because they are strong oxidizers), are separated from organic materials such as paper, fabrics, compost, wood, and charcoal.
- Acids and bases are separated from each other and from all metallic materials.
- Liquids (which include solvents and some of the acids) are contained so that any spillage from a leaking container does not come in contact with people, pets, or property that could be harmed.

Locking storage cabinets are ideal. However, a more modest storage plan may simply entail several plastic storage tubs stored in a locking storeroom. The table below summarizes these guidelines:

Chemical	Ideal Storage	Acceptable Storage
organic solvents (acetic anhydride, acetone, ethanol, hexane, toluene)	Locked flammables cabinet, away from sources of flame, in a ventilated, climate-controlled space	Away from sources of flame, in a ventilated, climate-controlled space; secured from children and pets
nitrates	Locked chemicals cabinet, away from organic materials, in a climate-controlled space	Away from organic materials, in a climate-controlled space; secured from children and pets
acids (HCl, HNO_3, H_2SO_4, acetic acid, benzoic acid, lauric acid, salicylic acid)	Separated from bases in a locked, non-metallic cabinet, in a ventilated, climate-controlled space	Separated from bases in a plastic or wooden tub or cabinet, in a climate-controlled space; secured from children and pets
bases ($NaOH$)	Separated from acids in a locked, non-metallic cabinet, in a ventilated, climate-controlled space	Separated from acids in a plastic or wooden tub or cabinet, in a climate-controlled space; secured from children and pets
other compounds	Locked chemicals cabinet in a climate-controlled space	Climate-controlled space; secured from children and pets

Waste Disposal and Clean Up

Most of the experiments in this book involve specific steps that must be taken so that waste is disposed of properly. In many cases, you can't just pour things down the drain. Prior to per-

forming an experiment, be sure to read the waste disposal section at the end and have the materials ready that you will need for clean up and disposal.

Note the following important factors that apply to waste disposal:

1. If your sanitary sewer feeds into a private septic system, pouring *any* chemicals down the drain should be avoided. Even small amounts of some chemicals can disrupt the proper functioning of a septic system.
2. Never dispose of anything in the storm sewer, that is, by pouring it in the street, creeks, streams, or anywhere else rain water is channeled.
3. In many communities, the following practices are acceptable methods of waste disposal for small waste generators such as homes and small schools:
   - pouring small amounts of *certain* cations and anions[1] down the drain.
   - discarding of dried compounds in the trash.
   - diluting and neutralizing acids and bases, followed by pouring the resulting salt and water down the drain.

   We describe how these methods should be applied, in a fashion that is acceptable in most locations, at the end of each individual experiment. However, note that heavy metals, solvents, and other environmentally sensitive chemicals may never be discarded in the trash or the sanitary sewer.
4. Even though the procedures we describe are accepted in many locations, yours may not be one of them. You should contact your local officials to find out about regulations that apply in your own community. Start with contacting the Solid Waste and Wastewater Treatment departments in your city or county.
5. Some wastes must be disposed of at a local city or county hazardous waste collection facility. For homes and families, these facilities usually collect waste without charging any fee. For schools, they may charge a fee or they may require you to arranging for a private contractor to collect your chemical waste. Either way, schools will be in much better shape and may save money by making sure all your wastes are clearly labeled with contents, including species and concentration.
6. Obtain two plastic containers, of size 0.5 gal to 1 gal each, with wide-mouth, tight-fitting plastic lids. Label these as "Solid Hazardous Waste" and "Liquid hazardous Waste." Keep these handy for disposal of wastes throughout the course of study. After the experiments have been completed, take these containers to a hazardous waste collection facility for disposal. Maintain a list of all chemicals added to each container, including quantity and concentration.

Work Area

To maintain a safe work area for your experiments, here are some guidelines you should follow:

1. Make sure you have adequate ventilation.
2. Protect your work surface. You can purchase a plastic mat for the purpose from a craft store. Examples from hobbylobby.com are the 18" × 24" self-healing rotary mat for $34.99 and the

1 These terms refer to species dissolved in water. When a chloride salt or sulfate or nitrate compound dissolves in water, the compound comes apart (*dissociates*) to form positive cations and negative anions in the solution. For example, when salt (sodium chloride) dissolves in water, the NaCl crystal dissociates and becomes individual sodium (Na^+) and chlorine (Cl^-) ions in the water. These are just individual atoms, but they have a charge (shown by the + and – signs), so they are called ions.

17" × 23" rotary cutting mat for $24.99.

3. Keep curtains, loose papers, stored materials, and other such items away from your work area. You will be using an alcohol burner often and do not want the risk of surrounding material catching fire.
4. Make sure you have a fire extinguisher and phone in your work area.

Safety Procedures

It is very important that everyone involved in the chemistry experiments learn the following safety procedures and follow them conscientiously:

1. The experiments in this book involve toxic substances, flames, fragile glass, and concentrated acids and bases. Accordingly, students should always work under the supervision of an adult.
2. Everyone in the vicinity of the chemistry work area should wear appropriate protective goggles, nitrile gloves, and a laboratory apron when working with chemicals or flames. Wear a face shield when handling concentrated acids.
3. Make your arrangements for cleanup, treatment, storage, and disposal of waste before the experiment begins.
4. Keep the Safety Data Sheet (SDS)—formerly known as the Material Safety Data Sheet (MSDS)—for every chemical you acquire. The SDS is supplied with the chemical when it is purchased. Read the SDS for every chemical you use, and take note of information about toxicity, vapors, and other concerns that require special precautions.
5. When handling hot substances or apparatus, use tongs or wear heat-resistant gloves.
6. Never mix chemicals together randomly just to see what will happen. History is full of people who did this, only to discover that the result was poisonous fumes, an explosion, or some other disaster.
7. Follow the instructions for the experiments closely and do not take short cuts.
8. Be very careful and alert when you are heating items with the alcohol burner so that you do not accidently knock the burner over. A toppled alcohol burner can spill alcohol all over your work surface and instantly set it on fire. One of your authors has seen this happen.
9. Use great care when handling glassware. As we always say, there are three ways to break something—improper procedures, silliness, or carelessness—and all are bad in a lab!
10. Make sure you have a phone in your work area in case you ever need to call for help.
11. Always follow written procedures, and don't take short cuts. Do not revise procedures to suit yourself without consulting with a responsible and knowledgeable person who knows about the kind of work you are attempting to perform.
12. Never taste substances used in chemistry experiments and never taste any substance resulting from a chemistry experiment.
13. Do not eat or drink on your chemistry work area. When it comes to the possibility of accidently ingesting a poisonous substance, take no chances.
14. Never use chemical apparatus for holding food or drink. It may look cool to drink water from a beaker, but in beakers hydrochloric acid and water look exactly alike. Reserve the chemistry apparatus for chemistry experiments and nothing else.
15. Always keep long hair tied back out of the way, remove jewelry, and don't wear loose, blow-

sy, or baggy clothing while working on the experiments.

16. Make sure there is adequate ventilation in your work area.
17. Make sure you have a fire extinguisher in your work area.
18. When working with acids, keep a full box of baking soda in the area to use as a neutralizing agent in the event of a spill. In the event of a spill, bury the liquid in a liberal application of baking soda until the fizzing stops.
19. Exercise care in everything you do, pay attention, and avoid horseplay.
20. When preparing solutions of acids and bases, always pour the concentrated acid or base into pure (distilled) water. Never pour water into concentrated acid or base solutions. When acids or bases are mixed with water, a great deal of heat is released. Pouring into water disperses the acid or base into the water where the heat can be absorbed. Otherwise, the heat produced can cause dangerous flash boiling and splashing of the concentrated acid or base.
21. If smelling the vapors of a substance is part of your procedure, always gently waft the vapors toward your nose with your hand. Do not sniff vapors by placing your nose down into a container where vapors may be concentrated.
22. Treat unknown substances as if they were flammable, corrosive, or toxic.
23. Keep your work area tidy. If you spill a bit of water on a table, you know what it is but others may not, and they must assume it is dangerous.

Permitting

Be advised that in some states—Texas in particular—individuals and private schools are required to obtain a permit from the state to possess certain lab apparatus and chemicals. This requirement is a result of the rise of illegal drug manufacturing. Public schools and colleges are exempt from the Texas permit requirement.

Two of the items on the list requiring a permit in Texas are the Erlenmeyer flask and the Florence flask. Erlenmeyer flasks are used in many of the experiments in this book. (Beakers and other apparatus specified in this book do not require a permit.)

In Texas, the Department of Public Safety administers the permitting for so-called Precursor Laboratory Apparatus. We contacted the DPS office to find out more about the permitting process and were told that there is no fee and that the only result of filling out the form to obtain a permit would be an inspection of where the apparatus would be stored. The goal of the inspection is to ensure that the apparatus is secure (that is, locked) so that it cannot be used for illicit purposes.

Be advised also that some chemical suppliers will not supply chemicals to customers who have given the supplier reason to suspect that the customer does not have the necessary permit.

The form for requesting a Texas permit can be obtained from the Department of Public Safety website under Services/Regulatory Services/Precursor Laboratory Apparatus.

Individuals and private schools in states other than Texas may or may not be subject to similar permitting requirements.

Chemical Notes

1. Quantities specified in the chemicals list are the smallest we were able to source, and are suitable for a single student or group. Schools large enough to have several students and who will repeat the experiments each year should consider purchasing larger, more economical quantities.

2. Make arrangements for chemical storage before you buy your chemicals. See the Storage section at the beginning of Introduction Part 2.
3. Spend some time online looking around and you may find better prices for small quantities.
4. Lots of chemicals are available through shops on eBay.
5. If any of the suppliers listed in the Apparatus and Chemicals Lists is no longer around, try safe-fire.com, which brokers a lot of eBay sales. Try also an internet search using the name of the chemical followed by the word "supply." This should turn up a host of options.
6. For all ethanol applications except Experiment 18, denatured ethanol may be used. Denatured ethanol has had ingredients such as methanol and isopropyl alcohol added to render it unfit to drink, thus allowing it to be sold at lower cost without the taxes that apply to alcoholic beverages. So-called "absolute ethanol," required for Experiment 18, is 200-proof ethyl alcohol, but contains trace amounts of benzene and is thus not fit for human consumption and should never be consumed.
7. Chemical precursors: We have avoided them except for Experiment 18. Acetic anhydride is a precursor for the manufacture of heroin. For this reason, acetic anhydride is a controlled substance (U.S. DEA List II precursor) and it is not advisable to possess this substance at your home. This is why we recommend that home school students skip Experiment 18. Technically, you can possess acetic anhydride at home if you obtain the necessary permit from your local authority (see Permitting on the previous page).

Introduction Part 3
Preparation of Solutions and Glass Tubing

I·3

Preparing Stock Solutions

To perform the experiments in this manual, preparation of several stock solutions is required. For example, 6.0 *M* and 1.0 *M* HCl (hydrochloric acid) are used in several experiments, so you should plan to mix quantities of these that can be stored in plastic bottles for use throughout the course. The first experiment requiring one of these HCl solutions is Experiment 4.

In other experiments, small quantities of solutions of soluble ionic compounds are required. Some of these are only used once and can be prepared at the time of the experiment. Others are required more than once and should be prepared and stored for later use. Such solutions are first called for in Experiment 3.

The table below (continued on the next page) summarizes the solutions that need to be prepared for the experiments in this book.

Experiment	Solutions	Concentration	Quantity
3	LiCl, NaCl, $MgCl_2$, KCl, $CaCl_2$, $SrCl_2$, $CuCl_2$, $ZnCl_2$	0.5 *M*	5 mL ea
4	HCl	6.0 *M*	15 mL
5	HCl	6.0 *M*	90 mL
5	$Ca(NO_3)_2$, $CuSO_4$, $Mg(NO_3)_2$, $Fe(NO_3)_3$, $FeSO_4$, $SnCl_4$, $Zn(NO_3)_2$, $AgNO_3$	0.2 *M*	5 mL ea
6	$MgCl_2$	0.2 *M*	5 mL
6	$AgNO_3$	0.1 *M*	5 mL
8	$FeSO_4$	0.16 *M*	60 mL
8	$KMnO_4$	0.05 *M*	75 mL
8	$AgNO_3$	0.1 *M*	25 mL
8	Na_2CO_3	0.05 *M*	15 mL
8	H_2SO_4	3.0 *M*	30 mL
9	HCl	6.0 *M*	10 mL
9	acetic acid, CH_3COOH	1.0 *M*	30 mL
10	NaCl, NaI, Na_2SO_4, Na_2CO_3, $Ba(NO_3)_2$, $AgNO_3$, $Pb(NO_3)_2$, $Cu(NO_3)_2$	0.1 *M*	5 mL ea
10	HNO_3 (This solution is listed here for completeness, but does not need to be prepared. The item on the chemicals list is 25 mL of 1.0 *M* solution.)	1.0 *M*	25 mL
11	NaOH	0.2 *M*	150 mL
12	HCl	0.1 *M*	100 mL
12	NaOH	0.2 *M*	100 mL
13	NaOH	1.0 *M*	100 mL
13	HCl	0.5 *M*	200 mL
13	HCl	1.0 *M*	100 mL

Experiment	Solutions	Concentration	Quantity
14	iodine	0.005 M	30 mL
14	HCl	1.0 *M*	30 mL
14	acetone	4.0 *M*	30 mL
14	starch	1%	15 mL
15	NaOH	0.2 *M*	150 mL
15	acetic acid, CH_3COOH	0.1 *M*	75 mL
15	oxalic acid, $H_2C_2O_4$	0.1 *M*	75 mL
16	H_2SO_4	1.0 *M*	200 mL
16	H_3PO_4 (This solution is listed here for completeness, but does not need to be prepared. The item on the chemicals list is 25 mL of 1.0 *M* solution. To test four supplements, four 25 mL quantities of H_3PO_4 will be needed.)	1.0 *M*	100 mL
16	$KMnO_4$	0.04 *M*	100 mL
17	$Al(NO_3)_3$	1.0 *M*	10 mL
17	$Cu(NO_3)_2$	1.0 *M*	10 mL
17	$Fe(NO_3)_3$	1.0 *M*	10 mL
17	$Ni(NO_3)_2$	1.0 *M*	10 mL
17	$AgNO_3$	1.0 *M*	10 mL
17	$NaNO_3$	1.0 *M*	10 mL
18	H_2SO_4 (This solution is listed here for completeness, but does not need to be prepared. The item on the chemicals list is 25 mL of 18 *M* solution and may be used in Experiment 18 as is.)	18 *M*	1 mL
18	$FeCl_3$	1% by mass	1 mL

Summarizing the above, the preparations shown on the next page are needed if all the experiments are to be performed. Many of the amounts shown are only approximate, but are estimated high so that you don't run out of a particular solution. (Note that preparation of only 1 mL of any solution is probably not convenient. Simply prepare a larger quantity instead, such as 5 mL.)

Before preparing any standard solutions, you must be familiar with the calculation of molar mass, with the calculation of molarity, and with the procedure for mixing a standard solution in a volumetric flask. These topics are described below and in the following sections of the texts:

Calculation of molar mass:

General Chemistry or *Principles of Chemistry*	Section 2.4.3
Chemistry for Accelerated Students or *Accelerated Chemistry*	Section 1.5.5

Calculation of molarity:

General Chemistry or *Principles of Chemistry*	Section 10.3.1
Chemistry for Accelerated Students or *Accelerated Chemistry*	Section 8.4.1

Use of a volumetric flask:

General Chemistry or *Principles of Chemistry*	Section 10.3.1
Chemistry for Accelerated Students or *Accelerated Chemistry*	Section 8.4.1

Solution	Concentration	Quantity	Solution	Concentration	Quantity
acetic acid CH_3COOH	0.1 *M*	30 mL	KCl	0.5 *M*	5 mL
acetic acid CH_3COOH	1.0 *M*	75 mL	$KMnO_4$	0.04 *M*	100 mL
acetone C_3H_6O	4.0 *M*	30 mL	$KMnO_4$	0.05 *M*	75 mL
$AgNO_3$	0.1 *M*	35 mL	LiCl	0.5 *M*	5 mL
$AgNO_3$	0.2 *M*	5 mL	$MgCl_2$	0.2 *M*	5 mL
$AgNO_3$	1.0 *M*	10 mL	$MgCl_2$	0.5 *M*	5 mL
$Al(NO_3)_3$	1.0 *M*	10 mL	$Mg(NO_3)_2$	0.2 *M*	5 mL
$Ba(NO_3)_2$	0.1 *M*	5 mL	NaCl	0.1 *M*	5 mL
$CaCl_2$	0.5 *M*	5 mL	NaCl	0.5 *M*	5 mL
$Ca(NO_3)_2$	0.2 *M*	5 mL	Na_2CO_3	0.05 *M*	15 mL
$CuCl_2$	0.5 *M*	5 mL	Na_2CO_3	0.1 *M*	5 mL
$Cu(NO_3)_2$	0.1 *M*	5 mL	NaI	0.1 *M*	5 mL
$Cu(NO_3)_2$	1.0 *M*	10 mL	$NaNO_3$	1.0 *M*	10 mL
$CuSO_4$	0.2 *M*	5 mL	NaOH	0.2 *M*	400 mL
$FeCl_3$	1%	1 mL	NaOH	1.0 *M*	100 mL
$Fe(NO_3)_3$	0.2 *M*	15 mL	Na_2SO_4	0.1 *M*	5 mL
$FeSO_4$	0.16 *M*	60 mL	oxalic acid $H_2C_2O_4$	0.1 *M*	75 mL
$FeSO_4$	0.2 *M*	5 mL	$Ni(NO_3)_2$	1.0 *M*	10 mL
HCl	0.1 *M*	100 mL	$Pb(NO_3)_2$	0.1 *M*	5 mL
HCl	0.5 *M*	200 mL	$SnCl_4$	0.2 *M*	5 mL
HCl	1.0 *M*	130 mL	$SrCl_2$	0.5 *M*	5 mL
HCl	6.0 *M*	115 mL	starch	1%	15 mL
H_2SO_4	1.0 *M*	200 mL	$ZnCl_2$	0.5 *M*	5 mL
H_2SO_4	3.0 *M*	30 mL	$Zn(NO_3)_2$	0.2 *M*	5 mL
iodine	0.005 *M*	30 mL			

Students studying at home should learn about molar mass and molarity and then explain these topics to the adult who will be supervising the experimental work. This way the student can take the lead in preparing the solutions, but the supervisor can check and verify the student's calculations and measurements.

Some of the common items of apparatus you will need for preparation of stock solutions are shown in Figure I.1. Figure I.2 shows the mass balance, plastic spoons, and weigh boats needed for measuring out amounts of solid compounds.

The measurement tools used for preparing these solutions include the digital mass balance, 50-mL volumetric flask, 250-mL volumetric flask, and 10-mL graduated cylinder, all listed in the apparatus tables on pages 9 and 10. We describe the use of these items in the examples to follow. Also required are plastic storage bottles, both medium-sized and small, as describe in the Introduction Part 1.

Note that if you need to prepare a certain concentration of a solution, such as 0.1 *M* HCl, the concentration you end up with will not be exactly 0.1 *M*. However, you will be able to calculate the concentration very *precisely* from the measured amounts of substances that go into the solution. To prepare a given solution, you first calculate the amount of a substance (in grams or mL)

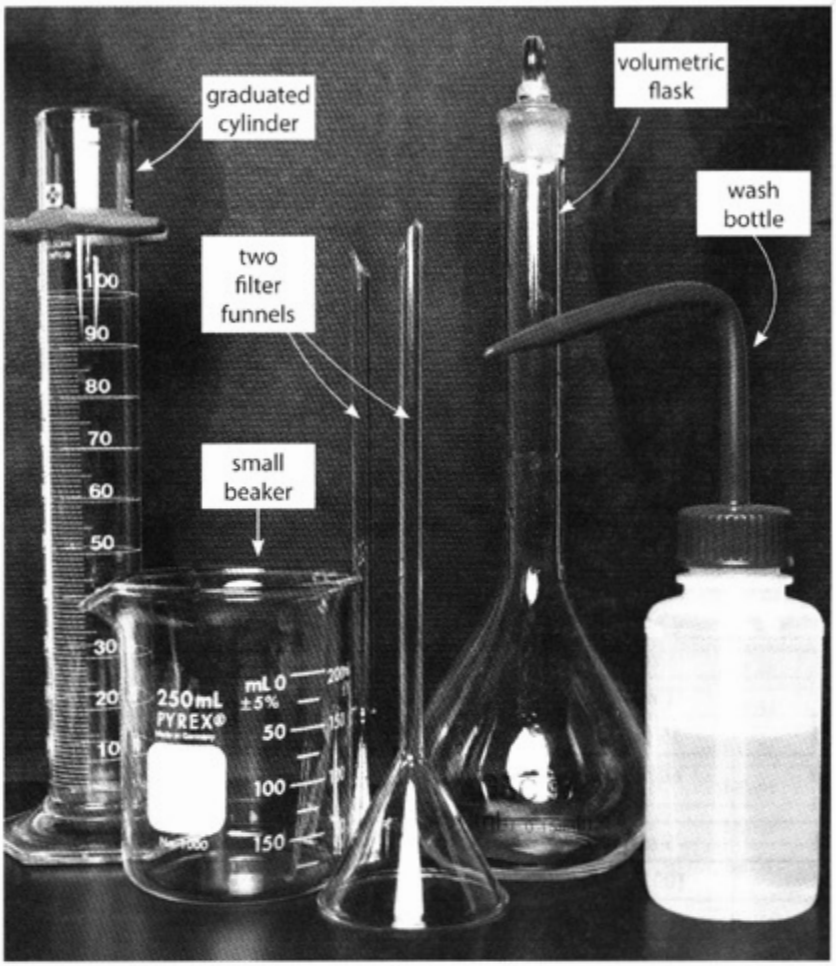

Figure I.1. Common items needed for preparing stock solutions.

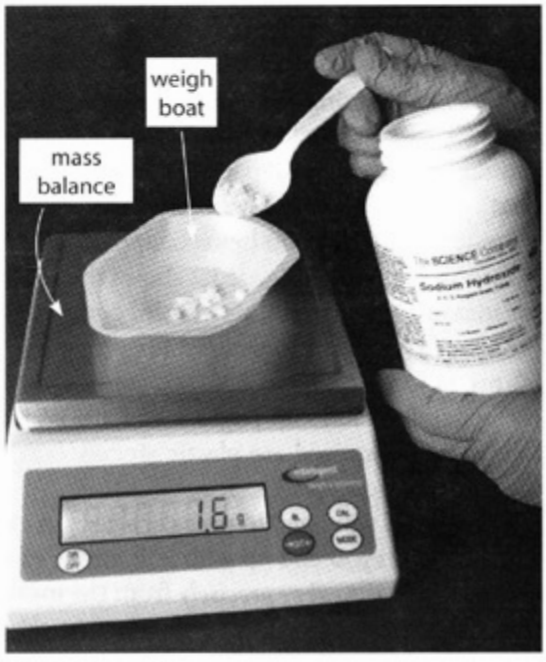

Figure I.2. Measuring out an amount of solid using a mass balance, plastic spoon, and weigh boat.

This manual includes:

- *19 solid experiments for first-year chemistry*
- *Detailed safety procedures*
- *Detailed chemical disposal procedures for each experiment*
- *Guidelines for your work area and chemical storage*
- *Complete lists of apparatus and chemicals*
- *Sources and costs for all materials*
- *Procedures and examples for preparing solutions*

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