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Chapter 2: Atoms

Overview

Chapter 2 begins with the Greek concept of matter and moves chronologically forward through the development of the atomistic model of matter.

Lecture Outline

2.1 Atoms: Ideas from the Ancient Greeks
- The Greek philosophers had two main ideas regarding matter:
- the atomistic view (Leucippus and Democritus)
- the continuous view (Aristotle)

2.2 Scientific Laws: Conservation of Mass and Definite Proportions
- Lavoisier was the first great experimentalist. More than anything, he introduced experimental chemistry to Western Civilization. Through his experiments he formulated the law of conservation of mass, which states: Matter is neither created nor destroyed during a chemical reaction.

2.3 John Dalton and the Atomic Theory of Matter
- John Dalton summarized the work of Lavoisier and Proust to form the famous atomic theory.

2.4 The Mole and Molar Mass
- The mole and Avogadro's number
- Molar mass, atomic mass
- Mass and atom ratios
- Moles

2.5 Mendeleev and the Periodic Table
- The periodic table: Mendeleev and Meyer
- John Dalton established relative atomic masses using hydrogen as a base.
- Mendeleev arranged a table of elements according to increasing atomic weights placing elements with similar properties in the same column. This was the beginning of the modern periodic table!

2.5 Atoms and Molecules: Real and Relevant

Demonstrations

1. Electrolysis of water.

2. Fill three flasks with zinc (gray powder), sulfur (yellow powder), and zinc sulfide (white powder), and show them to the class to illustrate how the properties of a compound differ from those of the component elements. [Or use mercury (silver liquid), oxygen (colorless gas), and mercuric oxide (red powder).]

3. Use samples of metals and nonmetals to demonstrate the difference in their properties. (Aluminum foil, copper wire, nickel coin, zinc strip; capped bottle of liquid bromine, balloon filled with hydrogen, bottles of carbon, sulfur, etc.)

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4. Using the largest nuts and bolts you can find, start with unequal numbers of nuts and bolts (e.g., 5 and 7). Connect the pairs of nuts and bolts, with some remaining unpaired, to illustrate the law of definite proportions.

5. Heat a sample of HgO in a large test tube with a burner. Mercury droplets form on the inside of the tube. Test for oxygen with a glowing splint, which bursts into flame when inserted into the test tube.

Review Questions

1. (a) The atomic view of matter assumes that matter is made up of small unit particles that cannot be further subdivided and still be the same kind of matter, while the continuous view of matter is just that— continuous throughout with no smaller particle. (b) The Greeks believed that there were four basic elements: earth, air, fire, and water, while today we recognize the existence of elements that are pure chemical substances made of a single atom.

2. Democritus described the tiny ultimate particle as "atomos" (which means "cannot be cut"). Matter appears continuous, and without experimental chemistry there is no way to prove that matter is not continuous. The discoveries are summarized in the laws of definite proportions and multiple proportions.

3. discrete: a, c, e; continuous: b, d

4. Robert Boyle, in *The Sceptical Chymist* (1661), stated that if a substance could be broken down into simpler substances, it was not an element.

5. A compound contains elements in certain definite proportions and in no other combinations. All samples of water will have 2 atoms of hydrogen and 1 atom of oxygen. The ratio of atoms yields a constant 2:1 volume ratio.

6. Lavoisier is the "father" of modern chemistry. He was the first to carry out a series of experiments in which the masses of reactants and products were carefully recorded. These experiments led Lavoisier to formulate the law of conservation of mass.

7. The law of definite proportions.

8. (a) Dalton's atomic theory states: "No atoms are created or broken apart in a chemical reaction." This is a restatement of the law of conservation of mass. When 3 g of carbon is allowed to react with 8 g of oxygen, 11 g of carbon dioxide is formed. (b) One of the statements of Dalton's atomic theory is that "compounds are formed when atoms of different elements combine in fixed proportions." This is a restatement of the law of definite proportions. (c) One statement of Dalton's atomic theory is that "compounds are formed when atoms of different elements combine in fixed proportions." This is a restatement of the law of definite proportions but may also explain the law of multiple proportions.

9. The law of multiple proportions.

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10. Elements can combine in more than one set of proportions. (They will still of course combine in small whole-number ratios.) (a) The ratio of the oxygen in ClO_2 to oxygen in ClO, the second compound, is 2:1. (b) The ratio of fluorine ClF_3 to fluorine in ClF 3 parts to 1 part by mass. (c) The ratio of oxygen in P_4O_6 to oxygen in P_4O_{10} is 6:10, which reduces to 3:5 by mass.

11. Rectangle C cannot represent the mixture after reaction. Rectangle C contains 15 oxygen atoms; there are 14 oxygen atoms in the initial mixture. The law of conservation of mass has been violated.

12. (a) Avogadro's number represents the number of particles contained in one mole.
(b) 6.02×10^{23} oxygen atoms. (c) 6.02×10^{23} molecules (d) 28.02 g.

13. Dmitri Mendeleev linked the mass of elements to chemical properties and created periodic law and thus the first form of the periodic table.

14. Oersted's experiment proved that aluminum could not be broken down further; it was an element.

Problems

15. (a) The container would weigh the same regardless of how much time passed. (b) No. The mouse would exchange gases with the surroundings.

16. The iron atoms have not been destroyed; they are in solution.

17. c. Carbon dioxide gas will be generated and released as the anti-acid pill dissolves.

18. (a) The carbon, which forms the diamond, has been converted to carbon dioxide and escaped into the atmosphere. (b) The carbon in the wood is converted to carbon dioxide, but the residual ash is not. Burning the diamond in an enclosed environment would trap the carbon dioxide for further analysis.

19. $\dfrac{2.02\text{ g H}}{24.02\text{ g C}} \times 78.5\text{ g C} = 6.60\text{ g H}$

20. $\dfrac{44.01\text{ g nitrous oxide}}{28.01\text{ g nitrogen}} \times 48.7\text{ g nitrogen} = 76.5\text{ g nitrous oxide}$

21. $\dfrac{36.03\text{ g C}}{44.10\text{ g } C_3H_8} \times 88.20\text{ g } C_3H_8 = 72.06\text{ g C}$

$\dfrac{12.01\text{ g C}}{44.01\text{ g } CO_2} \times 300.06\text{ g } CO_2 = 81.88\text{ g C}$

It takes 81.88 g of carbon to form 300.06 g of carbon dioxide, and you only have 72.06 g of carbon available from 88.20 g of propane. The answer violates the law of conservation of mass.

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22. Mass before the reaction = 2.796 g of zinc + 2.414 g of sulfur = 5.210 g
Mass after the reaction = 4.169 g of zinc sulfide + 1.041 g of sulfur = 5.210 g
Yes, the experiment obeys the law of conservation of mass.

23. Mass before the reaction = 1.00 g of zinc + 0.80 g of sulfur = 1.80 g
Mass after the reaction = 1.50 g zinc sulfide
Total mass before 1.80 g – mass after 1.50 = 0.30 g of sulfur (answer b)

24. None of the three methods will destroy the atoms. Incineration is a chemical change.

25. (a) $\frac{2.02\text{ g hydrogen}}{18.02\text{ g water}}$ x 775 g water = 86.9 g hydrogen

(b) $\frac{16.00\text{ g oxygen}}{18.02\text{ g water}}$ x 775 g water = 688 g oxygen

26. $\frac{2.02\text{ g hydrogen}}{18.02\text{ g water}}$ x ? kg water = 125 kg hydrogen

$$\text{? kg water} = 125\text{ kg hydrogen x}\frac{18.02\text{ g hydrogen}}{2.02\text{ g water}} = 1120\text{ kg water}$$

27. $\frac{3.0\text{ parts carbon}}{3.0 + 8.0\text{ parts carbon dioxide}}$ x 14 kg carbon dioxide = 3.8 kg carbon

28. $\frac{3.0 + 8.0\text{ parts carbon dioxide}}{3.0\text{ parts carbon}}$ x 0.4 g diamond = 2 g carbon dioxide

29. Statement number two of Dalton's atomic theory says, "All atoms of a given element are alike, but atoms of one element differ from atoms of any other element." (a) The different masses of atoms of calcium and vanadium support Dalton's atomic theory. (b) The same mass of two different elements violates statement two of Dalton's atomic theory. (Dalton did not predict the existence of isotopes.)

30. Yes, it agrees with statement number two of Dalton's atomic theory, which says, "All atoms of a given element are alike, but atoms of one element differ from atoms of any other element."

31. The atoms are neither being created nor destroyed; they are being rearranged.

32. a

33. d; $\frac{8\text{ units O}}{1\text{ units H}}$ x $\frac{2\text{ atoms H}}{1\text{ atom O}} = 16$

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34. a; $\frac{57 \text{ unit F}}{14 \text{ units N}} \text{ x } \frac{1 \text{ atom N}}{3 \text{ atoms F}} = \frac{19}{14}$ by mass

35. Assume that there is 1 g of carbon suboxide and that the mass ratio is 0.5296:0.4704
Divide both by 0.5296 to get a mass ratio of 1.0000:0.8882 in carbon suboxide. The ratio of oxygen in all three compounds is 1:2:3.

36. 8.0:85.5

37. Calculate the mass ratio of Sn to O in SnO. 0.742 g Sn / 0.100 g O = 7.4:1.
Calculate the mass ratio of Sn to O in the unknown. 0.555 g Sn / 0.150 g O = 3.7:1
or 7.4:2. Compare the oxygen mass ratios of the two oxides. 1:2; thus the second oxide has 2 oxygen atoms for every oxygen atom in the first oxide. The formula of the second oxide is SnO_2.

38. Divide all oxygen and nitrogen ratios by the smallest oxygen to nitrogen ratio to obtain X 4.00:1.75, Y 2.00:1.75, and Z 1.00:1.75.

39. Calculate the ratio of Fe in hematite to the ratio of Fe in wusitite: 0.558g/0.558 g =1 Calculate the ratio of O in hematite to the ratio of O in wusitite: 0.240g/0.160 g =1.5
Multiply both by 2 to get whole numbers and you obtain Fe_2O_3 for hematite.
Calculate the ratio of Fe in magnetite to the ratio of Fe in wusitite: 3.35g/0.558 g =6 Calculate the ratio of O in magnetite to the ratio of O in wusitite: 1.28g/0.160 g =8
Reduce to the smallest whole numbers and you obtain Fe_3O_4 for magnetite. Yes.

40. Divide both carbon and hydrogen percentages by the carbon percent in each compound to obtain C : H ratios V 1.00:0.25 and W 1.00:0.20. The dividing by the smallest hydrogen amount yields hydrogen ratios of 1.00:1.25.

41. $1.000 \text{ g C x } \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.08326 \text{ mol C x } \frac{6.02 \text{x} 10^{23} \text{ atoms C}}{1 \text{ mol C}} = 5.01 \text{x} 10^{22} \text{ atoms C}$

42. 16.00 g/mol O + 2(1.01g/mol H) = 18.02 g/mol H_2O
6.02 x 10^{23} atoms of O and 2(6.02 x 10^{23} atoms of H) = 1.20 x 10^{24} atoms of H

43. (5 mol)(12.00 g/mol) = 60.00 g C-12. (5 mol)(12.01 g/mol) = 60.05 g C.
(To one significant figure, the correct number of significant figures. To use, both answers are 60 g.)

44. 1.01/12.00 and 1.01/12.01

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45. $\text{Sample 1}: \frac{0.937\text{ g C}}{1.000\text{ g}} \times 100\% = 93.7\%\text{ C}; \frac{0.0629\text{ g H}}{1.000\text{ g}} \times 100\% = 6.29\%\text{ H}$

$\text{Sample 2}: \frac{0.229\text{ g C}}{0.244\text{ g}} \times 100\% = 93.8\%\text{ C}; \frac{0.0153\text{ g H}}{0.244\text{ g}} \times 100\% = 6.27\%\text{ H}$

$\text{Sample 3}: \frac{0.094\text{ g C}}{0.100\text{ g}} \times 100\% = 94\%\text{ C}; \frac{0.0063\text{ g H}}{0.100\text{ g}} \times 100\% = 6.3\%\text{ H}$

All ratios are constant to two significant figures. The solid is a pure compound!

46. $\text{Sample 1}: \frac{0.862\text{ g C}}{1.000\text{ g}} \times 100\% = 86.2\%\text{ C}; \frac{0.138\text{ g H}}{1.000\text{ g}} \times 100\% = 13.8\%\text{ H}$

$\text{Sample 2}: \frac{1.295\text{ g C}}{1.549\text{ g}} \times 100\% = 83.6\%\text{ C}; \frac{0.254\text{ g H}}{1.549\text{ g}} \times 100\% = 16.4\%\text{ H}$

$\text{Sample 3}: \frac{0.826\text{ g C}}{0.988\text{ g}} \times 100\% = 83.6\%\text{ C}; \frac{0.162\text{ g H}}{0.988\text{ g}} \times 100\% = 16.4\%\text{ H}$

Sample 1 does not agree with samples 2 and 3. The liquid is a mixture.

47. $\frac{1\text{ part by mass F}}{2.09\text{ part by mass U}} \text{ x } \frac{238}{19} = \frac{6\text{ F}}{1\text{ U}}$

48. From the first experiment we note that 3.06 g of hydrogen produced 27.35 g of water when allowed to react with oxygen. By applying the law of conservation of mass, 24.29 g of oxygen is required. Next, calculate the ratio by mass of hydrogen to oxygen in water. 3.06 g hydrogen / 24.29 g oxygen = 1 part hydrogen to 8 parts oxygen. Next, compare the ratio (1:8) with the masses of hydrogen and oxygen produced in the electrolysis experiment: 1.45 g hydrogen / 11.51 g oxygen = 1 part hydrogen to 8 parts oxygen. The results are consistent with the law of definite proportions.

49. From the first experiment we note that 0.312 g of sulfur produced 0.623 g of sulfur dioxide when allowed to react with oxygen. By applying the law of conservation of mass, 0.311 g of oxygen is required. Next, calculate the ratio by mass of sulfur to oxygen in sulfur dioxide: 0.312 g sulfur/0.311 g oxygen = 1 part sulfur to 1 part oxygen. The 1.305 g of sulfur in the second experiment requires 1.305 g of oxygen (1:1 by mass); thus, 2.610 g of sulfur dioxide is produced in the second experiment.

50. $\frac{92.61\text{ g mercury}}{100.00\text{ g mercuric oxide}} = 0.9261\text{ g mercury/g mercuric oxide}$

$0.9261 \text{ x (X g mercuric oxide)} = 100.00\text{ g mercury}$

$\text{X g mercuric oxide} = \frac{100.00\text{ g mercury}}{0.9261\text{ g mercury/g mercuric oxide}}$

$\text{X g mercuric oxide} = 108.0\text{ g mercuric oxide}$

51. Table 2.1 indicates 1 ratio of 1.000 g oxygen:0.4375 g nitrogen. The nitrogen ratio is 0.4375:0.5836 or 1.000:1.334 or in whole numbers 3:4.

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52. When gasoline is burned, it combines with oxygen from the atmosphere to form carbon dioxide.

53. The law of conservation of mass. The mass of the products is the same as the mass of the reactants.

54. a) $\frac{14.01\text{ g N}}{3.03\text{ g H}} = \frac{4.62\text{ g N}}{1.00\text{ g H}}; \frac{28.00\text{ g N}}{6.05\text{ g H}} = \frac{4.62\text{ g N}}{1.00\text{ g H}}$

The N and H are in the same ratios; thus 34.05 g of NH_3 will be produced.

b) $\frac{4.62\text{ g N}}{1.00\text{ g H}} = \frac{X\text{ g N}}{11.0\text{ g H}}; X = \frac{(4.62\text{ g N})(11.0\text{ g H})}{1.00\text{ g H}} = 50.8\text{ g N}$; 61.8 g NH_3 produced

c) $\frac{4.62\text{ g N}}{1.00\text{ g H}} = \frac{X\text{ g N}}{2.0\text{ g H}}; X = \frac{(4.62\text{ g N})(2.0\text{ g H})}{1.00\text{ g H}} = 9.2\text{ g N}$ required

Remaining N = 11.0 g – 9.2 g = 1.8 g N.

55. a) Using Mendeleev's masses for S and Te: (32+125)/2=78.5
b) Using values from the modern periodic table: (32.06+127.60)/2=79.83

56. a) neither b) rare c) hazardous d) neither e) hazardous

57. Titanium dioxide replacing lead in paints, metal salts replacing lead as stabilizers in plastics, and lead-free adhesives used in electronics.

58. Mercury is toxic and can leach from landfills into groundwater.

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#21 Acid Neutralization by Antacid

Reagents

6 M hydrochloric acid [HCl]	30 mL/pair
sodium hydroxide pellets [NaOH]	20 g/pair
phenolphthalein	1–2 mL/pair
distilled water	1300 mL/pair

Common Materials

antacid tablets, 3 brands (Alka Seltzer™ suggested)	2 tablets of each/pair

Special Equipment

1 50-mL pipette with safety bulb	1/pair
1 500-mL volumetric flask with solid stopper to fit	1/pair
mortar and pestle	1/pair

Laboratory Equipment

100-mL clean squeeze bottle
500-mL Erlenmeyer flask with solid stopper to fit
150-mL Erlenmeyer flask
50-mL graduated cylinder
centigram balance
hot plate

Notes

Tablets need to be crushed in order to dissolve quickly. White tablets are better. Colored tablets may obscure the endpoint determination.

Disposal

Flush all solutions down the drain with a lot of water.

ACID NEUTRALIZATION BY ANTACID PRE-LAB QUESTIONS

1) Some antacids neutralize acid very quickly, while others neutralize slowly over a longer period of time. The antacids that produce carbon dioxide gas neutralize acid the fastest, whereas antacids containing hydroxides tend to operate over a longer period of time. Name a common antacid that offers immediate relief.
Alka-Seltzer would provide fast relief because of all the carbon dioxide produced as it effervesces.

2) If an antacid tablet requires warming to dissolve, or if it dissolves slowly, would you expect it to work quickly or be designed to operate over an extended period of time?
It takes time for ingested substances to reach body temperature; therefore, one would expect the antacid described to act slowly, over an extended period of time.

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3) What color would you expect phenolphthalein to be if it was added to the gastric juices of your stomach?
Phenolphthalein would appear clear, or colorless, in gastric juice because digestive secretions are acidic.

4) Why would it not be a good idea to use antacids as a calcium supplement?
Antacids are intended to alter the pH of the stomach environment. Other calcium supplements are available that will not increase the risk of alkalosis.

5) One of the principles of green chemistry is atom economy—that all reactants are included in the products. Why is it important that a chemist be able to determine exactly when a reaction is complete, that is, when the two reactants are completely reacted?
If a reaction has reached completion but one reactant continues to be added to the system, the excess is wasted. The ability to determine when a reaction is complete allows chemists to conserve reagents and conduct experiments in keeping with principles of green chemistry.

6) What happens to the pH of your stomach if you take more antacid than necessary to neutralize the acid?
When more antacid is taken than necessary, the pH of the stomach can be overneutralized, making it slightly basic. The condition can be harmful and is referred to as alkalosis.

ACID NEUTRALIZATION BY ANTACID SAMPLE REPORT SHEET

PART A: DENSITY OF NaOH

Mass of cylinder and NaOH solution _____ g
minus mass of cylinder − _____ g

Mass of 10 mL NaOH solution __*10.0-11.0*_____ g

$$\text{Density} = \frac{\text{mass of solution}}{\text{volume}} = \frac{10.0 - 11.0}{10\ \text{mL}} = \text{}$$ __*1.0-1.1*____g/mL

PART B: STANDARDIZATION OF THE SODIUM HYDROXIDE SOLUTION

Initial bottle mass _____ g
minus final bottle mass − _____ g

Mass of NaOH added ___*18.0-20.0*_____g

$$\text{Volume of NaOH added} = \frac{\text{mass added}}{\text{density}} = \frac{18.0 - 20.0\ \text{g}}{1.0 - 1.1\ \text{g/mL}} = \text{}$$ _*18.0*__mL

$$\text{Molarity of NaOH} = \frac{(0.36\ \text{M HCl})(50\ \text{mL HCl})}{\text{volume NaOH}} = \frac{(0.36\ \text{M HCl})(50\ \text{mL HCl})}{18.0\ \text{mL}} = \text{}$$ __*1.0*__M

**All other answers will depend on the brands used.*

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PART C: NEUTRALIZATION WITH ANTACIDS

	#1	#2	#3
BRAND NAME OF TABLETS	_____	_____	_____
Mass	_____g	_____g	_____g
BASE ADDED			
Initial solution and bottle mass	_____g	_____g	_____g
Final solution and bottle mass	_____g	_____g	_____g
Difference (base added)	_____g	_____g	_____g
Volume of base = difference / density	_____mL	_____mL	_____mL
ACID ADDED = (50 mL)(0.36 M) =	18 mmol	18 mmol	18 mmol
BASE ADDED = volume times base molarity	= _____ mmol	_____mmol	_____mmol
ACID NEUTRALIZED = mmol acid added minus base added	= _____ mmol	_____mmol	_____mmol
ACID NEUTRALIZED PER TABLET	= _____mmol	_____mmol	_____mmol
ACID NEUTRALIZED PER GRAM = (answer above divided by mass of tablet)	= _____mmol	_____mmol	_____mmol

PART D: QUESTIONS

1. Read the antacid label to find the basic compounds and write balanced equations showing the reaction with the hydrogen ion.

   Brand #1

   The reactions will vary according to brand, but most will contain CO_3^{-2} or $Mg(OH)_2$:

   Brand #2 $CO_3^{-2} + 2H^+ \rightarrow H_2CO_3 \rightarrow H_2O + CO_2$

   Brand #3 $Mg(OH)_2 + 2H^+ \rightarrow Mg^{2+} + 2H_2O$

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2. Which antacid appears to be best at relieving acid stomach?
   This varies according to the brands used.

3. Which antacid has more neutralizing power per gram?
   This varies according to the brands used.

4. In recent commercials, some antacids brag that they contain calcium. If calcium is used by the body to form bones and teeth, is it an advantage to be able to obtain calcium for the body as heartburn is treated?
   When basic compounds such as calcium carbonate react with the hydrogen ion, which is acidic, carbonic acid is produced and quickly dissociates into water and carbon dioxide. This leaves the calcium ion free to be used by the body to build bones and teeth. Any nontoxic metal ion that is combined with the carbonate ion will work, so providing a free ion that the body can use is logical.

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#22 Nature's Indicators

Reagents

0.1 M hydrochloric acid [HCl]	20 mL/pair
0.1 M sodium hydroxide [NaOH]	20 mL/pair
pH test paper	1 roll/pair
red litmus paper	1 container/pair
blue litmus paper	1 container/pair

Common Materials

red cabbage	1 head/lab section
beets	1/pair
concentrated grape juice	20 mL/pair
lemon juice	1 mL/pair
ammonia household cleanser	1 mL/pair
vinegar	1 mL/pair
clear soft drink	1 mL/pair
white or clear shampoo (clear is better)	1 mL/pair
liquid drain cleaner	1 mL/pair
paring knife	1/pair

Laboratory Equipment

2 250-mL beakers
100-mL graduated cylinder
7 100-mL beakers
7 test tubes
stirring rod
eyedropper
hot plate

Notes

Canned beets and red cabbage will also work.

The skins of black grapes will also work well for indicator preparation; however, this gives essentially the same results as the concentrated grape juice. The grape juice should be 100% juice as opposed to a grape drink. Other plants that will produce indicators are petals from violets, petunias, hydrangea, and hibiscus; the skins of tomatoes, turnips, red apples, peaches, pears, and red onions; and the juices of pomegranates, cherries, raspberries, blueberries, and blackberries. (Source: WonderScience magazine published by the American Chemical Society)

The vegetables may also be heated (not boiled) in ethanol to produce an indicator. By this method, less time is required to evaporate the solution down to the desired concentration of color. However, care must be taken when heating ethanol.

There are both acidic and basic drain cleaners. A basic drain cleaner such as Drano™ will provide a second basic solution.

Disposal

Dispose of your pH solutions, one at a time, by pouring them down the drain with a large amount of water.

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NATURE'S INDICATORS PRE-LAB QUESTIONS

1) Hydrangea plants (*Hydrangea macrophylla*) produce very large flower clusters and are common garden shrubs in central and southern states. Many people believe that there are two varieties of this shrub—blue and pink—when, in fact, there is only one. Many homeowners have planted a hydrangea of one "variety" only to have it slowly transform to the other over a period of years. Give an explanation for this phenomenon in light of the introductory information for this investigation.
The pH of the soil determines the color of the pigment in the petals because at least one component of that pigment is a natural indicator.

2) Litmus is either red or blue. It is useful only to determine if a substance is classified as an acid or a base. Indicators that are capable of specifying a particular pH exhibit a range of color changes. Would you expect these "universal indicators" to be a single compound, two compounds combined, or several compounds combined? Support your position.
Since most indicators exhibit only a single color change at a narrow pH range, a universal indicator must be a combination of several substances, each covering a separate range of transition.

3) Would an experiment using indicators to determine the pH of common substances work in an already colored substance, such as a cola beverage? Why or why not?
It would not be useful to use a color indicator in a colored substance, especially one that is darkly colored because the existing color would mask the color of the indicator.

4) Nearly all indicators are organic molecules that are sensitive to destruction by strong solutions, especially bleaching cleansers. Could the pH of chlorine bleach be determined with an indicator derived from a plant? Explain.
Probably not. Plant substances are organic, and chlorine bleach destroys organic molecules. If it gave an indication of pH, it would be short-lived.

5) A child goes to the kitchen sink to rinse the glass from which he just drank grape juice. As the water runs into the glass, the juice residue turns from purple to light blue. What is happening?
The grape juice contains a natural indicator that appears dark purple at a specific pH range. As the juice is diluted, the pH moves closer to neutral, and the transition range of the indicating substance is crossed so that it changes color.

6) Why is it important to know whether or not a home care product is strong acidic?
Substances that are strongly basic or acidic can damage living tissues and some objects. Care should be taken when using them.

NATURE'S INDICATORS SAMPLE REPORT SHEET

INDICATOR COLOR

	Cabbage	Beet	Grape	Blue Litmus	Red Litmus
pH = 1	*dark pink*	*dark pink*	*pink*	*red*	*red*
pH = 3	*light pink*	*light pink*	*light pink*	*red*	*red*
pH = 5	*light purple*	*very lt. pink*	*very lt. pink*	*red*	*blue*
pH = 7	*very lt. purple*	*very lt. pink*	*very lt. pink*	*red*	*blue*
pH = 9	*light blue*	*very lt. pink*	*clear*	*red*	*blue*
pH = 11	*green*	*pink*	*clear*	*blue*	*dark blue*
pH = 13	*lime green*	*yellow*	*green*	*blue*	*dark blue*

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INDICATOR USED * __*Cabbage*_____

SUBSTANCE	pH by indicator	pH by paper
Lemon juice	*1*	*2*
Vinegar	*3*	*3*
Soft drink	*5*	*7*
Shampoo	*7*	*7*
Ammonia cleanser	*11*	*10*
Drain cleaner	*11*	*8*

**Beets give the following: 1,3,7,7,11,9.*
Grapes give the following: 1,3,5,7,11,9.

QUESTIONS

1. Are beverages usually acidic or basic?
   Beverages are usually acidic or neutral: water is neutral, while orange juice is acidic. This is true because many beverages contain fruit juices or have acid added for flavor.

2. Why shouldn't shampoo be too acidic or too basic?
   Shampoo must be neutral because the acid or base could damage the hair.

3. Which indicator did you like best and why?
   Student response here.

4. Which indicator covers the largest range of pH?
   The cabbage, beet, and grape juice cover the full pH scale, but the cabbage changes to a different color at each pH increment we checked.

5. Which indicator produced the most variation in color?
   cabbage

6. Why are there two types of drain cleaners?
   The bathroom drain cleaner has acid, which breaks down protein in hair that is usually found in bathroom drains. The second type is basic and is used to react with the grease in kitchen clogs and helps to free the clog.

7. Comment on how closely your pH determinations using the experimental indicator scale matched the pH determinations with the commercial pH paper.
   Answers will vary, but the results should be very close.

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#23 pH and Flammability of Household Products

Reagents

ethanol [CH_3CH_2OH]	2 mL/pair
acetone [CH_3COCH_3]	2 mL/pair
sodium tripolyphosphate [$Na_5P_3O_{10}$]	2 mL/pair
sodium pyrophosphate [$Na_4P_2O_7$]	2 mL/pair
sodium carbonate [Na_2CO_3]	2 mL/pair
sodium silicate [Na_2SiO_3]	2 mL/pair
pH test paper	8-10 strips/pair

Common Materials

vanilla extract	2 mL/pair
nail polish remover	2 mL/pair
cologne	2 mL/pair
aftershave lotion	2 mL/pair
paint thinner	2 mL/pair
oven cleaner	2 mL/pair
hair spray	2 mL/pair
toilet bowl cleaner	2 mL/pair
hand dishwashing detergent	2 mL/pair
machine dishwashing detergent	2 mL/pair
chlorine bleach	2 mL/pair
vinegar	2 mL/pair
drain cleaner	2 mL/pair
ammonia cleaning product	2 mL/pair
other products from home	2 mL/pair
matches	1 book/pair

Laboratory Equipment

evaporating dish
50-mL beaker
stirring rod
laboratory burner

Notes

The unused paint thinner should not be flushed down the drain but should instead be carefully sealed for use in another semester. The small amount of paint thinner given to the students should be consumed by the flames. Be sure it is a flammable paint thinner.

There are both acidic and basic drain cleaners. Drano™ is basic; Works™ is acidic.

Disposal

Paint thinner will contaminate water. It should be completely consumed by the flames. It could also be evaporated in a fume hood.

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pH and FLAMMABILITY PRE-LAB QUESTIONS

1) In many homes, multiple flammable compounds normally reside under the kitchen sink. Another common storage place for household cleaning supplies and solvents is the "utility" closet, which may also house a gas-fueled water heater or furnace. Comment on the risks and wisdom of this practice. Can you suggest alternatives?
Any place in which an open flame or electrical sparks exist is a hazardous place to store flammable substances; especially unventilated areas where vapors can build up. A good alternative is a ventilated storeroom where there are no gas-fueled appliances or appliances on thermostats that generate small sparks when they cycle on.

2) Assume you are the corporate attorney for a company that produces, packages, and markets multiple household cleaners and solvents. What suggestions would you make to the company CEO concerning consumer warnings?
Correct responses may include but may not be limited to the following:
   - *Flammables should be stored in ventilated areas and away from open flames and electrical sparks.*
   - *Never mix cleaning products.*
   - *Note caustic warnings on products of low or high pH.*
   - *Keep all household products away from children.*
   - *Obtain the toll-free Poison Control number.*

3) It has been suggested that a labeling system for easy identification of pH and flammability ratings for common substances should be instigated. If this system used color-coding for ease of identifying the characteristics of a substance, what suggestions would you make for the design?
Answers will vary.

4) Which of the substances we will use in this lab can you find in your own home, apartment, or dorm room?
Answers will vary.

5) How can you reduce the risk of accidents and injuries involving household chemicals in your domicile?
Read and follow all warnings and directions for household substances. Adhere to proper storage techniques. Use all household products in open or ventilated areas. Wear protective clothing and gloves when using caustic substances.

6) One principle of green chemistry regards inherently safer chemistry for accident prevention. Is this principle being followed by marking flammable or acidic or basic materials?
Yes. If consumers are conscious of the pH of compounds and the potential risks involved in their use, they can be more cautious and even perhaps use less.

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pH and FLAMMABILITY OF HOUSEHOLD PRODUCTS
SAMPLE REPORT SHEET

I. FLAMMABILITY

	Ignites with Match	Ignites with Stronger Flame
Ethyl alcohol	X	
Acetone	X	
Vanilla extract		X
Nail polish remover	X	
Cologne	X	
Aftershave lotion		X
Paint thinner		X
Oven cleaner		
Hair spray	X	

II. pH

	Brand	pH
Toilet bowl cleaner	*Saniflush*	*2*
Hand dishwashing detergent	*Ajax*	*6*
Machine dishwashing detergent	*Sunlight*	*10*
Bleach	*Vista*	*10*
$Na_5P_3O_{10}$		*8*
Na_2CO_3		*10*
Na_2SiO_3		*10*
Ammonia cleaner		*10*
Vinegar		*4*
Oven cleaner		*14*

III. QUESTIONS

1. Which products include adequate warnings about flammability?
   Answers will vary depending on the brands used.

2. Which products need to include more warnings about flammability?
   Answers will vary depending on the brands used.

3. Which of the products tested are unsafe for skin contact? (Products with pH values between 5 and 10 are probably safe for at least short periods of time.)
   Toilet bowl cleaner
   Vinegar

4. Which of the products tested have adequate warnings concerning pH on the label?
   Answers will vary depending on the brands used.

5. Why wouldn't you use machine dishwashing detergent to wash dishes by hand?
   The pH of the machine dishwashing detergent is basic and is not safe for prolonged use.

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6. Why is it suggested to use gloves when using oven-cleaning products?
   Oven cleaner is not safe for skin due to the pH.

7. Because of environmental concerns, phosphates have been replaced with other builders such as sodium carbonate and sodium silicate. Does this change make a difference in safety to the consumer?
   Sodium carbonate and sodium silicate are more basic than phosphates. That means that sodium carbonate and sodium silicate can be more dangerous to the consumer than phosphates.

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#24 Buffers

Reagents

1 M acetic acid [CH_3COOH]	10 mL/pair
1 M sodium acetate [CH_3COONa]	10 mL/pair
1 M acetic acid and 1 M sodium acetate (buffer solution)	20 mL/pair
1 M hydrochloric acid [HCl]	50 mL/pair
1 M sodium hydroxide [NaOH]	50 mL/pair
wide range pH paper	1 roll/pair

Common Materials

Laboratory Equipment

50-mL beakers	5/pair
10-mL graduated cylinder	

Notes

Be sure students stir the solutions well after each addition before taking the pH measurement.

Disposal

All solutions may be mixed to neutralize and poured down the drain with lots of water.

BUFFERS PRE-LAB QUESTIONS

1) When a person exerts a great deal of physical energy, as in running a race or playing one-on-one basketball, one of the by-products of muscular activity that takes place is lactic acid. If the blood buffering system cannot handle the lowered pH, what condition could result?
Acidosis could result as the lactic acid lowers the pH of the blood. The lowered pH could in turn affect proteins in nearby cells. This is the cause of the stiffness and soreness associated with the use of muscles that are not accustomed to a higher level of activity.

2) Many consumer products are buffered to protect the body from dangerous pH changes. Pharmaceutical compounds are usually either basic or acidic and, less frequently, neutral compounds. What systems in the body need the protection of a buffer if the substance is ingested? Injected?
Ingested substances that are acidic or basic must be shielded from the stomach lining if the pH is very far from neutral, or if the exposure will be extended. Substances that are injected will make use of the blood buffer system. (Inhaled substances can cause irritation to the lining of the nose, mouth, throat, esophagus, and lungs.)

3) Many fertilizers are formulated to help maintain specific pH levels for certain applications. Will making the fertilizer the desired pH be enough to accomplish the result? Explain your reasoning.
Not necessarily. The nitrates in fertilizer enter the nitrogen cycle in which several nitrogen compounds take part. These various compounds can further alter the pH of the soil as the chemical processes progress.

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4) Baking soda (sodium hydrogen carbonate, $NaHCO_3$) acts as a buffer, as does sodium tetraborate [$Na_2B_4O_7$], also called borax. Both are used as a water softener in laundry applications. Each compound raises the pH of the system and then buffers it to keep it consistent. Both of these compounds are active ingredients in pool maintenance products. The hypochlorite ion (ClO^-) is the ingredient used to "shock" a pool. What happens to the pH of the pool?
The hypochlorite ion acts as a base when introduced to the pool water, taking a hydrogen atom from a water molecule and forming hypochlorous acid. This leaves the remaining hydroxide ion free in the pool water. The hydroxide ion initially raises pH, but as sunlight, oxygenation from splashing, and the disinfecting action of the acid reduces the amount of hypochlorite in the water, the pH returns to a more neutral range. In the meantime, the pool has been cleared of bacteria and organic waste.

5) The hypochlorite ion is also the active ingredient in chlorine bleach. Why do people spend large sums of money for pool products that are labeled with cute names like "Alk-Up®" or "SoftSwim®" (actually, $Na_2B_4O_7 \cdot 10H_2O$) instead of buying the substances off grocery store shelves?
Most consumers do not have the knowledge necessary to maintain the pool water quality on their own. Testing solutions for pH and other indicators of water condition are available with instructions that allow a person with virtually no chemical experience to maintain their pool environment. It is also easier to purchase all the necessary chemicals at one place catering to pool needs than to get some things at a grocery store, while others are available only at specific businesses.

6) One of the principles of green chemistry concerns inherently safer chemistry for accident prevention. Might buffers be important in following that principle of green chemistry?
Any method of preventing extreme conditions of pH will reduce the occurrence of chemical-related accidents.

BUFFERS SAMPLE REPORT SHEET

I.

	Water	Acetic Acid	Acetate Ion Sodium Acetate	Acetic Acid-Acetate Buffer
	pH	pH	pH	pH
1 drop HCl	_____	_____	_____	_____
2 drops HCl	_____	_____	_____	_____
20 drops HCl	_____	_____	_____	_____
2 mL HCl	_____	_____	_____	_____
3 mL HCl	_____	_____	_____	_____
4 mL HCl	_____	_____	_____	_____
5 mL HCl	_____	_____	_____	_____
6 mL HCl	_____	_____	_____	_____
7 mL HCl	_____	_____	_____	_____
8 mL HCl	_____	_____	_____	_____
9 mL HCl	_____	_____	_____	_____
10 mL HCl	_____	_____	_____	_____
11 mL HCl	_____	_____	_____	_____

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II.

1 drop NaOH	_____	_____	_____	_____
20 drops NaOH	_____	_____	_____	_____
2 mL NaOH	_____	_____	_____	_____
3 mL NaOH	_____	_____	_____	_____
4 mL NaOH	_____	_____	_____	_____
5 mL NaOH	_____	_____	_____	_____
6 mL NaOH	_____	_____	_____	_____
7 mL NaOH	_____	_____	_____	_____
8 mL NaOH	_____	_____	_____	_____
9 mL NaOH	_____	_____	_____	_____
10 mL NaOH	_____	_____	_____	_____
11 mL NaOH	_____	_____	_____	_____

III. Buffer pH _____ add 5 mL water _____ add 10 mL water _____

IV.QUESTIONS

1. Which is the best at resisting pH change when acid is added: water, acetic acid, acetate ion, or buffer?
   The buffer is the best.

2. Which is the worst at resisting pH change when acid is added: water, acetic acid, acetate ion, or buffer?
   The water is the worst.

3. Which is the best at resisting pH change when base is added: water, acetic acid, acetate ion, or buffer?
   The buffer is the best.

4. Which is the worst at resisting pH change when base is added: water, acetic acid, acetate ion, or buffer?
   The water is the worst.

5. Why does the buffer solution have a large pH change after 10 mL is added?
   The amount of acid added has overcome the conjugate base's ability to absorb. (i.e., the base has been used up.)

6. Why would it be useful to "buffer" an aspirin tablet? (Aspirin is acetyl-salicylic acid.)
   The acid can be uncomfortable in the digestive tract which is already acidic. With the buffer, the tablet will resist lowering the pH of the stomach even more.

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#25 Oxidation - Reduction

Reagents

zinc, mossy	1 g/pair
tincture of iodine	20 mL/pair
1M copper (II) sulfate [$CuSO_4$]	30 mL/pair
1M sodium chloride [NaCl]	10 mL/pair
1M acetic acid [$HC_2H_3O_2$]	0.5 mL/pair

Common Materials

aluminum foil	2 (4 in. × 4 in.) squares/pair
coins, different metals	2/pair
paper towels	1 sheet/pair
chlorine bleach	0.5 mL/pair

Special Equipment

voltmeter with leads	1/lab

Laboratory Equipment

3 50-mL beakers

Notes

Disposal

Wet zinc dust exposed to air can burst into flames. It is important that students not put wet zinc dust in the trash; it can cause fires in the trash. The wet zinc solutions should be spread on a metal pan to dry. It must be in a metal pan for the chemical reaction to form zinc oxide. Dry zinc oxide will form, which can be buried in a landfill.

OXIDATION AND REDUCTION PRE-LAB QUESTIONS

1) Have you ever experienced a little jolt while the dental assistant was cleaning your teeth? It happens when the metal instrument he or she is holding touches a metallic filling, or more often, the metal base to a crown. It is called galvanic shock. What is happening?
A difference in voltage potential exists between the two metals that are in contact, the instrument and the dental work, and this potential is in a liquid environment with plenty of ions in solution. That is the perfect recipe for a small current.

2) Some people will test a small 9-volt battery to see if it is still usable by touching the terminal end of it to their tongue (not a wise practice, by the way). Why doesn't it work just as well to lay a finger across the two terminals?
The surface of a finger is often very dry, and therefore no current can be supported.

3) Explain why care must be taken when serving food from sterling silver if the food is acidic?
Acidic foods provide the necessary ions in solution to support a current. Depending uon whatever other substances are present, especially sulfur, an environment allowing the silver to be oxidized and bond with another element is likely.

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4) Consider a galvanized iron pipe full of dirty water that may contain ions of other metals. The metal ions might have reduction potentials compared to that of the iron so that a voltaic cell is produced that would corrode the pipe. The presence of zinc may prevent the corrosion. On a table of reduction potentials, would you expect zinc to fall between iron and the other metal, or would zinc be located either above or below both iron and the other metal? Explain your reasoning.
In order for the zinc to react before the iron, it would have to lie between the iron and the other metal on the activity series. If it were to either side of the pair, it would not be able to "interfere" with the reaction.

5) In Procedure 7, the directions are to recover copper metal from copper solutions. Is this consistent with the principle of green chemistry: use of renewable feedstocks?
By recovering the copper, it could be saved and used in other applications rather than being discarded in a landfill or down the drain.

OXIDATION AND REDUCTION SAMPLE REPORT SHEET

I. VOLTAIC CELL VOLTAGE _____V *(Voltage depends on coins used.)*

INSTRUCTOR'S INITIALS _____

1. Would other coins work?
Yes, any two different metals.
2. Would pieces of metal work?
Yes, as long as the metals are different.
3. Would other ionic compounds like KBr work instead of NaCl?
As long as the ionic compound was a salt in the molten state or in solution, it would allow the current to pass. Crystalline salts would not.

II. ZINC, IODINE, CHLORINE

	Zinc/Iodine	Copper(II) Sulfate/Aluminum	Copper(II) Sulfate
Initial color	_____	_____	_____
Final color	_____	_____	_____

Color after addition of zinc/iodine _____

Color after addition of bleach _____

Color after addition of 1 M CH_3COOH _____
(if necessary)

1. Compare the aluminum foil pieces.
The foil turned dark, almost black.

2. Compare the beakers of copper(II) sulfate.
The beaker that was set aside is a darker color.

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3. Is zinc in the first solution? In what form?
   Yes. It was a solid, which became ions when it dissociated in solution.

4. In what form is the zinc when the purple color is gone from the solution?
   Zinc is in a solid form.

5. Does bleach change the zinc back to the metal?
   No, it changes into $Zn(OH)_2$, which puts Zn^{2+} ions into solution.

6. In what form is the chlorine after the purple color has disappeared from the solution?
   The chlorine is in the gaseous Cl_2 form.

III. COPPER AND ALUMINUM

1. What does the difference in color in the copper solution indicate?
   The copper in solution has been reduced to copper metal, which then attached to the aluminum. The solution becomes a lighter blue as the copper ions leave.

2. What happened to the aluminum foil?
   The copper attaches to it and replaces the aluminum ions, which leave and go into solution. Holes may appear in the foil if it is left too long.

3. In what form is the copper at the end of the investigation?
   The copper is solid.

4. Could copper be recycled by collecting it on aluminum foil?
   Yes.

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#26 Single Replacement Reactions

Reagents

1 M calcium nitrate [$Ca(NO_3)_2$]	1 mL/pair
1 M copper (II) nitrate [$Cu(NO_3)_2$]	1 mL/pair
1 M iron (II) nitrate [$Fe(NO_3)_2$]	1 mL/pair
1 M magnesium nitrate [$Mg(NO_3)_2$]	1 mL/pair
1 M tin (II) nitrate [$Sn(NO_3)_2$]	1 mL/pair
1 M zinc nitrate [$Zn(NO_3)_2$]	1 mL/pair
1 M hydrochloric acid [HCl]	1 mL/pair
calcium metal pieces, small	1/pair
copper metal wire, small	1/pair
iron metal pieces, small	1/pair
magnesium metal ribbon, small pieces	1/pair
tin metal pieces, small	1/pair
zinc metal pieces, small	1/pair

Common Materials

Special Equipment

test tubes, small	7/pair

Notes

This can be done with less solution in microtitration plates, if they are available.

This investigation works well in conjunction with the Double Replacement Reactions investigation. Begin the double replacement lab after the "5-minute" check.

Disposal

With the exception of zinc, any solid metals remaining should be removed from the solutions and deposited into a trash bin. The zinc should be thoroughly dried before disposal. The solutions can be flushed down the drain with lots of water.

SINGLE REPLACEMENT REACTIONS PRE-LAB QUESTIONS

1) Platinum is a precious metal used in the finest jewelry. Where on the activity series would you expect to find it? Explain your reasoning.
Coins and jewelry are made from metals that undergo very little corrosion so that they retain their value. Therefore, we would expect to find platinum at the lowest portion of the table.

2) Sodium metal is near the top of the activity series and therefore reacts easily with moisture in the air, oxygen, and weak acids. Devise a storage method for elemental sodium.
Any method that would be effective in isolating the metal from air and moisture should be accepted as an appropriate answer. Vacuum packaging and storing under a hydrocarbon such as kerosene are common methods.

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3) Use the activity series in your textbook to predict which of the following combinations will result in a reaction. Write "yes" or "no" in the blank before each combination.
__*no*__ a) metallic iron in a solution of lithium nitrate
__*yes*__ b) metallic zinc in a solution of copper sulfate
__*yes*__ c) metallic strontium in a solution of nickel chloride

4) Which of the following two combinations would you expect to produce the fastest reaction?
_____ a) Chromium and cadmium nitrate
__*X*__ b) Barium and lead (II) nitrate

5) One of the principles of green chemistry is less hazardous chemical syntheses. How might knowledge of the activity series relate to this principle?
If a chemist needs to produce ions of a specific metal in solution, he can choose a metal from the activity series that will accomplish the task, but that is inexpensive and nonhazardous. Likewise, the activity series could be used to determine how best to recover an expensive metal from a solution.

SINGLE REPLACEMENT REACTIONS SAMPLE REPORT SHEET

I. REACTION TIMES AND CHANGES OBSERVED
First METAL Assigned: Fe

Time	HCl	$Zn(NO_3)_2$	$Fe(NO_3)_3$	$Ca(NO_3)_2$	$Mg(NO_3)_2$	$Sn(NO_3)_2$	$Cu(NO_3)_2$
Within 5 minutes	*bubbles*						
30 minutes							
2^+ hours							*less blue in solution*
never		*X*	*X*	*X*	*X*	*X*	

Second METAL Assigned: Zn

Time	HCl	$Zn(NO_3)_2$	$Fe(NO_3)_3$	$Ca(NO_3)_2$	$Mg(NO_3)_2$	$Sn(NO_3)_2$	$Cu(NO_3)_2$
within 5 minutes	*bubbles*					*zinc turns dark*	*zinc turns dark*
30 minutes							
2^+ hours			*yellow tint*				
never		*X*		*X*	*X*		

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III. ACTIVITY SERIES DETERMINATION

	Zn/Zn^{2+}	Fe/Zn^{2+}	Ca/Zn^{2+}	Mg/Zn^{2+}	Sn/Zn^{2+}	Cu/Zn^{2+}
Time			*5 min*	*5 min*		
Points			*3*	*3*		
	Zn/Fe^{3+}	Fe/Fe^{3+}	Ca/Fe^{3+}	Mg/Fe^{3+}	Sn/Fe^{3+}	Cu/Fe^{3+}
Time	*2 hrs*		*5 min*	*30 min*		
Points	*1*		*3*	*2*		
	Zn/Ca^{2+}	Fe/Ca^{2+}	Ca/Ca^{2+}	Mg/Ca^{2+}	Sn/Ca^{2+}	Cu/Ca^{2+}
Time			*5 min*	*5 min*		
Points			*3*	*3*		
	Zn/Mg^{2+}	Fe/Mg^{2+}	Ca/Mg^{2+}	Mg/Mg^{2+}	Sn/Mg^{2+}	Cu/Mg^{2+}
Time			*5 min*			
Points			*3*			
	Zn/Sn^{2+}	Fe/Sn^{2+}	Ca/Sn^{2+}	Mg/Sn^{2+}	Sn/Sn^{2+}	Cu/Sn^{2+}
Time	*5 min*	*2 hrs*	*5 min*	*5 min*		
Points	*3*	*1*	*3*	*3*		
	Zn/Cu^{2+}	Fe/Cu^{2+}	Ca/Cu^{2+}	Mg/Cu^{2+}	Sn/Cu^{2+}	Cu/Cu^{2+}
Time	*5 min*	*5 min*	*5 min*	*5 min*		
Points	*3*	*3*	*3*	*3*		
	Zn/H^{+}	Fe/H^{+}	Ca/H^{+}	Mg/H^{+}	Sn/H^{+}	Cu/H^{+}
Time	*30 min*	*30 min*	*5 min*	*30 min*	*5 min*	
Points	*2*	*2*	*3*	*2*	*3*	
	Zn Total	Fe Total	Ca Total	Mg Total	Sn Total	Cu Total
Total Points	*9*	*6*	*21*	*16*	*3*	*0*

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IV. QUESTIONS

1. How useful would you say the activity series is for aiding chemists in knowing the probable outcome of a reaction involving two metals?
   It would be very useful to know which metal would react with which ion.

.

2. Write a balanced equation below for each of the reactions for the first metal you were assigned. (Give the reactants for each attempted reaction. For those in which nothing was visible, write "no reaction" following the yield sign.)
   $Fe(s) + 2\,H^{+} \rightarrow Fe^{2+} + H_2(g)$
   $Fe(s) + Cu^{2+} \rightarrow Fe^{2+} + Cu(s)$

3. List the metals we tested in order of activity, with the most active metal first and the least active metal last. (For example, the metal with the most points would be the most active and be placed at the beginning of the list.)
   calcium, magnesium, zinc, iron, tin, and copper

4. How well does this agree with the accepted activity series: calcium, magnesium, zinc, iron, tin, and copper?
   It does agree.

5. What factors could explain any discrepancies you find?
   Student may not notice the evidence of a reaction until it has been progressing for a while. The metal might have been coated with oil, dirt, and so on, which restricted a reaction.

6. According to the data for our class, where in the series would you place hydrogen?
   The acid reacted with all but copper. It belongs between tin and copper.

7. Magnesium and calcium are not expected to react with themselves, and yet there was a definite reaction. What was happening? Consider their position relative to hydrogen in the activity series.
   There was a slight reaction with water.

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#27 Silver Tarnish Removal

Reagents

sodium bicarbonate [$NaHCO_3$]	13 g/pair
thioacetamide [CH_3CSNH_2]	6.5 g/class
sodium chloride [NaCl]	13 g/pair

Common Materials

tarnished silver	1 piece/pair
aluminum foil	2 ft length/pair
bleach (sodium hypochlorite solution)	(for disposal only)
paper towels	
liquid soap	

Special Equipment

2000-mL beaker
forceps or tongs
hot plate

Notes

Jewelry, silverware, small salt and pepper shakers, and the like, generally give better results than silver coins because coins tend to have much more than simple tarnish on the surface. Removing the "goo" that accumulates in everyday use is difficult to do without also removing the tarnish by abrasion. (We have had good luck suggesting that our students bring something from home to clean.) Many times, flatware and jewelry can be found inexpensively at flea markets and used semester after semester.

Disposal

The thioacetamide will cause tarnish and should not be put into the water system. The thioacetamide solution should be added slowly to a solution of sodium hypochlorite (bleach). When the solution has cooled to room temperature, it can be flushed down the drain with plenty of water. The bleach solution should be in an excess of about 25%.

SILVER TARNISH REMOVAL PRE-LAB QUESTIONS

1) List foods that should not be served from silver serving dishes.
Foods that contain sulfur, for instance, eggs, meats, fish, poultry, and many leafy vegetables, will increase the likelihood of tarnishing on silver.

2) Silver stored in some plastics tend to tarnish quickly. What would you suspect is the reason?
Sulfur is present in many plastics.

3) How could silver be protected from tarnish in homes with gas-fueled furnaces and ranges?
The silver can be placed into sealed storage places or encased in fabrics that are treated to remove sulfur from the air before it reaches the silver. (This fabric is referred to as "silver cloth.")

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4) Some lotions and cosmetic products will cause silver to tarnish on contact. What is happening?
The products must contain sulfur that will react readily with the silver.

SILVER TARNISH REMOVAL SAMPLE REPORT SHEET

I. INSTRUCTOR'S INITIAL FOR CLEAN SILVER_____

II. QUESTIONS

1. Look at the aluminum foil. What happened to the sulfur?
The sulfur bonded to the aluminum instead of the silver. The aluminum becomes darkened and may become thin as it bonds to the sulfur.

2. Would this method be preferable to a paste polish if you wanted to remove the tarnish from the crevices of a very intricate piece of silver? (Removing the tarnish from the crevices of a very old piece devalues the piece in the eyes of antique collectors.)
This method would be preferable to a paste method because pastes use abrasives to remove the tarnish and thus remove silver along with the sulfur.

3. Why is it necessary for the silver and the aluminum to touch?
In order to allow an exchange of electrons, the two metals need to touch.

4. Is it necessary to be in a chemical laboratory to clean silver?
No, it is not necessary. This procedure can be done at home.

5. Silver cleaning kits are sold on TV and in stores that contain a large plate. The silver to be cleaned has to make contact with the plate. What material do you think is used to make the plate?
The plate is made of some type of metal, probably aluminum or zinc.

6. Why should this method not be used for silver with stones in it?
The stones could be loosened, they may react with the solutions, or glue could be dissolved.

7. Why would cleaning silver pieces by abrasion eventually cause the loss of detail in the pattern on the piece?
Abrasive methods remove the tarnish, which is silver sulfide. Therefore silver is removed.

8. Is causing silver ions to become silver atoms consistent with the principle of green chemistry, use of renewable feedstocks, as listed in Hill's text?
Yes. Ions exist primarily in solution, and changing them to the solid metal would allow the metal to be recovered and reused.

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#28 Organic Qual Scheme

Reagents

hexane [$CH_3(CH_2)_4CH_3$]	unknown
n-octene [$CH_2=CH(CH_2)_5CH_3$]	unknown
2-chloro,2-methyl propane [$CH_3C(Cl)(CH_3)CH_3$]	unknown
benzaldehyde [$C_6H_5C(O)H$]	unknown
resorcinol [$C_6H_4(OH)_2$]	unknown
acetic acid (conc.) [CH_3COOH]	unknown
ethanol [CH_3CH_2OH]	unknown
acetone [$CH_3C(O)CH_3$]	unknown
isobutylamine [$CH_3CH(CH_3)CH_2NH_2$]	unknown
pH paper	1 roll/pair
litmus, red and blue	several strips/pair
1% iron (III) chloride solution [$FeCl_3$]	2 mL/pair
cerric nitrate solution (4g in 10 mL 2M HNO_3)	2 mL/pair
acetone (as a test reagent) [CH_3COOH]	2 mL/pair
1% potassium permanganate [$KMnO_4$]	2 mL/pair
copper wire (1 cm lengths)	3/pair

Common Materials

food coloring	1-2 drops/pair
paper towels	

Laboratory Equipment

watch glass
small test tubes
stirring rod

Special Equipment

waste container marked “organics and water”

Notes

Hexane, n-octene, and 2-chloro, 2-methyl propane are chosen because they are large enough molecules as to give a definitively negative solubility test. This makes the determination easier. Likewise, propionaldehyde, resorcinol, acetic acid, ethanol, acetone, and isobutylamine were chosen because they are small enough to give a very definite positive solubility test. At this level of instruction, it is advisable to keep the tests as easily identifiable as possible. (Note that 2,3 dimethyl phenol does NOT work for an easy phenol identification.)

pH paper may lead to errors for neutral substances as students may interpret the value as 6 or 8.

Disposal

All solutions should be sealed in a waste container marked “organics and water.”

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ORGANIC QUAL SCHEME PRE-LAB QUESTIONS

1) In identifying an unknown organic compound, determining the class to which it belongs is only the first procedure. What else would need to be known in order to identify the compound specifically?
The molar mass of the molecule.

2) Only tiny amounts of an unknown are required for each test. Why is this advantageous?
In a real-world situation, a sample brought to a lab for testing may be very small.

3) How does using a small amount for each test make the principle of green chemistry, prevention, better to prevent waste, as listed in Hill's text?
The smaller the amount of material used for a test, the less that must be disposed of later.

4) If you knew that a compound of the alcohol class was toxic to living cells and made a good antiseptic, could you suspect this to be true of other alcohols as well? Explain.
Yes. It is the functional group in common with all the other substances of a class that imparts the particular physical and chemical properties that characterize the class of organic compounds.

ORGANIC QUAL SCHEME SAMPLE REPORT SHEET

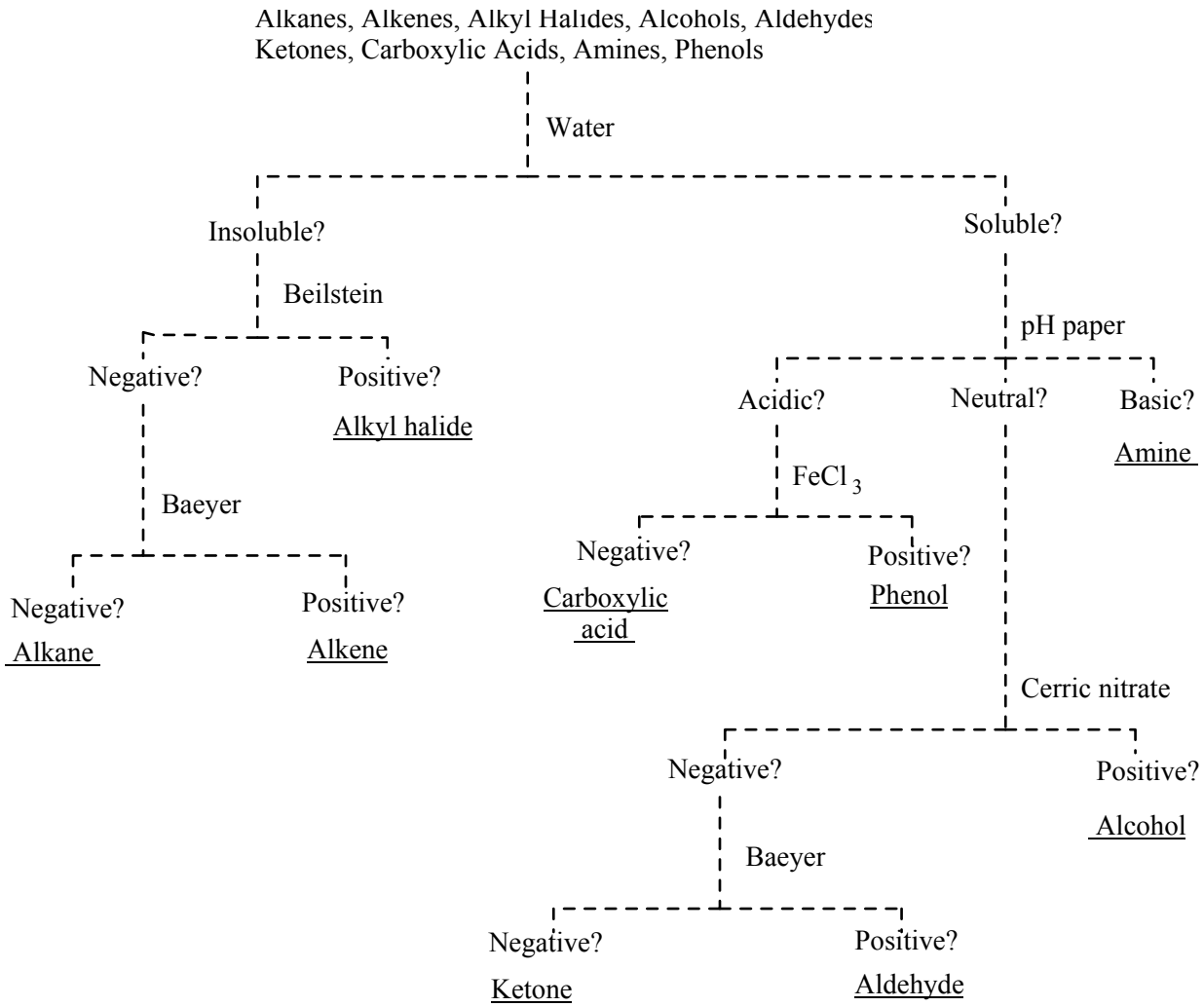
OBSERVATIONS

Water solubility
Two layers form with insoluble substances.
pH
Answers will vary according to which substance is tested and the type of pH paper used.
$FeCl_3$
A positive result becomes tinted purple, while a negative result remains slightly yellow.
Cerric nitrate
A positive test changes to red, while a negative test remains yellow.
Baeyer
A positive test turns brown, while a negative test remains purple.
Beilstein
A negative test produces only a yellow or an orange tint to the flame, while a positive test gives the flame a greenish tint.

Trace the dotted lines according to your test results to find the classification of the unknown.

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I. Classification of the unknown *(student responses)*

#1 _____
#2 _____
#3 _____

II. QUESTIONS

1. Study the qual scheme and give an example of an incorrect determination that could be made by performing the tests out of order.
   If the Baeyer test was performed before the solubility test, one could incorrectly identify a ketone as an alkane or an aldehyde as an alkene.

2. List an application in which a qual scheme would be useful.
   Responses will vary but could include identifying contaminates in water, forensics, quality control.

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3. Many organic compounds have distinct odors. Why doesn't one simply sniff the unknown to make an identification?
   Many organic compounds are also toxic by inhalation or can cause damage to tissues and the brain.

4. Mark over the dotted lines with a dark line according to your test results to find the classification of the unknown. If more than one unknown was analyzed, use a different color for each unknown and provide a color key.

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#29 Synthesis of Esters

Reagents

salicylic acid [$C_7H_6O_3$]	0.1 g/pair
methanol [CH_3OH]	2 mL/pair
6M sulfuric acid [H_2SO_4]	1 mL/pair
acetic acid, concentrated [CH_3COOH]	2 mL/pair
n-octanol [$CH_3(CH_2)_7OH$]	0.5 mL/pair
n-pentanol [$CH_3(CH_2)_4OH$] (n-amyl alcohol)	1 mL/pair
ethanol [CH_3CH_2OH]	1 mL/pair
butyric acid [$CH_3(CH_2)_2COOH$]	1 mL/pair
benzyl alcohol [$C_6H_5CH_2OH$]	2 mL/pair
propanoic acid [CH_3CH_2COOH]	0.5 mL/pair
isobutyl alcohol (2-methyl propanol) [$CH_3CH(CH_3)CH_2OH$]	1 mL/pair
formic acid [HCOOH]	1 mL/pair

Laboratory Equipment

250-mL beaker
6 small test tubes
test tube holder
hot plate

Notes

If the butyric acid stays in the hood and is capped, the smell should not become overbearing.

Disposal

Esters are organic substances that will contaminate waterways if they are flushed down the drain. Each bottle of ester can be left open in a hood to evaporate. Although the students should not be given the idea of putting chemicals into the air, the alternative disposal methods are to incinerate the esters or bury them in a toxic waste site.

SYNTHESIS OF ESTERS PRE-LAB QUESTIONS

1) Since we know that esters are produced from an alcohol and a carboxylic acid, would it be worth the time and expense for chemists to simply try every possible combination in an to attempt to discover new scents and flavors? Support your opinion.
Many people consider the number of potential organic compounds to be limitless, for all practical purposes. It would probably not be worth the time and expense since all the recognizable scents and flavors are generally found in nature. Humans might not find unnatural flavors or scents pleasurable.

2) Any chemical process involves side reactions and a bit of unreacted reagent. Why should you not taste or use any of the ester you will produce in this lab?
It has not been purified to remove products from side reactions or unreacted substances.

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3) How would the purity of the esters synthesized in this experiment compare with commercial products?
The esters would not be as pure as commercially synthesized compounds that are purified multiple times to ensure a minimal amount of impurity in the finished product.

4) Vanilla flavoring is a combination of several compounds isolated in nature from the vanilla bean. However, only two of the compounds make up the largest percentage of the mixture, and together those two compounds give the familiar flavor we know. Pure vanilla extract is quite expensive, but imitation vanilla, which contains the two major compounds synthesized in a lab, is not. List the advantages and disadvantages for the use of the pure extract.
Artificial vanilla is an advantage because it is much less expensive than the vanilla isolated from the vanilla bean, but the flavor is not as "full" because it does not contain the great variety of compounds found in natural vanilla.

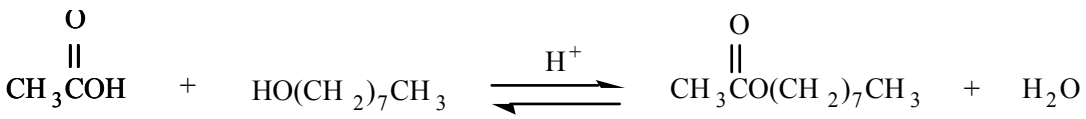
5) Many pharmaceuticals are synthesized copies of compounds found in nature. There is not enough of the natural substance to fill the needs of the world's population, and even if there were, the cost of isolating it from all the other things that come with it is exorbitant. Why do you think that the widespread and inexpensive availability of things such as aspirin and insulin is a relatively recent phenomenon?
Until scientists had the knowledge and the technology to analyze a compound to determine its composition and then the ability to synthesize that molecule, large amounts of natural compounds were not able to be isolated without great time and expense.

6) This experiment uses a reaction that requires an excess of alcohol to force all of the carboxylic acid to be reacted. How does this relate to the principle of green chemistry, prevention (the leftover carboxylic acid would be waste), as listed in Hill's text?
The alcohol is the less expensive of the two compounds required for the reaction. Also, the extra alcohol evaporates and is not a problem in the environment. Therefore it is prudent to make certain that all of the acid is consumed in the reaction.

SYNTHESIS OF ESTERS SAMPLE REPORT SHEET

I. For each compound write a complete reaction equation showing the removal of the atoms that become the water molecule. Give observations of aromas and appearance. (One example is included in item 2.)

1. methyl salicylate -"oil of wintergreen"—*appearance is crystalline, odor is reminiscent of medicine, minty.*
2. octyl acetate—"orange peelings"—*the liquid is clear, coconut smell.*



3. n-amyl acetate—"banana oil"—*clear liquid, banana extract*
4. benzyl acetate—"jasmine"—*flowery odor*

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5. ethyl propionate—"rum"—*clear liquid, alcohol smell*
6. isobutyl formate—"raspberry"—*raspberry odor*
7. methyl butyrate—"apple"—*apple smell*
8. ethyl butyrate -"pineapple"—*pineapple extract*
9. benzyl butyrate—"cherry"—*thick white liquid, artificial cherry smell*

II. QUESTIONS:

1. What are the physiological properties (effects on humans) of these esters? This information can be found in a Merck Index or online.
   Esters are poisonous to humans. They can cause headaches, nausea, and dizziness in large quantities. However, the amount used in food flavorings is very small because of the potency of the molecules.

2. Is it valid to be concerned about "synthetic" flavorings in food? Explain.
   No, the synthetic molecules are identical to the molecules found in nature.

3. List several common materials or products that contain esters.
   cosmetics, household products, cleaners, foods, soaps, perfumes, air fresheners

4. How would the use of esters change if they were not volatile?
   If esters were not volatile, they would not evaporate; hence there would be no smell, and they would only be useful in foods as flavorings. (However, even flavor is, to a large extent, due to the sense of smell.)

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#30 Polymers

Reagents

hexamethylenediamine [$H_2N(CH_2)_6NH_2$]	1.5 g/pair
sodium hydroxide pellets [NaOH]	0.5 g/pair
phenolphthalein (or food coloring)	1 mL/pair
sebacoyl chloride [$ClCO(CH_2)_8COCl$]	1 mL/pair
hexane [C_6H_{14}]	25 mL/pair
phthalic anhydride	8 g/pair
sodium acetate	0.3 g/pair
glycerol (glycerine)	2 mL/pair
ethylene glycol	1 mL/pair
sulfuric acid 18 M (for disposal)	50 mL
Parafilm™	as needed
distilled water	

Common Materials

large metal paper clips	1/pair
aluminum foil (tear 4-in. strips from roll and halve)	1 4" × 4" piece/pair
food coloring (or phenolphthalein)	
ruler (cm — to measure beaker)	

Laboratory Equipment

- 2 watch glasses
- ring stand
- laboratory burner
- 2 utility clamps
- tweezers or forceps
- 150-mL beaker
- 50-mL beaker
- large beaker (400- or 600-mL)

Special Equipment

disposable test tubes	1/pair

Notes

Disposal

Hexamethylene diamine, sebacoyl chloride, and hexane are all irritating to humans. Ethylene glycol is toxic. It would not be good to place any of these in the water system.
The solid polymers and foil can be thrown into the trash. When all of the polyester has dissolved, the sulfuric acid in the test tubes can be flushed down the drain with lots of water. Hopefully, the nylon reactants will be used up. If not, mix the remaining reactants together to form a ball of nylon that can be thrown into the trash.

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POLYMERS PRE-LAB QUESTIONS

1) Study the structural reaction equations for the production of the two polyester polymers. Are the polymer products homopolymers or copolymers?
Both polyesters are copolymers.

2) What structural difference do you see in the molecules of the two polyesters? How might the structure alter the viscosity, mechanically?
The polyester formed with the glyptal is more three dimensional, and the molecules would have more opportunity to "hang up" on each other. This could increase the viscosity.

3) Is the nylon a homopolymer or a copolymer?
The nylon is a copolymer.

4) Which reactions are condensation reactions, and which are addition reactions?
The polyester reaction is a condensation polymerization reaction because one H_2O molecule is produced for every linkage made in the chain. The nylon reaction is a condensation polymerization reaction because a HCl molecule is produced.

5) Which of addition or condensation polymerization is more in tune with the principle of green chemistry of atom economy as listed in Hill's text?
In addition polymerization, no atoms are released as by-products of the reaction.

POLYMERS SAMPLE REPORT SHEET

I. INSTRUCTOR'S INITIALS
LINEAR: _____ GLYPTAL: _____ NYLON: _____

II. ROPE LENGTH
Circumference of large beaker _____cm *($C = \pi \times diameter$)*
Number of turns of beaker _____
Rope length = circumference × turns = _____cm × _____
Rope length = _____cm

III. QUESTIONS
1. Which of the polyesters is more viscous?
The glyptal is more viscous; it is thicker and flows less than the linear polymer.

2. Did the difference in viscosity fit your prediction based on the structures of the molecules?
The structure of the glyptal causes it to be more brittle because it is cross-linked.

3. Is either polyester brittle?
They may both be brittle, but the glyptal should be more brittle.

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4. Describe the properties of the nylon rope.
   It is slimy feeling and fibrous. When it dries, it is fragile and crumbly.

5. Did you find that the strength and brittleness of the nylon rope changed as it dried? Support your answer with your observations and hypotheses.
   As the nylon rope dried, it became fibrous and very brittle. This could be caused by the increased amount of linking that occurs as the fluid portion evaporates.

6. Why was the experimental procedure designed so that there were only small amounts of the excess reactants remaining?
   Hexamethylenediamine and sebacoyl chloride are irritating to the eyes, skin, and respiratory system. These chemicals can also damage the water system; so if they are not used completely, they can cause bodily or environmental harm.

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#31 Polymer Properties

Reagents	
acetone	10 mL/pair
polyvinyl alcohol	4 g/pair
Common Materials	
10-oz Styrofoam® cups	4/pair
paper clips	1/pair
4% Borax® (sodium borate) solution	50 mL/pair
8% Borax® (sodium borate) solution	35 mL/pair
Elmers Glue®	60 mL/pair
12-in. rulers (marked in cm)	1/pair
Laboratory Equipment	
100-mL graduated cylinder	
150-mL beaker	
stirring rod	
Special Equipment	
Acetone-resistant gloves	1 pair/student

Notes

The Borax® solutions required heating with constant stirring in order to get all of the solid dissolved. The liquid is clear when all of the borate is in solution.

Disposal

All acetone should be absorbed/evaporated. Other solutions can be poured down the drain with excess water.

POLYMER PROPERTIES PRE-LAB QUESTIONS

1) Styrofoam® is very brittle. What will you expect to find when you examine the hardness of styrene?
It will also be brittle and hard but much more dense.

2) The slime produced in steps 5–7 will continue to cross-link and exclude water molecules from its matrix until all the water is gone. What will you expect to happen to the elasticity of the slime with time?
As the moisture is excluded and the cross-linking increases, the slime should get denser.

3) As water leaves the glue and borate polymers produced in steps 8–11, they become less and less elastic until, eventually, they are solids. How will you store them if you want to keep them?
Storage in a sealed container should slow the evaporation of water from the polymers.

4) Why might a toy manufacturer be interested in polymer properties?
Many children's toys are bouncy, elastic, or very pliable. Depending on whether the manufacturer wants a soft, pliable toy for an infant or a hard, durable toy for an older child, the polymer properties are determined by the chemical makeup. The density and elasticity of a ball will determine what it is good for.

5) Many people visualize polymers being continually recycled to new products. How does this relate to the principle of green chemistry, use of renewable feedstocks, as listed in Hill's textbook?
If a polymer can be reused indefinitely through recycling, it will save the petroleum and other raw materials that are consumed to form it.

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POLYMER PROPERTIES SAMPLE REPORT SHEET

I. STYROFOAM® TO STYRENE

	Mass	Initial Volume	Final Volume	Sample Volume
Styrofoam	_____g	_____mL	_____mL	_____mL
Styrene	_____g	_____mL	_____mL	_____mL
Density	Styrofoam *.048* g/mL		Styrene *.92* g/mL	

II. BORATE POLYMERS

	I	II	III
Highest bounce	*14* cm	*20* cm	*22* cm

	Mass	Initial Volume	Final Volume	Sample Volume
I	_____g	_____mL	_____mL	_____mL
II	_____g	_____mL	_____mL	_____mL
III	_____g	_____mL	_____mL	_____mL

Density I *1.13* g/mL II *1.12* g/mL III *1.19* g/mL

Elasticity and resiliency observations *(Elasticity decreases as density increases.)*

I *Stretches easily if pulled slowly.*
II *Tears if pulled very far.*
III *Stretches slightly.*

Tensile strength observations *(Tensile strength increases with density of the polymer.)*

I *Tears when pulled quickly.*
II *Tears easily when pulled quickly.*
III *Pops apart when pulled quickly, but one must pull harder than for the other two.*

II. QUESTIONS

1. Why are the densities of styrene and Styrofoam® so different?
   The Styrofoam® is full of tiny air pockets that make it lightweight and an excellent insulator.

2. Which of the three borate polymers is the most dense?
   The one made with 8% Borax® and Elmer's Glue®.

3. Which of the three borate polymers has the most bounce?
   The one made with 8% Borax® and Elmer's Glue®.

4. Is there a relationship between density and bounce?
   Yes, the more dense polymer had the greater bounce properties.

5. Which of the three borate polymers is the most elastic?
   The one made with the polyvinyl alcohol.

6. Is there a relationship between resilience and bounce? How about the amount the ball deformed as it hit the surface?
   The more resilient the polymer is, the less it deforms, but the greater the bounce.

7. Which of the three borate polymers has the most tensile strength?
   The one made with the 8% Borax and Elmer's Glue.

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#32 Nuclear Radiation

Reagents

alpha source	1/pair
beta source	1/pair
gamma source	1/pair
lead sheet	1/pair

Common Materials

smoke detector	1 per lab
plain white paper	several sheets/pair
aluminum foil	1 sheet/pair

Special Equipment

Geiger counter	1/pair

Notes

For demonstration purposes, finding an older style lantern mantle with the pink center or a piece of old Fiestaware pottery in orange, will provide the opportunity to see that we have radiation around us in objects we use. (The glaze in the old orange Fiestaware is colored with uranium salts.) It can be found fairly easily at flea markets, and many dealers will give away broken pieces if they know they are to be used in education. Be sure the piece is not a reproduction.

Disposal

There are no reagents or products to be disposed of in this investigation.

NUCLEAR RADIATION PRELAB QUESTIONS

1) Which of the three types of radiation is the most penetrating?
The gamma ray is the hardest to stop.

2) A certain percent of all carbon in living systems is radioactive carbon-14. How does this relate to "background" radiation?
It is a contributing factor in all background measurements.

3) Is food served from older pieces of orange Fiestaware® radioactively contaminated? Would the food served on Fiestaware® emit anything that would register on a Geiger counter?
No, the food itself would have to contain radioactive isotopes to be radioactive. No activity would be measured from the food. In order for the dishes to be harmful to one's health, a piece of the glaze would have to be ingested.

4) There are many uses of radiation in medicine. Radioactive sources can be used to tag the activity in specific organs of the body for diagnostic studies. Radiation is often used for therapy to alter the course or rate of progression of certain diseases. Why then are we concerned with adding radiation sources to the environment or with increasing amounts of radiation that make it through our atmosphere?
Nuclear medicine employs radiation sources with very short half-lives, so that within a few days, there is no detectable increase over the normal level of radioactivity in the

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body. Environmental sources pose a different risk. Because the radiation sources are constantly present, the exposure is long term and therefore constitutes a greater risk overall.

5) Some building supplies like cement have been found to have radioactive materials as part of the building supply. How does this relate to the principle of green chemistry, designing safer chemicals, as listed in Hill's textbook?
Radioactive materials cannot be removed from the sand and clay that become a part of cement and bricks. They are a part of the background radiation that we live with. However, these materials have a very low level of radiation and pose no health threats.

NUCLEAR RADIATION SAMPLE REPORT SHEET

I. BACKGROUND RADIATION ___*57*__ counts/5 min = __*11.4*__ counts/min
** This will vary depending on geographical location, building construction, and counter sensitivity.*

II. DISTANCE FROM SOURCE
** This will vary depending on the strength of the sources but should decrease exponentially.*

	1 cm	2 cm	3 cm	4 cm	5 cm	6 cm	7 cm	8 cm	9 cm	10 cm
BETA	*17.6*	*16.2*	*15.2*	*14.6*	*14.0*	*13.3*	*12.5*	*(background)*	____	
GAMMA	*20.6*	*18.6*	*16.8*	*15.0*	*13.9*	*(background)*	____	____	____	

III. ALPHA *should be same as background count*

IV. BETA

no paper	1 sheet	2 sheets	Al foil
17.5	*17.0*	*15.2*	*(background)*

number of sheets required to match background level *4*

V. GAMMA

no paper	1 sheet	Al foil	lead
20.5	*20.2*	*19.2*	*9.6*

VI. SMOKE DETECTOR outside case *14.8* next to source *15.7*

VII. QUESTIONS

1. Would you be safe from an alpha, beta, or gamma radiation source if you were a mile away from the radiation source?
The alpha and beta radiation would pose no problem, but if the gamma ray was energetic enough, it could travel the distance. However, the "density" of the radiation at that distance makes it unlikely to be a problem.

2. Why are people not concerned about radiation sources in our homes such as luminous clock faces, smoke detectors, indicator lights on appliances (krypton-85), electric blankets (promethium-147), and fluorescent lights (thorium -229)?
The amount of radiation is small, and we are usually an adequate distance from the sources. These are low-energy sources, and they would have to be ingested to pose a problem.

3. What would be the problem with using a radioactive isotope that emitted a high-energy gamma rays in addition to the alpha particles in a smoke detector?
The high-energy gamma would escape the case and over time be a health risk to people near it.

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4. Why did manufacturers stop making luminescent watch hands with radium? (Radium emits high-energy gamma rays.)
   The radium is worn close to the body, and so the radiation can be readily absorbed.

5. If polonium is in tobacco, would being in the room with a smoker increase your radiation exposure?
   Yes, but only a small amount. The more second-hand smoke, the more radiation.

6. Describe how the Geiger counter is designed to allow a person to differentiate between beta and gamma rays.
   The tube on the Geiger counter has a thick metal covering that will shield beta radiation from entering the tube and being registered. Gamma radiation easily penetrates the metal covering. The covering can be rotated to shield or to allow beta radiation into the tube.

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#33 Radioactive Half-Life

Common Materials

pennies	160/pair
plastic container with a lid	1/pair
clear plastic storage bags with marbles (or stones)	3/pair

Notes

All materials used in this investigation can be saved and used for future labs.
Suggested ratios for marbles in each sample substance:
Meteor: 3 light colored (uranium): 1 dark colored (lead)
Charcoal: 3 light colored (C-14): 7 dark colored (N-14)
Wine: 1 clear (tritium): 3 colored (helium)

RADIOACTIVE HALF-LIFE PRELAB QUESTIONS

1. After three half-lives, what percentage of atoms has decayed?
   87.5% (50% + 25% + 12.5%)

2. Usually a radioactive substance is stored for 10 half-lives so that it is no longer a hazard to humans. How long would a uranium-238 sample need to be stored to equal 10 half-lives?
   4.5×10^{10} years or 45 billion years

3. If the wine is 50 years old, how many half-lives of tritium are represented by 50 years?
   4.07 half-lives

4. Usually, dating an object by measuring the radioactivity remaining in the object is valid for the range of one half-life to 10 half-lives. For less than one half-life, there is not enough difference in the number of isotope particles or the decay count-rate. After 10 half-lives, there is too little radioactivity left. What is the valid range for Uranium-238, in years?
   2.25 billion to 45 billion years

5. If charcoal can be dated, can soot on the ceiling of a cave be dated?
   Since soot is a form of charcoal, and if heat does not alter the half-life of carbon-14, then yes.

6. One of the overall objectives of the principles of green chemistry is to protect people from dangerous chemicals.

   a. Why is it important to know what chemicals are radioactive?
   The amount of radioactive particles and energy that emanate from a substance is important to its safety. Also important is the possible length of exposure and the distance a person will be from the source. All of these factors determine the potential danger.

   b. Why is it important to know how long radioactive materials should be stored to be safe?
   Radioactive substances that are produced as by-products of other reactions or that are removed from the Earth's crust need to be safely disposed. Half-life is the most important piece of information.

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RADIOACTIVE HALF-LIFE SAMPLE REPORT SHEET

PART A. HALF-LIFE PLOT

Number of Half-lives	Number of Heads Up Pennies			
	1	2	3	Average
Beginning	160	160	160	
One Half-life				
Two Half-lives				
Three Half-lives				
Four Half-lives				

PART B. AGE OF AN OBJECT

**NOTE: All data will vary according to the ratio of light and dark marbles in the simulated substances.*

I. Meteor

	Uranium	Lead	Total
Number of marbles			

$t_{½}$ = Uranium half-life = 4.5×10^9 yr

$$\lambda = \text{Decay constant} = \frac{0.693}{t_{1/2}} = \frac{0.693}{4.5\times10^9\ yr} = 1.5\times10^{-10}\ \text{yr}^{-1}$$

$$\ln\frac{\text{atoms uranium}}{\text{atoms initial}} = -\lambda t$$

atoms initial = # atoms of uranium + # atoms of lead

$$t = \frac{\ln -}{-1.5\times10^{-10}\ \text{yr}^{-1}} = \qquad \text{yr (age of meteor)}$$

II. Charcoal

	Carbon-14	Nitrogen-14	Total
Number of marbles			

Carbon-14 half-life: $t_{½}$ = 5730 yr

Decay constant: = λ = $0.693/t_{½} = 0.693/5730$ yr = 1.21×10^{-4} yr^{-1}

$$\ln\frac{\text{atoms carbon}-14}{\text{carbon initial}} = -\lambda t$$

carbon initial = # atoms of carbon + # atoms of nitrogen

$$t = \frac{\ln -}{-1.21\times10^{-4}\ \text{yr}^{-1}} = \qquad \text{yr (age of charcoal)}$$

$$\frac{\text{Age of charcoal} - \text{Current year}}{\text{Date volcano erupted}} \qquad \frac{-}{\qquad\qquad} \qquad (201?)\ \text{B.C.}$$

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III. Wine

	Tritium	Helium-3	Total
Number of marbles			

$$\text{Tritium } t_{½} = 12.3 \text{ yr}$$

$$\text{Decay constant: } \frac{0.693}{t_{1/2}} = \frac{0.693}{12.3\,\text{yr}} = 5.63\times10^{-2}\,\text{yr}^{-1}$$

$$\ln\frac{\text{atoms tritium}}{\text{atoms initial}} = -\lambda t$$

atoms initial = # atoms of tritium + # atoms of helium

$$t = \frac{\ln -}{-5.63\times10^{-2}\,\text{yr}^{-1}} = \qquad \text{yr (age of wine)}$$

C. QUESTIONS

1. Was your friend cheated? Is the wine 50 years old?

2. What other objects might be dated with carbon dating?
   bones, prehistoric animal droppings in cave dwellings, furniture or other wooden artifacts in tombs

3. What other objects might be dated with uranium-lead dating?
   rock structures

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#34 Salt on Ice

Reagents

isopropyl alcohol [C_3H_7OH]	125 mL/pair
sodium chloride [NaCl]	160 g/pair
calcium chloride [$CaCl_2$]	10 g/pair

Common Materials

ice	3000 mL/pair

Laboratory Equipment

1000-mL beaker
large test tube with a 1-hole stopper to fit
thermometer

Notes

Disposal

The solutions can be flushed down the drain with excess water.

SALT ON ICE PRE-LAB QUESTIONS

1) Salt produces ions when it dissolves in water. However, the ions also provide the means for faster rusting of most iron-containing substances. What are the implications of this practice for automobile owners in areas that have many days of freezing weather?
Salt placed on roadways is splattered upon the car, causing deterioration to paint and protective coatings, and certainly rust on any exposed iron or steel structures.

2) There are salts that would deliver more ions in solution than magnesium or calcium chloride. Aluminum sulfate would deliver five ions per formula unit, but the sulfate ion and the aluminum ion are both ions that could alter the pH of the water in the environment. What are some other effects that would have to be taken into consideration before choosing a random salt for the icy roads?
Placing metal ions into the environment can result in a variety of reactions. Many of the negative ions have undesirable properties including the ability to alter pH. Still other ions are toxic when they enter the food chain.

3) Can you think of a reason that people don't use calcium chloride or magnesium chloride in their ice cream freezers at home?
They are not as readily available, and they are more expensive.

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4) The salt that is used to melt ice on roads recrystallizes once the ice is melted and the water has evaporated. The trouble is that most if it is on the underside of cars or on the roadside, where all the slush was thrown by cars passing by. Think of an alternative to salt that would increase safety in cold weather but not spread foreign ions in the environment? Would it work as well for continual freezing rains?
Some liquids, including many alcohols, are effective in lowering the freezing point of water. The difficulty is in keeping them on the surface of the road. Smaller molecules of alcohol will evaporate into the atmosphere. As liquids are diluted, they become less useful so that continued freezing rain will not be affected by their presence. Sand is used in some locations to increase the friction of the ice, but it does not alter the amount of ice.

5) One of the principles of green chemistry is to design safer chemicals. Would that suggest that a chemical that caused no harm but caused ice to melt would be greener?
Not necessarily. The use of any substance that must be removed from the Earth's crust and refined in a laboratory where energy and other resources are required is not in keeping with green chemistry. As with everything, costs, effects, and potential benefits must be weighed in order to make an informed decision.

SALT ON ICE SAMPLE REPORT SHEET

I. *The following are sample data only:*

Salt Added	0 g. NaCl	10 g. NaCl	30 g. NaCl	50 g. NaCl	70 g. NaCl	10 g. $CaCl_2$
Original temperature	*22.3*	*22.3*	*21.8*	*21.5*	*22.0*	*20.3*
Temperature at: 1 min.	*11.0*	*10.5*	*10.0*	*10.0*	*7.5*	*9.5*
2 min.	*9.0*	*5.0*	*4.0*	*0.5*	*–1.5*	*3.5*
5 min.	*2.1*	*1.8*	*–0.5*	*–3.5*	*–4.0*	*1.0*
10 min.	*1.8*	*0.8*	*–2.0*	*–4.0*	*-5.5*	*2.0*
Final difference in temperature	*20.5*	*21.5*	*23.8*	*25.5*	*27.5*	*78.3*
Initial mass of beaker + ice	*569.3*	*533.2*	*594.8*	*576.4*	*597.7*	*588.9*
Minus mass of beaker	*289.1*	*289.1*	*289.1*	*289.1*	*289.1*	*289.1*
Initial mass of ice	*288.2*	*244.1*	*305.7*	*287.3*	*308.6*	*299.8*
Final mass of beaker and ice	*393.4*	*353.8*	*450.3*	*394.9*	*361.1*	*391.5*
Minus mass of beaker	*289.1*	*289.1*	*289.1*	*289.1*	*289.1*	*289.1*
Final mass of ice	*113.3*	*64.7*	*161.2*	*105.8*	*72.0*	*102.4*
% ice melted =100% x $\frac{\text{initial mass – final mass}}{\text{initial mass}}$	*59.6*	*73.5*	*47.3*	*63.2*	*76.7*	*65.8*

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II. QUESTIONS

1. Is there a difference in the rate of cooling for the different amounts of salt?
   Yes, the rate increased with the amount of salt added.

2. Was there a difference in the amount of frost produced on the outside of the large beaker?
   Yes, faster cooling produced more frost.

3. Is it possible for the surroundings to be so cold that salt will not cause the ice to melt?
   Yes, the surroundings could be colder than the lowered freezing point of the water.

4. Which amount of salt caused the most ice to melt?
   70 g NaCl

5. Which amount of salt caused the lowest temperature?
   70 g NaCl

6. Is it possible to add more salt than is needed?
   Yes

7. Which melted ice faster, NaCl or $CaCl_2$? Why?
   $CaCl_2$ because each molecule produces 3 ions in solution while NaCl produces only 2.

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#35 **Copper Cycle**

Reagents

clean copper turnings or wire	0.500 g/pair
red and blue litmus paper	1 strip/pair
nitric acid, concentrated [HNO_3]	5 mL/pair
8.0 M sodium hydroxide [NaOH]	10 mL/pair
6.0 M hydrochloric acid [HCl]	10 mL/pair
zinc, mossy	1 gram/pair
distilled water	

Common Materials

Special Equipment

9.0-mm Buchner funnel with filter flask and safety flask	1/pair
filter paper circles to fit Buchner funnel	2 pieces/pair
analytical balance	1/4 pair
forceps	1/pair
dropper	1/pair

Laboratory Equipment

150-mL beaker
250-mL beaker
hot plate
10-mL graduated cylinder

Notes:

Aluminum wire also works well in place of the zinc in the last part of the procedure. A wire is sometimes easier to remove once all the color has left the solution.

Disposal

Leftover zinc, solid copper, and filter papers should be deposited in the trash. All other fluids may be rinsed down the drain with excess water. Unused acids and bases should be neutralized and rinsed down the drain with excess water.

COPPER CYCLE PRE-LAB QUESTIONS

1) In what instances would continued mining of a metal be preferable to recycling processes?
When recycling is more expensive, or more importantly, more unfriendly to the environment, mining would be preferable.

2) List one or two metals that would not be readily available for recycling programs because of the general manner in which they are used. Are these metals occasionally found in their pure form in nature? Are they relatively expensive or inexpensive metals?
Silver, gold, and platinum are metals used in jewelry and currency because they do not easily corrode. Such objects are not considered disposable; therefore these metals are not often available for major recycling operations.

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3) Would you expect metals on the upper or lower end of the activity series to be more easily recyclable? Explain your reasoning.
Metals that are least reactive will be the ones that are easiest to convert back to their pure, elemental state. Such metals are found at the lower end of the activity series and are often found in their pure form in nature.

4) When landfills are to be used for the disposal of water-soluble materials, what are the major environmental concerns?
Water-soluble compounds travel easily throughout the ecosystem in waterways, groundwater, the atmosphere, and animal and plant tissues. Anything placed into a landfill can potentially enter the general ecosystem.

5) Discuss the advantages and disadvantages of recycling efforts aimed at toxic metals.
Recycling toxic metals keeps them from being disposed of in landfills or in the open environment. However, the by-products of the recycling process will contain small amounts of the toxic elements, and these can get into the ecosystem. There are also other concerns in the recycling process, such as energy requirements and other chemicals that are necessary for the process.

6) How would you expect percent yield to be affected by increasing the number of reactions in a metal cycle? How would this most likely impact recycling processes?
The more separate reactions in a series, the greater chance of reducing the percent yield because of inefficient reactions, incomplete reactions, and side reactions. This means that any recycling process will not be able to recover 10% of the atoms.

7) How does recycling copper relate to protecting the environment?
All of the copper metal that is recycled results in less copper that must be mined from the Earth's crust.

COPPER CYCLE SAMPLE REPORT SHEET

I. DATA AND OBSERVTIONS

PART A. PREPARATION OF COPPER (II) NITRATE

Mass of copper metal used *0.485* g

Maximum amount of copper that could possibly be recovered *0.485* g

Observations

As the nitric acid begins to react with the copper, the liquid turns from clear to yellow, to light green, and finally to dark blue-green. The container becomes very hot, and steam is visible. A brown-red gas is produced that is denser than air as evidenced by its tendency to remain in the bottom of the beaker.

Balanced equation

$Cu(s) + 4\ HNO_3\ (aq) \rightarrow 2\ NO_2\ (g) + Cu(NO_3)_2\ (aq) + 2\ H_2O\ (l)$

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PART B. PREPARATION OF COPPER (II) HYDROXIDE

Observations

When the water is added, the solution goes from dark blue-green to a lighter blue color. As the NaOH is added, a deep blue gel immediately forms. The reaction is slightly exothermic. The gel clumps and falls to the bottom of the beaker. The supernatant liquid gradually loses its blue tint.

Balanced equation

$Cu(NO_3)_2\,(aq) + 2\,NaOH\,(aq) \rightarrow Cu(OH)_2(s) + 2\,NaNO_3(aq)$

PART C. PREPARATION OF COPPER (II) OXIDE

Observations

As the blue $Cu(OH)_2$ warms, the outside margin begins to turn brown and then black. With continued heating, the black spreads toward the center, and eventually the entire precipitate is black. The CuO is a fine powder when stirred.

Balanced equation

$Cu(OH)_2\,(s) \rightarrow (s) + H_2O(l) + CuO\,(s)$

PART D. PREPARATION OF COPPER (II) CHLORIDE

Observations

As the hydrochloric acid is dribbled over the black solid, it slowly appears to disintegrate as the liquid turns a yellow-green tint. Repeated applications of the liquid are required to convert all of the black solid to a dissolved compound in solution. As the product solution is diluted, the color changes from yellow-green to a light aqua tint.

Balanced equation

$CuO\,(s) + 2\,HCl\,(aq) \rightarrow CuCl_2\,(aq) + H_2O\,(l)$

PART E. PREPARATION OF COPPER METAL

Observations

Very shortly after the metal is introduced to the aqua solution, the surface darkens and bubbles are seen. The reaction accelerates and becomes quite exothermic. A rust-colored feathery/flaky solid is seen to form on the metal and can be dislodged by agitation. The color slowly fades from the solution until no more solid is deposited. After filtration, the solid is found to be powdery.

Balanced equation

$CuCl_2\,(aq) + Zn\,(s) \rightarrow Cu\,(s) + ZnCl_2\,(aq)$

$Zn\,(s) + 2\,HCl\,(aq) \rightarrow ZnCl_2\,(aq) + H_2\,(g)$

Amount of copper recovered: *0.479* g

Percent yield of copper recovered *98.7* %

II. QUESTIONS

1) If a student begins with 1.8 g of copper metal and has a 67% return for the laboratory procedure, what mass of copper is present after drying?

   x/1.8 = .67 x = 1.2 g

2) Thinking of the implications in this procedure for the recycling of copper metals—

   a. What might be some drawbacks to recycling processes?
   Cost of reagents, cost of disposing by-products, energy costs, environmental pollutants generated in the process, and the like, are all things to be considered.

   b. What advantages are there to recycling copper?
   Copper is not a renewable resource, and it is wise to keep it in use.

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c. What environmental concerns come into question with the procedure?
By-products must be disposed of, heat is necessary and must be produced for some of the reactions, and the requirements for creating many of the reagents needed in the process may not be environmentally friendly.

d. When would recycling not be the best way to deal with waste metals?
If the recycling process is more harmful to the environment than the mining and purification processes, it would not be a prudent practice. The exception is when we run short of a particular metal and recycling becomes the only alternative.

3) If a student begins with 0.85 g of copper metal and expects 98% return, what is the minimum mass of zinc metal he should place into the final reaction mixture?
0.85g Cu (1 mol Cu/63.55 g Cu) (1 mol Zn/1 mol Cu) (65.41 g Zn/1 mol Zn) (100%/98%) = 0.89 g Zn

4) A student gets a return of 100.5%. Give as many plausible explanations as you can think of for the obvious error.
The copper may still have a moisture content, adding mass. The copper may contain pieces of zinc. The student may have forgotten to subtract the mass of the weighing paper.

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#36 O_2 and CO_2 in Breath and Air

Reagents

calcium hydroxide solution, saturated [$Ca(OH)_2$]	1500 mL/pair

Common Materials

small birthday candles	1/pair

Special Equipment

100-mL Erlenmeyer flask	1/pair
2-hole stopper to fit the Erlenmeyer flask	1/pair
medium 1-hole rubber stopper (#5 or #6)	1/pair
wax pencils	1/4 students
hose clamps	2/pair

Laboratory Equipment

3 lengths of tubing
2 1000-mL beakers
250-mL beaker
100-mL graduated cylinder
funnel

Notes

Exhaled breath is generally 79.4% nitrogen, 16.7% oxygen, and 3.8% carbon dioxide. The hose assembly should be assembled beforehand.

Disposal

The solutions can be decanted off the settled solid and flushed down the drain with plenty of water. The solids can be thrown in the trash.

O_2 AND CO_2 IN BREATH AND AIR PRE-LAB QUESTIONS

1) If we exhale mostly carbon dioxide, why does a person doing CPR blow into the mouth of an accident victim?
There is still some oxygen in exhaled breath. Our lungs only remove a portion of the oxygen in the air while it remains in our lungs.

2) Carbonic acid is carbon dioxide in water. What common foods contain carbonic acid?
Many beverages contain carbonic acid as a result of the carbon dioxide dissolved in them. Carbonated beverages include sodas and sparkling juices.

3) Does the fact that fish live in water prove that oxygen dissolves in water?
Yes, as members of the animal kingdom, fish require oxygen for survival, and it must be absorbed from the water.

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4) One of the principles of green chemistry is to design less hazardous chemical syntheses. Is it important to know what gases are in the air when doing chemical syntheses?
Any reaction that occurs in an open container will be subject to side reactions with any or all of the gases present in the air. Knowing the potential by-products would be important to controlling them.

O_2 AND CO_2 IN BREATH AND AIR SAMPLE REPORT SHEET

The following is sample data.

PART A. O_2 IN AIR

250-mL beaker volume	*274.5* mL		Procedure 14
minus final volume	- *186.5* mL		Procedure 14
volume O_2 in air	*88.0* mL		

% O_2 in air = $\frac{O_2 \text{ volume} \times 100\%}{\text{beaker volume}} = \frac{88.0 \text{ mL} \times 100\%}{900 \text{ mL}} = 9.8\ \%$

PART B. CO_2 IN BREATH

volume of displaced H_2O	*121.0* mL		Procedure 11
volume through $Ca(OH)_2$	- *115.0* mL		Procedure 12
volume CO_2 in breath	*6.0* mL		

% CO_2 in air = $\frac{CO_2 \text{ volume} \times 100\%}{\text{volume of displaced } H_2O} = \frac{6 \text{ mL} \times 100\%}{12 \text{ mL}} = 50\ \%$

PART C. O_2 IN BREATH

unlighted candle volume	_____ mL		Procedure 15
lighted candle volume	- _____ mL		Procedure 16
volume O_2 in breath	_____ mL		

% O_2 in breath = $\frac{O_2 \text{ volume} \times 100\%}{\text{volume of displaced } H_2O} = \frac{\text{mL} \times 100\%}{\text{mL}} = \text{_____}\%$

IV. QUESTIONS

1. What would be the effect on your results if the CO_2 did not come in contact with the $Ca(OH)_2$ solution?
The reaction would not occur.

2. What difference would you find if you pumped air from an air compressor instead of blowing air from your lungs in order to saturate the water?
The compressor air would not saturate the water quickly because the CO_2 content in regular air pumped by the compressor is low compared to that from the lungs.

3. What difference would you find if you pumped air from an air compressor instead of blowing air from your lungs in filling the flask?
Air from a compressor is taken from the atmosphere and has different composition than air from lungs. It has much less CO_2 and much more O_2.

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4. If you used a compound other than calcium hydroxide, what would be the necessary requirement for that compound?
   A compound that could produce a solid with CO_2, acid, and water would be necessary. It would need to form an insoluble salt of carbonate.

5. What would be the difference if calcium hydroxide were not a base?
   Since it would be acidic or neutral, the CO_2 gas would not be produced.

6. Would CPR work if your breath had no oxygen in it?
   No, our lungs do not remove all of the oxygen from the air we breathe before it is exhaled. If they did, we would not be able to deliver oxygen to a victim.

7. How does this investigation relate to buffers in the blood and the optimum pH of blood?
   One of the most important buffers in the human body is the carbonic acid/bicarbonate ion buffer. Blood gas levels are directly related to lung function.

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