Appendix A

MATERIALS

CONTENTS OF MATERIALS KIT

- 1 video, "Hazardous Materials/Waste Disposal"
- 1 500-mL barrel
- 1 scoop
- 1 240-mL bottle containing iron (III) nitrate crystals
- 2 480-mL bottles of mineral oil
- 1 packet of 240 aluminum washers
- 1 packet of 240 iron washers
- 1 vial containing black and beige high density polyethylene squares
- 2 copper wires
- 8 30-mL dropper bottles of Liquid A (3% hydrogen peroxide)
- 8 30-mL dropper bottles of Liquid B (50,000 ppm copper chloride)
- 8 30-mL dropper bottles of Liquid C (0.1 M hydrochloric acid)
- 8 30-mL dropper bottles of 5% ammonia
- 2 vials of pH paper (orange)
- 8 pH color charts
- 2 packages of potassium iodide paper (white)
- 50 plastic cups (9 oz)
- 40 lids for plastic cups
- 16 narrow-mouthed 140-mL graduated cups (to serve as a base for the funnel)
- 8 funnels
- 8 metal screens
- 16 droppers
- 16 pairs of forceps
- 16 30-mL graduated cups
- 16 plastic spoons
- 16 plastic vials with lids
- 8 magnets
- 8 30-mL dropper bottles of ethanol
- 1 60-mL refill bottle of ethanol
- 8 30-mL dropper bottles of water (shipped empty)
- 8 60-mL dropper bottles of methanol
- 8 30-mL dropper bottles of potassium thiocyanate (0.1 M solution)
- 40 effervescent tablets
- 16 stir sticks
- 1 set of Material Safety Data Sheets

ITEMS NOT SUPPLIED IN THE KIT

(denoted with an * in the Materials lists in the Teacher's Guide)

- 16 SEPUP trays
- 16 pairs of safety goggles
- 1 overhead projector
- 1 videocassette recorder
- 1 TV monitor
- 1 graduated beaker
- matches
- masking tape (optional)
- paper towels
- 16 calculators
- 32 sheets of graph paper (optional)
- 16 rulers (optional)
- 16 computers with graphing software (optional)

MATERIAL REPLENISHMENT

Replacements for any kit item, including those items listed below, can be purchased from Lab-Aids. The following information is for your use if you want to prepare your own replacement solutions or obtain items locally. Use appropriate caution if you prepare the solutions yourself.

Each recipe will produce enough solution to refill eight 30-mL bottles.

Teachers should wear safety goggles and a face shield as well as a lab apron and plastic or rubber gloves when handling acids with a concentration greater than 1 mole. Students should not be allowed to handle or assist in the preparation of corrosive solutions, such as acids or bases greater than 1 molar concentration.

If acid or another chemical is splashed into the eyes, it should be flushed out immediately. Flush the eyes at an eyewash fountain that meets the specifications of the American National Standard for Emergency Eyewash and Shower Equipment, ANSI Z358.1-1990 (or later edition) for at least 15 minutes. While flushing, hold the eyelids away from the eyeball and instruct the victim to continuously move his or her eyes up, down, left, and right so as to permit the flowing water to flush out the space around and behind the eyeball. Meanwhile, call a local physician to determine whether further treatment is necessary.

Chemicals splashed on skin should be flushed off with copious running water for at least 15 minutes. If reddening or blistering appears, take the victim to a physician as soon as possible.

Chemicals that have splashed on clothing but that have not yet penetrated fabric through to the skin should be treated by rinsing the fabric free of the chemical with water. If it is necessary to remove the clothing to conduct the rinsing, do so promptly. Wearing a lab apron is recommended to avoid chemical spills on clothing.

Ammonia, 5% (household ammonia)

Use clear, nondetergent ammonia from the grocery store.

Ethanol

Use reagent-grade ethanol.

Iron (III) nitrate solution

Dissolve 36 grams of $Fe(NO_3)_3 \cdot 9H_2O$ in 1 liter of distilled water for a 5,000 ppm iron nitrate solution.

Liquid A (3% hydrogen peroxide)

Use household hydrogen peroxide (H_2O_2), which typically has a concentration of 3%.

Liquid B (50,000 ppm copper chloride)

Dissolve 33.5 grams of $CuCl_2 \cdot 2H_2O$ in 250 mL of distilled water.

Liquid C (0.1 M hydrochloric acid)

Dilute 1 part of 0.5 M HCl with 4 parts of water. Be sure to always pour acids slowly into water.

Methanol

Use reagent-grade methanol.

Mineral oil

Use commercially available mineral oil.

Potassium thiocyanate solution (0.1 M)

Dissolve 2.5 grams of potassium thiocyanate in 250 mL of water.

Water

Use tap water.

Appendix B

BACKGROUND

TOPICS

Chemical Reactions

Chemical and Physical Properties

Use of Potassium Iodide to Test for Oxygen

Testing Iron Nitrate

Flammability, Flash Point, and Flame Tests

Mixtures and Compounds

Department of Transportation (DOT) placards

Chemical Reactions

Chemical reactions are common occurrences that can be observed during everyday activities such as cooking, cleaning, and washing. However, chemical reactions cannot be observed at the molecular level. Indirect indicators are used to infer that they have taken place. For example, the appearance of a solid precipitate when copper chloride solution is mixed with ammonia is an indicator that a chemical reaction has occurred.

Evidence that a chemical reaction may be occurring includes the following:

- Temperature change
- Color change
- Formation of a new substance
- Emission of a gas
- Emission of light

The following familiar activities are all examples of chemical reactions:

- Burning fuel to heat homes
- Combustion of gasoline to power automobiles
- The human body using a reaction between food and oxygen to produce carbon dioxide and water, releasing energy
- Baking bread or making cookies
- Making a cement sidewalk
- Charcoal broiling a steak
- Coloring or "perming" hair

Chemical and Physical Properties

The physical properties of a substance include its phase (solid, liquid, or gas), color, odor, freezing point, and boiling point. These properties may be observed without changing the chemical composition of the substance. For example, when water freezes to form ice, it is still chemically water.

Chemical properties usually refer to how a substance interacts with specific other substances. For example, when wood burns, heat, water, carbon dioxide, light, and smoke are given off, and ash is left. There is more than just a change in appearance. The wood has reacted with oxygen in the air during burning.

Both physical and chemical properties can be used to identify a substance. However, chemical properties are often more useful than physical properties for this purpose. Consider two different white solids: sodium hydrogen carbonate (baking soda) and ammonium chloride. Even with the use of a hand magnifier, it is difficult to tell these two compounds apart. However, when vinegar is added to these solids, they can be more easily distinguished. Baking soda reacts with vinegar; the evidence of a chemical reaction is bubbling and the release of gas. Ammonium chloride does not react with vinegar. The difference in the reactions of these two substances with vinegar indicates that these substances are chemically different, though they may appear the same physically.

Use of Potassium Iodide to Test for Oxygen

The potassium iodide paper contains both potassium iodide and starch. When the paper is acidified with hydrochloric acid, any oxidizing agent capable of converting iodide ions to elemental iodine will cause the starch to react and change to a blue-black color. This is similar to placing a solution of iodine on a potato, which likewise turns the potato blue-black.

Testing Iron Nitrate

In Investigation 5, "Looking at Liquids," potassium thiocyanate is used in a simulated test for toxicity. The reaction between iron (found in the waste mixture) and thiocyanate ions produces a complex ion that is deep red in color.

$$Fe^{3+} + SCN^{1-} \text{ produces } FeSCN^{2+} \text{ (red)}$$

Adding hydrochloric acid to very dilute solutions inhibits side reactions with water, intensifying the color. This is a sensitive test that can detect iron ions down to 5 parts per million. Tests involving color changes can serve as quick and invaluable tools in the field for both identification and quantification of unknown materials.

The iron (III) nitrate solution that forms the orange-brown part of the simulated hazardous waste is acidic in water. Over time, it is capable of reacting with the iron washers, producing insoluble precipitates containing iron (II) ions. This lowers both the acidity and the oxidizing ability of the solution. As a result, after a few days, few iron (III) ions are available to produce the red complex ion. This is why it is essential to test the iron nitrate solution within a few days of preparing the simulated hazardous waste.

Flammability, Flash Point, and Flame Tests

There are degrees of flammability. Extremely flammable substances often produce vapors that ignite from the flame of a match; moderately flammable substances support combustion more easily if a wick is present; nonflammable substances do not burn under normal conditions. Extremely flammable substances often have a flash point, or a temperature at which sufficient vapors are present to cause a fire if a flame or spark is present. Handlers of hazardous materials are especially interested in knowing the flash points of flammable liquids that they encounter on the job. One of the tools used by the HAZMAT team shown in the video segment of Investigation 1, "What's in the Barrel?" provides information on the internal temperature of the barrel—useful information for the safe handling of potentially flammable substances.

A flame test is a method of identifying a substance. A flame test is typically conducted by placing a small amount of the substance to be tested on the end of a looped metal wire and holding the looped end in the center of a flame.

Mixtures and Compounds

All matter consists of chemicals which may be present either as pure substances (elements or compounds) or as mixtures. A mixture consists of two or more substances that are not combined chemically and are usually relatively easy to separate. Examples of common mixtures include seawater, concrete, soil, air, and fruit salad. Mixtures can often be separated by physical means, such as filtration and distillation. Forceps, magnets, sieves and filters, and even phase changes (evaporating or freezing to isolate parts of the mixture) are other means of physical separation. For example, saltwater, which is a mixture, can be separated by evaporating (or boiling) the water, leaving behind the salt.

Mixtures can be either heterogeneous or homogeneous. A heterogeneous mixture is one in which some or all of the components can be distinguished from other components. Sand and water or sand and salt mixtures are heterogeneous. A homogeneous mixture is one that appears the same throughout—the different components of the mixture are uniformly mixed and cannot be distinguished. Homogeneous mixtures are also known as solutions. Examples of solutions include tea and sugar dissolved in water.

Mixtures are often compared with compounds. A compound consists of two or more elements that are combined chemically and are often difficult to separate. A chemical reaction is needed to separate compounds. For example, common compounds include salt, sugar, and water. A chemical reaction is needed to separate salt, a compound also known as sodium chloride, into the elements sodium and chlorine.

Department of Transportation Placards

Many common products are manufactured by industries such as the petroleum industry. Trucks are the principal means of transporting such materials from refineries or plants where they are made to factories where they are used and then to disposal facilities where wastes are processed or discarded. An estimated 60% of all hazardous materials travel U.S. highways. The U.S. Department of Transportation (DOT) requires trucks that carry hazardous chemicals to be marked with diamond-shaped placards that help describe the contents of the truck. The placards describe any potential hazards that the contents may pose (such as toxicity). They also contain four-digit numbers that identify the chemicals being transported (see the following table). Each state police car usually carries a list of these numbers and a description of the properties of each chemical. In addition, the truck driver carries a set of papers, known as a manifest, that identifies the contents of the shipment.

U.S. DEPARTMENT OF TRANSPORTATION CHEMICAL CODE NUMBERS

ID #	Substance	Hazard Class	ID #	Substance	Hazard Class	ID #	Substance	Hazard Class
0001	Alarm devices, explosive	1	1133	Cement, rubber	3	1693	Tear gas	6
0012	Cartridges for weapons	1	1153	Ethylene glycol (antifreeze)	3	1759	Medicines, corrosive	8
0033	Bombs	1	1155	Ethyl ether	3	1789	Hydrochloric acid	8
0096	Photo-flash powder	1	1198	Formaldehyde, solution	3	1760	Rust preventers, weed killers	8
0221	Warheads, torpedo	1	1203	Gasoline	3	1830	Sulfuric acid	8
0294	Mines	1	1226	Cigarette lighter, fluid	3	1845	Dry ice	2.2
0333	Fireworks, Type A	1	1262	Octane	3	1863	Fuel, aviation	2.1
0338	Cartridges for weapons	1	1263	Paint	3	1867	Cigarettes	4
1001	Acetylene	2.1	1270	Petroleum oil	3	1888	Chloroform	6
1002	Air, compressed	5	1301	Vinyl acetate	3	1903	Liquid disinfectant	8
1005	Ammonia	8	1324	Film	4	1944	Matches, safety	4
1011	Butane	3	1381	Phosphorus	4	1986	Alcohols	3
1013	Carbon dioxide	2.2	1350	Sulfur	4	2014	Hydrogen peroxide	5
1016	Carbon monoxide	2.3	1325	Medicines, cosmetics	4	2016	Ammunition, non-explosive	6
1017	Chlorine	2.3	1327	Hay or straw, wet	4	2069	Ammonium nitrate fertilizers	5
1038	Ethylene	3	1361	Charcoal	4	2210	Pesticide, water reactive	3
1044	Fire extinguisher	2.2	1365	Cotton	4	2217	Seed cake	4
1045	Fluorine	6	1372	Fibers, animal or vegetable	4	2761	DDT	6
1046	Helium	2.2	1373	Fabric, animal or vegetable	4	2910	Radioactive material	7
1049	Hydrogen	2.1	1401	Calcium	4	2975	Thorium metal	7
1066	Nitrogen	2.2	1477	Nitrates	5	2979	Uranium, metal	7
1072	Oxygen	5.1	1493	Silver nitrate	5	3028	Batteries, dry	8
1075	Liquefied petroleum gas	3	1553	Arsenic acid solution	8	3245	Genetically modified microorganisms	6
1079	Sulfur dioxide	8	1641	Mercury oxide	6	3319	Nitroglycerin	1
1090	Acetone	3	1654	Nicotine	6			
1114	Benzene	3	1692	Strychnine	6			

Key to Hazard Classes

1	explosive	2.3	toxic gas	5	oxidizer	7	radioactive
2.1	flammable gas	3	flammable liquid	6	irritant, toxic and infectious	8	corrosive
2.2	inert gas	4	flammable solid				

Appendix C

ASSESSMENT

Scoring Guide: Analyzing Data (AD)

Identifying scientific evidence, evaluating its significance, and then using the evidence, and the student's evaluation of it, to arrive at a logical interpretation.

Feedback Form: Analyzing Data (AD)

Provides students with criteria for Levels 3 and 4 on the Scoring Guide to clearly communicate expectations for the task.

Frequently Asked Questions about SEPUP Scoring Guides

These include answers to practical questions about using the assessment system.

Exemplars for Embedded Assessment Questions

Student responses at each of the four levels of the Scoring Guide.

Assessment Item Bank

The test item bank includes multiple choice and short answer questions that test a range of student outcomes, from knowledge of terms to comprehension and application of knowledge. It also includes at least one item that can be scored with the Scoring Guide used in the module and may include additional extended response items.

Answers to Item Bank

Answers to multiple choice items and exemplars for extended items are provided.

Scoring Guide: Analyzing Data (AD)

Level 0	Your response is missing or not relevant.
Level 1 *On your way*	• You identify evidence and/or • You explain what you think the evidence means.
Level 2 *Almost there*	• You explain what you think the evidence means. • You use some evidence to support your ideas.
Level 3 *Complete and correct*	• You use evidence to support a logical interpretation of the data. • You evaluate the source, quality, and/or quantity of evidence.
Level 4 *Above and beyond*	You accomplish Level 3 and go beyond in some significant way such as: • You present a thorough examination of evidence. • You connect your ideas with the science concepts learned. • You provide an explanation for why alternative ideas were discarded. • You provide suggestions for further relevant investigations. • You include a diagram or visual to clarify your ideas.

Feedback Form: Analyzing Data (AD)

Your response is **complete and correct** if:	YES	ALMOST	NO
You use evidence to support a logical interpretation of the data.			
You evaluate the source, quality, and/or quantity of evidence.			
Comments:			

You accomplish the **above and go beyond** in some significant way such as:	YES	ALMOST
You present a thorough examination of evidence.		
You connect your ideas with the science concepts learned.		
You provide an explanation for why alternative ideas were discarded.		
You provide suggestions for further relevant investigations.		
You include a diagram or visual to clarify your ideas.		
Other:		
Comments:		

Frequently Asked Questions about the SEPUP Scoring Guide

1. *Do the Levels 4–0 correspond with traditional grades A–F?*
Although on the surface, Levels 4–0 seem to correspond with traditional grades, for this module, they do not. For example, a 4 should not be equated with an A, and a 2 should not be equated with a C. The Scoring Guide is a tool for documenting student development over time. It is designed to help students understand learning expectations and, as they work through the module, internalize expectations for performance on relatively higher level tasks or questions that require comprehension, application, or analysis. The Scoring Guide should help you and your students monitor learning progress. Because the top levels of the Scoring Guide describe major learning goals, it is unlikely that very many students will be able to achieve a Level 3 at the beginning of a module. Some students may be able to improve a scoring level over the course of a module, while others will require a longer period of time to improve their performance. Thus, we would not expect that consistent 3s would be necessary for a student to get a good grade, especially at the beginning of a unit or course.

2. *Should I show the Scoring Guide to students?*
The Scoring Guide can be shown to students. However, our experience indicates that the amount of text on the page may overwhelm many students. Thus, you may wish to introduce the assessment system by presenting the Feedback Form. This form lists the criteria for Level 3 and 4 answers and clearly communicates the expectations for the task. You may need to spend some time clarifying the criteria for the students. You can then keep the Scoring Guide for your own use in scoring student work. If you do present the full Scoring Guide to students, we recommend that you discuss each level with the students and provide examples. Then have students score a practice problem and give them individual feedback on the scores they chose. Where necessary, explain why you would have given a different score. This type of preparation will help your students get the most out of the assessment system.

3. *Can the Scoring Guide be used for grading?*
The Scoring Guide can be used for comparing work to a standard, but the standard in the Scoring Guide must be put into the context of your class and your local standards. In addition, assessment tasks vary in difficulty. Keep in mind that the four levels in the Scoring Guide are not designed to be a linear scale, and that the Scoring Guides generally provide information about fairly high-level student outcomes. Your overall grading system is likely to include other criteria such as completion of assignments and class participation. One teacher might grade students' investigations and assign the score on the embedded assessment question a value of 4 out of a total possible 20 points, with the remaining 16 points determined by other criteria. Another teacher might decide that students who are able to improve by 1 scoring level over a semester or a year would receive an A or B for this aspect of their work.

4. *Why is there only one Scoring Guide for different questions?*
The skills and understandings that are referred to in the Scoring Guide can be applied to numerous situations. By providing just one Scoring Guide in each module, we hope to give students an opportunity to internalize the criteria in one performance area. The full SEPUP assessment system includes additional variables that are described in the SEPUP Assessment System section of the Introduction to this module. Other modules focus on different Scoring Guides. We encourage you to incorporate your own rubrics as well.

5. *How can the Scoring Guide help me set performance expectations in the classroom?*
We encourage teachers to tailor the Scoring Guide to their classroom and local standards. The most important thing is to define and maintain consistent scoring levels. Only by being consistent with a Scoring Guide and its interpretation can you determine how students

are progressing over time. Help your students understand the performance expectations by revisiting the Scoring Guide, discussing what each level means, providing examples, and involving students in practice scoring and "real" scoring. Inviting students to moderate scores, that is, to discuss their reasons for a score with other students, can also help students take ownership. In addition, the Feedback Form is designed to be easy to use and to help you provide clear feedback.

6. *How can the Scoring Guide help me foster student development?*
   An important function of the Scoring Guide is to track student development over time, so it is most useful when it is used repeatedly over an entire course. Teachers have found that using Scoring Guides helps students understand the learning expectations. Using Scoring Guides can also help students focus on learning goals instead of grades. You should encourage students to monitor their own progress. This is the first step toward independent learning. Imagine a classroom in which your students regulate their own learning! Scoring Guides can also influence teaching. By assessing students accurately with the Scoring Guide, many teachers have found that they learn more about their students than with traditional grading and, as a result, they can modify their teaching to enhance opportunities for students to learn. The changes in teaching that result from assessment help focus instruction and foster student development.

7. *Why are there occasional spelling and grammatical errors in the student exemplars?*
   The exemplars are based on actual student work. Unless the spelling and grammatical errors are severe enough to diminish the clarity of the answer, they have been ignored in assigning a score, as spelling and grammar are not part of the variables under consideration. If they were important for the assignment, they would be assessed with a separate score.

Exemplars for Embedded Assessment Questions

ACTIVITY 1 QUESTION 2

How many different substances do you think are in the classroom barrel? Explain your reasoning.

Level 1

There are five: three solids and two liquids.

Level 2

I observed a total of five substances (four solids and one liquid). The solids were black squares, beige squares, silver circles, and black circles. The circles had holes in the middle and were flat. The squares were flat too. The upper layer of the liquid was clear and had the squares floating in it. The lower layer of the liquid was brown and had the solid circles at the bottom.

Level 3

We were given a sample of the mixture that looked like it contained all of the substances found in the barrel. Based on observation alone, there were six different substances in our sample. I observed two different liquids (one was colorless and one was orange). There were also four different types of solids: dark circles, shiny circles, black squares, and brown squares. There could be more substances, but you can't tell from just looking.

Level 4

Five. The waste was made up of a liquid that had separated into two different layers: orange and clear. I think there were three solids in the liquid waste because there were three different-looking shapes in the waste. There were flat squares of two different colors: black and white. Even though they're different colors, I think they are both the same because they were floating and they looked the same. There were also donut-shaped disks at the bottom of the waste. There could be other solids hidden in the orange liquid. It would be better to pour out the waste into a shallower container and look more closely.

ACTIVITY 4 QUESTION 2

Several local companies have just released a list of solid wastes they once produced. Not all of these solids are present in your hazardous waste mixture. The following table [on the student page] provides more information.

a. *Predict which of the substances listed in the table would float in water. The density of water is 1.00 g/cm^3. Hint: A substance must be less dense than water in order to float in it.*

   Lithium and high-density polyethylene (HDPE) should float in water because both are less dense than water.

b. *Predict which of the substances in the table would float in ethanol. The density of ethanol is 0.79 g/cm^3. Hint: A substance must be less dense than alcohol in order to float in it.*

   Lithium should float in ethanol because it is less dense than ethanol.

c. *Use your answers to 2a and 2b and the other information provided in the table to identify each solid you tested. Support each identification with at least two pieces of evidence.*

Level 1

I used the copper chloride reaction to identify the donut-shaped disks as aluminum and iron. The black and white squares are HDPE based on the results of the density tests.

Level 2

The squares are HDPE because HDPE has a density of 0.95 g/cm^3. This means that it should float in water, which the squares did. Also, it should sink in ethanol because it is more dense than ethanol. The plastic squares sank in ethanol.

The dark disks were nickel. They were magnetic and did not react with copper chloride. The silver disks were aluminum because they reacted with copper chloride and are more dense than water.

Level 3

The silvery circles are aluminum because aluminum is a metal that reacts quickly with copper chloride, just like this metal did in the lab when it formed bubbles. The silvery circles can't be iron, which also reacts with copper chloride, because iron is magnetic and the silvery circles are not.

The dark circles are iron because iron is a magnetic metal that reacts slowly with copper chloride. The dark circles are magnetic and caused a slow color change in the copper chloride. This was the most difficult solid to identify because the only evidence that showed that it was iron and not nickel was the reaction with copper chloride. The table doesn't say what kind of reaction occurs, only that it happens slowly. It would help if we knew what kind of reaction occurs between iron and copper chloride. Both the light- and dark-colored squares are high-density polyethylene (HDPE). HDPE is the only solid nonmetal that (1) floats in water and (2) sinks in ethanol, just like the squares did when tested.

Level 4

The black circles were iron. Iron is magnetic like the dark disks were. Also, the disks slowly reacted with copper chloride, like iron does. The silver disks were aluminum because they reacted quickly with copper chloride and sank in water. Aluminum was the only solid that reacts quickly with copper chloride and is more dense than water.

Both the light and dark squares were HDPE. I know this because of their density. The squares floated in water and sank in ethanol. The only solid that should do this is HDPE.

If we could measure the exact density of each solid, we would know if the identifications are correct. We could compare our measurements to the exact density of each solid.

ACTIVITY 5
QUESTION 2

Several local companies have just released a list of liquid wastes they once produced. Not all of these liquids are present in your hazardous waste mixture. The following table [on the student pages] provides more information.

a. *Create a graphic organizer, similar to the one created in Investigation 4, "So Many Solids," to help you identify each liquid.*

See Transparency 5.1, "Key to Identifying Liquids," for a sample response.

b. *Identify each liquid that you tested. Support each identification with at least two pieces of evidence.*

Level 1

The two liquids were mineral oil and iron nitrate.

Level 2

I tested two liquids. One was iron nitrate solution. It was orange and odorless. The other was mineral oil. It was slightly flammable and it wasn't toxic.

Level 3

Iron nitrate was one liquid. It wasn't flammable, so it had to be iodine, iron nitrate, or nitric acid. It couldn't be iodine, since iodine is not reactive and the liquid was. It wasn't nitric acid because it didn't have a strong odor. Mineral oil was the other liquid. It wasn't miscible in methanol, so it had to be mineral oil or iso-octane. It wasn't iso-octane because it didn't smell like gasoline.

It would help if we had a real test for toxicity instead of a simulation since it is an important test for identifying the liquids.

Level 4

One of the liquids is a clear, colorless liquid that is flammable, not reactive, not toxic, and not miscible in water or methanol. The only liquid that it could be is mineral oil. Iodine, iron nitrate, and nitric acid are all not flammable, but the clear liquid is. Iso-octane is toxic and the clear liquid isn't. Lauric acid solution is miscible in methanol and the clear liquid isn't. So this liquid has to be mineral oil.

The other liquid is iron nitrate. It is soluble in water and methanol, like iodine solution, iron nitrate, and nitric acid. But it can't be iodine because iodine is not toxic, and the brown liquid is. Nitric acid has a strong odor, but the iron nitrate does not. It would be good to have more tests. My i.d.'s should be correct if the information provided in the table is complete.

ACTIVITY 7
QUESTION 4

What mode of transportation would you recommend for transporting the hazardous waste to the disposal site? Support your answer with evidence.

Level 1

Choose the one with the lowest number of accidents that year.

Level 2

Sending things by ship is the best. Ships had the fewest number of accidents and no injuries or deaths in 2000.

Level 3

I recommend using the highway. It had the lowest percentage of accidents in 2000. The highway had 1.2% accidents compared to 2.1% on the water. This means that if there were 100 shipments by water, there might be two accidents. If there were 100 shipments by highway, there might be only one accident. So even though transportation by water had the fewest number of accidents, it was not likely to be safer. It would help to have data from other years to make sure that this is true every year.

Level 4

Air transport is the best because there were no deaths and a low percentage of accidents (1.6%). We should find out the number of accidents each year for five years and calculate the average number of accidents per year. I bet that air transport would have fewer accidents and deaths on average.

ACTIVITY 8
QUESTION 4

Recommend a route for transporting the barrels from Toxic City to Cleanville. Support your recommendation with evidence.

Level 1

The highway is the cheapest at $20 per mile. Cheaper is better because the money can be used for something else.

Level 2

The air route is the shortest and probably the fastest. That means there is less time for accidents to happen. Air transport also had a low accident rate in 2000 (1.6%).

Level 3

I would recommend the highway route following Route 2, Interstate Highway, and Route 4. It's safe, cheap, and avoids Tourist Town. The highway is the safest mode of transportation, with an accident rate of 1.2%. This is lower than the rate for any of the other transportation modes. It would help to know whether the highway in this area is more dangerous than the other routes because of local conditions (like really curvy roads). The highway also is one of the cheaper options, at $20,000. Using Interstate Highway also avoids Tourist Town, which should make the people of the town happy.

Level 4

Going through the Scenic Highway is the cheapest and safest. It only costs $11,000 and that is under the budget. The percentage of accidents on highways is less than 2%. That's why I chose it. But I would only allow trucks carrying certain types of materials to go this way. I would not allow trucks carrying extremely flammable or toxic substances. If there was an accident, it wouldn't be as bad because there would be less chance or fire or poisoning the environment.

Assessment Item Bank

1. It is possible to accurately identify pure substances based on:
   a. evidence such as safety data.
   b. hazard categories such as biohazard.
   c. physical properties such as miscibility.
   d. All of the above.

2. While walking through an open field, a HAZMAT team discovers a rusty 55-gallon barrel. There is nothing written on it. What should they do first?
   a. Carefully open the barrel and examine its contents.
   b. Put on protective clothing before going any closer.
   c. Leave the barrel for someone else to find and examine.
   d. Transport the barrel to a hazardous waste facility for disposal.

3. While playing with a friend, you see small white clouds coming out of a broken pipe. Which one of the following statements is true?
   a. It is possible that the cloud is a hazardous material.
   b. The cloud cannot be hazardous because it is a gas.
   c. Broken pipes release hazardous materials into the air.
   d. The cloud is steam, which is not hazardous.

4. The label on a container of a drain cleaner says: "Harmful or fatal if swallowed. Causes severe irritation to eyes, skin, mouth, and clothing." Which type of hazard does the drain cleaner pose?
   a. It is flammable.
   b. It is radioactive.
   c. It is an acid.
   d. It is toxic.

5. Mineral oil is less dense than water. Mercury, a liquid metal, is more dense than water. If you were to mix mineral oil, mercury, and water together, which liquid would float to the top?
   a. Mercury
   b. Mineral oil
   c. Water
   d. Both mercury and mineral oil

6. What does a HAZMAT team need to know before moving hazardous waste?
   a. Why the waste has been abandoned.
   b. What hazards the waste poses.
   c. Where the waste came from.
   d. How long the waste has been there.

7. The most important reason hazardous materials should be handled carefully is because they are:
   a. expensive to transport.
   b. rare and difficult to replace.
   c. needed for everyday work like cleaning.
   d. dangerous to human health.

8. An unlabeled barrel of liquid waste is found at an old industrial site. The contents of the barrel do not burn. Potassium iodide paper turns black when placed in a sample of the waste. According to the tests, which one of the following statements best agrees with this evidence?
   a. The liquid waste is reactive.
   b. The liquid waste is flammable.
   c. The liquid waste is not hazardous.
   d. The liquid waste may quickly evaporate.

9. The contents of a large can are tested. The contents of the can do not dissolve in water and do not react with pH paper. When placed in acid, the contents of the can bubble, and the odor of rotten eggs is produced. Based on this information only, which one of the following conclusions can be made?
   a. The can contains a liquid.
   b. The can contains a solid.
   c. The contents of the can react with acid.
   d. The contents of the can are corrosive.

10. If you place a solid in water, you can determine its:
    a. relative density
    b. toxicity
    c. flammability
    d. All of the above.

11. Which of the following is an example of a mixture?
    a. Mineral oil
    b. Aluminum washers
    c. Saltwater
    d. All of the above.

12. It is easiest to identify a mixture that is made up of:
    a. a gas dissolved in a dark liquid.
    b. an orange solid and a clear liquid.
    c. two clear, colorless liquids.
    d. several odorless gases.

13. Which of the following properties can be used to separate a mixture?
    a. Color
    b. Density
    c. Size
    d. All of the above.

Use the following table to answer Questions 14 and 15.

	Physical State	Density (g/cm^3)	Magnetism
Carbon	solid	2.26	nonmagnetic
Nickel	solid	8.90	magnetic
Zinc	solid	7.13	nonmagnetic

14. You must identify an unknown substance using only the information shown in the table. Which of the following tests could help you narrow down the identity of the substance?
    a. Place the substance in water.
    b. Hold a magnet near the substance.
    c. Observe that the substance is a solid.
    d. Carefully smell the substance.

15. Your teacher holds up a solid and informs you that this solid is less dense than zinc. Based on this information, the solid could be:
    a. Carbon
    b. Nickel
    c. Zinc
    d. None of the above.

16. A scientist is conducting tests to identify an unknown solid. Which of the following would be the most helpful for identifying the solid?
    a. A graph showing the cost of different substances
    b. A table showing the reactivity of different substances with water
    c. A list of household substances that are hazardous
    d. A written procedure describing how to conduct a miscibility test

17. You have been asked to separate the contents of a barrel. The barrel contains sand, motor oil, water, gravel, small pieces of metal, and pieces of cork. Develop a procedure to separate the contents of the barrel.
    a. What materials will you need?
    b. Describe your procedure step by step. Be sure to explain exactly what you would do at each step.

18. You must transport 15 barrels of flammable waste to Tinytown, which is 300 miles away. You are provided with safety data shown in the table below.

Transportation Mode	No. of Shipments	No. of Accidents	No. of Injuries
Air	10	6	0
Highway	500	50	5
Railway	300	15	10
Water	150	15	0

    a. Create a table to record and calculate the following for each transportation mode: (1) the percentage of accidents and (2) the percentage of accidents that resulted in injuries.
    b. Which mode of transportation do you recommend for shipping the waste? Support your answer with evidence. Be sure to explain how the evidence supports your recommendation.

Assessment Item Bank Answer Key

1. c. physical properties such as miscibility.
2. b. Put on protective clothing before going any closer.
3. a. It is possible that the cloud is a hazardous material.
4. d. It is toxic.
5. b. Mineral oil
6. b. What hazards the waste poses.
7. d. Dangerous to human health.
8. a. The liquid waste is reactive.
9. c. The contents of the can react with acid.
10. a. relative density
11. c. saltwater
12. b. an orange solid and a clear liquid.
13. d. All of the above.
14. b. Hold a magnet near the substance.
15. a. Carbon
16. b. A table showing the reactivity of different substances with water
17. a. The materials needed will depend on student plans but will likely include a dropper, magnet, forceps, and perhaps a sieve.

    b. Answers will vary. One possible procedure follows:
    1. Remove cork with forceps.
    2. Use dropper to remove the top layer of oil.
    3. Pour the water off of the solids.
    4. Use a magnet to remove the iron pieces.
    5. Use forceps to separate the gravel, sand, and small pieces of metal.
18. a. A completed table is shown below.

Comparing Safety Data

Transportation Mode	% of accidents	%. of accidents resulting in injuries
Air	60%	0%
Highway	10%	10%
Railway	5%	67%
Water	10%	0%

b. The following are exemplars for the four levels of the ANALYZING DATA variable.

Level 1

Water is best. It doesn't have that many accidents and no injuries.

Level 2

I would transport the barrels by highway. It is the most common and it had almost the lowest percent of accidents and a low percent of accidents.

Level 3

I would recommend transporting the barrels by water. My recommendation is based on safety data. I might change my recommendation if I had other information, like cost. Water had a low percentage of accidents and none of the accidents resulted in injuries. Using percents to compare modes is better than numbers because it helps make the information easy to compare.

Level 4

Highway. The highway didn't have too many accidents (10%) or injuries (10%) compared to the other modes. The railway had a lower percentage of accidents, but a lot of the accidents resulted in injuries. The railway has fewer accidents but is more dangerous. Highway also has the most shipments in the Tinytown area (500), so it's probably the cheapest. I wish I knew how much each type cost. I also want to know what each route would look like and if there are any other factors I need to think about.

Appendix D

GLOSSARY

Biohazard. A living organism or its by-product that is harmful to the health of humans or other living things. For example, human blood is considered a biohazard because it can transmit infectious diseases.

Clear. Transparent or see-through. A clear substance can be either colored, like food coloring, or colorless, like water. See *colorless.*

Colorless. Having no color. See *clear.*

Compound. A pure substance made up of atoms of two or more elements bonded together in definite ratios.

Corrosive. The ability of a substance to dissolve or wear away other substances, such as metals or human tissue. Strong acids and bases are corrosive.

Density. The relationship between mass and volume of a substance; the mass per unit volume, specifically grams per milliliter. Density equals mass divided by volume ($d = m/v$).

Evidence. Information that is gained by direct observation or from reliable sources which can be used to inform decision making.

Flame test. A method of identifying a substance. A flame test is typically conducted by placing a small amount of the substance to be tested on the end of a looped metal wire and holding the looped end in the center of a flame.

Flammable. Easily ignited.

HAZMAT team. An abbreviation for a hazardous materials team; a group of individuals who have the skills needed to investigate, identify, and transport hazardous materials. See *hazardous.*

Hazardous. Harmful to the health of humans or other living things because of toxicity, flammability, corrosiveness, reactivity, radioactivity, or infectiousness.

Indicator. A substance that changes color in the presence of another chemical or group of chemicals. For example, universal indicator is an acid-base indicator that shows by color the pH of a substance.

Infer. To conclude by reasoning from evidence. For example, if we see a child running toward a school building in the morning as the bell rings, we can infer that the child is late for school.

Miscible. The ability of substances (usually liquids) to mix together. For example, milk and water are miscible, whereas oil and water are not.

Mixture. A physical combination of two or more substances. Mixtures do not usually have a fixed composition: the amount of one or more of the substances in the combination can vary.

MSDS. An abbreviation for Material Safety Data Sheet, which is a list of the chemical and physical properties of a specific chemical.

Observe. To see or otherwise detect something.

Oxidizer. A substance that readily accepts electrons from another substance, often resulting in combustion. Oxygen is an example of an oxidizer.

pH. The expression of the acidic or basic strength of a solution. The pH scale is logarithmic, with each number representing a ten-fold increase in hydrogen ion concentration; 14 is least acidic (most basic), 7 is neutral, and 1 is most acidic.

Phase. A homogeneous state of matter: either solid, liquid, or gas.

Physical property. An intrinsic property of a material, such as density, melting point, or hardness.

Radioactive. Capable of releasing energy in the form of particles or electromagnetic waves.

Reactive. Capable of exploding when exposed to other substances (such as air or water) or emitting toxic fumes when mixed with other substances.

Simulation. A model or example of a real-life situation or event.

Solubility. A measure of the amount of a substance that will dissolve in a specified amount of another substance at a particular temperature. Often measured in grams per liter at 25°C.

Toxic. Poisonous; the capability of a substance to cause harm to living systems, either through a single dose (acute toxicity) or a long-term series of doses (chronic toxicity).