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#16 How to Clean Up an Oil Slick

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I. INTRODUCTION

Description

The task of cleaning up and recovering oil from an oil spill is not easily accomplished. In this laboratory exercise, the students will learn about how an oil spill is contained and cleaned up. They will investigate an oil absorbing polymer that is hydrophobic, absorbs up to 19 times its own weight in nonpolar liquids, floats on water, and can be reused or disposed of by incineration or burial in accordance with local regulations.

Student Audience

This lab is intended for chemical technology students. It can also be used effectively in a high school or one semester introductory college chemistry course.

Goals for the Experiment

This experiment will allow the student to:

- discover that a nonpolar polymer will absorb nonpolar substances such as oil,
- learn that a nonpolar polymer will not absorb water,
- discover that some polymers absorb both polar and nonpolar substances, and
- discuss the uses of nonpolar polymers, such as polypropylene.

Recommended Placement in the Curriculum

This activity should be placed during the introduction sections on polymers in the chemical technology course. It could also be incorporated in the sections on solubility in other high school or college chemistry courses.

II. STUDENT HANDOUT

How to Clean Up an Oil Slick

Scenario

You have just been hired by a small company that has previously specialized in environmental restoration and has just begun to expand its operation to include oil spill clean up. The company is so new into this field that standard lab analyses procedures have not yet been created.

You just received word of a large oil spill in the Great Lakes. The spill has been contained and most of the oil has been collected with the use of a large vacuum system. However, there are small pockets of oil (on the order of 1000 liters each) that are approaching the shore. The team in charge of cleaning up this oil spill wants information on which sorbent would be most efficient for collecting these pockets of oil. Unfortunately, the team has not provided you information about the type of oil present in the spill. The team also requests information about the absorbing power of the sorbent in order to determine the amount of sorbent that will be needed at the site. Because standard procedures have not yet been developed, a little experimentation is required.

Safety, Handling, and Disposal

- Goggles should be worn when performing this activity.
- The oils may be flammable and should be kept away from flames.
- The oils should be used in a well ventilated area.
- The 3M Oil Sorbent and oils should be placed into a specified waste container and then disposed of according to local regulations.

Materials

Per class

- 3M Oil Sorbent
- cotton (cotton balls)
- oils: 10W-30, 10W-40, 3-in-1 Household Oil, mineral oil, vegetable oil, lamp oil
- analytical balance (weight to nearest milligram)
- distilled water

Per student or pair of students

- disposable gloves
- 2 weighing boats
- small containers for oil and for water
- 2 paper clips

Per group

- beaker (600 mL or larger)
- stirring rod
- measuring device to measure 5 mL (graduated cylinder or teaspoon)

Procedure

Part A Using 3M Sorbent to Clean Up Oil and Water

1. Gloves should be worn in this experiment to keep the oils away from the skin.
2. Each student will work with one of the different types of oils. Record, in your lab notebook, the type of oil you are experimenting with.
3. Cut four 2-cm by 2-cm squares from your 3M Oil Sorbent sample.

4. Weigh one of the 3M Oil Sorbent samples on the analytical balance and record the weight in a data table.
5. Shape the paper clip into a hook. Poke the hook through the sorbent sample and use it to lower the sample into your oil. Leave the sorbent in the oil for 30 seconds and then remove. Hold over the oil and allow to drip for 30 seconds.
6. The saturated square should not be placed directly onto the balance pan, because the oil may damage the balance. Re-weigh the 4 cm^2 sample (now saturated with oil) using a weighting boat. You may want to simplify the calculations by taring the balance with the empty weighing boat on it.
7. Determine the total mass of oil that was absorbed and the percent increase in mass of the sorbent.

$$\textit{total mass of oil absorbed} = \textit{final mass of sample} - \textit{initial mass of sample}$$

$$\%\ \text{increase} = \frac{\text{mass of oil absorbed}}{\text{initial mass of absorbent}} \times 100\%$$

8. Repeat Steps 3–7 two more times using the same type of oil.
9. Repeat Steps 3–8 using distilled water.
10. Create a data table summarizing your results. Include the average percent increase in mass for the oil and water samples.

Part B Using Cotton to Clean Up Oil and Water

1. Repeat the procedure in Part A, Steps 3-10, substituting a cotton ball in place of the 3M Oil Sorbent.

Part C Comparing Data

1. Find other students who tested the same type of oil that you tested. Form a group with these students.
2. Analyze and compare your data with other group members' data. Is the data consistent among group members?
3. Write a group recommendation that describes your choice of adsorbent to be used and the absorbing power of that absorbent. Justify your recommendation. Have each member of the group sign the recommendation. One representative from the group should take this recommendation to the lab manager (instructor). The lab manager will then provide you with his or her recommendations.

Part D Cleaning Up a Mock Oil Spill

1. Make a mock oil spill as follows. Fill a large beaker with 500 mL of tap water. Add (spill) 5 mL of oil on top of the water.
2. Place a cotton ball onto the top of the water. Push the cotton around with a stirring rod, similar to what a ship might do. You cannot "dab" the cotton ball, because a large ship would not be capable of doing that on a large scale.
3. Continue to add cotton balls until it appears that all or most of the oil has been absorbed. Record your observations.

4. Repeat the mock oil spill, but this time use the 3M Oil Sorbent to absorb the oil. Record your observations.
5. Take the data from your group and include it in the Table of Class Data.
6. Once all the class data has been collected, a representative from each group will come forward and summarize their group's data. Each representative will also submit their group's recommendation of adsorbent to clean up the oil spill.
7. After all groups have submitted their recommendations, a final class recommendation should be written and sent to the Team Supervisor (instructor).

Questions

1. The oil used in automobiles is a petroleum product. Use the Merck Index to describe the composition of oil. Briefly summarize your findings. Based on your findings, would you classify oil as a polar or nonpolar substance?
2. Draw the structure of water. Is water polar or is it nonpolar?
3. Would you classify 3M Oil Sorbent as polar or as nonpolar? Explain your answer.
4. Cotton is a fiber composed of cellulose. The structure of cellulose can be found in any organic or biochemistry textbook, the Merck Index, or on the Internet at www.psrc.usm.edu/macrog/cell.html. Draw the structure of cellulose. Is cotton made up of a polar or nonpolar substance? Explain.
5. Explain cotton's behavior with the oil and with the water.
6. Which substance, 3M Oil Sorbent or cotton, is the better adsorbent for cleaning up oil?

References

The International Tanker Owners Pollution Federation Ltd., London. http://www.itopf.com/

The Merck Index, 12th Edition. Merck & Co., Inc. Whitehouse Station, NJ. 1996.

Sea Sweep, Inc. (A Colorado Corporation founded 1 May 1990). http://www.seasweep.com/

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III. INSTRUCTOR NOTES

How to Clean Up an Oil Slick

Purpose

To investigate the behavior of several different polymers in the presence of polar and nonpolar substances.

Time Required

This lab should take about two hours.

Group Size

Students should work individually or in pairs to do Parts A and B. Parts C and D should be done in groups of 3-4 students (or more depending on the number of different oils available).

Materials

Per class

- 3M Oil Sorbent
- cotton (cotton balls)
- oils: 10W-30, 10W-40, 3-in-1 Household Oil, mineral oil, vegetable oil, lamp oil
- analytical balance (weight to nearest milligram)
- distilled water

Per student or pair of students

- disposable gloves
- 2 weighing boats
- small containers for oil and for water
- 2 paper clips

Per group

- beaker (600 mL or larger)
- stirring rod
- measuring device to measure 5 mL (graduated cylinder or teaspoon)

Safety, Handling, and Disposal

- Goggles should be worn when performing this activity.
- The oils may be flammable and should be kept away from flames.
- If the Oil Sorbent material or cotton was used to absorb crude or fuel oils, it can be disposed of by incineration or burial in accordance with local regulations. If it was used to absorb mineral or cooking oil, it can be disposed of in the trash receptacle.

Points to Cover in Prelab

- Review polarity. Students need to have a firm understanding of this concept to get the most from this lab.
- The instructor could present this material as if it were an orientation seminar for those laboratory workers (students) just hired yesterday to help in the clean up of the oil spill.
- Oil spills like those that occurred in the Persian Gulf War, or caused by oil tankers such as the Exxon Valdez, can be very damaging to the environment. There are a lot of methods being employed to clean up these spills. The best method to clean up an oil spill is to collect the oil. The first step in this process is to contain the oil. Booms are used for this process. There are several types of booms. They can be specialized or can be improvised by using fences or bales of hay.
- Once the oil has been contained, it is collected using skimmers or sorbents. The suction skimmers are like large vacuum cleaners that suck up the oil. The drawback is that they suck up

the water as well. Adhesion skimmers sweep an adhesive material through the oil which the oil sticks to. The oil is then squeezed out of the material.

- Sorbents are materials that are used to absorb substances. There are natural sorbents such as straw, as well as synthetic sorbents such as polypropylene. Other sorbents include non-woven, anti-stats, peat types, rubberizers, cellulose types, vermiculite, and floor sweep (diatomaceous earth). Many of these sorbents are polymers. Most synthetic polymers are hydrophobic, meaning that they "hate water," and will therefore not absorb water. Other polymers are hydrophilic, "water-loving," which do absorb water.
- 3M Oil Sorbent™ is made from polypropylene. It is a fibrous polymer which is loosely woven, composed of microbundles. The microbundles promote dispersion of liquid throughout the sorbent. This allows the polymer to absorb more oil, up to 19 times its own weight according to the manufacturer.

Procedural Tips and Suggestions

- Create a sign-up sheet or draw one on the chalkboard so that the students can sign-up to experiment with one of the different types of oils. Make sure that there are at least three people (or two pairs) signed up for each type of oil.
- Less experienced students may find it easier to think in terms of "absorbing 7.8 times its mass in oil" instead of a 781% increase. You may wish to change the calculations if this is the case.
- The oil can be very messy. The use of gloves is recommended. You may also wish to place the balance inside a large clear plastic bag if possible.
- The pieces of 3M Oil Sorbent can be precut into 2-cm x 2-cm squares to save lab time.

Sample Results

3M Oil Sorbent				
	Mineral Oil	3-in-1 Household Oil	5W30 Lubricant Oil	Water
Initial Mass of Absorbent (g)	0.308	0.410	0.382	0.420
Mass of Substance Absorbed (g)	2.407	2.73	2.385	0.425
% Increase	781	665	625	1.10
Cotton Balls				
	Mineral Oil	3-in-1 Household Oil	5W30 Lubricant Oil	Water
Initial Mass of Absorbent (g)	0.620	0.257	0.336	0.762
Mass of Substance Absorbed (g)	11.1111	4.789	7.092	14.987
% Increase	1790	1860	2110	1970

Sample Results for Mock Oil Spill

- The 600-mL beaker was filled with 500 mL of tap water. 5.0 mL of mineral oil were added to the water and gently stirred. A cotton ball was placed on top of the mixture and gently spread around with a stirring rod. When this cotton ball was saturated, a second cotton ball was added and spread around. A total of seven cotton balls were added to the beaker. The first cotton ball became suspended just below the water. The other six cotton balls sunk to the bottom of the beaker. There was still a small amount of oil on top of the water.
- The 600-mL beaker was again filled with 500 mL of tap water. 5.0 mL of mineral oil were added to the water and gently stirred. A 2-cm x 2-cm square of 3M Oil Sorbent was placed on top of the mixture and gently moved around with a stirring rod. When this square could no longer absorb any additional oil, a second square was added and spread around. It appeared to be about 1/4 of the way saturated with oil. Both pieces of 3M Oil Sorbent floated on top of the water. There was a very small film of oil still remaining on top of the water.
- Even though the cotton absorbs oil very well, it also absorbs water. If cotton was used on an oil spill, it would require tremendous amounts of cotton and then one would have to go to the bottom of the ocean to retrieve the cotton.

Group Recommendation

The best absorbent to use for the clean-up of the oil spill would be 3M Oil Sorbent, or an equivalent sorbent. It absorbs oil very well, usually around 600-700 percent increase in mass. After having absorbed the oil, it remains less dense than water and therefore floats on the surface of the water. It would be relatively easy to retrieve the sorbent once it has become saturated with oil. Cotton absorbs oil better than 3M Oil Sorbent but it is not the best absorbent to be used in a body of water because it also absorbs water. When it absorbs water, it becomes more dense than water and sinks below the surface. The absorption of water also limits the cotton's uptake of oil. With the cotton sinking to the bottom of the ocean there is also the major task of retrieving the cotton. If this is not clear to the students at this point, it should become clear when they do Part D.

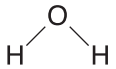
Plausible Answers to Questions

1. The oil used in automobiles is a petroleum product. Use the Merck Index to describe the composition of oil. Briefly summarize your findings. Based on your findings, would you classify oil as a polar or nonpolar substance?

A. Petroleum oil is made up of hydrocarbons, chiefly of the paraffins, cycloparaffins, or of cyclic aromatic hydrocarbons, with small amounts of benzene hydrocarbons, sulfur, and oxygenated compounds. Based on this information, oil is classified as a nonpolar substance.

2. Draw the structure of water. Is water polar or is it nonpolar?

A: Water is polar.

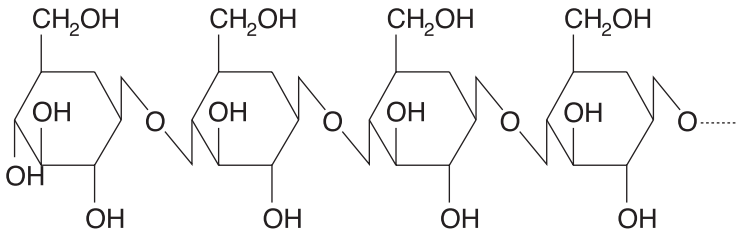


3. Would you classify 3M Oil Sorbent as polar or as nonpolar? Explain your answer.

A: Nonpolar; 3M Oil Sorbent absorbed the oil but not the water.

4. Cotton is a fiber composed of cellulose. The structure of cellulose can be found in any organic or biochemistry textbook, the Merck Index, or on the Internet at www.psrc.usm.edu/macrog/cell.html. Draw the structure of cellulose. Is cotton made up of a polar or nonpolar substance? Explain.

A. Cotton is a polar substance. Cellulose has many polar OH groups attached to its skeleton of thousands of D-glucose units.



5. Explain cotton's behavior with the oil and with the water.

A: Cotton absorbs the water because they are both polar substances and thus attracted to each other. Cotton, composed of cellulose, has a fibrous tertiary structure. There are pores between the layers of cellulose enabling the oil or water to become entrapped.

6. Which substance, 3M Oil Sorbent or cotton, is the better adsorbent for cleaning up oil?

A: Students will probably state that cotton is the better sorbent. Cotton absorbed more oil than 3M Sorbent, and would therefore appear be a better absorbent for oil. However, see the Group Recommendation.

Extensions and Variations

1. Enviro-Bond™403, sold by Flinn Scientific, is another polymer that absorbs several types of hydrocarbons. It works well with Marvel Mystery Oil, but it does not work with mineral oil or with cooking oils. It is especially formulated to bond quickly and safely to many types of liquid hydrocarbons including oil, diesel fuel, and gasoline. This polymer is designed for oil spill and waste clean-up purposes. The procedure used with 3M Oil Sorbent and cotton could also be done with Enviro-Bond™ 403. Other materials which could be tried include paper towels, tea bags, and kitty litter (in tea bags).
2. A larger scale oil spill could be simulated in a large glass container such as an empty fish container. The container could be filled with water. A toy boat could have its hull filled with oil. The boat could then be poked with a nail to simulate an accident. The 3M sorbent could be cut into long strips so that it can be used to contain the spill, as well as to absorb the oil.
3. The students could search the Internet for information on different polymers being used as sorbents in oil spills. Key words to use in the search include: oil spill clean-up polymer.

Resources for Materials

3M Oil Sorbent can be purchased from the 3M company. They sell bales of 100 sheets for about $70.00. Sheets are large and can be cut into many pieces.

3M Occupational Health and Environmental Safety Division
3M Center Bldg. 220-3E-04
St. Paul, Minnesota 55144
1-800-328-1667

Cotton balls and various types of oils can be purchased at your local grocery or discount store. Read the label on the "cotton" balls carefully as some "cosmetic puffs" which look like cotton are actually polyester.

References

The International Tanker Owners Pollution Federation Ltd., London. http://www.itopf.com/

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3M Advertising Literature: "3M Brand Oil Sorbent," "3M Powersorb High Performance Sorbents," and "Where to use 3M Oil Sorbent," 3M Occupational Health and Environmental Safety Division, St. Paul, MN.

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Sarquis, A.M. *Chain Gang—The Chemistry of Polymers,* Terrific Science Press, Miami University Middletown, Middletown, Ohio, 1995.