

Solids in Cigarette Smoke

Introduction

Chapter 1 in *Chemistry in Context* deals with air quality and various air pollutants. One of the important contributors to indoor air pollution is cigarette smoke. Cigarette smoking is a widespread habit in our society, and it is likely that the social, political, aesthetic, and medical issues resulting from cigarette smoking have affected smokers and non-smokers alike. The addictive nature of nicotine and the impact of cigarette smoking on the health of smokers has been extensively studied over many decades. In more recent years, the effect of so-called “second-hand smoke” or sidestream smoke, inhaled by nonsmokers has been evaluated and is now recognized as a significant issue for indoor air pollution. This laboratory investigation focuses on studying the smoke inhaled by smokers as well as sidestream smoke. You will use a simple apparatus to simulate the smoking process and will collect, weigh, and observe the solid particles produced by a burning cigarette. This will allow you better insight into the quantity and nature of the solids in cigarette smoke.

Background Information

A burning cigarette produces harmless carbon dioxide (CO_2) and water, but many of the other substances produced are not so harmless. Along with CO_2 , carbon monoxide (CO) is produced. This toxic gas competes with oxygen in the bloodstream, reducing the amount of oxygen that is available to cells. Blood concentrations of carboxyhemoglobin, where the oxygen carrier hemoglobin is bound to CO instead of O_2 , are about 10 times higher in a smoker than in a non-smoker. The nicotine in tobacco gets vaporized to a gas and is inhaled intact. Various minerals and carbon-based compounds are present as dust or ash. In total, cigarette smoke contains more than 4,000 different chemicals.

Some of the chemicals in cigarette smoke are proven carcinogens (cancer-causing substances). Others have the ability to serve as promoters of cancer when carcinogens are also present. According to the American Lung Association, cigarette smoking is the primary cause of lung cancer in the United States.

Emphysema is a chronic condition, affecting 2.0 million Americans living in the United States. It is a condition resulting from overinflation of structures in the lungs known as air sacs, or alveoli, which occurs when the alveoli walls begin to break down. The result is a loss of elasticity in the lungs as well as a decrease in the ability of the lungs to deliver oxygen to the bloodstream. In smokers, emphysema develops slowly after years of exposure to the irritation of cigarette smoke. Emphysema and chronic bronchitis together are classified as chronic obstructive pulmonary disease (COPD). Cigarette smoking is responsible for 83% of the cases of COPD.

Some of the compounds in cigarette smoke also affect nonsmokers who inhale so-called second-hand smoke. This is the smoke emanating from the burning end of the cigarette. It can be inhaled by the smoker as well as by nearby individuals and is also referred to as sidestream smoke. Inhalation of sidestream smoke is sometimes called passive smoking. In a 1993 report, the U.S. Environmental Protection Agency (EPA) concluded that 3,000 lung cancer deaths annually are due to passive smoking by nonsmokers.

Overview of the Experiment

1. Set up smoking apparatus or, if it is already set up for you, verify that connections are tight and that you understand how it works.
2. “Smoke” a filter cigarette to determine the amount of solids theoretically inhaled by the smoker and the amount of solids in second-hand smoke.
3. Repeat step 2 with another filter cigarette of the same brand.
4. Repeat steps 2 and 3 using a nonfilter cigarette.
5. Dispose of the filter paper, the burned cigarettes and ash, and clean up the apparatus.
6. Report your data and do the calculations.

Materials Needed

Equipment	Expendable items
<ul style="list-style-type: none"> • “smoking” apparatus (one per group of students) • ruler • balance 	<ul style="list-style-type: none"> • filter cigarettes • nonfilter cigarettes • filter paper • matches

EXPERIMENTAL PROCEDURE

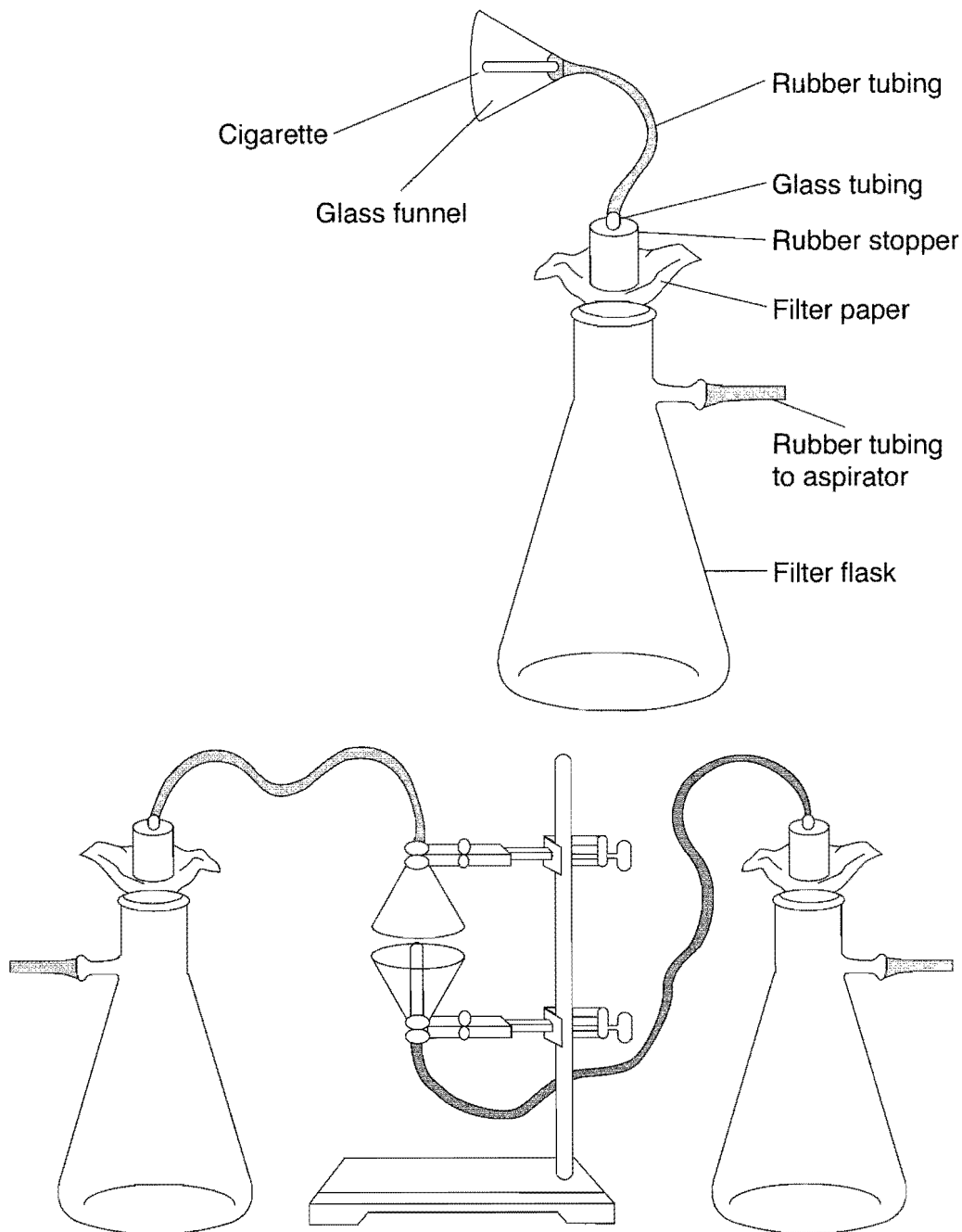
I. Setting Up the Apparatus

The apparatus is illustrated on the next page. Your instructor will probably already have it set up for you, but you should verify that you understand how it works and that the connections are tight. See the illustrations on the next page. Each apparatus is attached to a vacuum aspirator. This is a special adapter on the water faucet. When the water is turned on, the water flow draws air in from the side opening. This serves to pull air through the cigarette, allowing it to be “smoked.” The second job of the vacuum aspirator is to pull the sidestream smoke through the appropriate filter. This allows you to measure the sidestream smoke AND prevents that smoke from entering the room and turning you into a second-hand smoker.

II. Smoking Cigarettes

Do a total of four trials. Carry out this procedure four times: **twice** with a filter cigarette and **twice** with a nonfilter cigarette. You may use the cigarettes provided, or you may test your own brand of filter or nonfilter cigarette if you obtain your instructor’s permission. You need to do two trials on each type of cigarette you test.

1. Pretest the vacuum aspirator to make sure that when you turn on the water it drains into its sink and does not splash excessively. Your instructor will demonstrate approximately how fast the water flow should be. There may always be some splashing, so move notebooks and papers out of the way to keep them dry.



2. Obtain two pieces of filter paper. On the outside edge of one, mark a “1” for first-hand or smoker smoke, and on the other, mark a “2” for second-hand smoke. Weigh each piece carefully using the analytical balance and record the weights.
3. Weigh a filter-tip cigarette. With a pencil, make a horizontal mark 5 cm from the end of the cigarette that will be lit. This is how far you will allow the cigarette to burn. Insert the end of the cigarette NOT to be lit into the funnel that will be attached to the “smoker’s” flask.
4. Insert the two pieces of filter paper into the appropriate flasks and seal each flask with a rubber stopper with the tubing attached. It is important that you do not poke any holes in the filter paper, so the filter paper should be loose around the bottom of the stopper. However, there should be a good seal around the mouth of the flask.
5. Adjust the clamps holding the funnels so that there is about a 1/4 to 1/2 inch gap between the rims of the two funnels. A smaller gap will make it difficult for enough air to get in to burn the cigarette, and a larger gap will allow the sidestream smoke to escape into the room. You should keep the gap consistent for all tests.
6. Make sure your instructor checks your set-up before you light the cigarette.
7. Light the cigarette. At the same time, SLOWLY turn on the water to start the vacuum aspirator. At the appropriate flow rate, it should take about 3 to 5 minutes to smoke a cigarette down to the line. If your cigarette burns a lot faster than this, you should discard the data and repeat this part of the experiment.
8. When the cigarette has burned down to the line, break the connection between the smoker’s flask and the aspirator and put out the cigarette (you don’t have to collect the ashes on the cigarette). Leave the aspirator on 1 minute to finish collecting the second-hand smoke.
9. Break the connection to the second-hand smoke flask and then turn off the aspirator. Carefully remove the two pieces of filter paper and weigh each.
10. Weigh the unconsumed part of the cigarette (do not weigh the ashes).
11. Write down your observations about the appearance of each filter paper after the smoking exercise.
12. Throw the filter papers and the cigarettes in the trash, making sure the cigarettes are completely extinguished first. Wipe out the funnels with a paper towel to remove any solid residue. Reattach the flasks to the vacuum aspirator. Wash your hands.
13. Repeat the whole procedure with the other cigarettes until a total of 4 have been “smoked.”

III. Calculations

A. Amount of Solids in Cigarette Smoke Relative to Total Mass Smoked

This calculation is to determine the amount of solids in the smoker’s smoke and in sidestream smoke relative to the total mass burned when the cigarette was smoked. Carry out this calculation twice for each cigarette smoked: once for the smoker’s smoke and once for the second-hand smoke.

First, calculate the mass of cigarette consumed and the mass of solids left on the filter papers:

$$\text{mass of cigarette consumed} = \text{initial mass of cigarette} - \text{final mass after burning}$$

$$\text{mass of solids on filter paper} = \text{final mass of filter paper} - \text{initial mass of filter paper}$$

Next, calculate the mass (in milligrams) of solid per gram of cigarette consumed:

$$\text{mg of solids per gram of cigarette consumed} = \frac{\text{mass of solids on filter paper}}{\text{mass of cigarette consumed}} \times 1,000$$

B. Solids in Second-Hand Smoke as a Percentage of Solids in Smoker's Smoke

This calculation gives a relative comparison of the amount of solids in second-hand smoke versus the amount that would theoretically be directly inhaled by the smoker. The higher this number, the greater the amount of solids in smoke that go into the room, rather than go into the smoker's lungs. This relative comparison makes it possible to compare one smoking experiment to another, since in each experiment, the actual amount of solids produced depends in part on how much of the cigarette was smoked.

$$\% \text{ second-hand smoke} = \frac{\text{mass of solids in second-hand smoke}}{\text{mass of solids in smoker's smoke}} \times 100$$

C. Average of Two Values

You should average the calculated values obtained in the two trials. It's important to do the calculations first and then average the results, rather than averaging the mass measurements and then doing the calculations.

$$\text{average} = (\text{value 1} + \text{value 2}) \div 2$$

Sharing Results

Your instructor may ask you to post your results or share them in some way with other students. By looking at a large set of data, it should be possible to see patterns more clearly and also to confirm whether your results are consistent with those from other students.

Questions To Be Answered After Completing This Experiment

Write out answers to the following questions on a separate sheet of paper and hand it in along with the data sheet.

1. How do filter and nonfilter cigarettes compare with regard to the amount of solids in the smoke? Do filters make a significant difference? Do your results agree with what you would expect? Explain your reasoning.
2. What do you conclude from your data about the importance of second-hand smoke?
3. When repeat trials are run in any scientific experiment, it is important to see how well they agree with each other. Looking at your own data, do you see any significant discrepancies between the two trials for either type of cigarette? If so, you need to suggest a possible reason or reasons for the variation.
4. If class results were assembled, how well do your results agree with the rest of the class? If there is a significant difference, you need to suggest a possible reason or reasons for the variation.
5. When a cigarette is actually smoked, it is puffed or dragged on. In other words, it is not continually drawn on as are the cigarettes in this experiment. Tell how you could modify the apparatus and experimental procedure to more nearly mimic actual smoking.
6. Does the “second-hand smoke” data collected in this experiment accurately mimic the exposure of an actual passive smoker to the smoke of a single cigarette? To a roomful of burning cigarettes? Explain your answers.

Name _____

Date _____

Partner _____

Lab Section _____

Data Sheet—Experiment 4**Filter Cigarette** (what brand?): _____**Trial 1****Trial 2****Mass of cigarette consumed**

Initial mass of cigarette (g)		
Mass after burning (g)		
Mass of cigarette consumed (g)		

Smoker's flask (#1)

Final mass of filter paper (g)		
Initial mass of filter paper (g)		
Mass of solids on filter paper (g)		
Milligrams of solids per gram of cigarette consumed (mg)		

Second-hand smoke flask (#2)

Final mass of filter paper (g)		
Initial mass of filter paper (g)		
Mass of solids on filter paper (g)		
Milligrams of solids per gram of cigarette consumed (mg)		

% of smoke as second-hand smoke		
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Averages

Smoker's smoke: mg solids per gram of cigarette consumed _____ mg

Second-hand smoke: mg solids per gram of cigarette consumed _____ mg

Percent of smoke as second-hand smoke _____ %

Name _____

Date _____

Partner _____

Lab Section _____

Data Sheet—Experiment 4, page 2**Nonfilter Cigarette** (what brand?): _____**Trial 1****Trial 2****Mass of cigarette consumed**

Initial mass of cigarette (g)		
Mass after burning (g)		
Mass of cigarette consumed (g)		

Smoker's flask (#1)

Final mass of filter paper (g)		
Initial mass of filter paper (g)		
Mass of solids on filter paper (g)		
Milligrams of solids per gram of cigarette consumed (mg)		

Second-hand smoke flask (#2)

Final mass of filter paper (g)		
Initial mass of filter paper (g)		
Mass of solids on filter paper (g)		
Milligrams of solids per gram of cigarette consumed (mg)		

% of smoke as second-hand smoke		
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Averages

Smoker's smoke: mg solids per gram of cigarette consumed _____ mg

Second-hand smoke: mg solids per gram of cigarette consumed _____ mg

Percent of smoke as second-hand smoke _____ %