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#17 What Is Special About Polyethylene Food Storage Bags?

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I. INTRODUCTION

Description

In this investigation students compare a polyethylene bag designed for recycling or garbage disposal with a polyethylene food storage bag. For food product safety, it is essential that materials in the container not contaminate the food. The bags intended for food storage contain measurably less hexane extractables (low molecular weight oligomers and additives) than the bags intended for waste handling. Bags are cleanly cut into two centimeter squares, weighed and exposed to warm hexane solvent for a specified time. After the time is up, the hexane is removed and allowed to evaporate. (Two rinses of the bag pieces with small amounts of hexane may be performed.) Once the hexane has evaporated, the residue is weighed (ideally at the next laboratory period), and the percent hexane extractables calculated. The procedure is similar to that suggested in the Code of Federal Regulations (see references).

Student Audience

This investigation is appropriate for advanced high school chemistry (if procedure is modified, carried out over a couple days or as a special project), general chemistry, organic, polymer, or chemical technology students.

Goals for the Experiment

- Since this is a modified gravimetric procedure, weighing (but not weighing a filtered precipitate) correctly is necessary.
- Understanding that lower molecular weight materials are smaller and more soluble in a compatible solvent than similar much higher molecular weight materials.
- Understanding that food packaging materials must meet the requirements of special regulations.
- (optional) Understanding that IR spectroscopy quickly suggests the nature of the extractables.

Recommended Place in the Curriculum

This investigation would be appropriate when studying topics such as:

- polymers,
- solubility and gravimetric analysis,
- hydrophobic properties, or
- commercial applications of chemistry.

II. STUDENT HANDOUT

What Is Special About Polyethylene Food Storage Bags?

Scenario

The compatibility of a package and its product is a central issue in the packaging industry. Many "plastic" bags in use today are LDPE, low density polyethylene. In terms of hydrophobic properties, polyethylene can be considered to be a very large version of the fats and oils found in foods (as well as the hexane used in the investigation). In the consumer market, some LDPE bags are sold for lining home and work waste baskets, home trash disposal, and handling of recyclables. Other LDPE bags are sold as food storage bags.

A friend opening a catering service wonders if it is safe to occasionally use the large trash type bags for large item food wrapping rather than special ordering extra large sized food storage bags. As a chemistry student and friend, you agreed to check into this and found a procedure that tests the hexane extractable content of polyethylene films. You find it hard to believe that there is much difference between the two plastic bags so you set up the following experiment with the approval of your instructor.

Safety

- Safety goggles must be worn.
- The use of hexane, a flammable solvent, requires special precautions. All work with hexane should be done in a well ventilated area; a fume hood is recommended. If hoods are not available for all students, solvent vapors should be vented in the hood.
- Hexane is highly flammable. Be sure no open flames or other sources of ignition are present.
- Review the Materials Safety Data Sheets (MSDS) of all chemicals used in the experiment.
- Dispose of used reagents according to your teacher's instructions.

Materials

Per student

- goggles
- graduated cylinder
- 4 100–250 mL beakers
- spatula
- 2 glass stirring rods
- boiling sticks

Per class

- scissors
- plastic bags
    - food grade storage bags
    - trash or recycling bags
- hexane
- balances
- hot plates or steam plates
- (optional) FT-IR spectrometer

Procedure

1. Label a 100 mL beaker “A.” Making sure it is clean and dry, weigh this beaker to the nearest 0.001 gram.
2. Obtain a LDPE food storage bag and cut it into squares about 2-cm x 2-cm. (Cut the bag cleanly so ragged edges don’t leave bits of “plastic” behind.) Place a total of about 1.5 grams of plastic bag squares into the beaker. Try to avoid getting dust, dirt, or skin oils on the plastic bag squares. Weigh the beaker of plastic squares to at least the nearest 0.001 gram. Determine the weight of the plastic squares.
3. Using a beaker labeled “B,” repeat Steps 1 and 2 using a clean garbage type LDPE bag.
4. Add 50 mL hexane to each beaker and stir the plastic squares so that air pockets are removed. Add a boiling stick to each beaker.

   CAUTION: Hexane is highly flammable, be sure no open flames or ignition sources are present when using hexane.
5. Place the beakers on a hot plate set on the lowest setting.

   CAUTION: Do not use a setting higher than the lowest setting of the hot plate. Hexane is highly flammable.
6. Keep the beakers on the barely warm hot plate for about 50 minutes. Record the time the plastic pieces are exposed to the warm hexane. Ideally the hexane’s temperature should be just below boiling. In practice, the hexane may actually boil, but the boiling should be minimized. (The boiling sticks will help to prevent boiling over.) When the time is up, remove the beakers from the hot plate.
7. Label another set of beakers (clean and dry) “A*” and “B*” and weigh them.
8. Using a stirring rod to minimize splashing and drips, pour the hexane from beaker “A” to beaker “A*” without transferring the plastic pieces. Two small washes of about 10–15 mL new hexane may be used to wash the plastic pieces and chase the remaining exposed hexane solution into the beaker.
9. Repeat Step 8, transferring from beaker “B” to beaker “B*.”
10. Allow the hexane to evaporate to near dryness on a low hot plate. When about 5 to 10 mL of hexane remains, remove the beakers from the hot plate and allow the last traces of hexane to evaporate at room temperature to avoid charring. Alternatively, the beakers may be evaporated to dryness at room temperature in a fume hood.
11. Consult your instructor about when to determine the hexane extracted residue by weighing beakers “A*” and “B*.” (Experience indicates that it is best to do this at the next laboratory period; the last traces of hexane take about 1 to 2 hours to evaporate. Trying to hasten evaporation by leaving the beaker on the hot plate too long will only give charred samples.)
12. Calculate the percent by weight of hexane extractables.

$$\text{weight - \% hexane extractables} = \frac{\text{mass of extracted materials}}{\text{mass of plastic squares}} \times 100\%$$

13. Record the weight-% hexane extractables for each bag in your lab notebook. Ask your instructor about comparing your data on both bags with the data obtained by your colleagues.

Questions

1. What is the difference between the hexane extractable content of the two bags?
2. Is this difference significant and consistent? (This question is best answered if the data generated by other students is considered. A statistical analysis of class averages and standard deviation of both types of bags along with a student t-test would be useful.)
3. What did the hexane extract from the polyethylene films?
4. Hexane is hydrophobic, “water-hating,” and immiscible with water. What types of food materials does the hexane extraction model?
5. Why is hexane used in this procedure rather than food materials themselves?
6. Do your test results of the recycle type bag fall within the amount of hexane extractables suggested for polyethylene used in articles that contact food (other than articles used for packing or holding food during cooking)? Check the recommendations in the CFR reference or get them from your teacher.
7. Discuss potential sources of error in this investigation and how these errors would alter the results.

References

Maximum Extractable Fraction in n-Hexane, *Code of Federal Regulations: Food and Drugs 21*, Part 177.152, *Fed. Regist.*, 1996.

Feigenbaum, A. et. al. “Safety and Quality of Foodstuffs in Contact with Plastic Material” *J.Chem.Educ.* **1993**, *70,* 883–886.

III. INSTRUCTOR NOTES

What Is Special About Polyethylene Food Storage Bags?

Purpose

The purpose of this laboratory investigation is to determine the difference between a polyethylene bag designated for food storage, and a similar polyethylene bag not intended for food storage. A gravimetric method is used, and the requirements for safe food packaging considered.

Time Required

One 2-hour laboratory session plus additional weighing time at a later laboratory period should be sufficient for the lab work. This does not include pre-laboratory discussion or post-laboratory wrap-up. The heating period is 50 minutes, this is shortened from the two hours suggested in standard procedures. (It is possible that the heating time could be further shortened to 30 minutes in a high school setting. Test this with the bags you intend to use with your students.)

Suggested Group Size

Individual work is recommended. (If cost is a major consideration, students might work in pairs with one student analyzing the food bag and the other student analyzing the waste type bag.)

Materials

Per student

- goggles
- graduated cylinder (50- or 100-mL)
- 4 100–250 mL beakers (taller beakers will reduce the flash hazard)
- spatula
- 2 glass stirring rod
- boiling sticks

Per class

- scissors (good quality which provide a clean cut)
- plastic bags
    - food grade storage bags such as Kroger Clear Plastic Food Storage Bags with ties
    - trash or recycling bags such as Ruffies RECYCLE (clear kitchen recycling bags)
- hexane (75 mL per student per run; if each student does 2 bag samples, this is 150 mL per student)
- balances (Analytical balances are preferred but results can be obtained with balances that weigh to 0.001 grams if that is what is available.)
- hot plates or steam plates
- (optional) FT-IR spectrometer (If the extracted residue is to be analyzed as well as the films, then salt plates and a heat lamp are necessary as well—these might be considered standard IR handling materials.)

Safety

- Safety goggles must be worn.
- The use of hexane, a flammable solvent, requires special precautions. All work with hexane should be done in a well ventilated area; a fume hood is recommended. If hoods are not available for all students, solvent vapors should be vented in the hood.

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- Hexane is highly flammable. Be sure no open flames or other sources of ignition are present.
- Review the MSDS of all chemicals used in the experiment.
- Dispose of used reagents according to local ordinances.

Points to Cover in Pre-Laboratory

- Introduce the idea of the migration of materials found in food packaging into the food along with the related safety issues.
- Use the concepts of like dissolves like and polymer functionality to explain why hexane is used in the investigation and how this relates to lipophilic foods.
- The power of a simple gravimetric determination might also be considered. Gravimetric analysis principles could be taught with this activity but the procedure does not require it—the scenario question can be answered with balances that weigh to ±0.001 grams.
- The flammability of hexane should be stressed.
- If the students do not have access to the CFR reference, you may wish to tell them that it states that a maximum of 5.5% hexane extractables is permitted with a 2-hour extraction.

Procedural Tips and Suggestions

- The precision and accuracy of this method can be discussed if the classes data is combined. Use a student's t-test to compare means.
- You may wish to have the class investigate several brands of each type of bag for comparison.

Sample Results

Note that a ±0.1 mg balance was used here. A ±1 mg balance would also have given reasonable results.

Weight of food storage bag sample: 1.9274 g.
Weight of hexane extractables from sample: 0.0441 g.
Weight % hexane extractables: 2.29%

Weight of recycle bag: sample 1.1097 g.
Weight of hexane extractables from sample: 0.0728 g.
Weight % hexane extractables: 6.56%

Weight of dry-cleaning bag sample: 1.2230 g.
Weight of hexane extractables from sample: 0.0740 g.
Weight % hexane extractables: 6.05%

Plausible Answers to Questions

1. What is the difference between the hexane extractable content of the two bags?

A: Typical results show the food storage bags gave about 2.3% hexane extractables while the trash handling and dry-cleaning bags gave about 6.6% and 6.1% hexane extractables respectively. Students answers should be based on their data.

2. Is this difference significant and consistent? (This question is best answered if the data generated by other students is considered. A statistical analysis of class averages and standard deviation of both types of bags along with a student t-test would be useful.)

A: The difference is significant. In the sample results, the trash and dry-cleaning bags gave two-and-a-half to three times the amount of hexane extractables. Multiple runs (when, for example, class data is compared) should be reasonably consistent.

3. What did the hexane extract from the polyethylene films?

A: In the case of the trash handling bag and the food storage bag, the extracted material appears to be mostly polyethylene-like by IR spectroscopy. Presumably these are lower molecular weight oligomers (polymers containing relatively few monomers). IR spectroscopy of the dry cleaning bag extractables shows some other absorptions, possibly these are due to polymer additives, fillers, and pigments.

4. Hexane is hydrophobic, “water-hating,” and immiscible with water. What types of food materials does the hexane extraction model?

A: Fat, oils and other lipid materials are modeled by hexane.

5. Why is hexane used in this procedure rather than food materials themselves?

A: Hexane is volatile so the procedure can be done in a timely fashion. Fats and oils are very high boiling materials, quantitative removal of the fat or oil from the plastic film after exposure is not easy and removal of the extracted material from the fat or oil at the end is not easy.

6. Do your test results of the recycle type bag fall within the amount of hexane extractables suggested for polyethylene used in articles that contact food (other than articles used for packing or holding food during cooking)? Check the recommendations in the CFR reference or get them from your teacher.

A: No, typical results show that the amount of extractables after 50 minutes of extraction is 6.6%. The CFR states that only 5.5% extractables are permitted in a 2 hour extraction. The 6.6% after only 50 minutes clearly falls outside this limit. The 2.3% hexane extractables of the food storage bag after 50 minutes appears like it would fall within the 5.5% limit in a 2 hour extraction time. Hence the caterer in the scenario should buy food storage bags, rather than substituting trash handling bags.

7. Discuss potential sources of error in this investigation and how these errors would alter the results.

A: Answers will vary but should include, for example, incomplete drying of the hexane from the extractables. This would lead to a percentage which is too high.

Extension

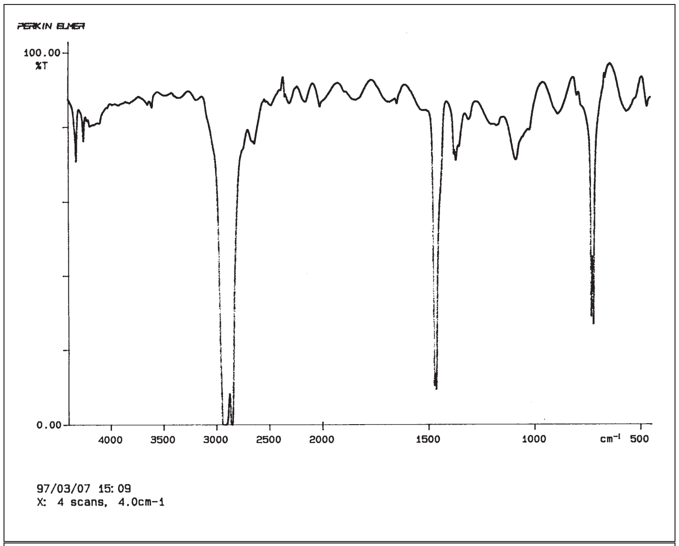
Further Analyses Of The Plastic Bag Pieces By IR Spectroscopy

What is extracted by the hexane from the plastic bags pieces? Low molecular weight oligomers of polyethylene and polymer additives might be distinguished by IR spectroscopy. Polyethylene oligomers will have spectra similar to the polyethylene film but polymer additives might show other peaks due to other functionality (functional group analysis).

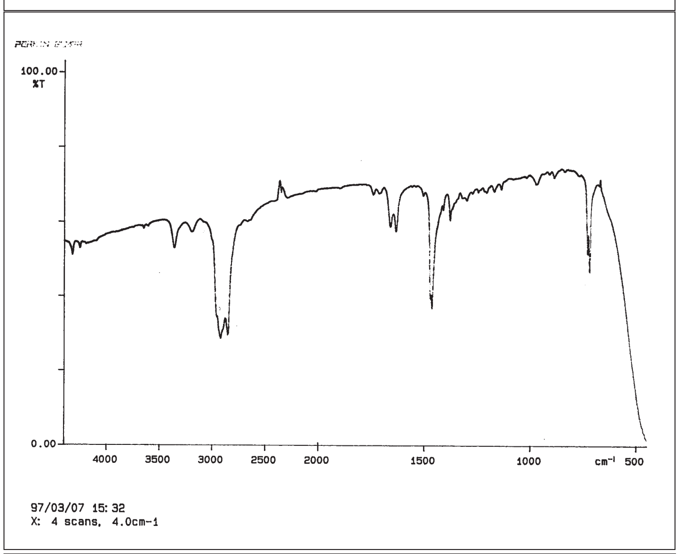
One way to address this question would be to use a spectroscopic method to compare the IR spectra of the bag pieces before and after extraction. IR spectroscopy of the bag pieces is easy, the bag piece is simply placed in the sample holder and the spectra recorded. FTIR is especially fast. The hexane extracted residue may be slurried in hexane and placed on a single salt plate. If the salt plate is then placed under a heat lamp, the hexane evaporates, leaving a fine film on the salt plate. The IR of this film is then recorded. If an IR or FTIR is not available, the following spectra may be presented to the student (as coming from an outside spectroscopy lab) and discussed.

Discussion of IR Results

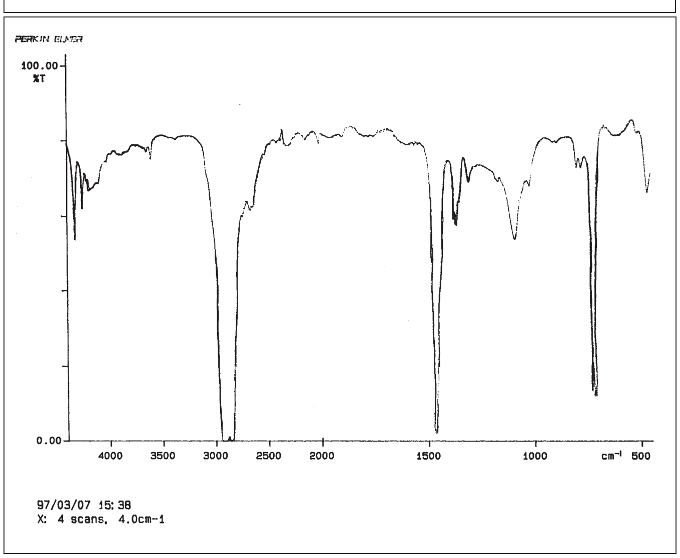
FTIR of the plastic squares (before and after warm hexane treatment) shows the bags to be polyethylene. FTIR of the hexane extracted material shows that to be mostly polyethylene, presumably smaller (more hexane soluble) oligomers. Polyethylene exhibits mostly C–H stretches and bends.



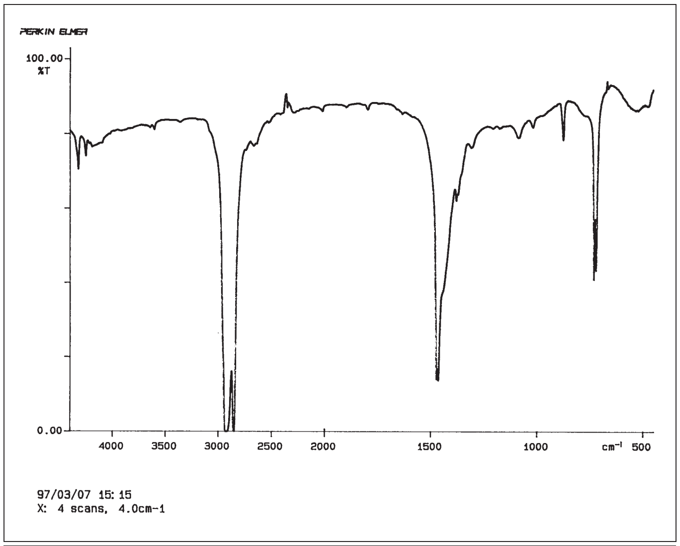
food storage bag before hexane extraction



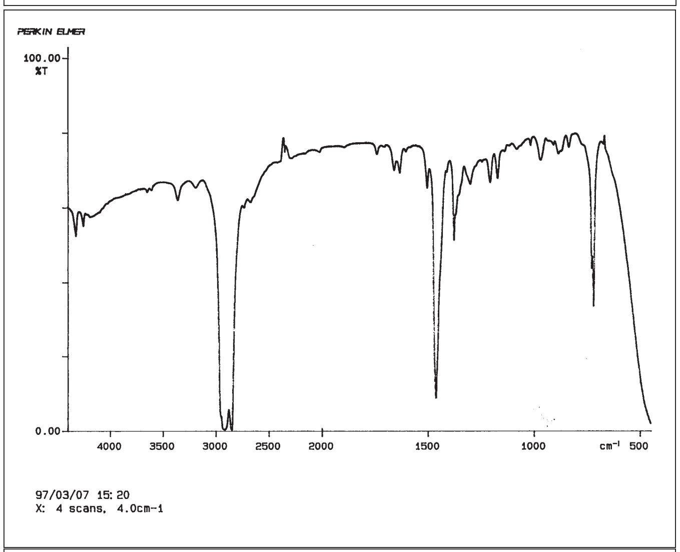
hexane extractables from food storage bag



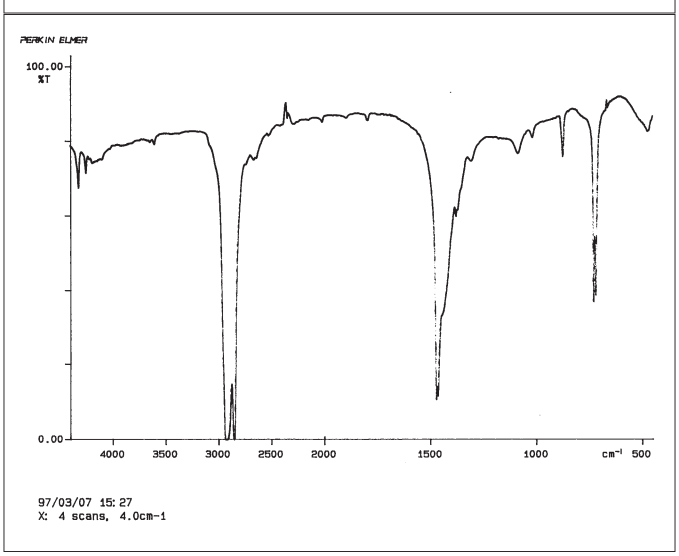
food storage bag after hexane extraction



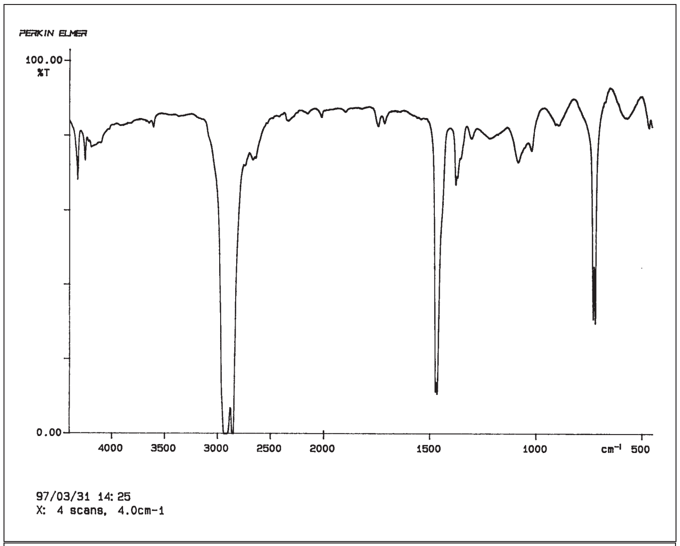
recylce bag before hexane extraction



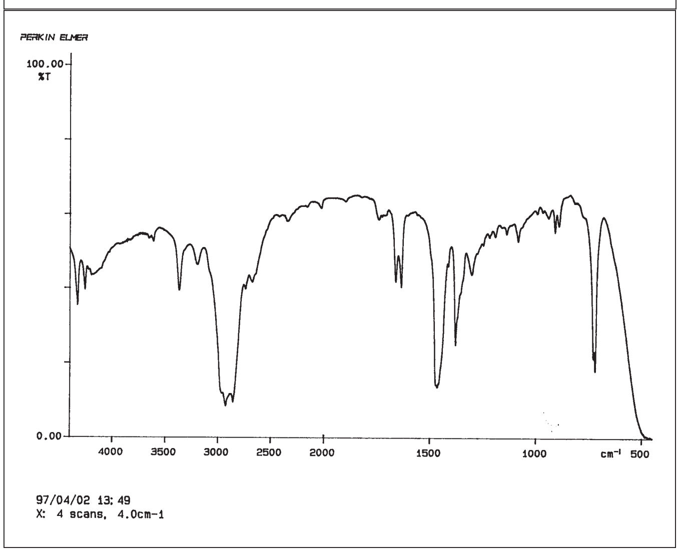
hexane extractables from recycle bag



recycle bag after hexane extraction



dry cleaning bag before hexane extraction



hexane extractables from dry cleaning bag

References

Maximum Extractable Fraction in n-Hexane, *Code of Federal Regulations: Food and Drugs 21*, Part 177.152, *Fed. Regist.*, 1996.

Feigenbaum, A. et. al. “Safety and Quality of Foodstuffs in Contact with Plastic Material” *J.Chem.Educ.* **1993,** *70,* 883–886.

Hileman, B. “Bisphenol A: Regulatory, Scientific Puzzle, Concerns about health effects of estrogen mimic trigger a flurry of intense research” *Chemical and Engineering News,* March 24, 1997, pp 37–39.

This laboratory procedure might also be discussed with respect to extraction of materials into the environment or food. The Hileman reference discusses the finding of Bis-phenol A in food samples and its history as an estrogen mimic.