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#22 Chemical Resistance and Synthetic Polymers

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I. INTRODUCTION

Description

These activities look at the chemical resistance of synthetic polymers. The activities include immersion, stain resistance, and stress cracking labs and both qualitative and quantitative analysis. Immersion testing is a alternative method for teaching solubility in which the polymer is the solute rather than typical salts and sugar which are often used. Chemical resistance can be used as one method to identify polymers, as well as being used to look at property changes which will effect service performance and aesthetics.

The stain resistance lab offers students an opportunity to develop and carry out a procedure of their own design.

Student Audience

These activities can be used for chemical technology and chemistry students at the university level. Modified, the activities are appropriate for high school level chemistry students.

Goals for the Experiment

The student will:

- relate molecular structures to the chemical resistance of polymers,
- use data to discuss service applications and possible performance of materials,
- complete chemical resistance testing and report appropriate data,
- using an industrial procedure, develop an appropriate investigation for stain resistance, and
- complete environmental stress cracking testing and relate data to service use.

Recommended Placement in the Curriculum

This investigation is appropriate during the study of

- solubility and polarity,
- structure and properties,
- chemical properties of materials,
- applications of materials,
- polymers, and
- the scientific method.

II. STUDENT HANDOUT

Chemical Resistance and Synthetic Polymers

Scenario

You have been employed by a building contractor who is not as knowledgeable as she would like to be about the many new synthetic polymer-based building materials. She would like to be able to recommend specific types of flooring to her customers based on economics and wearability. With this in mind, she has asked to you run chemical and mechanical tests on a variety of synthetic polymer floor tiles. These tests must be both reliable and reproducible and must involve the use of controls. Your first step is to check the standard methods presented in the "Annual Book of American Society for Testing and Materials Standards." The investigations below are adapted from that resource.

Background

Chemical resistance of polymers is a complex subject which is best understood through the study of polymer structures. Multiple factors effect chemical resistance including functionality, general morphology, degree of branching, density, bond distance, degree of crystallinity, and the energy needed to break bonds. For example, Teflon is impervious to chemicals due to its linear shaped chains, highly crystalline structure, and the strong covalent bonds between carbon and fluorine. Some nylons have symmetrical molecular structures and molecular flexibility which results in increased crystallinity. Nylons, because of the amide groups in their structure, have high hydrogen bonding ability which contributes to the overall material rigidity, the strength, and resistance to chemicals. However, these same oxygen and nitrogen groups will cause nylon to stain more readily than polyolefins. On the other hand, polystyrene has a nonpolar molecular chain structure, is chemically inert, and is resistant to water. It is also rigid below 100°C (Tg). To compound the complexity of this topic further, additives such as fillers, plasticizers, and colorants may react with chemicals, either masking or altering the chemical resistance of the base polymers.

Chemical resistance is very material-specific in polymers. The solubility and chemical resistance of polymers can even be used as a method of identifying plastics. Polyolefins such as polyethylene and polypropylene are soluble only in hot liquids such as toluene, o-dichlorobenzene, xylene, dichloroethane, and similar compounds. Polyvinyl alcohol is soluble in water while cellulose acetate and phenol-formaldehyde are soluble in acetone or acetic acid. This specificity is used in the adhesive industry and is the reason that PVC dope can only be used on PVC and not on any other plastic pipe. Choosing adhesives should not only be based on the adhesive but the substrate to which it will be applied. While a polymer may not dissolve in a given solvent, it may react by swelling. This response is also called solvation and is the reason for expanded polystyrene collapses in acetone.

Due to the general chemical resistance of polymers, plastics have become a common packaging material for both household and industrial chemicals. Polymer applications have also continued to increase to include a myriad of household and building materials. These materials must retain their mechanical properties, as well as their aesthetic appearance, even after exposure to chemical substances in the atmosphere and in service use. Environmental stress cracking is an industrial test which determines the change in polymers which relates to its mechanical function. Stain resistance deals with the aesthetic changes that result from common substances staining products during the service life of the product.

Safety, Handling, and Disposal

The level of hazard will depend on the solvents chosen for investigation.

- MSDS should be obtained and read for each reagent chosen following all precautions indicate in the document, as well as on the product label.
- Using household products will not necessarily lower hazards, therefore be certain to read and follow all label precautions.
- Dispose of any reagent in accordance with local ordinances.
- Chemical resistant goggles and gloves should be worn at all times in activities #1 and #3.
- Heat resistant gloves should be worn in activity #2 to prevent burns when placing samples in and out of the oven.
- Tremendous care should be taken when using the single edge razor to prepare samples in activity #3. Serious injury can occur if proper handling and procedures are not followed.

Materials

Investigation #1

- 4-inch x 2-inch sheet of each material to be tested (e.g. plastic sheeting, samples cut from recycle plastic bottles and packaging material, tygon tubing, cured rubber slabs, neoprene shoe soles, automotive hoses or tires, sandwich containers, etc.)
- 3 screw top test tubes and tops for each sample tested
- analytical balance
- permanent markers
- scissors or tin snips
- 4-inch diameter watch glass (larger will work also)
- eye dropper
- solvent to be tested (Teacher will supply a solvent that, during service life, would come into contact with the polymer sample being tested.)

Investigation #2

- household plastics (e.g. floor tiles, wall paper, plastic containers, Formica samples, different carpet samples)
- staining agents (e.g. shoe polish, juices, lipstick, markers, crayons, mustard)
- scissors or tin snips
- foil pans large enough to hold samples
- oven
- permanent markers
- sandpaper (optional)

Investigation #3

- polyethylene sheeting (e.g. milk jugs, coffee can lids, extruded sheet)
- scissors or tin snips
- single edge razor
- wire cutters
- solvents (e.g. water, oil, detergents)
- sample holder
- large test tube (at least 200 mm x 32 mm) and a foil covered cork

Procedure

Investigation #1 Short and Long Term Immersion Testing

1. Cut a 2-inch x 2-inch square from sample to be tested and place on watch glass. Cut 3 strips from remaining material 1/2-inch wide and save for long term immersion. The remaining sample material serves as a control throughout the activity. Work under a fume hood if material is volatile or if fumes are hazardous.
2. For short term immersion, flood the surface of the 2-inch x 2-inch sample with the chosen solvent keeping the surface wet for 10 minutes.
3. Rinse the sample with water and blot dry. Be certain to dispose of used solvent according to local ordinances.
4. Evaluate the sample compared to the control for changes in color, loss of gloss, tackiness, crazing, swelling, haze, or bubbles. Crazing refers to fine cracks which may extend in a network on or under the surface or through a layer of plastic material. Haze refers to the degree of cloudiness of a plastic material.
5. Create a data chart for the results.
6. For long term immersion, label the test tubes using permanent marker indicating A, B, and C along with the polymer name.
7. Weigh one of the 1/4-inch x 2-inch strips to 0.001 g. Place in test tube A and record the initial mass. Repeat for B and C.
8. Cover the samples with the chosen solvent and cap test tubes securely. Agitate the test tubes periodically during the immersion period.
9. After samples have been immersed in the solvent for 1–2 weeks, remove the samples, rinse, and blot dry. Be certain the sample is completely dry then mass each sample and record as the final mass for each A, B, and C.
10. Calculate the percent change in mass for each sample and average the results of A, B, and C using the following equation.

$$\frac{\text{final mass} - \text{initial mass}}{\text{initial mass}} \times 100\ \% = \text{percent change in mass}$$

11. Observe and record any visual changes as in short term immersion.
12. Calculate and record total hours of immersion.
13. Create a data chart for data obtained.

Investigation #2 Stain Resistance

This activity gives the student an opportunity to develop a procedure based on an industrial standard. Procedures are developed in line with standards but modified for specific materials to be tested and for specific equipment at a given site. All industrial sites must keep procedures on file and up to date but often students do not have an opportunity to develop procedures in the educational setting.

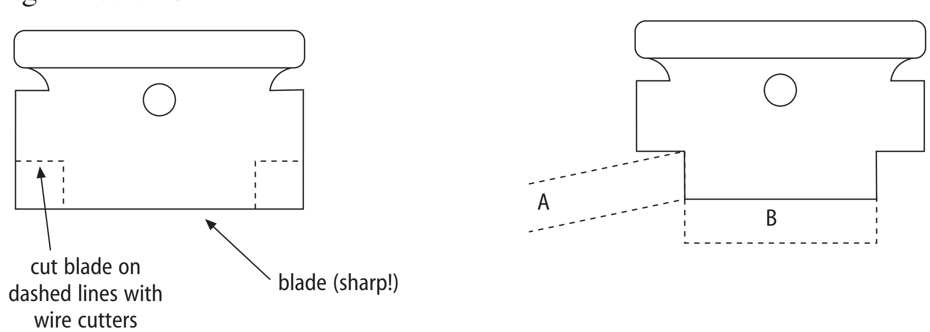
Stain resistance is a characteristic that is important to the aesthetic performance of a material in many service appli1cations. Flooring material, for example, needs to not only perform well mechanically with good resistance to cutting, tear, and abrasion but withstand staining from common household products such as shoe polish, foods, dirt, and beverages. Staining results from either chemical changes between the staining compound and the substrate or secondary forces which will not result in permanent staining and will come clean after wiping or cleaning with a detergent.

1. If available, read the industrial standard ASTM D2299-68 (Standard Recommended Practice for Determining Relative Stain Resistance of Plastics).
2. Develop and write a procedure for stain resistance that corresponds to lab time and equipment available.
3. Complete the designed experiment and record data.
4. Write a formal report of the findings as they relate to the service use of the material tested.

Investigation #3 Environmental Stress Cracking

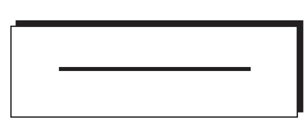
Environmental stress cracking is a measure of the susceptibility of a thermoplastic substance to crack or craze under the influence of stress and/or certain chemicals. In this investigation, it is done to determine the failure in the surface initiated brittle fractures of polyethylene sheeting (crazing). Polyethylene products have a tendency to prematurely fail in the presence of detergents, water, sunlight, or oil under relatively high strain. This testing introduces a combination of internal and external stresses that do not occur in traditional immersion testing. Materials may be chemically resistant in unstressed or laboratory atmospheres but will react differently in service conditions in which the material is stressed. Narrow molecular weight distributions of materials improves stress cracking resistance while highly crystalline and molecularly oriented structures have decreased resistance.

1. Cut sample polyethylene sheeting into ten 1.5 inch x 0.5 inch rectangles.
2. Carefully make a nicking jig out of a single-edged razor blade using the wire cutters as indicated in the diagram below.



A: 1/8 inch (3 mm)   B: 0.745–0.755 inches (18.9–19.2 mm)

3. Nick sample in the center as indicated below so it cuts the surface but does not go through the sample completely:



4. Curve samples and place into the sample holder. Place in test tube and cover with chosen solvent and foil covered cork.

5. Place tube in a constant temperature bath or oven at 50 °C or 100 °C depending on solvent and conditions. Leave samples for 48 hours (unless another time interval is desired)
6. Remove each sample at the specified time and observe for failure as indicated by crazing or cracking.
7. Compare results to other students using the same sample and solvent or same sample and different solvents.

Questions

Investigation #1

1. What has caused the samples to gain or lose mass?
2. Compare short and long term immersion results. Do the results correspond to one another?

Investigation #3

1. Relate results to applications of polyethylene such as packaging materials, bottles, wire coatings, and tubing.
2. Describe how chemical reactivity will differ if a plastic is under stress or not.
3. Where are the likely failure points in the various articles?
4. Which would have the higher ESCR (Environmental Stress Cracking Resistance), a bottle made of LDPE or one made out of HDPE?

References

1986 Annual Book of American Society for Testing and Materials Standards, Volume 8.01; ASTM: Philadelphia, PA, 1986:

- “D-543-84 Standard Test Method for Resistance of Plastics to Chemical Reagents”; pp. 175-180.
- “D-883-85 Standard Definitions of Terms Relating to Plastics”; pp. 466-481.
- “D-1239-55 Standard Test Method for Resistance of Plastic Films to Extraction by Chemicals”; pp. 568-570.
- “D-1693-70 Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics”; pp. 68-77.
- “D-2299-68 Standard Recommended Practice for Determining Relative Stain Resistance of Plastics”; pp. 337-338.

Carley, J.F. *Whittington’s Dictionary of Plastics;* Technomic Publishing Company: Lancaster, PA, 1993.

Rosato, D.V. *Rosato’s Plastics Encyclopedia and Dictionary;* Oxford University Press: New York, 1993.

Shah, V. *Handbook of Plastics Testing Technology;* John Wiley & Sons: New York, 1984.

III. INSTRUCTOR NOTES

Chemical Resistance and Polymers

Purpose

These activities will investigate various polymers and their chemical resistance. The activities will also explore the relationships between chemical resistance and product application and service performance.

Time Required

Activity #1 will take one extended lab period to do short term immersion and set up for long term immersion. The second part of the long term immersion will take one extended lab period and can be done after 1 week or more.

The procedure in Activity #2 can be done prior to the lab or in a previous lab period. The actual stain resistance testing can be completed in 2–3 hours. During the heating of test samples, procedures can be finalized and typed. An alternate time frame would be to complete the procedure and prepare samples in one lab period, heat overnight, and finish the next day. Analysis will take about 30 minutes to one hour.

Sample preparation for Activity #3 will take approximately 1–1.5 hours. The analysis and clean up will also take approximately 1–1.5 hours.

Suggested Group Size

This can be done by any size group. Activity #2 may be done in groups of 2–3 students.

Materials Needed

Investigation #1

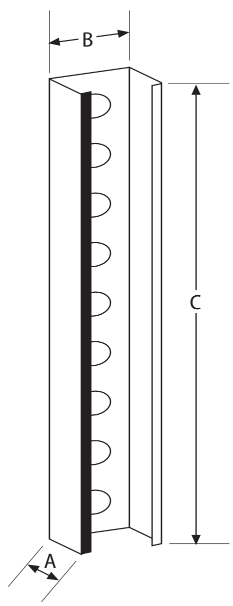
- 4-inch x 2-inch sheet of each material to be tested [e.g. plastic sheeting, samples cut from recycle plastic bottles and packaging material, cured rubber slabs, neoprene shoe soles, automotive hoses or tires, sandwich containers, HDPE (which is used to make automotive gas tanks) etc.] To simplify this experiment, use samples of the six recycle plastics. The student will observe the various reactions and can compare materials based on simple molecular structure and packaging applications.
- 3 screw top test tubes and tops for each sample tested
- analytical balance
- permanent markers
- scissors or tin snips
- 4-inch diameter watch glass (larger will work also)
- eye dropper
- solvent to be tested (Choose any solvent that during service life would come into contact with the polymer sample being tested) For automotive rubber materials, the student may choose gasoline, salt water, oil, antifreeze/coolants, or detergents/cleaning products. For plastic samples, any household solutions can serve as the solvent, as well as any acid, base, or organic solvent. Be certain proper safety precautions are taken according to product labels and MSDS for all solvents used.)

Investigation #2

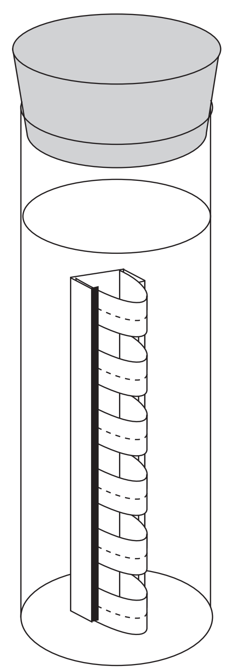
- household plastics [e.g. floor tiles, wall paper, plastic containers, Formica samples, different carpet samples (polypropylene), etc.]
- staining agents (e.g. shoe polish, juices, lipstick, markers, crayons, mustard, etc.)
- scissors or tin snips
- foil pans large enough to hold samples
- oven
- permanent markers
- sandpaper (optional)

Investigation #3

- polyethylene sheeting (Sheeting can be obtained from large packaged materials, milk jugs, or juice bottles. Manufactures of sheet material or thermoformers will usually be glad to provide material to you free or at minimal expense.)
- scissors or tin snips
- single edge razor
- wire cutters
- solvents (e.g. water, oil, detergents)
- large test tube (at least 200-mm x 32-mm) and a foil covered cork
- sample holder (The sample holder can be made from brackets used for shelving which are available in plastic and zinc in most hardware stores. See diagram for details. Diagram is not to scale.)



Holder



Test Assembly

A = 1.0 cm (3/8 inch)
B (outside) = 16 mm (5/8 inch)
B (inside) = 11.8 mm(.463 inch)
C = 16.5 cm (6.5 inches)

Safety, Handling, and Disposal

The level of hazard will depend on the solvents chosen for investigation.

- MSDS should be obtained and read for each reagent chosen. Follow all precautions indicated in the document, as well as on the product label. Using household products will not necessarily lower hazards, therefore be certain to read and follow all label precautions.
- Dispose of any reagent in accordance with local ordinances.
- Chemical resistant goggles and gloves should be worn at all times in activity #1 and #3.
- Heat resistant gloves should be worn in activity #2 to prevent burns when placing samples in and out of the oven.
- Tremendous care should be taken when using the single edge razor to prepare samples in activity #3. Serious cuts are a common injury in industry.
- Serious injury can occur if proper handling and procedures are not followed.

Points to Cover in Pre-Lab

Investigation #1

- This activity is an excellent alternative to traditional solubility labs of water and salt or sugar. Students usually need instruction on solubility and polarity prior to this activity to understand that this is no different then traditional solute/solvent activities.
- Safety considerations should be discussed including handling a variety of solvents and the proper disposal of each. To be certain students have read MSDS and label warnings, have students prepare a safety sheet prior to the lab activity for their solvent. The safety sheet must be approved prior to testing.

Investigation #2

- Review the standard with students to point out areas of modification.
  - The apparatus list should not be vague but a complete list of materials that includes everything they use for their procedure.
  - Test specimen preparation should include exact dimensions.
  - Since pre-made sheeting will be used, conditioning becomes arbitrary and does not need to be listed. The test atmosphere is also arbitrary since samples will be exposed to elevated temperatures in a closed environment.
  - The students should include a control which is assumed but not directly mentioned in the standard.
  - The time factor of 16 hours is not practical for many localities, including a one shift industrial lab and needs to be changed to 24 hours or a shorter time with a higher temperature. This may give rise to variable results. Heat history can affect polymer morphology.
  - The evaluation system for staining should be defined as in Note 3 of the standard.
- Discuss polymer morphology and the crazing/cracking phenomenon. Environmental Stress Cracking Resistance (ESCR) is a common phenomenon.
- Remind students that procedure writing is not a copying activity but the creation of a specific document based on a standard for your specific locality. Often students want to copy standards but this one is too vague to be used without the inclusion of specifics.
- Since this is an accelerated test, discuss key factors that will effect results such as temperature and test time. The temperature in the standard is raised to 50 °C but should not be so high as to

cause thermal degradation of the polymer being tested. A maximum temperature of 100 °C is suggested for no more than 2 hours for materials being tested. Students should remove all paper from samples, such as floor tiles, to prevent paper from burning. Likewise students should not leave heating samples unattended in case temperature chosen is too high and smoking occurs.

Investigation #3

- Discussion on the mechanism of solubility would be appropriate. Also the difference between internal inherent stress and external stress that occurs by bending or molding.
- Even though relatively non hazardous reagents will be used in this activity, read all MSDS or product labels for proper handling information and follow all precautions indicated.
- Demonstrate the technique to make the jig and how to notch samples. Razors can cause serious cuts if proper handling is not done.
- Determine the temperature and time interval to be used prior to the lab period.

Procedural Tips and Suggestions

Investigation #1 Short and Long Term Immersion Testing

- Work under a fume hood if material is volatile or if fumes are hazardous.
- Be certain to dispose of used solvent according to local ordinances.
- Crazing is a surface condition which results when fine cracks form on the surface of the material, as in old china. Definitions of terms describing plastics can be found in ASTM D-883, or Whittington’s or Rosato’s Encyclopedia and Dictionary of plastic terms.

Investigation #2 Stain Resistance

- Developing and writing a procedure is an important skill for students since excellent oral and written communication skills including procedure writing are often part of the job description of technicians in a polymer lab. Even process technicians are often required to write procedures for their job tasks to keep on file for ISO 9000 certification and FDA and EPA requirements. The procedure should mimic the standard in form but should be written specifically for the facility in which they will be working. See sample results for a suggested procedure.
- The formal report section could simply mimic the report section indicated in the ASTM method to include:
    - complete identification of polymer used,
    - identification of staining reagents,
    - method for measuring staining susceptibility,
    - extent of staining, and
    - any deviations from the original procedure.
- Another alternative could be for students to write a long form report with the following sections:
    - Summary (one page complete overview),
    - Introduction (paragraph that describes the purpose of the lab and asks the question - Why?),
    - Safety,
    - Description of materials to be tested,
    - Procedure that was developed,
    - Data,
    - Report and Conclusions (This section should respond to the introduction.), and
    - Modifications and Recommendations for further study.

Investigation #3 Environmental Stress Cracking

- The nicking jig should be checked periodically for imperfections and burs. If imperfection exists use a new jig. Any jig should be discarded after nicking 100 samples to be sure that the jig used is sharp.
- Depending on the solvent used, 2 liter preforms may be excellent if used as test tubes. (A preform is an object that has been subjected to preliminary, usually incomplete shaping or molding before undergoing complete or final processing. The preforms for 2 liter bottles look like large test tubes with a cap.) The number of samples tested may need to be less than ten and the sample holder cut to fit in the preform.
- Be certain that solvents are disposed of properly.

Sample Results

Investigation #1

Short Term Immersion: Student charts will vary depending on the characteristics observed.

Long Term Immersion:
Solvent: acetone
Time and Date In: 7-28-97 @ 9:00 AM
Time and Date Out: 8-4-97 @ 11:00 AM
Total Immersion Time: 170 hours

Sample	Initial Mass	Final Mass	% Change in Mass	Average % Change
Flexible PVC				
A	0.987	0.894	–9.4%	
B	0.954	0.872	–8.6%	
C	0.975	0.889	–8.8%	–8.9%
Rigid PVC				
A	0.963	0.946	–1.8%	
B	0.991	0.980	–1.1%	
C	0.952	0.940	–1.3%	–1.4%

Analysis: Both PVC samples showed some possible solubility in acetone. The samples all showed signs of swelling and softening rather than deterioration. The data suggests that the polymer was not soluble but the plasticizer may be soluble in acetone as indicated by the significant difference in %-change between the flexible and rigid materials.

Investigation #2

The following is a possible procedure written from ASTM D-2299:

Relative Stain Resistance of Plastics Used in Kitchen Construction

Introduction

This procedure outlines a method for testing plastics used in kitchen applications such as tile or carpet, counter tops, and wall paper for resistance to stains. This method is used to determine the resistance to staining for short term contact only.

Safety

The materials used in this procedure are common household solutions and items which do not present safety hazards.

Materials

- plastic samples: counter top laminate samples, floor tiles and carpet, wall paper, other plastics such as drainers, drain mats, and housings of appliances
- permanent marker
- staining materials: mustard, tomato paste, crayons, markers, tea, coffee, etc.
- foil pans
- forced air oven
- scissors or tin snips
- cleaning agents with and without abrasives
- soft cloth or paper toweling
- (optional) fine sand paper

Procedure

1. Cut 2-inch x 2-inch square samples of each plastic to be tested, one for each staining agent plus one control to be heated and one control to not be altered.
2. (optional) A second set of samples may be cut and then slightly abraded with sand paper to mimic worn surfaces.
3. Mark the backs of the samples with permanent marker identifying the plastic material and the staining agent.
4. Apply a uniform stain in the center of each sample forming a 1-inch circular stained area.
    - For thick liquids and pastes, stain should be approximately 1-mm thick or applied as a uniform coating such that the substrate can not be seen.
    - For solid materials and waxes, apply a uniform opaque stain.
5. Place samples in foil pans so the edges do not touch or overlap.
6. Place in a preheated 50 °C oven for 24 hours +/- 0.5 hour.
7. After heating, remove from oven and allow to cool for 15–20 minutes. Wipe the staining agent off with a soft cloth.

Data

Record your findings including the following:

- Compare an unstained portion to the control to see if any changes occurred from the heat aging alone.

- If staining occurs continue with the following steps:
  - Wipe half the stained area with a non-abrasive cleaner and compare to the control for color change and surface changes.
  - Wipe the other half of the stained area with a mildly abrasive cleanser and compare to the control for color change and surface changes.
- Compare stained area to control using the following scale:
  1. Excellent resistance: No color or surface changes.
  2. Good resistance: After using a non abrasive cleaning agent, no color or surface changes.
  3. Fair resistance: After using an abrasive cleaning agent, no color or surface changes.
  4. Poor resistance: After using a non abrasive cleaning agent, color changes or surface changes remain.
  5. No Resistance: After using an abrasive cleaning agent, color and surface changes remain.

Report and Conclusions

This should include:

- a complete identification of the material tested and polymeric composition,
- identification of staining agents,
- method of measuring resistance to staining and extent of staining,
- any changes due to heat exposure only, and
- any deviation from procedure.

The following would be a possible report for the above procedure:

Relative Stain Resistance of Plastics Used in Kitchen Construction

Complete ID:

Armstrong vinyl (PVC) floor tile, Item # 21411, Beige two tone, $1.16/sq.ft.

There did not appear to be any changes between the control and tested material as a result of heat exposure alone.

Staining Agents	grape juice	black shoe polish	tea	coffee	yellow mustard
Score	3	4	2	2	5

The following scale was used to determine extent of staining:

1. Excellent resistance: No color or surface changes.
2. Good resistance: After using a non abrasive cleaning agent, no color or surface changes.
3. Fair resistance: After using an abrasive cleaning agent, no color or surface changes.
4. Poor resistance: After using a non abrasive cleaning agent, color changes or surface changes remain.
5. No Resistance: After using an abrasive cleaning agent, color and surface changes remain.

There were no deviations from the written procedure.

Investigation #3

Results will vary by solvent and material used. Results will be recorded as percent failures after exposure for set time.

Plausible Answers to Questions

Investigation #1

1. What has caused the samples to gain or lose mass?

A: Samples that gain mass (a positive %-change value) could be the result of error in technique, samples that were not completely dry before massing, or the result of absorption. Samples that have swelled contain solvent and are indicated by a increase in mass and probably will appear swollen and more flexible. Samples that lost mass (a negative %-change in mass) are partially soluble in the chosen solvent. The other alternate explanation would be the solvent dissolved an additive out of the sample tested. Samples that are partially soluble may either be smaller in size, completely dissolved, or tacky.

2. Compare short and long term immersion results. Do the results correspond to one another?

A: Samples that are chemically resistant to the chosen solvent will likely have similar results (i.e. no visual changes and zero percent change in mass). Samples that are partially soluble in the chosen solvent may not show visually changes in short term immersion but will have negative percent changes in long term. Samples that are very soluble in the chosen solvent will likely show visual changes in short term immersion and have significant percent-changes in long term immersion or completely dissolve.

Investigation #3

1. Relate results to applications of polyethylene such as packaging materials, bottles, wire coatings, and tubing.

A: Packaging materials that are molded and shaped may have sufficient stress induced by the molding process such that they will react to stress cracking. When bottles are molded there is stress in the curvatures of the bottle. Liquid containers may experience stress cracking from within, effectively weakening the vessel. Bottles and containers that have the molded stress may also be nicked by abrasion causing potential for stress cracking when exposed to weather, solvents, etc. Large drums are an example of this type of container. Wire coatings and tubing or pipe are other examples of materials that may experience stress cracking, particularly at bends. The tubular shape creates a natural stress which may be more susceptible to stress cracking when exposed to weather and other solvents.

2. Describe how chemical reactivity will differ if a plastic is under stress or not.

A: Solubility results when a solvent overcomes ionic bonds and intermolecular forces. When a plastic is under a stress, the solvent is working on a weakened bonding site and the degree of solubility may be sufficient to break a bond that would not normally be attacked.

3. Where are the likely failure points in the various articles?

A: The failure points will tend to be locations where the materials are stressed. These would include, for example, areas where the plastics are bent or stretched.

4. Which would have the higher ESCR (Environmental Stress Cracking Resistance), a bottle made of LDPE or one made out of HDPE?

A: For a given MI (melt index), the LDPE would have the higher ESCR. However, the lower the MI, the better the ESCR. Polyethylene resins with MI<1.0g/10 minutes have excellent ESCR. Melt index is inversely related to Mw (molecular weight) and, along with density, is an important parameter used by the industry to characterize a polyethylene resin. Melt index describes the flow behavior of the PE at a specified temperature and pressure and is measured by the ASTM D1238 test method. If the MI of a resin is low, its melt viscosity is high and vice versa. Because a number of polymer properties depend on MI, it is imperative that the manufacturer keep the MI uniform for a given product type.

Extensions and variations

- For further investigation, vary the length of the immersion time and the temperature of the solvent to determine the effects on solubility. Caution should be taken when choosing solvents to be used at elevated temperatures.
- Develop an activity based on the results from immersion testing of the six recycle plastics (PETE, HDPE, V, LDPE, PP, PS) that would help you identify unlabeled packaging plastics.

References

1986 Annual Book of American Society for Testing and Materials Standards, Volume 8.01; ASTM: Philadelphia, PA, 1986:

- “D-543-84 Standard Test Method for Resistance of Plastics to Chemical Reagents”; pp. 175-180.
- “D-883-85 Standard Definitions of Terms Relating to Plastics”; pp. 466-481.
- “D-1239-55 Standard Test Method for Resistance of Plastic Films to Extraction by Chemicals”; pp. 568-570.
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