# IDENTIFICATION OF PLASTICS AND ELASTOMERS

## MINIATURIZED TESTS

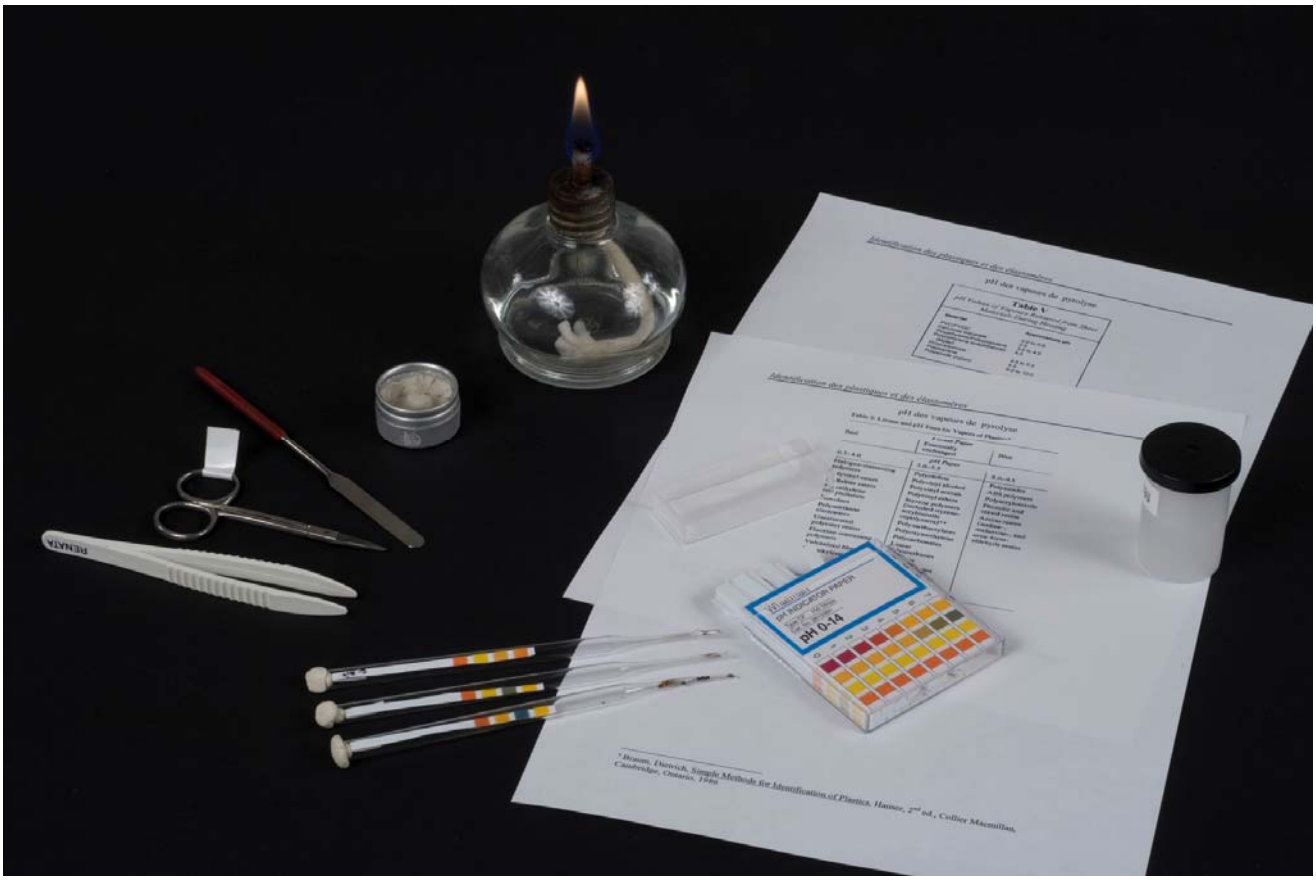


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**TABLE DES MATIÈRES**

## INTRODUCTION

The tests to identify plastics and elastomers described in this document are all drawn from the scientific literature. Our work thus consisted of miniaturizing them.

Conservators are often called upon to characterized a material in order to understand or anticipate its behavior over time, select a treatment, or authenticate or date museum objects. Since these objects are unique, precious, and irreplaceable, the sampling methods must be as uninvasive as possible. They must also

- be easy to use
- not require sophisticated equipment
- use inexpensive, readily obtainable products and
- provide reliable, reproducible results.

Some of our miniaturized tests are based on a wipe method using microscope slides and others, on a pyrolysis method using Pasteur pipettes.

## Wipe Method


For the wipe method, samples are collected by gently rubbing the surface of the object over the frosted end of a microscope slide.
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Samples are collected by gently rubbing the frosted end of a microscope slide over the surface of the object. The appropriate reagent is then deposited on the sample, on the slide. The development of a distinctive color is an indication of the composition of the sample. Microscope slides, which are widely used in laboratories, are inexpensive. This technique removes such a small amount of sample that it cannot be seen with the naked eye and can be barely detected using a binocular microscope.

The appropriate reagent is then deposited on the trace left, on the slide, by the rubbing of the sample.

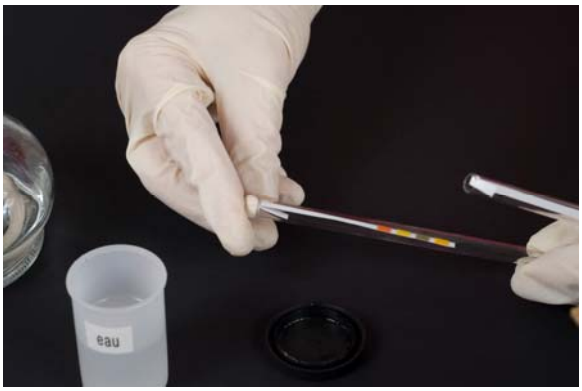
## Pyrolysis Method

Burning samples in a Pasteur pipette is a very effective technique in several respects. Like microscope slides, pipettes are widely used in laboratories and are inexpensive. The capillary end of Pasteur pipettes can be rapidly flame-sealed. The wide mouth of the tubular end of the pipette

The capillary end of Pasteur pipettes can be rapidly flame-sealed.

The tubular end of the pipette makes a useful funnel to collect the sample and push towards the capillary end.

makes it easy to insert the sample in the pipette, which falls into the sealed capillary end. Indicator strips or cotton swabs impregnated with reagent can also be inserted in the tubular end of the pipette. Once the sample and indicators have been placed in the pipette, the tubular end is sealed with modeling dough such as *Plasticine*. When the sample in the capillary end of the pipette is heated using the alcohol burner, its behavior (sublimation, melting, decomposition) as well as any characteristic combustion vapors (color) can be readily observed. If the sample softens and melts, it is may be a thermoplastic since thermosetting resins tend to keep their shape until they reach their combustion temperature. In addition, since the combustion vapors are trapped inside the pipette, they can react with the indicator strips or the cotton swabs impregnated with reagent. The results can be read within seconds or, at the most, minutes. After this step, the *Plasticin*e stopper can be removed, releasing the combustion vapor. Even very small samples release easily detectable odors that can be identified by the "nose test," which can be repeated as long and as often as required, which is not the case with samples vaporized in an open flame.



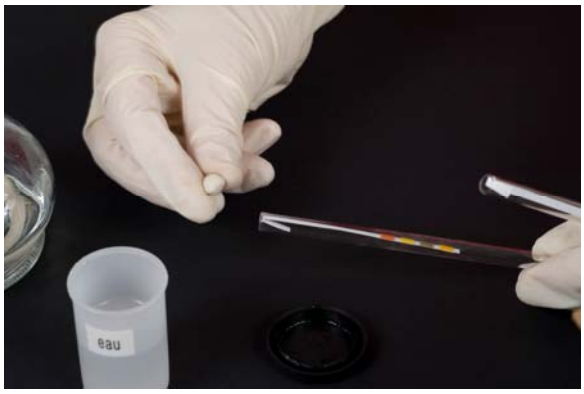

Once the sample and indicators have been placed in the pipette, the tubular end is sealed with modeling dough such as *Plasticine*. Then the sample in the capillary end of the pipette is heated using the alcohol burner, to free the combustion vapours.

## pH and Specific Gravity

The pH of the combustion vapor is a useful way of identifying plastics. A pH indicator strip is inserted in the tubular end of the pipette. We have obtained good results with Merck ColorPhast pH strips. Since the strips are slightly too wide, they are cut lengthwise. The strips are bent so that they are held in place by simple pressure against the wall of the pipette. Before inserting them in the pipette, the strips must be wetted. The tubular end of the pipette is then sealed with modeling dough. The sample in the capillary end of the pipette is then heated. Since the combustion vapor is heavier than air, the pipette is laid flat on the work surface for a few seconds or minutes, depending on the size of the sample, so that the vapor can come into contact with the pH strip. The color of the strip in the pipette is then compared to the pH reference scale provided with the strips. Refer to tables 1 and 2 (Appendices) for the pH values of the combustion vapors of most common plastics.


Merck ColorPhast pH strips are slightly too wide, they are cut lengthwise. The strips are bent so that they are held in place by simple pressure against the wall of the pipette.


The pH indicator strips must be wetted before use.

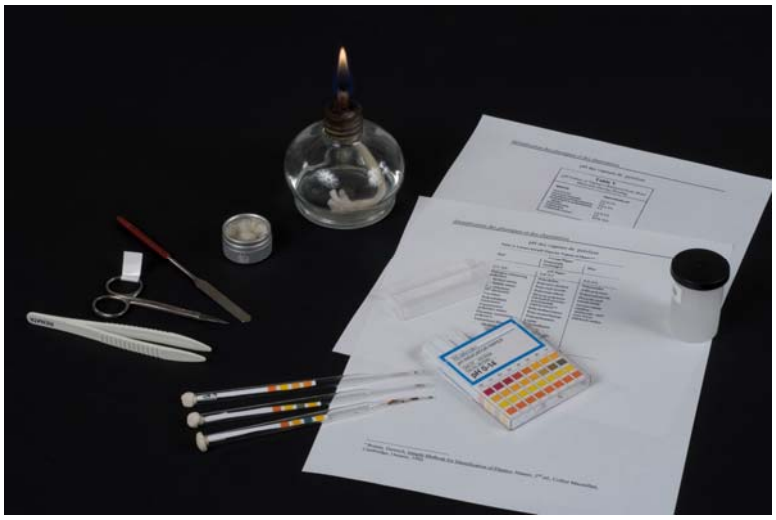



The strips are bent so that they are held in place by simple pressure against the wall of the pipette. The tubular end of the pipette is then sealed with modeling dough (*Plasticine*). The sample can then be brought to the flame.

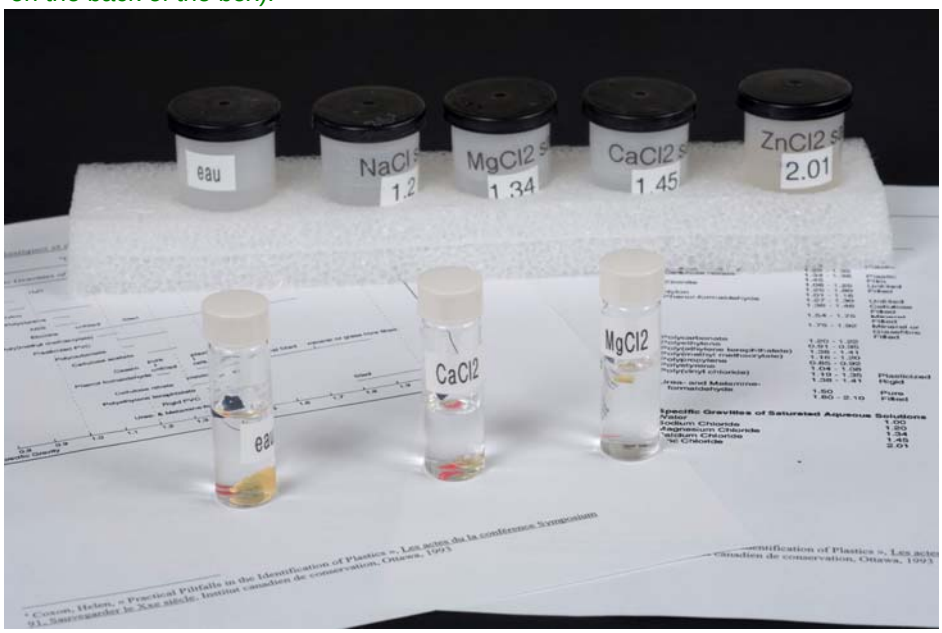
The sample is brought to the flame to free the vapours of combustion that will influence the indicators present in the pipette. Since the combustion vapours are heavier than air, the pipette is laid flat on the work surface for a few seconds or minutes, depending on the size of the sample, so that the vapour can come into contact with the pH strip.

The specific gravity of samples can be measured before vaporizing them by placing them in saturated salt solutions (see appendices for specific gravity reference tables and recipes for the salt solutions). A very small sample collected on the object can be floated in different solutions. It will float where it is less dense and it will sink when it is denser than the solution. All the polyolefins (polyethylene and polypropylene) will float in water. The presence of fillers in the resin will alter the specific gravity of the sample but this is taken into account in the reference tables. Plastic transformed into foam cannot be tested for specific gravity. The results of these two tests can be combined with those of the solubility test, another tried and true method. Conservators are generally able to identify, or at least characterize, a material based on the results of these tests.


The color of the strip in the pipette is then compared to the pH reference scale provided with the strips. Here, front top to bottom : pH 4.0, pH 6.0 and pH 9.0 (reading on the back of the box).



Refer to tables 3,4 and 5 (Appendices) for the pH values of the combustion vapours of most common plastics.



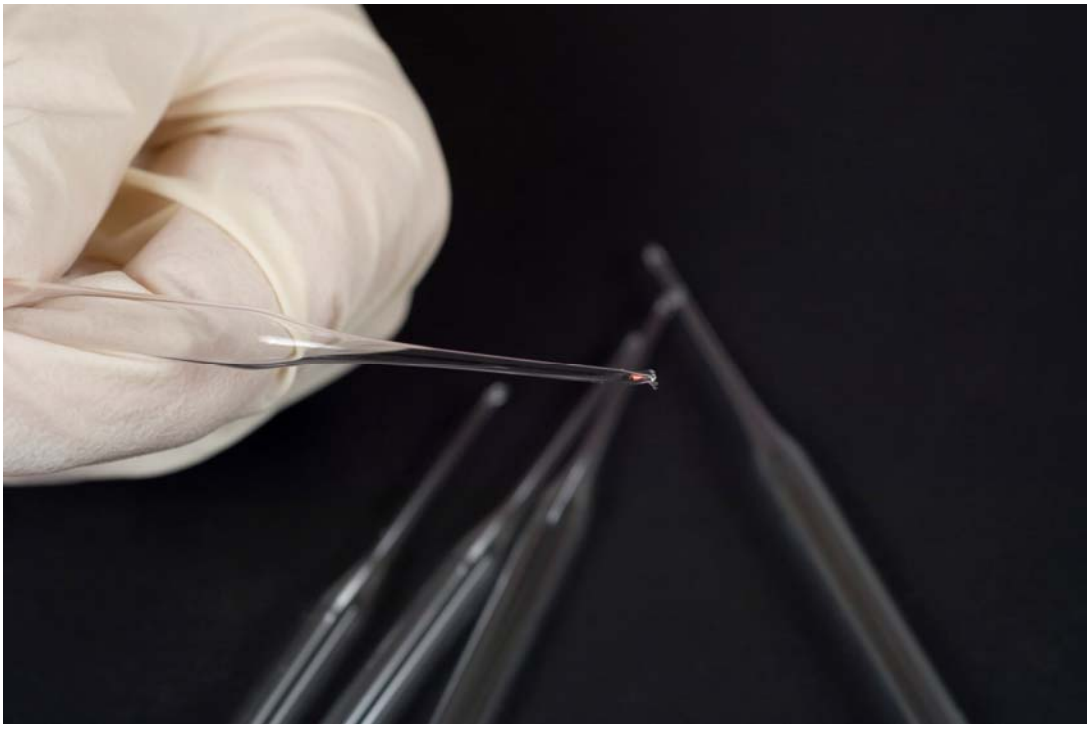

A very small sample collected on the object can be floated in different solutions. It will float where it is less dense and it will sink when it is denser than the solution. The specific gravity of samples can be measured by referring to specific gravity reference tables.

Reference plastics are required as controls They are also used to master the technique and to ensure that the reagents are still effective, or still useable, or not outdated. Each test sample should be run with a reference sample.

## Conclusion

Reference plastics are required as controls They are also used to master the technique and to ensure that the reagents are still effective, or still useable, or not outdated. Each test sample should be run with a reference sample.

Identifying plastics and elastomers is often complicated by the nature of the materials, which may be copolymers or mixtures of different polymers, or may contain fillers, plasticizers, stabilizers, colorants, etc. While these miniaturized tests cannot identify all plastics, they are simple, effective, and ideally suited to confirm the identity of many plastics and elastomers. This document describes the applications, required materials, protocols, interpretation, safety recommendations, and references for 7 miniaturized tests. The sources and prices of many of the materials are also provided.



The size of a sample to be submitted to a pyrolysis test can be so small, that it becomes hardly visible to the naked eye. Here, enlarged to enhance visualization.

## BEILSTEIN TEST

### Application

This is a pyrolysis test that is used to detect chlorine in vinyls (**polyvinyl chloride [PVC] and polyvinylidene chloride [PVDC]**), hydro chlorinated rubbers, and chloroprene rubber-based adhesives such as contact cement.

### Materials Required

Spool of small gauge copper wire
Small piece of balsa
Alcohol burner

### Procedure

The copper wire must be completely clean and free of any contamination. A fresh piece of wire should be used for each test. Cut a strand of small gauge copper wire is cut from the spool. Insert one end of the wire in a piece of balsa. Heat the other end in the flame of the alcohol burner until it becomes red hot. Touch the red-hot end of the copper wire to the sample and then place it back in the flame. A distinctive blue/blue-green color indicates a positive test, i.e., the presence of chlorine.

### Interpretation

This test can also be used to identify thermoplastics, which melt when touched with the red-hot copper wire, while thermosetting resins do not. Even if the test is negative for the presence of chlorine, it provides other useful information on the type of plastic. Hydro chlorinated rubbers may be confused with vulcanized rubber because they are similar in appearance, but they will give a negative result in the lead acetate test (see Lead Acetate Test). Certain rubber-like PVCs may be confused with rubber hydrochlorides. When in doubt, a carbon tetrachloride solubility test can be performed—rubber hydrochlorides are soluble in carbon tetrachloride while PVCs are not. The Beilstein test cannot be used for mineral chlorides. In addition, certain flame-retardants can produce false positives. When in doubt, measure the pH of the combustion vapor in the pipette—PVC vapor is very acid (pH ≈ 1; see tables 1 and 2 in the appendices for the pH values of combustion vapors).

### Recommendations

Test the procedure on a reference sample first. Since the test burns the surface of the test material, use a small gauge wire and select the zone to be analyzed carefully to minimize damage to the object. If the same wire is used for subsequent tests, cut off the heated end of the wire before performed the subsequent test to avoid cross-contamination.

## Reference

CCI Notes, Canadian Conservation Institute, Note 17/1

Cut a strand of small gauge copper wire from the spool. Insert one end of the wire in a piece of balsa to avoid burns to the fingers. Heat the other end of the wire in the flame of the alcohol burner until it becomes red hot. Lightly touch the surface of the material to be analyzed with the wire and return it to the flame. A bright green flame indicates the presence of chlorine ion.

## DIPHENYLAMINE TEST

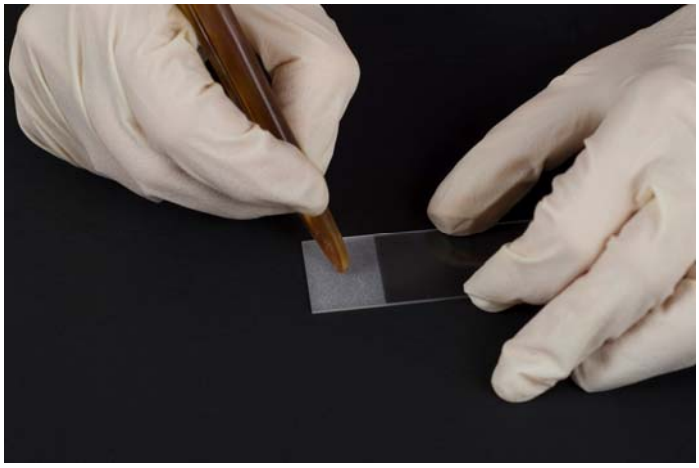
### Application

This wipe test is used to detect nitrogen oxides in **cellulose nitrates** (celluloid, Xylonite, Parkesine). This result is obtained by the wipe method.

### Materials Required

Microscope slides with frosted end
0.5% (w/v) diphenylamine in 70% sulfuric acid (70 parts acid in 16 parts water)
Disposable droppers or capillary tubes
Diphenylamine, free base, purified (Sigma-Aldrich, D2385, $20.00/5 g)

### Procedure



Gently rub the frosted end of the microscope slide against the surface of the object. Add a drop of reagent and spread it across the frosted end of the microscope slide. An intense blue color indicates a positive test.

Sample is collected by gently rubbing the surface of the object over the frosted end of a microscope slide.

### Interpretation

Since this test is very sensitive, surface contamination may occasionally result in a false positive. Clean slides must thus be used for each sample. When in doubt, perform Molisch's test on the sample. When cellulose nitrate is mixed with Molisch's reagent, a characteristic green color develops. This test cannot distinguish between cellulose nitrate and cellulose acetate photographic films. A simple, effective test can be used to differentiate between these two types of film. Refer to the KI-Starch Microtest at :

http://www.ccq.mcc.gouv.qc.ca/formulaires/test_iode_ang.pdf

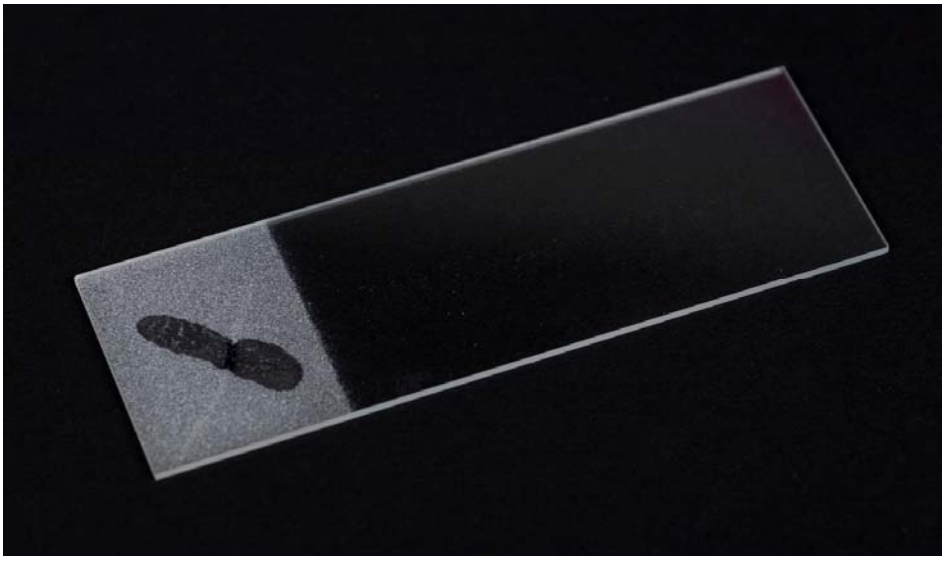
Add a drop of reagent and spread it across the trace left by the object rubbed across slide..

## Recommendations

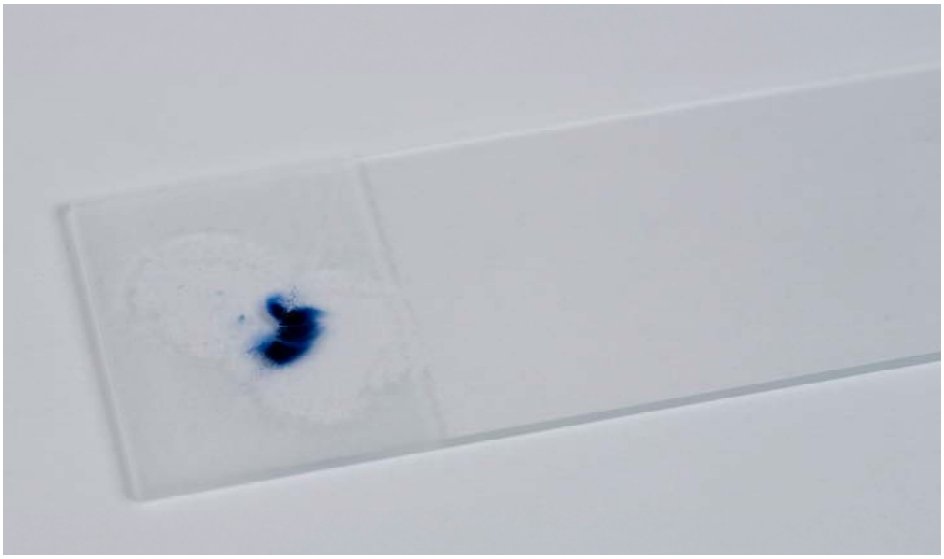
Sulfuric acid is a strong oxidant. To avoid accidents, remove the object from the work surface once the sample has been collected. Wear gloves and an apron. Open the bottle just prior to preparing the reagent and immediately close it when the desired volume has been removed. Protect the work surface.

## Reference

CCI Notes, Canadian Conservation Institute, Note 17/2



The reagent will react at the intersection point with the sample on the slide.



A deep blue stain indicates a positive result.

## LEAD ACETATE TEST

### Application

This test is used for detecting sulfur and, as such, is very useful for identifying **vulcanized rubbers**, whether soft, or hard like vulcanite and ebonite. It can also be used to identify protein materials such as hair, silk, and sinew. The result is obtained after pyrolysis of the sample.

### Materials Required

Lead acetate paper (Fisher, 14-862, $52.39/box of 24 vials containing 100 strips each)
Hydrogen peroxide diluted to 5% (v/v) in water
Pasteur pipettes (Fisher, 13-678-6G, 5 3/4", $18/box of 200)
Disposable droppers or capillary tubes
Alcohol burner
*Plasticine*

### Procedure

Seal the capillary end of the pipette in the flame. Collect a sample of material to be tested. A sample the size of the dot on an "i" is amply sufficient. Place the sample in the pipette. Trim a strip of lead acetate paper so that it can easily fit in the pipette. Bend one end of the strip to suspend it in the pipette and dip the other end in water. Insert the lead acetate paper in the pipette and seal the pipette, ensuring the paper strip is held in place by the *Plasticine*. To gain additional information from the sample, a pH test strip can also be inserted in the pipette before it is sealed (see pH and Specific Gravity section). Place the pipette in the flame so as to burn the sample. Since the sample is very small and the combustion vapor is heavier than air, the pipette must be deposited on the work surface for several minutes (10 minutes maximum) for the result to appear. If there is any sulfur in the sample, the paper will gradually turn brown as the lead acetate, which is white, is transformed into lead sulfide, which is black. Remove the paper from the pipette and place a drop of 5% (v/v) hydrogen peroxide on the brown part of the paper. If the brown color disappears, this means that the lead sulfide (brown color) has been transformed into lead sulfate (white), providing further confirmation of the presence of sulfur in the sample.


The lead acetate strip is cut lengthwise and wetted before it is introduced in the pipette, which is then sealed with modeling paste.

## Interpretation

Even if the result is negative, this test provides other useful information for identifying the material—behavior when heated, combustion vapor pH.

## Recommendations

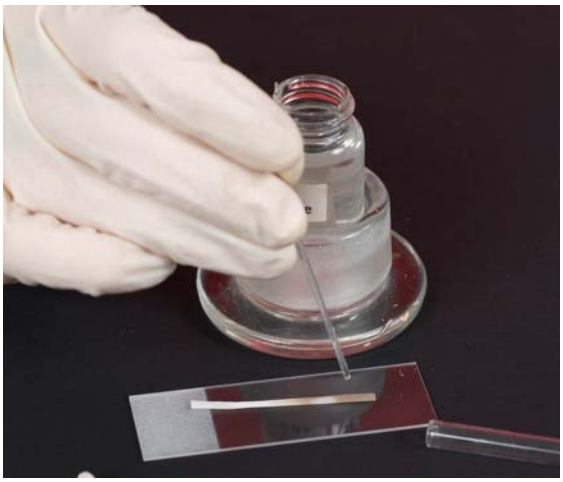
Even diluted hydrogen peroxide is corrosive. Always wear gloves and an apron. Once the sample has been collected, remove the object from the work surface. Since the test is destructive, it is better to master the technique first using reference samples.

## Reference

Browning, B.L., *Analysis of Paper, 2nd ed.,* Marcel Dekker, New York and Basel, 1977.

The sample is brought to the flame.


If the sample contains sulphur the indicator strip will turn black, after a few seconds.



If a drop of peroxide applied on the blackened zone makes the paper turn white, a positive result for sulphur is confirmed.

## HYDROXYLAMINE HYDROCHLORIDE TEST

### Application

This test is used to detect esters and acetate ions. It is useful for identifying objects made of **cellulose acetate** as well as **polyvinyl acetate**-based adhesives.

### Materials Required

**Solution 1**: 1 N potassium hydroxide in methanol (Fisher, SP220-1, $39/liter)
**Solution 2:** Saturated hydroxylamine hydrochloride solution in methanol (1 g/19 ml of methanol) (Sigma-Aldrich, 15J941-7, $6.60/100 g)
**Solution 3:** 1% (w/v) ferric chloride in water
**Solution 4:** 20% (v/v) hydrochloric acid in water
Hydroxylamine hydrochloride (Sigma-Aldrich, 15J941-7, $6.60/100 g)
Methanol
Ferric chloride (Sigma-Aldrich, 20.292-6, $8.80/100 g)
Disposable droppers
Disposable 3 or 5 ml test tubes
1 ml graduated pipettes or tuberculin syringes

### Procedure

The sample should be about the size of the head of a pin. Place the sample in a test tube. Add 1 ml of **solution 1** and two drops of **solution 2**. Shake, wait three minutes, then add two drops of **solution 3**. Shake and add **solution 4** a drop at a time, shaking after each drop. Up to ten drops may be required. If the test is positive, the solution turns violet-red. A yellow color does not indicate a positive test.

### Interpretation

Cyanoacrylate and cellulose nitrate have been reported to give false positives. However, the diphenylamine test for nitrate ions will have already eliminated cellulose nitrate as a possibility. It can be difficult to differentiate between cyanoacrylates and polyvinyl acetates—which are mainly used as adhesives—with the hydroxylamine test. However, a pyrolysis test can be performed to differentiate the two since cyanoacrylates are thermosetting plastics and do not melt before vaporizing when heated, while polyvinyl acetates are thermoplastics and soften and melt when heated.

### Recommendations

This is a destructive test and requires a relatively large sample. We thus recommend that the sample be used for a second test such as Molisch's test for cellulose. Since the proportion of reagents is critical for this test, it is important to master the procedure using reference samples before testing museum objects. The hydroxylamine hydrochloride solution is light-sensitive. It should be prepared in a brown bottle and verified using a reference sample prior to testing a sample from a museum object. Certain reagents are corrosive while others are toxic. Certain elementary precautions should thus be taken when preparing them such as wearing gloves and an apron. Also, avoid inhaling methanol fumes.

## Reference

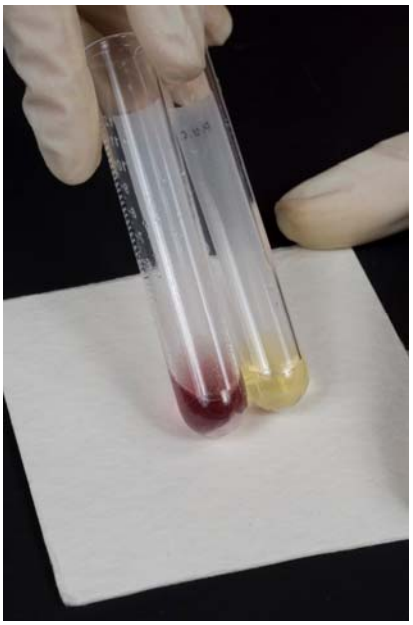
Coxon, H. C. 1993. Practical Pitfalls in the Identification of Plastics. In *Saving the Twentieth Century: The Conservation of Modern Materials*, Proceedings of a Conference: Symposium 91 – Saving the Twentieth Century, Canadian Conservation Institute, pp. 395-406.


The hydroxylamine hydrochloride test is performed in a test tube and requires 4 reagents

The reagents are added in the blank, in the reference and in the unknown tube.


Three minutes are spent between the addition of **solution 3** (2 drops) and **solution 2** (2 drops).


As for a titration test, the tube must be shaken between each drop of **solution 4** is added.



A positive result shows a pinkish violet solution. A yellow color is a negative result.

## FORMALDEHYDE TEST

### Application

This semi-quantitative test is used commercially to measure the concentration of formaldehyde in disinfectants and preservatives. It can be used to detect **urea-formaldehyde**, **phenol-formaldehyde**, and **melamine-formaldehyde**. The result is obtained after pyrolysis of the sample.

### Materials Required

Merckoquant® Formaldehyde Test kit (BDH-VWR, M1.10036.01, $59.47/100 test strips, a test tube, and a bottle of carbonate reagent)
Pasteur pipettes (Fisher, 13-678-6G, 5 3/4", $18/box of 200)
*Plasticine*
Alcohol burner

### Procedure

The manufacturer's protocol is easy to follow. However, very small or solid samples containing highly cross-linked formaldehyde such as phenol-formaldehyde and melamine-formaldehyde may give false negatives. To avoid this problem, we suggest heat-sealing the capillary end of a pipette and placing a sample the size of the dot on an "i" in the pipette. Then, place a drop of carbonate solution on half a test strip (cut in two longitudinally). The test strip will turn from yellow to pink. Bend one end of the test strip, insert it in the pipette, and hold it in place with the *Plasticine*. Heat the sample in the flame of the alcohol burner. Remove the pipette from flame. If there is any formaldehyde in the sample, the test strip will turn violet within approximately ten minutes. A pink color does not indicate a positive test.

### Interpretation

Apart from acetaldehyde and glutaraldehyde, which produce different colors, the manufacturer does not mention any substances that give a false positive.

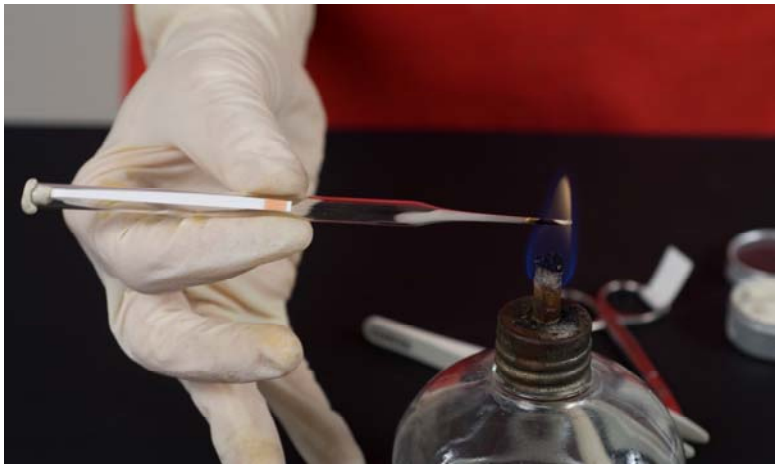
### Recommendations

Since this is a destructive test, we recommend using it only after a pyrolysis test has been performed to determine whether the sample is a thermosetting plastic (does not soften before burning) and the pH of the combustion vapor has been established. The combustion vapors of urea-formaldehyde and melamine-formaldehyde are alkaline (pH 9.5) while that of phenol-formaldehyde is neutral (pH ≈ 7.0). The test should be practiced using reference samples before testing a museum object.

### Reference

Commercial source


The indicator strip is cut lengthwise and a drop of reagent is applied on the yellow indicator band. It then turns to pink. The strip is inserted in the pipette, which is then sealed with modeling paste.



The sample is then exposed to the flame to release the combustion vapours.


After some time (a few seconds or at most a few minutes) a violet color appears showing the presence of formaldehyde in the sample.

## MOLISCH'S TEST

### Application

This test is used to detect cellulose as well as modified celluloses such as **cellulose acetate** and **cellulose nitrate**, which can be differentiated by the colors of the reaction products. Wood, paper, and cotton give positive reactions. This result is obtained by the wipe method.

### Material Required

Microscope slides with frosted end
2% (w/v) 1-Naphthol in ethanol (Sigma-Aldrich, N199-2, $18.00/100 g)
Ethanol (denatured or food grade)
Concentrated sulfuric acid
Disposable droppers or capillary tubes

### Procedure

Gently rub the frosted end of the microscope slide against the surface of the object. Place a drop of naphthol solution on the sample. Once the ethanol has evaporated, place a drop of sulfuric acid on the frosted end of the slide and draw it over the sample. Red indicates the presence of cellulose acetate while diffuse yellow-green is characteristic of cellulose nitrate.

### Interpretation

When wood is used as a filler it may give a false positive. However, translucent resins such as cellulosic resins do not contain fillers and therefore do not give rise to false negatives. This test cannot distinguish between cellulose nitrate and cellulose acetate photographic films. A simple, effective test can be used to differentiate between these two types of film. Refer to the KI-Starch Microtest at : http://www.ccq.mcc.gouv.qc.ca/formulaires/test_iode_ang.pdf

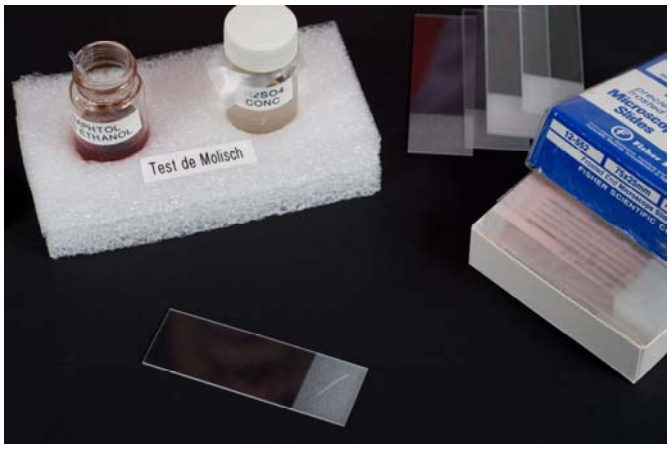
### Recommendations

Since this is a minimally destructive test, it can be used on the same sample before the hydroxylamine test. It should be noted that 1-naphtol is very toxic for humans (carcinogen and teratogen) and that sulfuric acid is very corrosive. As such, all the usual precautions should be taken. To avoid accidents, remove the object from the work surface once the sample has been collected. Wear gloves and an apron. Only open the bottles to remove the required amount of reagent and then close immediately. Protect the work area.

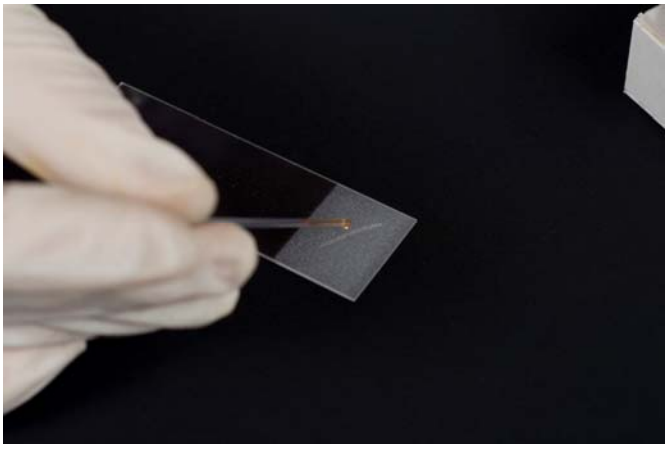
### Reference

Saunders, K. J., *The Identification of Plastics and Rubbers*, Chapman & Hall, 1966, p. 21.

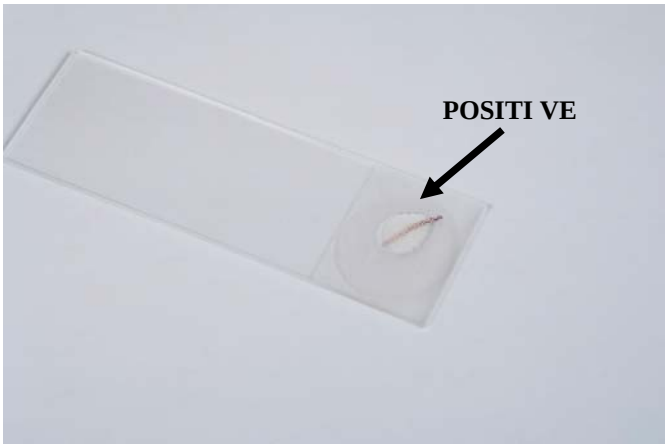
A sample is collected by gently rubbing the surface of the object over the frosted end of a microscope slide.



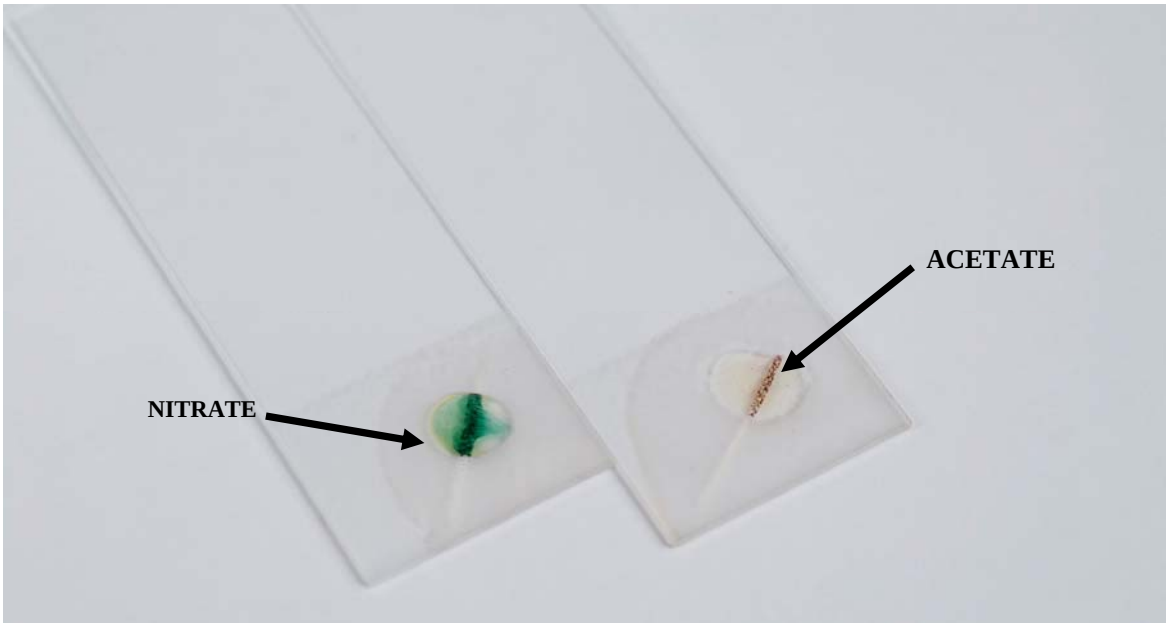

The Mollish's test uses two reagents. The first is in a volatile solvent.



Once the volatile solvent evaporated, the second reagent can be added.




A positive result is confirmed by a red color.




This test can also be a confirmation test for a cellulose nitrate if it gives a green color when positive.

## DIMETHYLAMINOBENZALDEHYDE TEST

### Application

This is a test used to detect **polyamides** (nylon), **polycarbonates**, and, using acetic acid, **polyurethanes**. This result is obtained by the pyrolysis method.

### Materials Required

Pasteur pipettes (Fisher, 13-678-6G, 5 3/4", $18/box of 200)
Cotton swabs
Disposable droppers or capillary tubes
Alcohol burner
*Plasticine*
Methanol
*p*-Dimethylaminobenzaldehyde (Sigma-Aldrich, 10,976-2, $17.20/100 g)
**Solution 1** - 14% (w/v) *p*-dimethylaminobenzaldehyde in methanol
**Solution 2** - Concentrated hydrochloric acid, or concentrated acetic acid (for polyurethane)

### Procedure

Heat-seal the capillary end of the pipette. Place the sample in the pipette. A sample the size of the dot on an "i" is amply sufficient. Place two drops of **solution 1** and two drops of **solution 2** on a cotton swab and place the swab in the pipette. Seal the pipette with *Plasticine*. Heat the sample over the flame. If the cotton swab turns blue or red-violet, the sample is a **polyamide** or a **polycarbonate**, respectively. These two polymers are very different and cannot be confused. This test is thus very useful for distinguishing polystyrene or acrylic from polycarbonate or polyester from nylon. When performed with acetic acid, this test can also be used to identify **polyurethanes**. A yellow color indicates a positive test.

### Interpretation

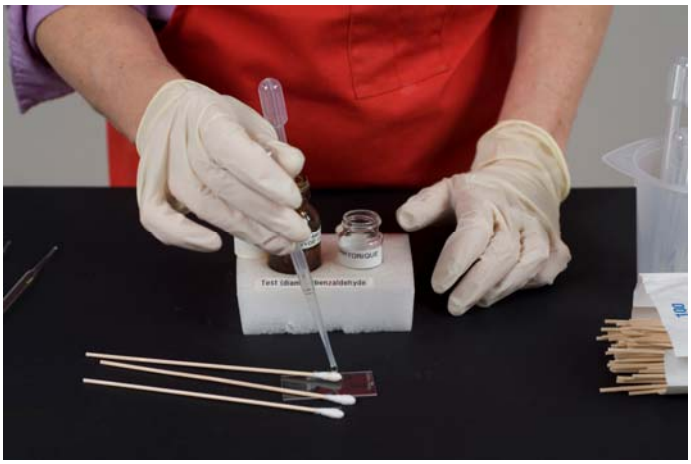
Polyester, polyethylene, and polystyrene do not give colored reaction products. This test may also give a false positive if proteins are present. When in doubt, perform a Biuret test. At present, we do not know whether any substances interfere with this test. We have, however, observed that, in the absence of *p*-dimethylaminobenzaldehyde, polycarbonate reacts with the hydrochloric acid to produce a red vapor. In addition, when polycarbonate burns, it produces a thick brown smoke while polyamide becomes transparent and does not smoke.

### Recommendations

Hydrochloric acid is very corrosive. To avoid accidents, remove the object from the work surface once the sample has been collected. Wear gloves and an apron. Open the bottle just prior to use and immediately close it when the desired volume has been removed. Protect the work surface. Do not inhale methanol fumes.

### Reference

Saunders, K.J., *The Identification of Plastics and Rubbers*, Chapman & Hall, 1966, p. 54.



The p-dimethylaminobenzaldehyde test requires two reagents. They are applied on a cotton swab. The later will be used as an indicator in the pipette, then sealed with modeling paste.

The sample is then exposed to the flame to free its combustion vapours.


Colour reactions obtained from three samples : the first is nylon, the second is a polycarbonate and the third, done with acetic acid in place of hydrochloric acid, is polyurethane.

## APPENDICES

**Table 1**
**pH Values of Vapours Released from Sheet Materials During Heating [1]**

| Material | Approximate pH |
|---|---|
| PVC/PVDC | 0.0–0.5 |
| Cellulose triacetate | 2.5 |
| Polyethylene/Polypropylene | 3.0–4.0 |
| Poly(ethylene terephthalate) | 4.0 |
| (Mylar) | 4.5–5.5 |
| Polycarbonate | 5.5 |
| Polystyrene | 9.0–10.00 |
| Polyamide (Nylon) | |

**Table 2**
**Litmus and pH Tests for Combustion Vapors of Plastics [2]**

| | **Litmus Paper** | |
|---|---|---|
| Red | Essentially unchanged | Blue |
| | **pH Paper** | |
| 0.5–4.0 | 5.0–5.5 | 8.0–9.5 |
| Halogen-containing polymers<br>Polyvinyl esters<br>Cellulose esters<br>Polyethylene terephthalate<br>Novolacs<br>Polyurethane elastomers<br>Unsaturated polyester resins<br>Fluorine-containing polymers<br>Vulcanized fiber<br>Polyalkylene sulfide | Polyolefins<br>Polyvinyl alcohol<br>Polyvinyl acetals<br>Polyvinyl ethers<br>Styrene polymers (including styrene-acrylonitrile copolymers)**<br>Polymethacrylates<br>Polyoxymethylene<br>Polycarbonates<br>Linear polyurethanes<br>Silicones<br>Phenolic resins<br>Epoxy resins<br>Cross-linked polyurethanes | Polyamides<br>ABS polymers<br>Polyacrylonitrile<br>Phenolic and cresol resins<br>Amino resins (aniline-, melamine-, and urea-formaldehyde resins) |

* Slowly heated in a pyrolysis tube.
** Some samples show slightly alkaline behavior.

[1] Coxon, H. C. 1993. Practical Pitfalls in the Identification of Plastics. In *Saving the Twentieth Century: The Conservation of Modern Materials*, Proceedings of a Conference: Symposium 91 – Saving the Twentieth Century, Canadian Conservation Institute.

[2] Braum. Dietrich, *Simple Methods for Identification of Plastics*, Hanser, 2nd ed., Collier Macmillan, Cambridge, Ontario, 1986.

**Table 3**
**Specific Gravity of Selected Plastics**[3]

| | | |
|---|---|---|
| ABS | 1.04–1.10 | |
| Casein | 1.26 | Pure |
| | 1.35 | Plastic |
| Cellulose acetate | 1.25–1.35 | |
| Cellulose nitrate | 1.34–1.38 | Plastic |
| | 1.45 | Film |
| Ebonite | 1.08–1.25 | Unfilled |
| | 1.25–1.80 | Filled |
| Nylon | 1.01–1.16 | |
| Phenol-formaldehyde | 1.27–1.30 | Unfilled |
| | 1.36–1.46 | Cellulose Filled |
| | 1.54–1.75 | Mineral Filled |
| | 1.75–1.92 | Mineral or glass fiber Filled |
| Polycarbonate | 1.20–1.22 | |
| Polyethylene | 0.91–0.95 | |
| Poly(ethylene terephthalate) | 1.38–1.41 | |
| Poly(methyl methacrylate) | 1.16–1.20 | |
| Polypropylene | 0.85–0.92 | |
| Polystyrene | 1.04–1.08 | |
| Poly(vinyl chloride) | 1.19–1.35 | Plasticized |
| | 1.38–1.41 | Rigid |
| Urea- and melamine-formaldehyde | 1.50 | Pure |
| | 1.80–2.10 | Filled |

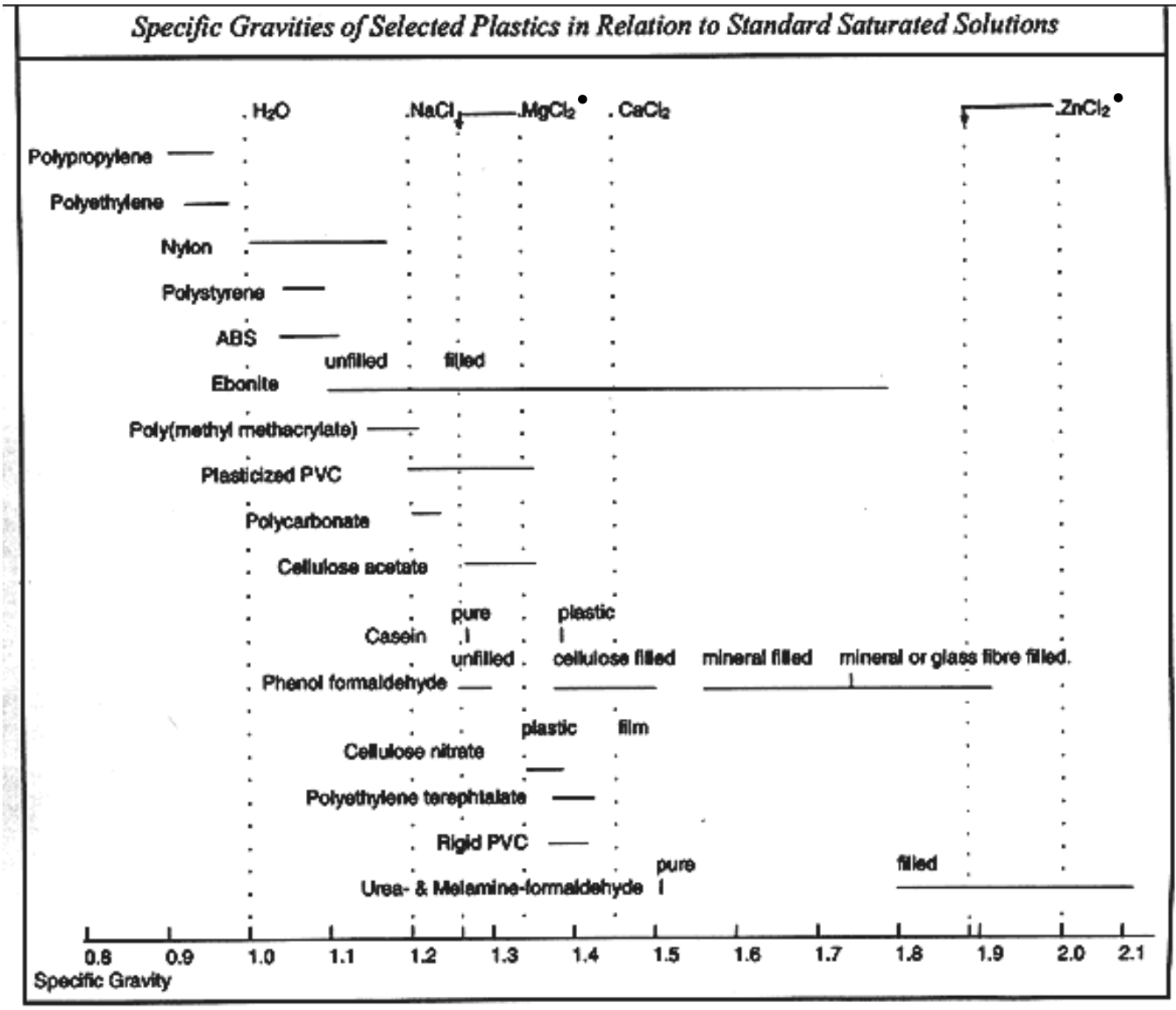
**Specific Gravities of Saturated Aqueous Solutions**

| | | |
|---|---|---|
| Water | 1.00 | |
| Sodium Chloride | 1.20 | 35.9g /100ml at 25°C |
| Magnesium Chloride | 1.26• | 54.2g/100ml at 20°C |
| Calcium Chloride | 1.45 | 74.5g/100ml at 20°C |
| Chlorure de zinc | 1.89• | 432g/100ml at 25°C |

• These values have been corrected to match the values in the *Merck Index.*

[3] Coxon, H. C. 1993. Practical Pitfalls in the Identification of Plastics. In *Saving the Twentieth Century: The Conservation of Modern Materials*, Proceedings of a Conference: Symposium 91 – Saving the Twentieth Century, Canadian Conservation Institute.

**Table 4**
**Specific Gravities of Selected Plastics in Relation to Standard Saturated Solutions**[4]




**• These values have been corrected to match the values in the *Merck Index***

[4] Coxon, H. C. 1993. Practical Pitfalls in the Identification of Plastics. In *Saving the Twentieth Century: The Conservation of Modern Materials*, Proceedings of a Conference: Symposium 91 – Saving the Twentieth Century, Canadian Conservation Institute.

**Table 5**
**Approximate densities of important plastics[5]**

| Density g/cm$^3$ | Material |
|---|---|
| 0.80 | Silicone rubber ( silica filled up to 1.25) |
| 0.83 | Polymethylpentene |
| 0.85-0.92 | Polypropylene |
| 0.89-0.93 | High pressure (low density) polyethylene |
| 0.91-0.92 | Polybutene-1 |
| 0.91-0.93 | Polyisobutylene |
| 0.92-1.0 | Natural rubber |
| 0.94-0.98 | Low pressure (high density) polyethylene |
| 1.01-1.04 | Nylon 12 |
| 1.03-1.05 | Nylon 11 |
| 1.04-1.06 | Acrylonitrile-butadiene-styrene copolymer (ABS) |
| 1.04-1.08 | Polystyrene |
| 1.05-1.07 | Polyphenylene oxide |
| 1.06-1.10 | Styrene-acrylonitrile copolymers |
| 1.07-1.09 | Nylon 610 |
| 1.12-1.15 | Nylon 6 |
| 1.13-1.16 | Nylon 66 |
| 1.1-1.4 | Epoxy resins, unsaturated polyester resins |
| 1.14-1.17 | Polyacrylonitrile |
| 1.15-1.25 | Cellulose acetobutyrate |
| 1.16-1.2 | Polyvinyl acetate |
| 1.18-1.24 | Cellulose propionate |
| 1.19-1.35 | Plasticised PVC (approx. 40% plasticizer) |
| 1.20-1.22 | Polycarbonate (based on bisphenolA) |
| 1.20-1.26 | Crosslinked polyurethanes |
| 1.26-1.28 | Phenolformaldehyde resins (unfilled) |
| 1.21-1.31 | Polyvinyl alcool |
| 1.25-1.35 | Cellulose acetate |
| 1.30-1.41 | Phenolformaldehyde resins filled with organic materials (paper, fabric) |
| 1.3-1.4 | Polyvinylfluoride |
| 1.34-1.40 | Celluloid |
| 1.38-1.41 | Polyethylene terephtalate |
| 1.38-1.41 | Rigid PVC |
| 1.41-1.43 | Polyoxymethylene (polyformaldehyde) |
| 1.47-1.52 | Urea and melamine formaldehyde with organic fillers |
| 1.47-1.55 | Chlorinated PVC |
| 1.5-2.0 | Phenoplast and aminoplast with inorganic fillers |
| 1.7-1.8 | Polyvinylidene fluoride |
| 1.8-2.3 | Polyester and Epoxy resins filed with fiber glass |
| 1.86-1.88 | Polyvinylidene chloride |

[5] Braum. Dietrich, *Simple Methods for Identification of Plastics*, Hanser, 2nd ed., Collier Macmillan, Cambridge, Ontar

| | |
|---|---|
| 2.1-2.2 | Polytrifluoromonochloroethylene |
| 2.1-2.3 | Polytetrafluoroethylene |