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The Beilstein Test: Screening Organic and Polymeric Materials for the Presence of Chlorine, with Examples of Products Tested

Introduction

Chlorinated organic materials are generally considered unsuitable for long-term conservation and museum applications due to their potential harm to objects. These materials may degrade and produce acidic gases, or additives such as plasticizers may migrate to objects. These products can be analyzed in detail in the laboratory, but conservators may use a simple test — the Beilstein Test — to screen their own materials for the presence of chlorine without having to submit samples for laboratory analysis.

The test is based on the reaction of chlorine with copper compounds at the high temperatures found in burner flames. These conditions produce excited, green-coloured copper atoms or ions that cause the normally colourless (or very slightly blue) flame to flare brilliant green (or sometimes blue-green).

Procedure

Use a copper wire thick enough not to melt too quickly (e.g., 12- or 14-gauge copper wire, stripped of its insulation, that is used for wiring houses). Heat the copper wire to glowing red in the flame of a Bunsen burner or propane torch.

Continue heating until no colour (other than the nearly invisible, slightly blue torch flame) is visible. There should be no green colour in the flame. Wash the wire intermittently with water and dilute nitric acid (10%) to remove materials that cause unwanted colouration. If washing fails, try a new wire. Once it is clean, take care to avoid touching the wire with fingers or objects other than the test material. When the flame is colourless, the test can proceed.

The test is best carried out in subdued lighting so that the colour of the flame can be seen easily. Vapours, fumes, or smoke from the sample must envelop the hot copper wire in the flame so that reactions between the tested material and the hot copper can occur. This can be accomplished in several ways:

1. Heat the wire to red-hot, then quickly touch a fragment of the sample to it and immediately return the wire to the flame. A plume of green is a positive test for the presence of chlorine. Do not touch the entire sample with the hot wire. Some plastics (e.g., cellulose nitrate, Celluloid) may burst into flame. (This reaction is usually considered a positive test for cellulose nitrate.)

2. With the wire red-hot and still at the edge of the flame, bring a fragment of the sample near the flame

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in the vicinity of the wire until the fragment chars and the smoke produced envelops the wire. A green flame is a positive test for the presence of chlorine.

3. With the red-hot wire in the flame, place a fragment of the sample near or into the flame until it starts to char. Quickly move the smoking sample to the air intake at the base of the burner so that the smoke is drawn in with air and is intimately mixed with the flame gases. A green flame surrounding the copper wire is a positive test for chlorine.

4. Heat the wire to red-hot. Then immediately touch the wire with a piece of the sample held beside the air intake at the base of the burner or torch, so that some of the fumes produced are drawn into the flame. A green flame is a positive test for chlorine.

The fourth method described is the most sensitive. It is also the best method to detect the presence of a volatile chlorinated material — perhaps a solvent such as methylene chloride.

Discussion

The Beilstein Test has been used for many decades to analyze organic and polymeric materials (Shriner *et al.* 1964; Vogel 1966). A very similar test is now used by refrigeration technicians to detect and localize leaks of freon-type refrigerants (i.e., chlorinated and fluorinated hydrocarbons). This test has also been recommended for detecting PVC coin storage products (Sharpless 1980).

The Beilstein Test is quite sensitive and requires a very small sample. There are, however, several possible sources of error. Residues from fingerprints can give weak false positive results. Chlorinated inorganic materials (i.e., pigments, fillers) can also give a false positive result, but these are usually not present so they rarely interfere with the test. The major difficulty encountered is that the sample may volatilize too rapidly, especially if it is a solvent. These volatiles are lost so quickly that they do not have time to react with the copper wire. To avoid this problem, the fourth method described above — introducing the fumes at the air intake for the flame — is recommended.

The test is suitable for screening a wide variety of products including plastic films and sheets, adhesives, rubbers, coatings, solvents, and fabricated items. Common materials that give positive results include poly(vinyl chloride), poly(vinylidene chloride), chlorinated rubbers, chlorinated epoxies, chlorinated solvents, and any compositions containing these materials.

The Beilstein Test has been used to examine a variety of materials at the Analytical Research Services laboratory at CCI. The presence or absence of chlorinated organics was confirmed by infrared spectroscopy or by radio-isotope excited X-ray energy spectrometry. The results are presented in the table below.

Examples of Beilstein Test Results for Various Polymeric Organic Materials

Product tested (manufacturer or supplier)	Beilstein result	Infrared or X-ray energy spectroscopy result
Sheets and Wrapping Films		
Aircap bubble pack with small bubbles (Smith Packaging)	+	polyethylene with poly(vinylidene chloride)
Aircap bubble pack with large bubbles (Smith Packaging)	–	polyethylene
Alcoa Film clear plastic food wrap (Alcan)	+	poly(vinyl chloride) plus ester
Saran Wrap (Dow)	+	poly(vinylidene chloride)
Stretch n'Seal (ESSO)	+	poly(vinyl chloride)
Baggies (Colgate Palmolive)	–	polyethylene
Glad Sacs (Union Carbide)	–	polyethylene
Mylar, 0.25 mil (Dupont)	–	poly(ethylene terephthalate)
Parafilm "M" (American Can Co.)	–	hydrocarbon wax
Protective Sleeves (for documents, photos, and currency)		
DF Snap-in-Page, No. 1042 3-ring photo slide enclosure page (Desmarais & Frères)	+	poly(vinyl chloride)
DF Snapin Archival Quality, 3-ring photo slide enclosure page, No. 1042X, (Desmarais & Frères)	–	polypropylene
VIS 3-ring photo slide enclosure page	+	poly(vinyl chloride)
Document Protector (DSS Stock No. 7510-21-843-7250)	+	poly(vinyl chloride)
Document Protector, Oxford No. M721 R (Carr McLean)	–	polypropylene
Document Protector (unknown)	–	cellulose acetate
Kodak Protective Photograph Sleeve	–	cellulose acetate
Coinserts (Canada Wholesale Supply)	+	poly(vinyl chloride)
Safeguard Coin Pages, Universal-Plastifilm Cat. No. 64 (Canada Wholesale Supply)	+	poly(vinyl chloride)
Scott Mounts for Stamps (Scott)	–	polystyrene

Examples of Beilstein Test Results for Various Polymeric Organic Materials		
Product tested (manufacturer or supplier)	**Beilstein result**	**Infrared or X-ray energy spectroscopy result**
Foam Gaskets and Weatherstripping		
Neoprene Foam Gasket	+	polychloroprene
Shur-Seal Weatherstrip Tape, white, No. 2270 (Drummond Metal Products)	+	poly(vinyl chloride) plus ester
Stanley Quality Self-Stick Closed Cell Vinyl Foam Weatherstrip Tape, white, No. 93-0251 (Stanley)	+	poly(vinyl chloride) plus ester
Eskimo Polyfoam Heavy Duty Door Weatherstrip, white, No. 64-2517-8	–	polyethylene
Climaloc Weatherstripping Foam Tape, white, No. 12001 (RCR International)	–	polyurethane
Climaloc Weatherstripping Foam Tape, white, No. 12005 (RCR International)	–	polyethylene
Tubing		
Tygon Laboratory Tubing, Formulation R-3603 (Norton Industrial Plastics)	+	poly(vinyl chloride)
C-Flex Tubing	–	silicone-hydrocarbon
Adhesives		
AdSol 604 poly(vinyl acetate) emulsion (Adhesive Solutions Ltd.)	+	no Cl in dry adhesive (by XES)
Magna-tac 1577 XH poly(vinyl acetate) emulsion (Beacon Chem. Co. Inc.)	–	some Cl (by XES)
Swifts 2928 poly(vinyl acetate) emulsion (ESCHEM Canada Ltd.)	+	strong Cl (by XES)
Other materials		
Hydrochloric acid, 0.05%	+	reagent HCl
Mactac wall covering - surface nap - adhesive back	 – +	
PVC Glove (Fisher Scientific)	+	poly(vinyl chloride)

References

Sharpless, Thomas W. "Corrosion: The Problem of Storage." *The Numismatist*, October 1980, p. 2453.

Shriner, Ralph L., Reynold C. Fuson and David Y. Curtin. *The Systematic Identification of Organic Compounds: A Laboratory Manual*. 5th ed. New York: John Wiley and Sons Inc., 1964, p. 64.

Vogel, Arthur I. *Elementary Practical Organic Chemistry. Part 2: Qualitative Organic Analysis*. 2nd ed. London: Longmans, Green and Co. Ltd., 1966, p. 96.

Texte également publié en version anglaise.

Copies are also available in English.

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