References for the Care of Plastics

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American Chemical Society. 1998. US Synthetic rubber program. http://www.acs.org/content/acs/en/education/whatischemistry/landmarks/syntheticrubber.html#early-synthetic-rubber-research (accessed 8/28/15).
This website summaries a commemorative booklet published by the American Chemical Society. Although focused on synthetic rubber, it does provide quite a bit of information about the history of natural rubber leading into synthetic rubber production and uses.

Applied Analytics. 2013. *Analysis in vinyl chloride (VCM) production process*. http://www.a-a-inc.com/documents/AA_AN030_Analysis-in-VCM-Production-Process.pdf (accessed 1/20/15).
This website explains the raw materials and how they are obtained and processed for the production of PVC.

AZo Materials. 2006. Natural rubber/latex: production of natural rubber. http://www.azom.com/article.aspx?ArticleID=3580 (accessed 8/29/15).
This website is managed by the AZo Network, which is a marketing company designed to publish information for the scientific community. This company supports AZo Materials, a database that publishes the latest information in material science and engineering. The site was particularly helpful for discussing the rubber production from the tree to further processing. It also lists some of the major applications of natural rubber.

Bakelite. 1910. The Journal of Industrial and Engineering Chemistry. 545-546.
Although a very dated entry, it helps provide some perspective to original process used to manufacture Bakelite that is not influenced by changes in technology. This entry also provides many of Bakelite's properties.

Bakelite. 1925. *Journal of Chemical Education* 2 (12): 1153-1155.
Another dated entry, like the source above, but helpful in describing the original method of manufacture and some of the most common historical uses from Bakelite when it was first patented and marketed to the public. This entry also describes some of its properties.

Bakelite Corporation. 1937. The Fourth Kingdom. Video. ~29 minutes. https://www.youtube.com/watch?v=GlCFBexBWGU (accessed 3/22/15).
A 1937 promotional video made that covers a brief history of Bakelite, how it is made, and used. The most useful aspect of the video is the historic footage of Bakelite being molded at the Bakelite plant elucidating how Bakelite was made commercially as well as a demo in which a chemist makes Bakelite in the lab as Leo Baekeland made it in his lab in 1907.

Billmeyer, F.W. 1984. *Textbook of Polymer Science*. 2nd ed. New York: J. Wiley & Sons.
This book provides a survey of the theory and practice of polymer science, engineering, and technology. A good reference book for identifying specific terms or processes.

Blackley, D. C. 1997. *Polymer Lattices: Science and Technology*, vol.2. London, UK: Chapman & Hall.
This book is a very detailed text on the chemistry and materials used in the manufacture of rubber.

Blank, S. 1990. An introduction to plastics and rubbers in collections. Studies in Conservation (35): 53-64.
This source gives a good introduction to plastics and rubber, which was helpful for identifying further topics of research.

Brady, G. S. and H. R. Clauser. 1997. *Materials Handbook*. 11th ed. New York, New York: McGraw-Hill Book Co.

Braun, D. 1999. Simple Methods for Identification of Plastics. 4th ed. Cincinnati, OH: Hanser Gardner Publication, Inc.
This publication lists spot test and analytical methods for identifying most plastics. The spot tests are detailed enough to re-create, but often not "re-creatable" in full with materials found in most conservation labs. What is particularly useful are the multiple tables that help with identification through visual analysis and basic properties.

British Plastics Federation. 2014. Injection Molding.
http://www.bpf.co.uk/plastipedia/processes/injection_moulding.aspx (accessed 9/16/14).
This website provided basic information on the injection molding process. The most helpful aspect of the website is a simple video showing the delivery of the plastic, the plastic's passage through the heated barrel and screw, and its injection into the mold through gates and runners.

Canadian Conservation Institute. 1993. The Beilstein test: screening organic and polymeric materials for the presence of chlorine, with examples of products tested. *CCI Notes* 17(1): 1-3.
This short article provides instructions on how to complete the Beilstein Test, which is used on polymeric materials to confirm the presence of chlorine. The article gives step by step instructions and a table of many materials that were tested using this test and then compared with analytical results from Infrared or x-ray energy spectroscopy. This is a quick easy test to help identify PVC.

Canadian Conservation Institute. 1993. The Diphenylamine Spot test for cellulose nitrate in museum objects. *CCI Notes* 17(2): 1-2.
A short article that provides instructions on how to complete the Diphenylamine Test, which is used to confirm the presence of nitrates. The article provides a instructions for preparing the reagent, executing the spot test, and inferences that can be drawn from the test.

Chalifoux, M. 2010. Care and identification of objects made from plastic. *Conserve O Gram* 8(4).
http://www.nps.gov/museum/publications/conserveogram/08-04.pdf (accessed 1/14/2015).
This *Conserve O Gram* provides basic information on identification, causes and signs of deterioration, recommendations including "dos" and "do nots." At the end of the document is a summary table of common plastics with trade names, year introduced, characteristics, early applications, degradation characteristics, and optimum environmental conditions.

Colton, J.S. 2009. Injection Molding – Process Description. http://www-old.me.gatech.edu/jonathan.colton/me4210/injectionmolding.pdf (accessed 9/16/14).
This website, published by the Georgia Institute of Technology, provides a good explanation of the injection molding process. It includes great schematics, diagrams, and pictures showing all the parts and their function.

Crespy, D., M. Bozonnet, and M. Meier. 2008. 100 years of Bakelite, the material of a 1000 uses. Angewandte Chemie International Edition 47 (18): 3322-3328.
This article focuses on the history of Bakelite. There is also an informative section on the manufacture of Bakelite and the three stages it passes through. The article also provides plenty of good illustrations: the original autoclave, several chemical structures, factory images, and many examples of objects made from Bakelite.

CustomPartNet. 2009. Injection Molding. http://www.custompartnet.com/wu/InjectionMolding (accessed 9/16/14).
This website, like the previous, has a good description of the injection molding process as well as great diagrams of the equipment. What was particularly helpful about this site was the illustration of the parts of the mold, how the part looked when removed from the mold, and any steps that are required after molding to make the finished product. In addition, it shows what types of shapes can be made via injection and which cannot.

David, F. 2008. Problem plastics, types of deterioration & where you find it. http://mmics.files.wordpress.com/2008/04/problem-plastics-check-list.pdf (accessed 1/14/2015).
Document has no listed author. However, there is a PowerPoint available online with notes that indicate the author may be Fran David. Document is a general guide listing types of degradation and properties that help to identify plastics. The document includes a table which lists common forms of degradation, causes of the degradation, and the types of plastic it is most likely to be found on. The document also lists other indicators (odors, corrosion, disintegrating tissue, heat) and basic facts and flow charts regarding problem plastics (cellulose nitrate, cellulose acetate, plasticized PVC, and polyurethane foam).

Garth Jones, R. 2014. PVC (polyvinyl chloride usage and history). *Materials World: The Journal of the Institute of Materials* 22(5): 50-52.
This is a short one-page article that provided some of the history of PVC, some of the physical properties of the polymer, and current methods of production.

Grattan, D., eds. 1993. Saving the twentieth century: the conservation of modern materials. Proceedings of a conference symposium '91 – saving the twentieth century, Ottawa Canada.
This publication includes multiple articles on rubber and plastics that range in topic from history and collection to treatment and analysis. It is broken up into several sections, which include: *modern materials in collections*, *conservation policies and plans*, *history of technology*, *processes of deterioration*, *case studies and specific problems with materials*, *testing and development of conservation processes*, and *methods of analysis and identification*.

Fenn, J. 1993. Labeling Plastic Artefacts. *Proceedings of a Conference Symposium '91 Saving the Twentieth Century*. Ottawa, Canada. 341-350.

Hall, A. and K. Wight. 2014. Surveying plastics at a design museum. *ICOM Committee for Conservation preprints*. 17th Triennial Meeting, Melbourne, Australia: ICOM.
Poster on surveying the plastics collection at the Cooper-Hewitt National Design Museum. The poster discusses how the survey was carried out: information was migrated from The Museum System (TMS) database via Excel to Microsoft Access to use as a platform for the initial survey. A PDF of the survey form was created and then uploaded to TMS as a line item. Information was made searchable on TMS. The survey serves as a model for future surveys at the Smithsonian, will be informative for future planning and in directing resource allocation as well as for funding applications. In addition, a visual dictionary was created that can be used by many.

Horie, C. V. 1987. Materials for Conservation. Oxford, UK: Butterworth-Heineman Ltd.

Hufnagl, F. 1997. Plastics + Design. Munich, Germany: ARNOLDSCHE Art Publishers.
This text is written in German with English translation. It provides good information on the history of plastics in design from the beginning until the present. It also includes several full-page illustrations of plastics used in design from pens and jewelry to furniture.

Indolatex. 2011. *Main uses of natural rubber*. http://indolatex.com/main-uses-of-natural-rubber/ (accessed 8/4/15).
This website is for a company that manufactures and sells natural rubber and natural rubber latex from Indonesia. Although an agenda is present, this site was helpful in establishing a summary of uses for natural rubber and synthetic rubber, although the overall utility of synthetic rubber may be downgraded here.

Katz, S. 1984. *Classic Plastics: From Bakelite to High-Tech*. London, UK: Thames and Hudson.

Kauffman, G.B. and R.B. Seymour. 1990. Elastomers: natural rubber. Journal of Chemical Education 67(5): 422-425.
This source provides a summary on the history, sources, chemical structure, and properties of rubber and includes the process of vulcanization and how it changes the rubber chemically. It is a very useful article in providing basic information on natural rubber.

Kauffman, G.B. and R.B. Seymour. 1991. Elastomers: synthetic rubber. Journal of Chemical Education 68(3): 217-220.
This source describes many of the different types of synthetic rubber providing a brief summary of how they are made, their chemical structure and properties.

Keneghan, Brenda. 2001. A survey of synthetic plastic and rubber objects in the Victoria and Albert Museum. *Conservation, Museum Management, and Curatorship* 19(3): 321-331.
The article describes a survey conducted at the Victoria and Albert Museum on objects made of or containing plastics and rubber. The survey served to provide information on the object, storage, damage (if any), and condition. The survey, which intended to better understand the condition of plastic objects in the collection determined that most are in good or fair condition. Those that were not were isolated for study. A list of vocabulary terms to describe observed damage to plastics is at the end for review.

Keneghan, B. and L. Egan, eds. 2007. *Plastics looking at the future and learning from the past*. London, UK: Archetype Publications Ltd.
This publication features papers from the conference held at the Victoria and Albert Museum in May 2007 on plastics. The publication is divided into sections, which include the conservation of plastics, scientific investigation, collecting plastics, aspects of design, and artist's intent.

Modern Plastics. 2007. *How to identify plastics*. http://www.modernplastics.com/how_to_identify_plastics.htm (accessed 1/26/15).
This site provides a chart on how different types of plastics respond to burning. The chart breaks down the types of plastics into categories of no flame, burns but extinguishes on removal from flame source, and continues to burn after removal from flame source. Within those categories observations on the odor, color of the flame, presence of dripping, and speed of burning is noted. A final column is reserved for general remarks.

Morgan, J. 1991. *Conservation of plastics: an introduction to their history, manufacture, deterioration, identification, and care*. London: Plastics Historical Society.
This is an overall source on plastics that provides and introduction on the production, manufacture, chemical properties, simple means of identification, and general care and cleaning. Although general, it is a good source to begin with.

Morgan, J. 1994. A Survey of plastics in historical collections. http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=32&ved=0CCMQFjABOB4&url=http%3A%2F%2Fwww.mlppreservationproject.com%2Fuploads%2FThe_results_of_a_survey_of_plastics.doc&ei=UeqaVcbsLoTZtQWC04HYCg&usg=AFQjCNFlaVPVmMUMrNr93tmtv3oO07W8XQ (accessed 7/6/15).
This source is a report written on a survey of plastics in museum collections by John Morgan through the Plastics Historical Society and The Conservation Unit of the Museum and Galleries Commission. The survey covered 19 museums with varying collections made wholly or partly from plastic. This accompanied by the conditions of storage and display areas as well as how the objects were packed. The most significant information found from the survey as well as what is known to be true about various types of plastics is summarized in a blurb for the most prevalent plastics and general recommendations for storing/preserving plastics as well as conclusions.

Mossman, S. 1993. Plastics in the Science Museum, London: A Curator's View. *Proceedings of a Conference Symposium '91 Saving the Twentieth Century*. Ottawa, Canada. 25-35.

National Public Radio. 2007. *Plastic turns 100: Bakelite's birthday*. http://www.npr.org/templates/story/story.php?storyId=11959165 (accessed 7/6/15).
This website provides access to a recording of All Things Considered on NPR on July 13, 2007. The recording provides historical information on the beginning of Bakelite, discussing specifically the patent and how Leo H. Baekeland came up with Bakelite. The recording further discusses plastic in general and some of its cultural implications. Although brief, some of the historical information provided was new information.

POPART. 2008. http://popart-highlights.mnhn.fr/wp-content/uploads/5_Active_conservation/2_Studies_in_cleaning_plastics/5_2_StudiesInCleaningPlastics.pdf (accessed 1/29/2015).
POPART collaborative presents an abundance of information on the identification of plastics in museum collections, a plastics collection survey, degradation assessment of plastics, and discussion of conservation of plastics.

Quye, A. and C. Williamson, eds. 1999. Plastics: collecting and conserving. Edinburgh: NMS Publishing Limited.
This text is a useful guide which discusses the various types of plastics, how to identify them, and how to properly care for them. It is a general guide which does not cover very specific information about any one plastic, but provides a good introduction to plastics in museums and collections.

Reilly, J. A. 1991. Celluloid Objects: Their Chemistry and Preservation. Journal of the American Institute of Conservation 30 (2): 145-162.

Shashoua, Y. 2008. *Conservation of plastics: materials science, degradation and preservation*. Oxford, UK: Elsevier Ltd.
Overall source on plastics in museum collections that provides abundant information on the history, technology, properties, identification, degradation, and conservation of plastics. In addition, this source provides useful charts on the most common plastics with quick information about names, properties, identification, and degradation.

Shashoua, Y. 2006. Inhibiting the inevitable; current approaches to slowing the deterioration of plastics. *Macromolecule Symposia* 238 (1): 67-77.
This article discusses the degradation and methods of storage to significantly reduce degradation of common plastics in museum collections that include: cellulose nitrate, cellulose acetate, poly (vinyl chloride), and PUR foams.

Shashoua, Y. 1995. 1995/23 Results of a field trial for the use of Ageless in the preservation of rubber in the department of ethnography. The British Museum, London, England.
This report discusses the results of a field trial beginning in 1991 of the effectiveness of storing rubber in oxygen-depleted atmospheres. The report includes evaluation of each of the objects in the study and the effectiveness of Ageless long-term, ultimately showing that rubber stored in oxygen-depleted environments is indeed effective. Following the report is an appendix for the procedure used to enclose the rubber objects and several images.

Shashoua, Y. and I. Skals. 2004. Development of a conservation strategy for a collection of waterproofed military uniforms. *The Conservator* 28(1): 57-65.
The article discusses the condition, materials, and likely causes of degradation of a collection of waterproofed military uniforms at the Danish Defense Museum. Included is a brief summary providing description, history, and deterioration of each of the waterproofing materials found. The article concludes with a preventive treatment

strategy for the collection as a whole that focuses on environmental parameters and rehousing the uniforms. The latter was specific to each type of waterproofing material in the collection.

Sidney, H. ed. 1998. *Handbook of Thermoset Plastics*. Westwood, NJ: Noyes Publications, 23-71.
A detailed text with information on the raw materials, how it is made, including the reaction chemistry, properties, processing, and applications. The most useful sections include how these plastics are manufactured, the various fillers, properties of those fillers, and different applications within the market.

Simpson, R. B., eds. 2002. *Rubber Basics*. Shawbury, UK: Rapra Technology Limited. 39.
This book is a glossary of all the materials and associated chemistry in the manufacture of rubber.

Strom, E.T. and S.C. Rasmussen, eds. 2011. 100+ years of Leo Baekeland and beyond. Proceedings of ACS Symposium Series 1080, Washington, DC.
This is a text with several articles from a symposium held by the American Chemistry Society. A majority of the articles discuss Leo Baekeland, the history of the invention, and its cultural implications. However, some of the articles discuss the chemistry and chemical formula of Bakelite, the latter of which is not discussed in many sources.

Tsang, J., E.W. Jentsche, R. Gieseking, and A.M. Seeger. 2009. Preserving modern marvels: the plastics collection at the National Museum of American History. *Art d'aujourd'hui, patrimoine de demain: conservation et restauration des ouvres contemporaines*: 125-130.
This article discusses a large collaborative project between curators and conservators at the National Museum of American History in which the plastics collections was surveyed and systematically identified using FTIR-ATR. This particular article focuses on Bakelite touching on the history, chemistry, use, identification, and briefly the condition issues associated with it and it should be stored for long-term preservation.

Van Oosten, T.B. A. Lorne, and O. Beringuer. 2011. *PUR Facts: Conservation of Polyurethane Foam in Art and Design*. Amsterdam, Netherlands: Amsterdam University Press.

Van Oosten, T.B. 1998. The degradation of early synthetic materials incorporated in the accessories of a textile collection: cellulose acetate, galalith and Bakelite. *International perspectives on textile conservation: papers from the ICOM-CC textiles working group meetings, Amsterdam 13-14 October 1994 and Budapest 11-15 September 1995.* 4-7.
This article contains more general information on early synthetics. It discusses: cellulose nitrate (in the greatest detail), cellulose acetate, Galalith, and Bakelite.

Van Oosten, T., Y. Shashoua, and F. Waentig, eds. 2001. *Proceedings of the ICOM-CC Modern Materials Working Group Interim Meeting: Plastics in art: history, technology, preservation*. Cologne, Germany.
This publication is the compilation of papers presented at the 2nd interim meeting of the ICOM-CC Modern Materials Working Group: Plastics in art: history, technology, preservation. Topics cover history, manufacture, training programs, analysis, and treatment associated with modern and contemporary art. Although a broad range of topics, many of the papers are focused on plastics.

VinylPlus. 2014. PVC. http://www.pvc.org/en/sitemap (accessed 1/14/2015).
The author of this document is Vinylplus, a voluntary sustainable development program initiated by the European PVC industry. Link is to the site-map, which eases navigation of the website. The website provides information of raw material, additives, manufacture, PVC products, properties, uses, health, transport, sustainability, and information on the industry. The most pertinent information is on how it is made, additives, and physical properties.

Vinyl Environmental Council. 2004. Introduction to PVC in PVC Factbook. http://www.vec.gr.jp/english/library/fact/chapter1.html (accessed 1/16/2015).
This document is a detailed source that includes what PVC is, how it is processed and used, safety, ability to be processed, and the types of applications it is used in. This document is also useful for more general information on plastics as it provides a breakdown of thermoplastic versus thermoset as well as a diagram showing the production flow of a typical petrochemical complex (with a focus on ethylene) and what components of petroleum create what plastics.

Waentig, F. 2008. *Plastics in art: a study from the conservation point of view*, trans. Dr. M. Scuffil. Fulda, Germany: Fuldaer Verlagsanstalt.
General source on plastics in museum collections that provides much information on the history, technology, properties, identification, degradation, and conservation of plastics. Similar to Shashoua's *Conservation of Plastics: Materials Science, Degradation and Preservation* in breadth of information, but differs in its organization. This source organizes the text by the type of plastic and then provides separate sections on historical and cultural context, iconology, and conservation.

Wheeler, R.N. 1981. Poly(vinyl chloride) processes and products. *Environ Health Perspect* 41: 123-128. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1568857/?page=5 (accessed 1/27/2015).
This describes the four methods of polymerization of PVC: suspension, emulsion, bulk, and solution polymerization. In addition, it provides information on how these processes change the polymer prior to processing with plasticizers, additives, and etc.

Wiliams, S. 1997. Care of objects made from rubber or plastic. https://www.cci-icc.gc.ca/resources-ressources/ccinotesicc/15-1-eng.aspx (accessed 7/6/15).
This is a general source for plastics and rubber, which provides helpful preventive measures for the care and long-term preservation. Although relatively brief, this source touches on the dimensional instability of early Bakelite. Organic fillers such as paper and wood pulp in Bakelite can absorb and desorb atmospheric moisture fairly easily. Dramatic changes in RH, although generally not good for any object, can cause cracking in this otherwise stable substrate.

Wilson, A.S. 1995. *Plasticizers: principles and practice*. London, UK: The Institute of Materials
This text is an in depth look at plasticizers and various additives in plastics with a specific focus on PVC and phthalate-type plasticizers, which at the time of publishing made up 90% of the market. A list of the significant plasticizers and additives found in PVC and how they affect the overall properties of the plastic. Additionally, there is section that discusses plasticizers for specific applications such as packaging versus medical applications, which is informative for having a better since of what plasticizer might be present in different types of utility and/or decorative art objects in a collection. Although greater emphasis is on PVC and plasticizers found in PVC, a section of the book does discuss plasticizers for polymers other than PVC.

Zhang, J., D. Thicket, and L. Green. 1994. Two Tests for the Detection of Volatile Organic Acids and Formaldehyde. Journal of the American Institute of Conservation 33. 47-53.