

COMMON DETERIORATION PROCESSES

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Objectives

At the end of this chapter you should:

- have a basic understanding of some deterioration processes;
- have a visual reference for some of the issues discussed in other sections; and
- have a basic understanding of some of the problems you may encounter in your collection.

Introduction

Deterioration is caused by physical damage and chemical activity—usually in combination. For many materials, physical damage can create conditions that are favourable for chemical activity.

For example, as aluminium corrodes, an aluminium oxide layer forms on the surface which protects the rest of the metal from corrosion. If this layer is scratched or broken in any way, un-oxidised aluminium will be exposed and it will corrode. Fortunately the corrosion produces a new oxide layer which protects the rest of the metal.

Iron objects are often coated to protect them from contact with moisture and oxygen. If they are not protected they rust. Rust is iron oxide; but unlike aluminium oxide it does not protect the underlying metal from further corrosion. If a coating applied to an iron object is scratched or broken in any way, the object rusts. At first, the rust is localised, but it spreads gradually over the whole object, destroying it totally.

Chemical activity often accelerates physical damage, or leaves objects more susceptible to physical damage. For example, pressure-sensitive adhesives—as used to make sticky tapes—age and become less sticky. The adhesives harden and no longer hold things together. This also happens to adhesives such as rubber cement. Collages and other items which include a lot of adhesives can fall apart once the adhesives have aged.

Paper that was once flexible and easy to use can become brittle, to the point where it crumbles away to fragments when handled roughly. This

extreme vulnerability to physical damage is a result of chemical deterioration. Acids within the paper attack the paper's fibres, making them shorter and much less flexible.

Examples of deterioration

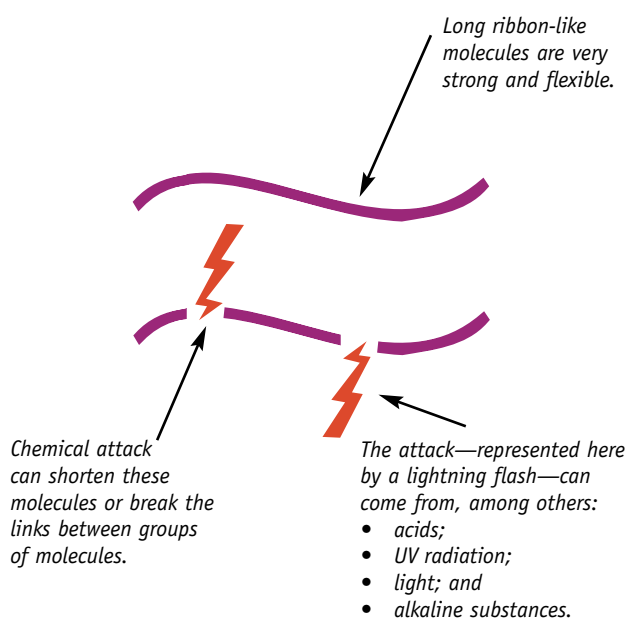
The following examples illustrate the common changes that occur in materials as they deteriorate chemically:

- flexible organic materials, for example, paper, fabrics and some plastics, often become brittle;
- the change in solubility characteristics and loss of flexibility of some adhesives, paint layers, varnishes and coatings;
- colour change, for example, dyes fading and becoming discoloured; and
- corrosion of metals.

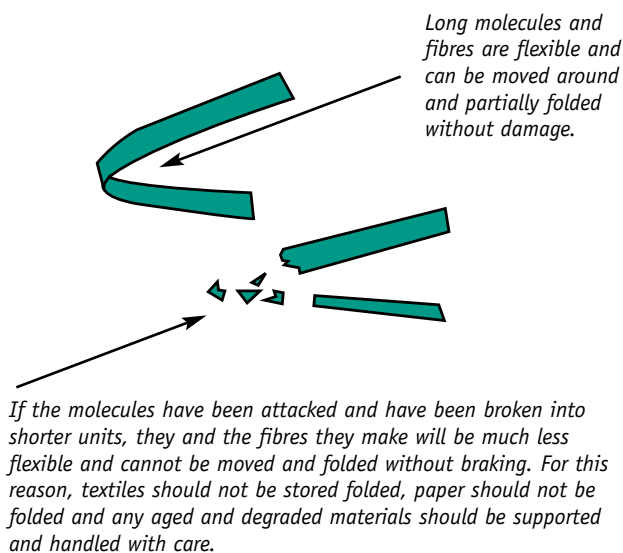
Flexible organic materials becoming brittle

Paper is made up of cellulose fibres. Fabrics are made up of cellulose, protein or man-made fibres.

All of these fibres are made up of long ribbon-like molecules. Flexible plastic films are also made up of long molecules.

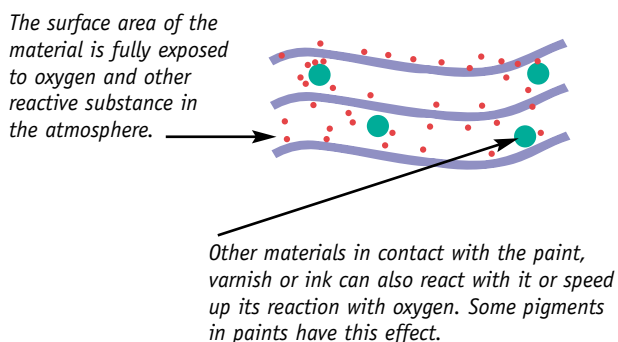
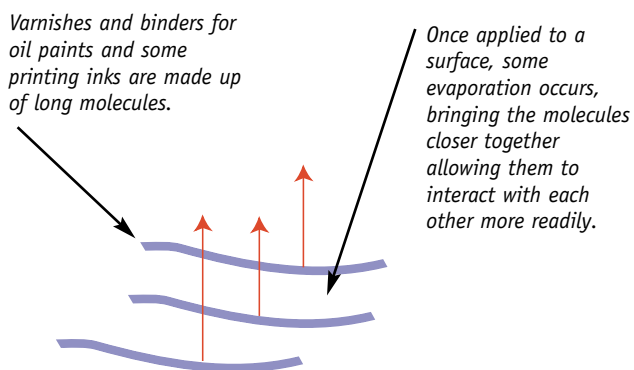


The shortening of the molecules has a major impact on the physical characteristics of the materials.

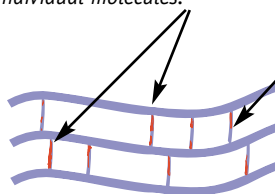


Change in solubility characteristics and loss of flexibility

Many paints, inks, varnishes and coatings dry by a combination of evaporation and chemical change. The chemical change that takes place is called crosslinking. The relative importance of evaporation and chemical change in the drying stage depends on the original formulation of the paint, ink or varnish.

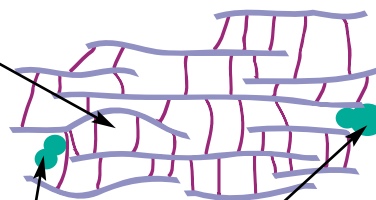


As chemical changes occur, crosslinks form between the individual molecules.



The formation of these crosslinks gives the drying effect. The varnish or paint becomes less sticky to the touch and it 'sets' or hardens, but it remains flexible.

If crosslinking continues the material becomes more rigid. As it loses flexibility, it is more likely to fracture and break up.



With a great number of crosslinks, it is harder for solvents to get into the material to dissolve it.

Solvents that were effective before crosslinking took place are sometimes able to act on the material to soften it even if they cannot fully dissolve it.

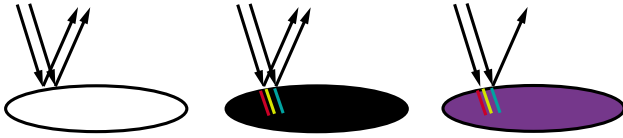
When it is part of the drying process, crosslinking is seen as a useful and desirable chemical reaction. But it is not desirable when it is seen as an ageing process which causes:

- sticky tape adhesives to set and become insoluble;
- varnishes to become less soluble and to discolour; and
- paint and ink films to become very hard and brittle.

It is important to note that crosslinking can occur at the same time as other parts of the same molecules are being broken into smaller units.

Colour change

We see materials as coloured because they selectively absorb some wavelengths of visible light and reflect others.



White objects appear white because they reflect all wavelengths of visible light.

Black objects appear black because they absorb all wavelengths of visible light.

Coloured objects selectively absorb some wavelengths and reflect others. A blue object, for example, absorbs all wavelengths apart from blue, which it reflects.

At a molecular level there are certain chemical groups which determine the absorption of particular wavelengths of light—these groups are called chromophores and are responsible for the colour of materials.

In organic materials, colour is associated with particular molecular structures that absorb and emit visible light of specific frequencies; that is, chromophores are groupings of atoms within a molecule.

For example:



represents two carbon atoms joined by a double bond. Each carbon is then bonded with a single bond to adjoining atoms. The single bonds are represented by -.



represents a carbon atom joined to an oxygen atom by a double bond. The carbon is then bonded with a single bond to adjoining atoms. The single bonds are represented by -.



represents two nitrogen atoms joined by a double bond. Each nitrogen is then bonded with a single bond to adjoining atoms. The single bonds are represented by -.

Double bonds are strong, but they are far more reactive than single bonds, so they are broken readily during chemical reactions.

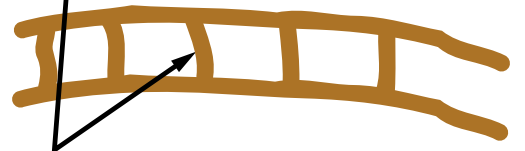
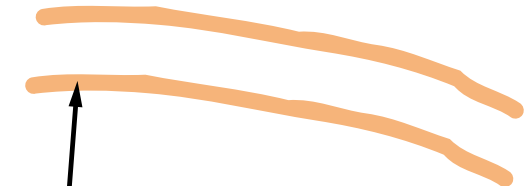
When talking about flexible materials becoming brittle, and the change in solubility characteristics and loss of flexibility of materials, we examined the breaking and crosslinking of large organic molecules. The chromophores described above occur in these molecules.



This long molecule is made up a chain of atoms jointed together, for example, it may be:
 $-C=C-C=C-C=C-C=C-C=C-C=C-C=C-C=C-C=O$



Breaking these molecules may involve breaking double bonds—this would lead to loss of colour.



Chemical crosslinking involves creating new bonds between molecules and atoms. These new bonds may be double bonds that produce chromophore groups. This could lead to darkening of colour or colour where there was no colour before ie. staining or discolouration.

If molecules are being broken down and crosslinked at the same time, a whole range of colour changes are possible. Just what the colour changes will be is difficult to predict.

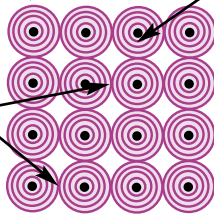
Corrosion of metals

The chemical deterioration of metals is known as corrosion.

This diagram represents a group of metal atoms bonded by metallic bonds to form a pure metal.

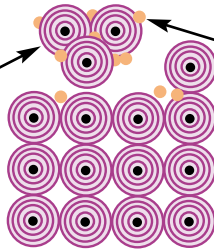
Each atom is made up of a nucleus which contains neutral particles called neutrons and positively charged particles called protons.

In a metallic bond, the individual atoms share electrons. This bond means that the atoms are connected in all directions, producing a cubic structure in the molecule.



Electrons, which are negatively charged particles, 'orbit' around the nucleus of the atom.

Corroded metal surfaces are often crumbly, while the un-corroded metal surfaces tend to be smooth and relatively even. For example, compare a piece of un-corroded iron and a piece of rusty iron.



When a metal corrodes, the metal atoms become bonded to other non-metallic substances. The metal atoms are removed from the cubic structure of the metal molecule.

Some metals are protected by a layer of corrosion. For example, when aluminium is exposed to air, it corrodes to form aluminium oxide which covers the surface of the metal item.

This layer of corrosion coats the metal surface and protects the underlying metal.

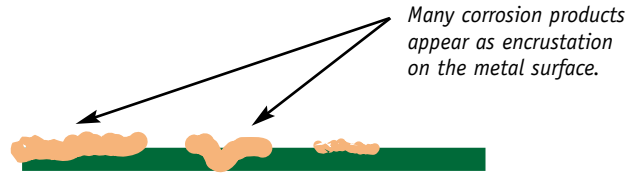


If the layer of corrosion is scratched or cleaned away the metal is left exposed.

Exposed metal will corrode, and the corrosion layer then protects the underlying metal.



Other metals like iron are not protected by their corrosion products.



Many corrosion products appear as encrustation on the metal surface.

If the corrosion products are cleaned away the extent of the damage can be seen.



If the metal is not protected corrosion will continue until all the metal has been corroded.

Some metal objects are electroplated. Electroplating is used to make cheaper metals look like silver. The physical properties of the materials are dominated by the underlying metal.

During the electroplating process the cheaper metal is coated with a fine layer of silver.

The silver layer protects the cheaper metal from corrosion.



If the plating is scratched or broken in any way, the underlying metal can start to corrode.



Wherever the underlying metal is in contact with air, moisture or any other agents of corrosion, it will deteriorate.



If the underlying metal is like iron i.e. its corrosion products do not protect it from further corrosion, the corrosion will move through the metal and will spread out under the layer of electroplating.

The encrustations of corrosion will lift the plating.

As stated earlier, this section provides a simplified overview of some of the processes of deterioration. For further information about the effects of these processes and on minimising these effects, please refer to the chapters relating to specific types of materials.

For more information

For more information about deterioration of paper and fabrics, please see *Caring for Cultural Material 1*.

For more information about corrosion in metals, please see *Caring for Cultural Material 2*.

If you would like further information about the deterioration of items in your collection, consult a conservator.

For further reading

Crafts Council Conservation Science Teaching Series 1982, *Science for Conservators Book 1—An Introduction to Materials*, Crafts Council, London.

Crafts Council Conservation Science Teaching Series 1983, *Science for Conservators Book 2—Cleaning*, Book 2, Crafts Council, London.

Mills John S. and White Raymond, 1987, *The Organic Chemistry of Museum Objects*, Butterworths, London.

Self-evaluation quiz

Question 1.

Which of the following statements are true?

- a) For many materials, physical damage can create conditions which are favourable for chemical activity.
- b) Physical damage and chemical deterioration are in no way linked.
- c) Chemical deterioration can accelerate physical damage.
- d) None of the above.

Question 2.

Crosslinking:

- a) is part of the drying process of oil paints, some printing inks, and varnishes;

- b) is part of the ageing process that makes some adhesives and varnishes less soluble over time;
- c) can lead to discolouration of some adhesives;
- d) is all of the above.

Question 3.

Which of the following statements are false?

- a) Crosslinking and breaking of molecules can occur simultaneously.
- b) The change in the length of organic molecules can have a major impact on the physical characteristics of materials.
- c) All metals are protected from further corrosion by their corrosion products.
- d) Chemical deterioration has no effect on the colour of materials.

Answers to self-evaluation quiz

Question 1.

Answer: a) and c) are true.

Question 2

Answer: d).

Question 3

Answer: c) and d) are false. Aluminium is an example of a metal that is protected by its corrosion products but many other metals are not. Aluminium will not be protected if the corrosion layer is broken. The breaking and re-forming of bonds in molecules, processes which are part of chemical deterioration, can have significant effects on colour changes, both fading and staining. Chemical deterioration causes these changes.

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