



How to Test for Gold and Tin – Canadian Conservation Institute (CCI) Notes 17/6

List of abbreviations

µm	micrometre
AIC	American Institute for Conservation of Historic and Artistic Works
g/cm ³	gram per cubic centimetre
g/mol	gram per mole
ICOM	International Council of Museums
nm	nanometre
wt%	weight percentage
w/v	weight per volume
w/w	weight per weight

Introduction

Gold and tin are two metals with considerably different uses. Gold is a precious metal used mainly for jewellery, coins and plating (gilding), as well as in applications that take advantage of its high electrical conductivity (in the electronics industry) or its resistance to corrosion (coatings, dentistry and medicine). Tin is an industrial metal often found in alloys and frequently used to plate iron and copper. Examples of objects containing these metals are shown in [Objects spot tested to detect gold](#) and [Objects spot tested to detect tin](#).

The tests described in this procedure use a battery to force metal ions into solution through a process known as electrolysis. Once in solution, the metal ions can be detected by the colour changes in the tests. The tests are similar to tests for iron and nickel, described in CCI Note 17/4 [How to Test for Iron and Nickel](#), except that detection is done with solutions prepared by the user rather than with commercial test papers. No samples are removed from the objects being tested, and no strong acids are used on the objects.

Both tests depend on the reducing power of tin in the +2 oxidation state (Sn²⁺ ions). In the spot test for gold, gold ions are forced into solution and react with Sn²⁺ ions, which reduce the gold ions to a black precipitate of gold metal. In the spot test for tin, Sn²⁺ ions are forced into solution and react with the chemical cacotheline, which is reduced by the Sn²⁺ ions to a purple form.

Spot tests are one of the simplest analytical techniques for identifying metals. This CCI Note describes the procedure and the required materials to detect gold or tin using spot tests. The first step in the procedure involves testing known samples of gold and tin to gain experience using electrolysis and carrying out spot tests. This step will also confirm whether the tests are working properly. Then, unknown metals can be tested. For more information on these spot tests, consult [The science behind the spot tests to detect gold and tin](#).

Procedure: carrying out spot tests to detect gold and tin

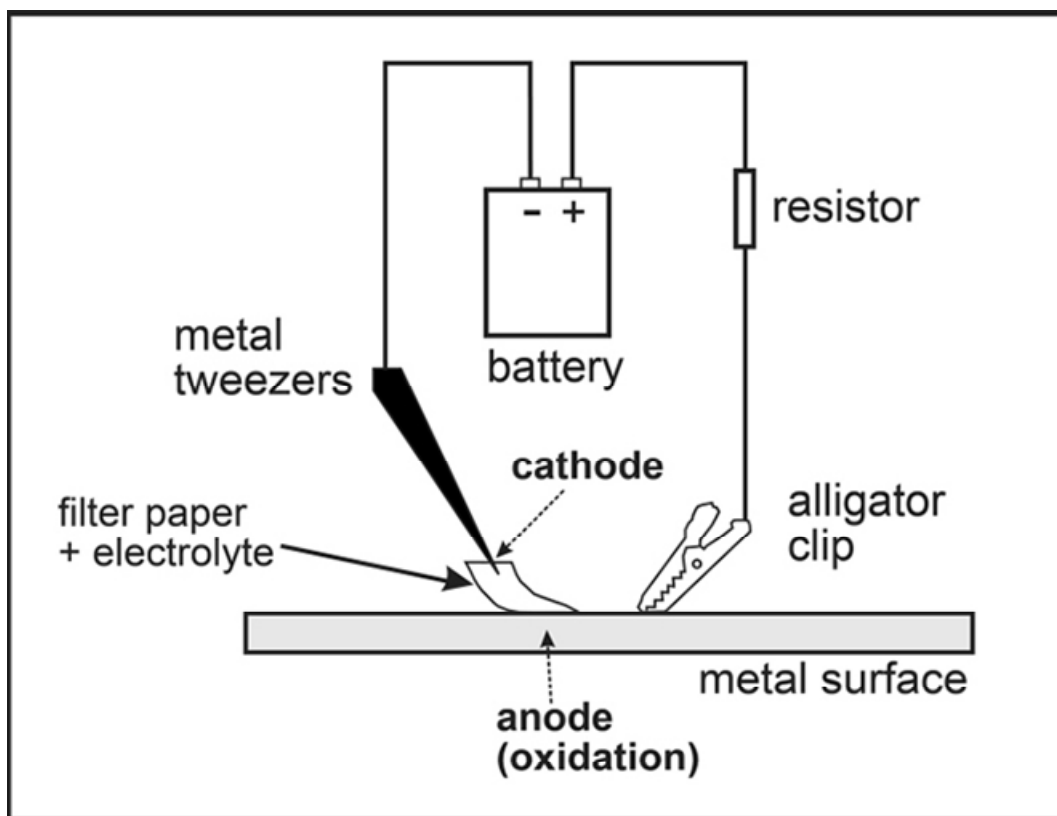
Prior to carrying out these tests or making the solutions, consult the safety data sheet for each chemical to be used. Wear recommended personal protective equipment such as eye protection, disposable gloves (for example, nitrile) and protective clothing. If possible, work in a fume hood when transferring concentrated hydrochloric acid.

Equipment and materials required for spot tests to detect gold and tin

- Gold object or gold coupon (such as gold foil or gold leaf)
- Tin object or tin coupon (such as tin foil)
- 9-volt battery
- Homemade electrolysis cables that contain stainless steel tweezers and an alligator clip; consult construction details in CCI Note 17/4 [How to Test for Iron and Nickel](#)
- Stock solution of saturated sodium chloride; for preparation instructions, consult [Stock solution preparation: saturated sodium chloride](#)
- Stock solution containing 20% (w/v) tin(II) chloride (SnCl_2) and 15% (w/w) hydrochloric acid for gold test; for preparation instructions, consult [Stock solution preparation: tin\(II\) chloride in hydrochloric acid](#)
- Stock solution saturated with cacotheline for tin test; for preparation instructions, consult [Stock solution preparation: saturated cacotheline](#)
- Water (deionized or distilled)
- Filter paper (such as Whatman no. 1 filter paper)
- Plastic tweezers
- Scissors
- Pipettes (Pasteur or plastic) or eyedroppers
- Small containers (such as disposable 10-mL beakers)
- Marker to label containers
- Aluminum foil (optional)
- Spot plate (white porcelain spot plates make it easy to see a colour change in the gold test; glass spot plates can be placed on a white surface)

Diagram of wiring for electrolysis

Figure 1 shows the wiring diagram for carrying out the spot test with the aid of a battery. Allow only the filter paper to touch the metal surface. **Do not** let the tweezers touch the metal surface or the alligator clip. Also, make sure the filter paper is completely wet between where it touches the tweezers and where it touches the metal surface. If part of the paper remains dry, then the circuit will not be complete, no current will flow and the metal will not corrode.



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Figure 1. Wiring diagram for using a battery to force a metal to corrode and form metal ions in solution. Metal tweezers hold the filter paper, which touches the metal surface. An alligator clip also touches the metal surface. The tweezers and alligator clip are connected to a battery. The resistor between the battery and alligator clip limits the current.

If the alligator clip is attached to the object (rather than just held against it to make contact, as in Figure 1), then aluminum foil can be placed between the clip and the object to keep the clip from scratching the object. For extra protection, the teeth of the clip can be filed off.

General advice

- Wear disposable gloves to avoid touching the filter paper and metals with bare hands.
- The test usually leaves a small mark. Choose an inconspicuous area to test, or be prepared to polish away the spot after the test. Do not perform the test if a small spot is unacceptable and polishing cannot be done.
- Cut small triangular pieces of filter paper from a larger sheet. The triangles should have a sharp point to help minimize any mark left by the test.
- Use plastic (not metal) tweezers to handle the filter papers, except during the electrolysis step.

- It may be necessary to degrease the metal surface before the test because a dirty surface can interfere with the test (use soapy water or acetone). The test will not work if a coating such as wax or lacquer is present.
- Optional: use a microscope to watch the procedure during electrolysis. This allows an even smaller spot to be tested.
- When preparing to test objects of unknown metal, start by testing known samples of gold and tin to see what the reaction should look like and to ensure the chemicals have not degraded. Keep known metal samples on hand for this purpose.

Spot test procedure to detect gold

This procedure is based on one presented by Laver (1978); a slightly different procedure is given by Odegaard et al. (2005).

1. Transfer a few millilitres of 20% (w/v) tin(II) chloride and 15% (w/w) hydrochloric acid into a small container.
2. Transfer a few millilitres of sodium chloride stock solution into a second small container.
3. Label both containers.
4. Set up the battery and electrolysis cables.
5. Cut a small triangular piece of filter paper.
6. Put a drop or two of saturated sodium chloride solution into a well of the spot plate.
7. Hold the alligator clip in one hand and touch it directly to the gold. Hold it steady to avoid scratching the object (or use aluminum foil).
8. In the other hand, hold the filter paper (point facing out) in the stainless steel tweezers.
9. Place the tip of the filter paper in the well so the paper wicks up the solution. (Alternatively, wet the paper with a few drops of the sodium chloride solution using a pipette or eyedropper.) The paper should be wet but not dripping with solution.
10. Touch the wet filter paper to the metal surface.
11. Hold for 10 seconds to allow electrolysis to occur.
12. Remove the filter paper and place it on the spot plate, so that the tip that touched the gold is extended over one of the wells in the spot plate.
13. Add a drop of the tin chloride and hydrochloric acid solution to the broader end of the filter paper (the part opposite the tip that touched the gold), and let the paper wick up the solution until it reaches the tip.
14. If gold ions are present, the tip of the filter paper will turn black.
15. After the test, use deionized water to rinse the test area on the metal to remove any residual salt solution, and dry the surface immediately.
16. Use clean water to rinse the tweezers after each use.

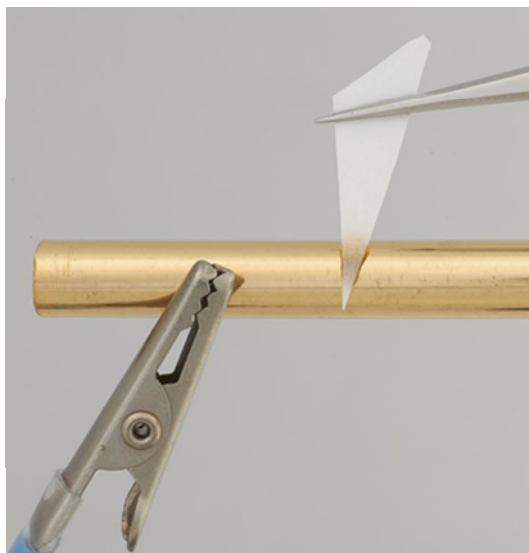
Results of the spot test to detect gold

Figure 2a shows a detail of the electrolysis system for the gold spot test. Sodium chloride solution has just been added to the filter paper, which is being held by the tweezers. The gold cylinder being

tested is in contact with the alligator clip and the filter paper. Figure 2b shows the filter paper after electrolysis for about 10 seconds. The tip of the filter paper has been darkened slightly by gold ions driven into solution by electrolysis.

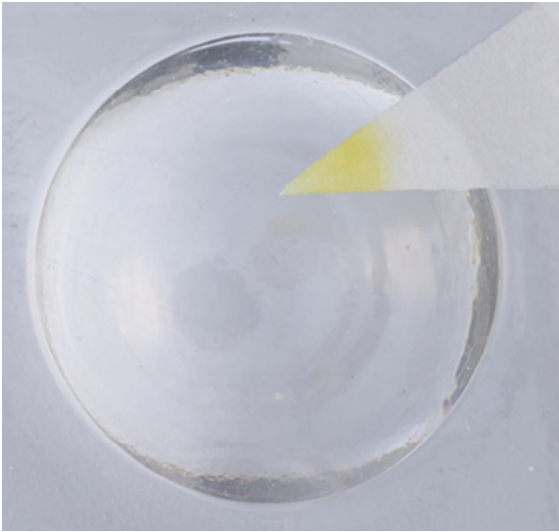


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Figure 2a. A detail of the electrolysis system at the start of the gold spot test.



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Figure 2b. A detail of the electrolysis system for the gold test after 10 seconds of electrolysis. The tip of the paper touching the gold has darkened.

Figure 3a shows the filter paper after electrolysis. The filter paper has been placed beside an empty well in a glass spot plate. The tip, yellow from gold released in the electrolysis, extends over the well. Figure 3b shows the filter paper after the reducing solution has been added. The tip of the paper has turned black, indicating a positive test for gold.



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Figure 3a. Detail of filter paper after electrolysis. The tip of the paper has turned yellow where it touched the gold in Figure 2a.



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Figure 3b. Detail of filter paper after addition of the reducing solution, the second step for the gold spot test. The tip of the paper that touched the gold has changed from yellow to black.

Figure 4 shows the spot left on a gold ring (probably 10 karat [K]) after electrolysis. This spot can be removed with an abrasive polish, as described in [Abrasive cleaning](#). The test can also be used to distinguish between imitation gold leaf (made from brass) and real gold leaf, but the electrolysis will consume a portion of a sheet of metal leaf. The test has been recommended for identifying gold plating, applied either by electroplating or by fire gilding (Thomson 1991), but it may give a weak or null result (Odegaard et al. 2005).

Electroplated objects appeared after 1840, when electroplating was patented. Prior to 1840, fire gilding (also called mercury or amalgam gilding) was used for gilding metal objects. For example, fire gilding was used to produce gilded copper alloys (known as ormolu) which were used as decorative elements in clocks, furniture hardware and lighting fixtures.



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Figure 4. The arrow indicates the corrosion spot on a yellow gold ring after electrolysis.

Spot test procedure to detect tin

The procedure here is adapted from ones by Laver (1978) and Feigl and Anger (1972). Here, the two solutions are mixed together in the well of a spot plate, rather than added one at a time to the filter paper.

1. Transfer a few millilitres of sodium chloride stock solution into a small container, such as a 10-mL disposable beaker.
2. Transfer a few millilitres of cacotheline solution into a second small container.

3. Label both containers.
4. Cut a small triangular piece of filter paper.
5. Set up the battery and electrolysis cables.
6. Using separate pipettes, add a drop of sodium chloride and a drop of cacotheline from the small containers to one of the wells of a spot plate (or a small container if a spot plate is not available).
7. Using clean, dry plastic tweezers, place the tip of the cut filter paper into the well of the spot plate and let the paper wick up the solution. The paper will turn yellow. The paper should be wet but not dripping with solution.
8. Transfer the wet filter paper to the stainless steel tweezers in the electrolysis setup. The tweezers are held in one hand, with the point of the paper facing out (away from the tweezers).
9. Using the other hand, touch the alligator clip directly to the tin object and hold it steady to avoid scratching the object (or use aluminum foil).
10. Touch the wet filter paper to the metal surface.
11. Hold for five seconds to allow electrolysis to occur.
12. If tin ions are present, the tip of the filter paper will turn purple.
13. The filter paper may leave a yellow or purple drop of liquid on the object. Immediately after the test, use clean water and rinse the test area on the metal to remove any chemicals. Then dry the surface.
14. Use clean water to rinse the tweezers after each use.

Results of the spot test to detect tin

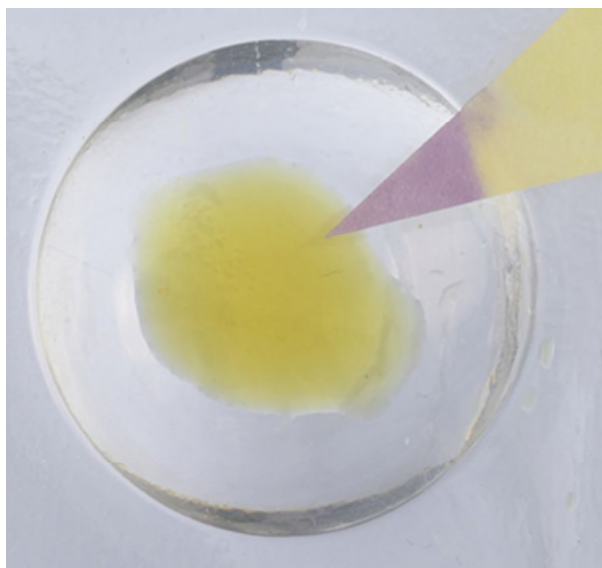
Figure 5 shows one well in a glass spot plate with the yellow test solution. The tip of a triangular piece of filter paper has been placed in the well, and the paper has wicked up the solution. Figure 6 shows a detail of the electrolysis system, near the beginning of the spot test to detect tin. The alligator clip and the filter paper are in contact with a rectangular sheet of tin-plated steel. The filter paper is yellow from the cacotheline solution. Figure 7 shows the tip of the filter paper after electrolysis. The purple colour indicates the presence of tin. The bottom of the well contains residual yellow solution of cacotheline and sodium chloride. The solution should be cleaned off the metal quickly; otherwise, it will leave a mark on the surface, either white on surfaces with a high tin content or black on tin alloys containing lead (such as old pewter).



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Figure 5. Filter paper in yellow test solution in the well of a glass spot plate.



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Figure 6. Detail of the electrolysis system at the start of the spot test to detect tin. It shows a piece of tin-plated steel, an alligator clip touching the tin and tweezers holding a piece of triangular filter paper. The filter paper has been wetted with the yellow test solution and appears darker where it touches the tin.



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Figure 7. Detail of the filter paper after electrolysis has been carried out on the tin-plated steel. The tip of the paper that touched the tin has turned purple.

Additional information

Abrasive cleaning

If the test has left a mark on a gold or tin object, an abrasive (such as precipitated calcium carbonate) can be used to remove it. More information on abrasive polishing is outlined in CCI Note 9/11 [How to Make and Use a Precipitated Calcium Carbonate Silver Polish](#). Polishing tin with an aqueous slurry of abrasive leaves a cloudy appearance, because the water corrodes the freshly exposed tin slightly. A slurry of ethanol and abrasive produces a shinier surface.

Purities and colours of gold alloys

The spot test to detect gold can be used on various gold alloys. In jewellery, purities of gold are given by the fraction of gold by weight, usually expressed either in karats (the fraction of gold multiplied by 24) or in parts per thousand. Common purities are 18K, 14K and 10K.

Alloying gold with other metals changes the colour from the familiar yellow of pure gold. Copper adds a red tinge, and silver, a green-white tinge. Palladium or nickel are added to alloys of gold and copper or gold and silver to bleach the yellow colour, resulting in white gold (Drost and Hausselet 1992). (This is the modern use of the term "white gold." The term was formerly used to refer to gold-silver alloys with more than 30% silver by weight.) White gold was developed as a substitute for platinum and is often used in gold jewellery to complement a diamond setting or to contrast with the yellows of other gold alloys.

Objects spot tested to detect gold

Figure 8 shows three rings that tested positive for gold. For the ring on the right, both the nugget and the band tested positive.



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Figure 8. From left to right: a ring of bright yellow metal, believed to be high purity gold, a patterned yellow band stamped 18K and a gold nugget on a plain gold band.

Spot tests to detect gold give erratic results for gold alloys of 10K or lower (Odegaard et al. 2005). Figure 9 shows rings that occasionally tested positive for gold in repeated tests.



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Figure 9. From left to right: a green stone in a yellow band stamped 10K, a school ring (black and red crest on a gold ring, which is probably 10K, although the stamp has mostly worn off) and three pearls set on a yellow band stamped 10K.

Figure 10 shows three rings made with white metal. Only the ring on the left, stamped 18K, tested positive for gold. Neither the school ring in the middle (stamped 10K) nor the plain ring on the right tested positive for gold. The density of the plain ring on the right was close to that of platinum.



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Figure 10. From left to right: a white metal band set with a single diamond and stamped 18K, a school ring (black and silver crest on a white metal band stamped 10K) and a plain white metal band. Only the ring on the left tested positive for gold.

Density measurements

Density measurements can sometimes provide an alternative to the spot tests described here. For example, platinum can be distinguished from white gold by its density. The density of pure platinum is 21.5 g/cm^3 (Lide 1998), whereas the typical density of 18K white gold is about 16 g/cm^3 and that of 14K white gold is below 15 g/cm^3 (Drost and Hausselt 1992). The density of the plain white metal band in Figure 10 was measured to be 18.6 g/cm^3 , indicating that it is likely a platinum alloy.

Density measurements are described in CCI Note 9/10 [How to Determine Metal Density](#). The balance described there is a top-loading balance and is not suitable for determining the density of small objects such as rings. Distinguishing a platinum ring from a white gold ring requires an analytical balance. Balances of this kind have readabilities of 0.1 mg to 0.01 mg, and most can weigh an object suspended below the balance.

Objects spot tested to detect tin

Examples of smaller objects that tested positive for tin are shown in Figure 11. The bear pendant in this figure is about 3 cm long. None of these pieces are magnetic. Figure 12 shows larger objects that tested positive for tin. The tin can, funnel and fork in this figure tested positive for tin and are magnetic, indicating they are tin-plated iron. Modern pewter, an alloy of mainly tin with small amounts of antimony and copper, is not magnetic.



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Figure 11. From left to right: two small toy hearts, a bear pendant and two small toy figures (a train engine above and an airplane below).



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Figure 12. From left to right: a tin can, a modern pewter bowl, a funnel and a fork.

Sensitivity and interferences

The spot test to detect tin has a practical detection limit of 10 wt% (Townsend 1988). The spot test to detect gold works reliably for 14K gold and higher purities but gives erratic results for gold alloys of 10K and lower. Gold-plated objects give only a weak positive result or sometimes no colour change at all, suggesting the base metal interferes with the electrolysis (Odegaard et al. 2005). The test leaves darker marks on 10K gold than on gold of higher purity.

There are no interferences in the spot test to detect gold; that is, no metals other than gold produce a black spot (a false positive) in the test. Copper and antimony interfere with the test for tin (Townsend 1988). When pure copper is tested with the tin spot test, the tip of the paper darkens slightly, but the

colour fades in a few minutes. Interference with antimony is rarely a concern, because conservators are unlikely to encounter antimony except together with tin. Modern pewter, for example, contains some antimony but is mainly tin.

Storage

According to Townsend (1988), the tin chloride and hydrochloric acid solution lasts about a month, and a solution of cacotheline lasts one to two weeks. In practice, solutions can be stored longer than this (for two months or more); however, they should always be tested on a known sample before they are used.

Tin(II) chloride is readily soluble in water. With an old bottle of tin(II) chloride powder, some of the tin(II) chloride may have oxidized to form water-insoluble white tin(IV) oxide (SnO_2). If this has happened, there may be some undissolved powder [the tin(IV) oxide] when the stock solution is prepared. Carry out a preliminary gold spot test with this stock solution to ensure that there is still enough tin(II) chloride for the test to work.

Additional procedures

Stock solution preparation: saturated sodium chloride

The following procedure can be used to prepare 100 mL of a saturated sodium chloride solution. The solubility of sodium chloride in water at 20°C is 35.9 g in 100 mL of water. A saturated sodium chloride solution can also be purchased.

Equipment and materials

- Sodium chloride (NaCl)
- Spatula
- Balance
- Water (distilled or deionized)
- Beaker (100 mL)
- Container to store the solution

Procedure

1. Use the spatula and the balance to weigh out roughly 37 g of sodium chloride.
2. Place about 100 mL of water in a 100-mL beaker.
3. Add sodium chloride to the water and swirl to dissolve.
4. If all the sodium chloride dissolves, add a little more of it.
5. When solid sodium chloride crystals remain undissolved on the bottom of the beaker, the solution above will be close to saturation.

6. Transfer the solution and any undissolved crystals to a container for long-term storage. It can take a few days to achieve saturation. If there are no more sodium chloride crystals at the bottom, add more crystals.
7. Label the container.

Stock solution preparation: tin(II) chloride in hydrochloric acid

The following procedure can be used to prepare 25 mL of a solution which contains 20% (w/v) tin(II) chloride (about 1 M) in 15% (w/w) hydrochloric acid (HCl, about 4.4 M). Tin(II) chloride, also known as "stannous chloride," is available in either the anhydrous form (SnCl_2 , molecular weight 189.62 g/mol) or the dihydrate form ($\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$, molecular weight 225.63 g/mol).

Equipment and materials

- Tin(II) chloride or tin(II) chloride dihydrate
- Hydrochloric acid, concentrated, 36–38% (w/w)*
- Water (distilled or deionized)
- Volumetric flask (25 mL)
- Graduated cylinder (10 mL)
- Pipettes (glass or plastic) or eyedroppers
- Balance
- Weighing paper
- Spatula
- Marker to label containers
- Brown glass bottle (for storing solution)

* Concentrated hydrochloric acid contains 36–38% (w/w) HCl, which corresponds to 11.64 M to 12.39 M. For the current procedure, the concentrated HCl is assumed to be 37% (w/w).

Procedure

1. Pour 6 mL of water into a 25-mL volumetric flask.
2. Work in a fume hood for this step. Carefully measure 9 mL of concentrated hydrochloric acid into a 10-mL graduated cylinder. Slowly transfer the acid into the 25-mL volumetric flask that contains the water. **(Important: always add concentrated acid to water.)** Mix well.
3. Using a spatula and a balance, carefully weigh 5.95 g of tin chloride dihydrate or 5.0 g of anhydrous tin chloride onto weighing paper. Transfer to the 25-mL volumetric flask. Swirl to dissolve the solid.
4. Add more water into the 25-mL flask until the solution reaches the 25-mL mark. Transfer the solution to a brown glass bottle and label.

Stock solution preparation: saturated cacotheline

The following procedure can be used to prepare an aqueous solution saturated with cacotheline. Cacotheline is commercially available as a complex hydrate with the formula $\text{C}_{21}\text{H}_{21}\text{N}_3\text{O}_7 \cdot \text{HNO}_3 \cdot \text{H}_2\text{O}$.

The molecular weight of this compound is 508.44 g/mol. The HNO_3 in the formula gives an acidic solution; the stock solution prepared as described below has a pH of about 3. Cacotheline should be treated as toxic. Although some safety data sheets do not identify it as toxic, others do. Moreover, its structure is similar to that of strychnine and brucine, which are toxic.

Equipment and materials

- Cacotheline
- Water (distilled or deionized)
- Volumetric flask (10 mL)
- Balance
- Weighing paper
- Spatula

Procedure

1. Pour a small quantity of distilled water into the 10-mL volumetric flask.
2. Use the spatula, weighing paper and balance to weigh out 0.06 g of cacotheline.
3. Transfer the cacotheline into the 10-mL volumetric flask and swirl to dissolve the solid.
4. Fill the volumetric flask to the 10-mL mark with distilled water.
5. If all the cacotheline dissolves, add more until some crystals remain on the bottom of the flask to ensure the solution is saturated. (The solution is orange.)
6. Label the flask.

The science behind spot tests to detect gold and tin

Oxidation-reduction reactions come into both of these spot tests in two ways. First, electrolysis is used to oxidize a metal and produce positive ions of the metal in solution. Second, an oxidation-reduction reaction involving these ions produces a colour change. In both spot tests, the oxidation part of the colour-change reaction is the conversion of Sn^{2+} ions to Sn^{4+} ions.

Electrolysis

Electrolysis occurs when an electric current forces oxidation and reduction reactions to occur. Electrolysis requires two electrodes immersed in an electrolyte (a salt dissolved in a solvent). An oxidation reaction occurs at one electrode, and a reduction reaction occurs at the other. In the electrolysis in the spot tests, the electrolyte is the salt solution used to wet the filter paper, and the two electrodes are the metal object being tested and the metal tweezers. For further details, consult CCI Note 17/4 [How to Test for Iron and Nickel](#).

Colour change: reaction between gold and tin chloride

For a gold object, electrolysis produces Au^{3+} ions. These ions react with chloride ions in the electrolyte to form gold-chloride complexes $[\text{AuCl}_4]^-$. The results of electrolysis can be written as:



The $[\text{AuCl}_4]^-$ complexes give the solution a yellow colour.

When an acidic tin chloride solution is added to the solution after electrolysis, an oxidation-reduction reaction occurs. The Sn^{2+} ions act as the reducing agent. As the Sn^{2+} ions are oxidized to Sn^{4+} , they reduce Au^{3+} to Au^0 (metallic gold). The net oxidation-reduction reaction (Vogel 1945) can be written as:

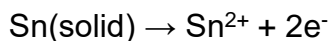


The newly formed gold coalesces into tiny colloidal particles, giving a black colour.

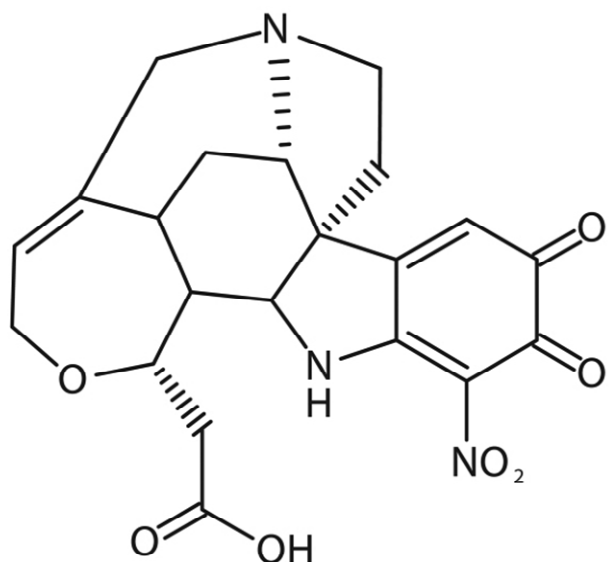
Extremely small gold particles (less than about $1\text{ }\mu\text{m}$) do not have the typical yellow colour of gold. The black colour of the colloidal particles is a result of the particles' wide range of sizes, as they absorb light through the whole colour spectrum. A similar black colour is found in coatings called gold-black, where particle sizes range from 5 nm to $8\text{ }\mu\text{m}$ (McKenzie 1978). In contrast, small gold particles (10 to 100 nm) with a uniform size can be coloured. For example, when gold particles are about 10 nm in diameter, the particles preferentially absorb green light, leaving a red-purple colour (Nassau 2001). Such particles are used to make pigments known as purple of Cassius in enamel and glass (Carbert 1980).

Colour change: reaction between tin and cacotheline

For a tin object, electrolysis produces Sn^{2+} ions. The reaction is given by:

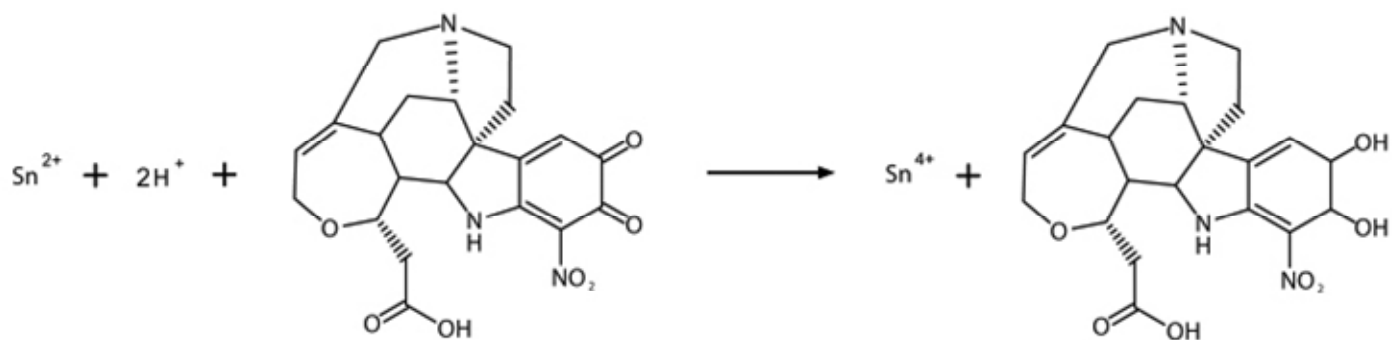


The Sn^{2+} ions are detected with cacotheline, which has a chemical formula of $\text{C}_{21}\text{H}_{21}\text{N}_3\text{O}_7$; its structure is shown in Figure 13:



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Figure 13. The chemical structure of cacotheline.

Tin ions react with the cacotheline molecule, as shown in Figure 14.



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Figure 14. One tin(II) ion, two hydrogen ions and the organic molecule cacotheline on the left react to give one tin(IV) ion and the organic molecule of the reduced form of cacotheline on the right.

The tin ions are oxidized to the +4 oxidation state (Sn^{4+}), and the cacotheline molecule is reduced (Ottaway 1972). The reduced form of cacotheline, called dihydrocacotheline, gives the purple colour after a successful spot test to detect tin.

Acknowledgements

Special thanks to Ute Werner, former CCI intern, for her help in developing this Note.

Suppliers

Note: the following information is provided only to assist the reader. Inclusion of a company in this list does not in any way imply endorsement by CCI.

Chemicals

Sodium chloride, concentrated hydrochloric acid, tin(II) chloride and Whatman filter paper are available from chemical supply companies such as Fisher Scientific. A saturated sodium chloride solution is made by Ricca Chemical and distributed by chemical supply companies, such as Fisher Scientific. Cacoetheline complex hydrate is available from chemical suppliers. In North America, it is available from TCI America and from Sigma-Aldrich.

- [Fisher Scientific](#)
- [Ricca Chemical](#)
- [TCI America](#)
- [Sigma-Aldrich](#)

Gold and tin

Thin sheets of gold and tin, called foils, to use as reference materials are available from chemical suppliers, such as Sigma-Aldrich. Gold leaf is available from gilding suppliers, such as Sepp Leaf Products.

- [Sigma-Aldrich](#)
- [Sepp Leaf Products](#)

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