Cover Image: Brisbane Charity Cup soccer sporting trophy - 1894

Cleaning by Chemical Reaction

YEAR 10 – CHEMICAL REACTIONS

QGC | FUTUREMAKERS | QUEENSLAND MUSEUM NETWORK Queensland Government

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Future Makers is an innovative partnership between Queensland Museum Network and Shell's QGC project aiming to increase awareness and understanding of the value of science, technology, engineering and maths (STEM) education and skills in Queensland.

This partnership aims to engage and inspire people with the wonder of science, and increase the participation and performance of students in STEM-related subjects and careers — creating a highly capable workforce for the future.

Australian Curriculum Links

YEAR 10

Science Understanding

Chemical sciences

Different types of chemical reactions are used to produce a range of products and can occur at different rates *(ACSSU187)*

Elaborations

- Predicting the products of different types of simple chemical reactions
- Using word or symbol equations to represent chemical reactions
- Investigating the effect of a range of factors, such as temperature and catalysts, on the rate of chemical reactions

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Science as a Human Endeavour

Nature and development of science

Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries *(ACSHE192)*

Use and influence of science

- People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities *(ACSHE194)*
- Values and needs of contemporary society can influence the focus of scientific research *(ACSHE230)*

Science Inquiry Skills

- Formulate questions or hypotheses that can be investigated scientifically *(ACSIS198)*
- Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods *(ACSIS199)*
- Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately *(ACSIS200)*
- Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies *(ACSIS203)*
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence *(ACSIS204)*
- Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data *(ACSIS205)*
- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS208)

Introduction

This learning resource has been designed to highlight how chemical reactions are used by Queensland Museum Network Conservators to clean delicate objects. The process of cleaning silver using electrolysis will be the major focus of this resource.

As this resource has been designed to complement classroom-based teaching and learning experiences, students are assumed to have developed knowledge about the following chemical science concepts from year nine science:

- All matter is made of atoms that are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms *(ACSSU177)*
- Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction mass is not created or destroyed *(ACSSU178)*
- Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer *(ACSSU179)*

Examine how Ellen King, a Process Engineer uses chemistry on a daily basis at the Curtis Island Liquefied Natural Gas (LNG) Plant. These videos are also available on the Queensland Museum Learning Resources page.

Part 1:
What is Museum Conservation Science?

MUSEUM PERSPECTIVES

A **museum conservator** is someone who documents, restores and preserves artifacts that are on display in museum exhibits or kept in museum stores. They use chemical and physical tests to determine the age and composition of different artifacts, and use their understanding of materials science and their problem-solving skills to determine how best to stabilise, restore and preserve the objects. Conservators train and teach museum curators and technicians, as well as give tours and provide research assistance to museum visitors.

- Conservators are responsible for ensuring each item is packed carefully for shipping or storage.
- Conservators create and construct precise skeletal mounts for fossils and life-sized replicas of specimens.
- Conservators preserve artifacts by ensuring the light, temperature, and humidity stay at the proper levels. They also clean the artifacts with cleansers that are best for each material, whether they are made of fabric, metal, paper, glass, pottery, wood, or stone.
- Museum conservators study the artifacts to determine their age, as well as precisely what they are made of. This often involves testing of the physical or chemical nature.
- Museum conservators must carefully document each item as they are the professionals that are responsible for the artifacts – no matter how many other hands have touched them. Conservators label each artifact with a number, and document the condition of each item with great precision.
- When they are not testing artifacts or restoring them to their original splendour, museum conservators often give tours of the exhibits, and present special programs to the public
- Museum conservators should possess many useful skills such as excellent attention to detail, an interest in research and preservation, good communication skills, and the ability to patiently teach others.
- Technology: New techniques for conservation such as Laser Cleaning and Portable X-ray fluorescence analysis and virtual re-construction.

Similar Careers

Curator, Archaeologist, Historian, Anthropologist, Archivist, Photographer, Photojournalist, Art Director, Exhibit Designer, Urban Planner, Editor, Architect, Psychology, Humanitarian
http://nma.gov.au/research/understanding-museums/ICook_etal_2011.html

Watch this video to see how an interest in Science, Technology and the Arts provided an opportunity for Sue Vallis to care for valuable collection items as Conservator at the Museum of Tropical Queensland. https://learning.qm.qld.gov.au/resources/1568354

Part 2:
The Handsomest Athletic Trophy in the Colony

Dented, damaged and tarnished, there was nothing in the Brisbane Charity Cup's name or appearance to suggest that it was once this State's most coveted sporting silverware.

The Queensland Museum Conservation team played an important role in the care of this impressive silver trophy after it was lost in the Brisbane floods of 1974. Discover some fascinating local history about the origins of 'football' in Queensland by reading an article written by Senior Curator of Social History, Mark Clayton at:
https://blog.qm.qld.gov.au/?s=the+handsomest

Image courtesy of State Library of Queensland –
Thistle defeated Brisbane City (3:0) to win the Brisbane Charity Cup in 1921. Seated bottom right is:
Jock Cumberford, who scored Australia's first goal on the tour of New Zealand the following year.

Read more: https://collections.qm.qld.gov.au/objects/316547/brisbane-charity-cup-soccer-sporting-trophy

Part 3:
Activity – The Electrolysis of Silver

Student Notes

Corrosion of Silver

Many gasses and materials cause silver to corrode. You may have seen this corrosion when a shiny silver object turns dark brown or black. Silver corrodes when it comes in contact with water and/or high humidity, dust, acids (commonly from fingertips), salts, oils and some metal polishes. It can also be caused by sulphur compounds, which are commonly released into the air (hydrogen sulphide) from car exhausts and found in protein based materials such as wool and leather. Wooden cabinets and wood products such as plywood, chipboard and custom wood also contain formaldehyde which will cause silver to corrode.

Museum conservators play an important role in caring for objects to ensure they are here for generations to come. The electrolysis of silver is a non-invasive technique that is preferred by conservators to clean and care for valuable silverware as the process doesn't remove any of the silver through abrasive rubbing.

Reduction reactions used in conservation.

Electrolysis is a process by which an electrical current is passed through a substance to effect a chemical change. The chemical change is one in which the substance loses or gains an electron (oxidation or reduction).

Reduction reactions are used in conservation in the attempt to recover metals from their corroded state. When a metal forms a compound, like in corrosion, its atoms have been oxidised (lost electrons), forming positive ions. Reduction (when an atom or ion gains electrons) can reverse the oxidation of the metal, therefore reversing the corrosion of the metal. This experiment is a conservation example for one method of cleaning silver using aluminium foil. Aluminium foil is packed around the silver object and put into an alkaline solution such as sodium carbonate in water.

In this activity you will conduct your own electrolysis experiment, using the same techniques as used by Museum Conservators to clean valuable silverware. You will also record and report on your findings (pp 16-25).

BEFORE

Image 2: The M.C Wadsworth trophy was awarded to the Brisbane Central membership of the WCTU (Women's Christian Temperance Union) for having the largest membership for eight of the ten years from 1966 -1975. The WCTU is associated with the women's suffrage movements throughout the world, actively encouraging women to take on an active role in public life (ID# 105400).
The trophy is a dark colour, rather than silver, indicating that the silver has corroded (also known as oxidised).

This trophy has been corroded (also known as tarnished, or oxidised) by hydrogen sulphide in the air. The chemical reaction that causes this reaction is shown below:

$$2\ Ag\ (s) + H_2S\ (g) \rightarrow Ag_2S\ (s) + H_2\ (g)$$

silver + hydrogen sulphide → silver sulphide + hydrogen

This process is called oxidisation because the silver loses electrons when it reacts with sulphur.

$$2\ \overset{0}{Ag}\ (s) + \overset{+1}{H_2}\overset{-2}{S}\ (g) \rightarrow \overset{+1}{Ag_2}\overset{-2}{S}\ (s) + \overset{0}{H_2}\ (g)$$

Silver (Ag) is losing electrons (0 to +1) so it is losing elections **= Oxidisation**

Hydrogen (H) is gaining electrons (+1 to 0) **= Reduction**

Equipment

- Silver object showing signs of corrosion (e.g. darkened colour).
  This could include silver cutlery or jewellery.
- Nitrile Gloves – for handling the object during its treatment.
  This is to prevent the transfer of any salts or dirt from your hands to the object.
- Safety glasses
- Toothbrush – for cleaning the surface and getting into the crevices.
- Toothpick/ skewers – for getting into crevices to dislodge polish residue.
- Detergent – a mild dish detergent is fine.
- Bowl/ container – use a plastic or glass container for this treatment.
  A metal container will interfere with the chemical process.
- Sodium Carbonate (Soda Ash)
- Aluminium foil
- Silver cloth – to polish and dry the object after treatment.
- Water – tap water is fine and the treatment works best if the water is warm or hot.

Note: the waste from this experiment may be washed down the sink.

Things to watch out for

- If the object is hollow then check carefully for pinholes in the surface. If water gets inside the item it will be very difficult to remove and can encourage corrosion. Holes can be filled with wax to prevent water ingress.
- The two metals need to be in contact for this process to work. Press the foil onto the silver surface to encourage contact. You will need to check the progress of the treatment from time to time.
- If there are any different metals attached to the silver then this treatment may not work as it is governed by the Metal Activity Series. This may affect objects which are silver plated as the base metal will have a different Activity to the silver plate.
- Increasing the temperature of the water will increase the rate of the reaction.

DANGER
POISONOUS GAS
HYDROGEN SULPHIDE

Hydrogen sulphide is the chemical compound with the formula H_2S. It is a colourless gas with the characteristic foul odour of rotten eggs. In large quantities it is very poisonous, corrosive, and flammable, however in this reaction only small amounts of hydrogen sulphide may be released.

https://jr.chemwatch.net/chemwatch.web/home#

TIME: APPROX 30MIN

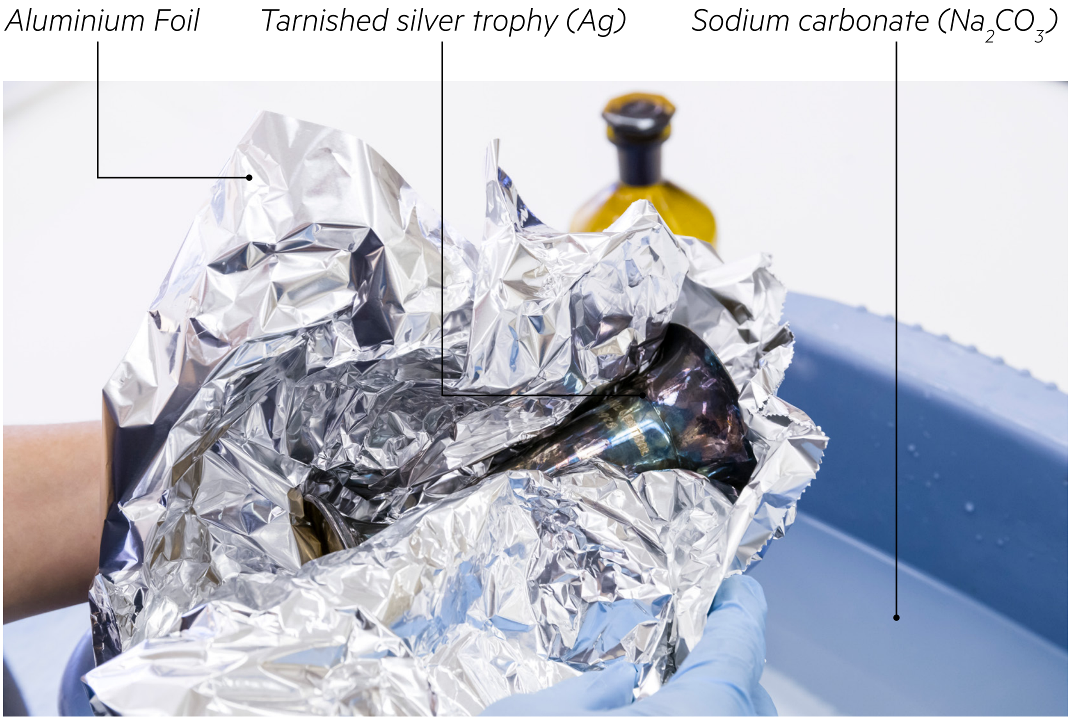
Method

STEP 1. Wash the item using a mild detergent (e.g. Lissapol) in warm water.

STEP 2. Use a toothbrush or toothpick to remove any polish residue or grime from the crevices.

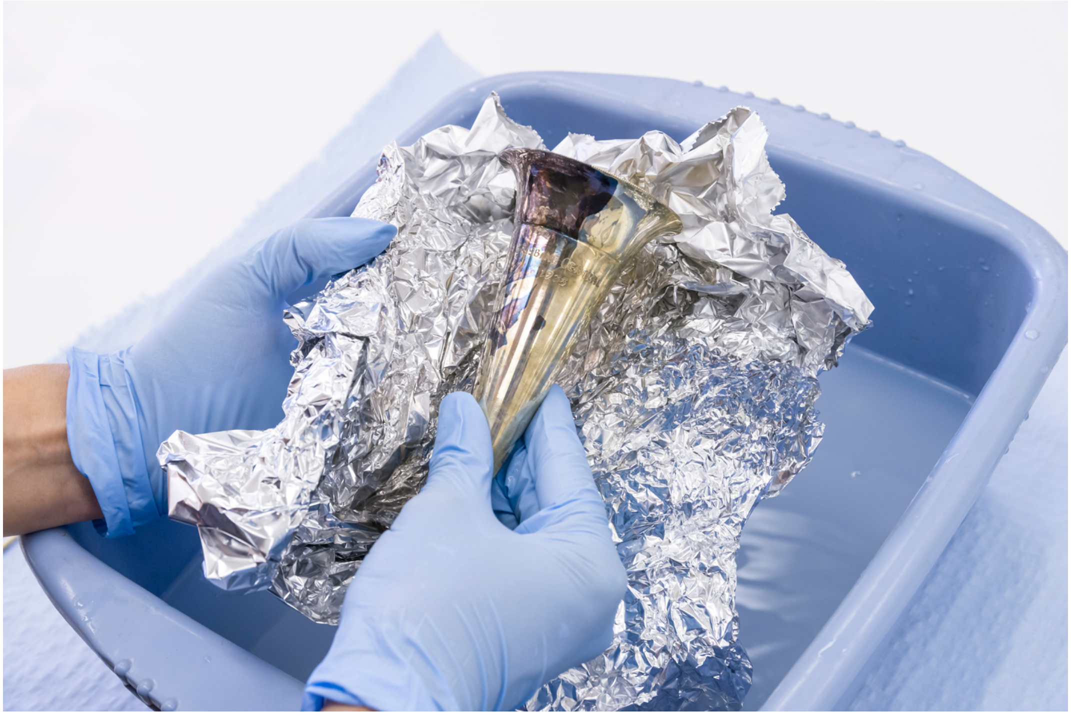
STEP 3. Rinse well with fresh water.

STEP 4. Make up the electrolytic bath in your bowl by adding sodium carbonate to **hot water** – _one tablespoon per litre is plenty_.



STEP 5. Wrap the object tightly in foil and place the silverware into the bath. You should see bubbles form.

STEP 6. Monitor the treatment and use a brush to agitate the surface of the object occasionally.



A number of chemical reactions occur during this process:

$2\ Ag\ (s) + H_2S\ (g) \rightarrow Ag_2S\ (s) + H_2\ (g)$

silver + hydrogen sulphide → silver sulphide + hydrogen

$Ag_2S\ (s) + 2\ Al\ (s) \rightarrow 6\ Ag\ (s) + Al_2S_3\ (s)$

silver sulphide + aluminium → silver + aluminium sulphide

$Al\ (s) + 3\ Ag^+ \rightarrow Al^{+3} + 3\ Ag\ (s)$

aluminium + silver ions → aluminium ions + silver

$Al_2S_3\ (s) + 6\ H_2O\ (l) \rightarrow 2\ Al(OH)_3 + 3\ H_2S\ (g)$

aluminium sulphide + water → aluminium hydroxide + hydrogen sulphide

Reduction reaction: An atom or group which receives electrons are said to have been reduced.

The **reduction** reaction restores metallic silver:

$3\ e^- + 3\ Ag^+ \rightarrow 3\ Ag\ (s)$

Oxidation reaction: An atom or group which loses electrons, either completely by making an ionic bond, or partially through a covalent bond is said to have been oxidised.

The aluminium **oxidation** reaction drives the reduction of silver:

$Al\ (s) \rightarrow Al^{+3}\ (aq) + 3\ e^-$

Redox reaction: Combining these two half reactions gives us the complete **redox** reaction:

$Al\ (s) + 3\ Ag^+ \rightarrow Al^{+3} + 3\ Ag\ (s)$

STEP 7. Once you are satisfied with the results then rinse the object in fresh water.

STEP 8. Dry the item using a soft cloth (or the sun), paying particular attention to any crevices.

STEP 9. Polish your object with a *silver cloth* to finish (see result overpage).

AFTER

Image 3. The M.C Wadsworth trophy after treatment. Here you can see the corrosion has been cleaned from the trophy and the trophy has been restored to its original silver colour. Compare the before image (Image 2) and to the after image above (Image 3).

Part 3:
Activity – The Electrolysis of Silver

Student Worksheet

BEFORE

Instruction: Using your phone's camera, record what your silver object looked like before and after the process.

BEFORE	**AFTER**

Instruction: Use your camera to document the different stages in the reaction and the results

1. What causes silverware to go black over time?

AFTER

2. A visitor at the Queensland Museum is watching you clean a silver trophy.

"That's incredible, how does that work?" they say.

You reply, *"Actually, it is just science!"*

How could you explain this process to a person without a science background?

3. During the electrolysis of silver experiment,

silver is ______________ and aluminium is ______________.

This is because silver is more/less reactive than aluminium?

Select an option:

4. Describe what happens if the silver and aluminium are placed in the water bath without touching?

5. Why does the aluminium have to be in contact with the silver?

6. How could you tell a chemical reaction occurred?

7. Hydrogen sulphide has a very distinct odour. Did you detect any odour being given off by the reaction? What did it smell like?

8. Why is the electrolysis of silver cleaning technique favoured by **Museum Conservators?**

9. Can you suggest any ways to *improve* this process?

10. As this is a **redox reaction**, could you use a different metal in place of aluminium to restore silver? Discuss your answer and indicate how you could set up an experiment to test your idea.

Extension Activity: Experimental Investigation

You are a scientist at the Queensland Museum who has been asked to find the most effective way to restore valuable corroded silver objects.

Conduct an experiment to determine the most effective temperature for the restoration of corroded silver objects.

Research question: What is the effect on the rate of reaction if you altered the temperature of the water?

(This task involves the use of thermometers). Use the camera on your phone to document each of the reactions at different stages.

Aim

Hypothesis

Safety

Materials

Method

Results (graph and written)

Discussion questions:

- What temperature is most effective for restoring silver objects?
- What temperature would you recommend curators use at the museum? Is this the same as your answer above? (Why/why not?)
- Why does the temperature affect the rate of reaction?

(i). Temperature of the water

Water temperature	**(C)**	**Predictions**	**Observations**
Cold water (tap)			
Warm water (tap)			
*Boiling water**			

* CAUTION BOILING WATER BURNS

Alternatively students could investigate whether the concentration of sodium carbonate has an effect on the rate of reaction

(ii) Quantity of sodium carbonate

Quantity of sodium carbonate	**Predictions**	**Observations**
None		
One tablespoon/litre		
One tablespoon/litre		

11. What did you observe happening on:

(i) The surface of the aluminium foil?

(ii) On the bottom of the container?

12. What is a **catalyst**?

13. What is the catalyst in this reaction?

Design Challenge

After it has been cleaned, silver will start to corrode within three to twelve months.

Use your knowledge from the above activities to design and create a display case for a silver trophy out of everyday materials.

Process

1. **Plan** your design below, including an explanation for how your display will reduce corrosion of the trophy.
2. **List** what materials you will need
3. **Create** your display using everyday materials.
4. **Test.** Place silver objects on the display and monitor temperature and weekly for signs of corrosion.
5. **Compare.** Which display is most effective? Why?
6. **Evaluate & Refine.** How would your display change if your materials and budget were unlimited?

Plan your design here

How will your design reduce corrosion on the trophy?

List what materials you will need here

Test Results

Comparison Findings

Refine your design here (unlimited budget)

Part 4:
Activity – The Electrolysis of Silver

Teacher Notes

Reduction reactions used in conservation

Reduction reactions are used in museum conservation in the attempt to recover metals from their corroded state. When a metal forms a compound, its atoms have been oxidised (lost electrons), forming positive ions. Reduction (putting electrons back into these ions) would give us, as one product of reaction, the metal itself. This experiment is a conservation example of one method of cleaning silver using aluminium foil. Aluminium foil is packed around the silver object and put into an alkaline solution such as sodium carbonate in water. The alkali strips the surface coating of oxide from the aluminium, and the electron exchange can occur.

A number of chemical reactions occur during this process:

$$2\ Ag\ (s) + H_2S\ (g) \rightarrow Ag_2S\ (s) + H_2\ (g)$$

silver + hydrogen sulphide → silver sulphide + hydrogen

$$3\ Ag_2S\ (s) + 2\ Al\ (s) \rightarrow 6\ Ag\ (s) + Al_2S_3\ (s)$$

silver sulphide + aluminium → silver + aluminium sulphide

$$Al\ (s) + 3\ Ag^+ \rightarrow Al^{+3} + 3\ Ag\ (s)$$

aluminium + silver ions → aluminium ions + silver

$$Al_2S_3\ (s) + 6\ H_2O\ (l) \rightarrow 2\ Al(OH)_3 + 3\ H_2S\ (g)$$

aluminium sulphide + water → aluminium hydroxide + hydrogen sulphide

Description

If you have any objects made from silver or plated with silver, you know that the bright, shiny surface of silver gradually darkens and becomes less shiny. This happens because silver undergoes a chemical reaction with sulphur-containing substances in the air. You can use chemistry to reverse the tarnishing reaction, and make the silver shiny again.

Testing whether an object is silver

Silver will tarnish when exposed to the air and especially when exposed to sulphur, which you can find in mustard. This can be cleaned off with weak vinegar and baking soda solution or a weak acid solution. Contact with materials that contain sulphur compounds, such as hardboiled eggs, mayonnaise, mustard, and rubber bands, can cause tarnish.

In air, a silver object can tarnish owing to the reaction of silver with hydrogen sulfide (H_2S). This is a gas found in the air as a result of some industrial processes and the decomposition of dead plants and animals. The reaction of silver with hydrogen sulfide to form tarnish is as follows:

$$2\ Ag(s) + H_2S(g) \rightarrow Ag_2S(s) + H_2(g)$$

The tarnish on silver can be removed with commercial silver polishes. This method usually removes the tarnish through abrasion. As a result, each time tarnish is removed, some of the silver is lost. However, tarnish can also be removed chemically through the reaction of aluminum with the tarnish. The aluminum is a more reactive metal than silver, so it reacts with the tarnish to chemically convert the tarnish back to silver. The reaction is as follows:

$$3\ Ag_2S(s) + 2\ Al(s) \rightarrow 6\ Ag(s) + Al_2S_3(s)$$

This activity allows students to remove tarnish from silver using the reaction of tarnish with aluminum.

Why this works

Silver tarnishes when it reacts with sulphur in the atmosphere to form silver sulphide (the black layer that forms on silverware). This is caused by sulphur compounds in the atmosphere, originating from the burning of fossil fuels and other industrial activity. Humans are also agents in producing tarnish – the salts and greases in our skin are highly corrosive and can cause tarnishing and mark a polished surface irreversibly.

This treatment reverses this chemical reaction, transforming the silver sulphide (Ag_2S) back to silver (Ag). It works because sulphur reacts preferentially with aluminium (Al).

In water, the sulphur from the silver sulphide (Ag_2S) dissolves into the electrolyte leaving the pure silver (Ag) behind. The dissolved sulphur reacts with the aluminium foil to form aluminium sulphide (Al_2S_3).

The sodium carbonate (Na_2CO_3) is required to remove the thin layer of aluminium hydroxide ($Al(OH)_3$) that forms on the aluminium foil; without this, the reaction would be unable to obtain a ready supply of aluminium ions (Al^{+3}), and as such could not proceed. The reaction between these two also produces hydrogen (H_2), which plays no part in the removal of the silver tarnish and is given off as a gas.

In this experiment, the silver sulphide (Ag_2S) reacts with aluminium (Al). Sulphur (S) atoms are transferred from silver (Ag) to aluminium (Al), freeing the silver metal (Ag) and forming aluminium sulphide (Al_2S_3). Chemists represent this reaction with the following equation:

$$3\ Ag_2S + 2\ Al \rightarrow 6\ Ag + Al_2S_3$$

silver sulphide + aluminium → aluminium sulphide

This type of reaction is called an **electrochemical reaction** because a tiny electric current flows between the silver and aluminium when the two are in contact and immersed in a sodium carbonate solution. The addition of the sodium carbonate improves the ease with which the electrons move between the silver and aluminium.

Reduction reaction: An atom or group which receives electrons are said to have been reduced.

The **reduction** reaction restores metallic silver:

$$3\ e^- + 3\ Ag^+ \rightarrow 3\ Ag\ (s)$$

Oxidation reaction: An atom or group which loses electrons, either completely by making an ionic bond, or partially through a covalent bond is said to have been oxidised.

The aluminium **oxidation** reaction drives the reduction of silver:

$$Al\ (s) \rightarrow Al^{+3}\ (aq) + 3\ e^-$$

Redox reaction: Combining these two half reactions gives us the complete **redox** reaction:

$$Al\ (s) + 3\ Ag^+ \rightarrow Al^{+3} + 3\ Ag\ (s)$$

Metals can be ranked in order of the ease with which they can shed electrons. Referring to the Metal Activity Series helps us to understand why silver is reduced and aluminium is oxidized.

Metal Activity Series (partial)

INCREASING EASE OF OXIDATION ↑

Aluminium (Al)
Zinc (Zn)
Iron (Fe)
Nickel (Ni)
Tin (Sn)
Lead (Pb)
Copper (Cu)
Mercury (Hg)
Silver (Ag)
Platinum (Pt)
Gold (Au)

INCREASING EASE OF REDUCTION ↓

Aluminium is the **reducing agent** and thereby reduces silver sulphide to elemental silver while forming aluminium sulphide. We use hot water because the reaction is faster when the solution temperature is higher. The solution carries sulphur released from the silver to the aluminium, where a layer of aluminium sulphide is formed. The aluminium sulphide then hydrolyses to form aluminium hydroxide, $Al(OH)_3$, and gaseous hydrogen sulphide, H_2S.

Did you detect a foul odour during this experiment? If the silver was heavily tarnished you may have. Hydrogen sulphide evolved in this reaction is the same smelly gas that rotting eggs give off.

The balanced equation for the dissolution of aluminium sulphide in water:

$$Al_2S_3 + 6\ H_2O \rightarrow 2\ Al(OH)_3 + H_2S\ (g)$$

What is the role of sodium carbonate? Aluminium in pure water would not remove silver tarnish because there is a film of aluminium hydroxide that stops the oxidation reaction. Sodium carbonate removes the surface film of aluminium hydroxide (by dissolving it) to expose fresh metallic aluminium, ready for oxidation. The dissolved sodium carbonate also increases the ionic strength of the solution, **which increases the rate of the reaction.**

The problem with this reaction is that eventually aluminium sulphide builds up on the aluminium foil and the reaction slows down and will eventually stop. **Observe:** The aluminium sulphide may adhere to the aluminium foil, or it may form tiny, pale yellow flakes in the bottom of the pan.

By adding sodium carbonate to the water, the sulphur reacts with hydrogen and forms bubbles of gas called hydrogen sulphide. This is also known as rotten-egg gas. This prevents the aluminium sulphide from building up on the foil and the reaction lasts longer.

Electrochemical reduction has also been used to reduce the corrosion on bronzes, using zinc granules as the other metal. Reactions of this type are also used in batteries to produce electricity.

Bibliography

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