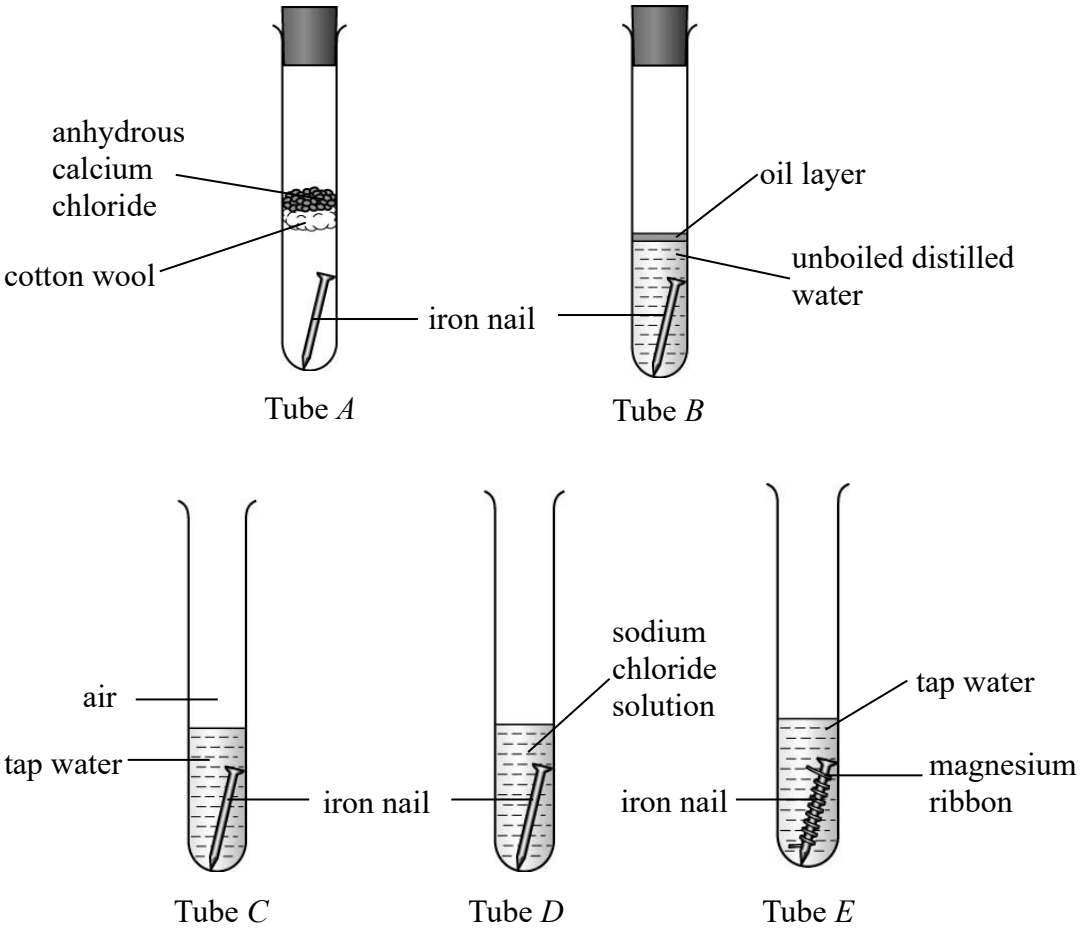
Chemistry: Chapter 13 Corrosion of metals and their protection
Combined Science (Chemistry Part): Chapter 13 Corrosion of metals and their protection

Sections 13.1−13.2
|!|ELB031313001O|!|
Five iron nails are placed at different conditions. The setup is shown below.



(a) What factors are essential for the rusting of iron?

(b) What is the purpose of placing anhydrous calcium chloride in tube *A*?

(c) Why oil and unboiled distilled water were used in tube *B*?

(d) If the air in tube *C* is replaced with car exhaust gas, would the iron nail in it rust faster? Explain your answer.

(e) Would the nail in tube *B* rust? Explain your answer.

(f) If the magnesium ribbon is replaced with magnesium powder, would the iron nail start rusting at an earlier time? Why?

[14M]

##
(a) The presence of both oxygen [1] and water [1].
(b) It absorbs moisture in air [1], removing one essential factor, water, to prevent or slow down rusting. [1]
(c) Oil prevents oxygen from dissolving in water again; [1] unboiled distilled water ensures no ions are present. [1]
(d) Yes. [1] Car exhaust gas contains many acidic pollutants [1], such as sulphur dioxide, carbon dioxide and nitrogen oxides. When they dissolve in water, acids form and the ions accelerate the rusting process. [1]
(e) Yes, [1] as there is some oxygen in unboiled distilled water. [1]
(f) Yes. [1] As magnesium powder provides a greater surface area for its reaction with air, [1] magnesium would run out earlier and therefore the nail would start rusting earlier. [1]
##

Section 13.3
|!|ELA031313002O|!|
(a) What substances (besides iron) are needed for rusting to occur?

(b) Explain why iron objects will not rust in
(i) a deep sea,

(ii) the outer space,

(iii) a desert.

(c) Will rusting be faster in sea water or river water? Explain.

(d) What can you say about the rates of corrosion of various metals in relation to their positions in the metal reactivity series? Are there exceptions to your statement?

[7M]

##
(a) Oxygen (air), water [1]
(b) (i) No or little oxygen [1]

(ii) No oxygen, no water [1]
(iii) Little water (very dry climate) [1]

(c) Sea water; it contains a high concentration of salts (e.g. sodium chloride), thus more conducting. [2]

(d) A metal higher in the metal reactivity series corrodes faster (except when there is a protective layer formed, e.g. Al, Zn) [1]

##

Section 13.4

|!|ELA031313003O|!|

A student was given three Petri dishes, with Dish *X* containing a single iron nail, Dish *Y* containing an iron nail partly wrapped with a copper strip and Dish *Z* containing an iron nail partly wrapped with a magnesium ribbon. All dishes contained a gel with a rust indicator solution.

(a) Explain how a rust indicator detects iron rust.

(b) State and explain the expected observation in Dish *X*.

(c) State and explain the expected observation in Dish *Z*.

(d) State and explain whether the iron nail in Dish *X* or Dish *Y* rusted faster.

[11M]

##

(a) As iron rusts, it forms $Fe^{2+}(aq)$ ions. [1] The rust indicator is a sensitive test for $Fe^{2+}(aq)$ ions (forming a blue colour) so it could easily detect iron rust. [1]

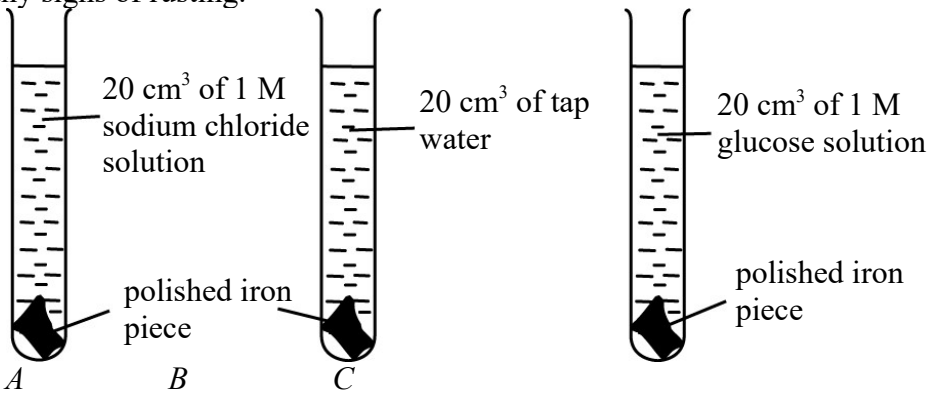
(b) A blue colour appeared (showing the iron nail rusted) [1] and the blue patches were mainly formed around the head and tip of the nail. [1] It was because these regions were sharply pointed and iron there changed into $Fe^{2+}(aq)$ ions more easily. [1]

(c) The blue colour did not appear (indicating the iron nail did not rust) [1] as magnesium, being more reactive, lost electrons more easily than iron. [1] Thus iron was prevented from losing electrons to form $Fe^{2+}(aq)$ ions and therefore did not rust. [1]

(d) The iron nail in Dish *Z* rusted faster [1] as it was connected with to copper strip. Since copper is less reactive than iron, [1] iron changes to $Fe^{2+}(aq)$ ions and rusts more easily. [1]

##

|!|ELA031313004O|!|
A student investigated the effect of some dissolved substances on the rate of corrosion of iron. He set up three test tubes as shown in the figure below and added 1 cm^3 of potassium hexacyanoferrate(III) solution to each. After half an hour, he inspected the tubes for any signs of rusting.



(a) Why should the iron pieces be polished (e.g. with steel wool) before the experiment?

(b) How can the rates of rusting be compared by the potassium hexacyanoferrate(III) solution added?

(c) Compare the rates of rusting in the three test tubes *A*, *B* and *C*. Explain your reasoning.

[4M]

##
(a) To provide a clean iron surface. [1]
(b) A deeper blue colour indicates more $Fe^{2+}(aq)$ ions produced and a faster rate of rusting. [1]
(c) Rusting in *A* is the fastest (become salt is present, so, the solution is more conducting); *B* and *C* are quite the same (as there is no salt present). [2]
##

Section 13.5
|!|ELA031313005O|!|
Barium (Ba), with atomic number 56, is in the same group with calcium and magnesium in the Periodic Table.
(a) Which metal, calcium or barium, is more reactive? Explain your answer.

(b) Write a chemical equation for the reaction between barium and dilute

hydrochloric acid.

(c) By what method is barium extracted from its ore?

(d) Can barium be used to prevent iron from rusting? Why?

[8M]

##
(a) Barium is more reactive. [1]
Barium has a lower position than calcium in the Periodic Table. [1] The lower a metal situates in the group, the more reactive it is. [1]
(b) $Ba(s) + 2HCl(aq) \rightarrow BaCl_2(aq) + H_2(g)$ [1]
(c) Barium is extracted by electrolysis of its molten ore. [1]
(d) Yes. [1] Barium should be more reactive than iron because it is more reactive than calcium, which is at a higher position than iron in the metal reactivity series. [1] Barium can prevent iron rusting by sacrificial protection. [1]
##

|!|ELB031313006O|!|
Galvanizing (zinc-plating) is commonly used to prevent iron from rusting.
(a) Write a chemical equation to describe the overall change in iron rusting.

(b) Explain how a zinc coating could prevent iron from rusting.

(c) Suggest a daily use of galvanized iron.

(d) State whether the exposed parts of iron would rust if the zinc coating is partly damaged.

(e) Albert was given an iron can coated with tin. He scratched the tin surface of the iron can and claimed, 'the exposed iron parts would not rust due to sacrificial protection by tin.' Comment whether his statement is correct.

(f) Explain whether zinc is suitable for making food cans.

[10M]

##
(a) $4Fe(s) + 3O_2(g) + 2nH_2O(l) \rightarrow 2Fe_2O_3 \cdot nH_2O(s)$ [1]

(b) The zinc coating prevents iron from contacting with air and moisture. [1] When the zinc coating is damaged, iron will not rust but zinc, being more reactive, corrodes instead. [1]
(c) Galvanized iron is used in making buckets. [1]
(d) The exposed parts of iron would not rust. [1]
(e) His statement is incorrect. [1] If the coating was damaged, the exposed parts of iron lost electrons to form $Fe^{2+}(aq)$ ions (and rust) more easily [1], as tin was less reactive than iron. [1]
(f) Zinc is not suitable for making food cans [1] as it is poisonous. [1]
##

|!|ELA031313007O|!|
Explain how iron is prevented from rusting in the following cases.
(a) The steel legs in piers are connected to the negative terminal of a d.c. source.

(b) Zinc blocks are attached to the hull of a ship.

(c) An iron bridge is painted.

(d) Bicycle chains are often greased.

(e) Paper clips are coated with plastic.

[10M]

##
(a) The negative terminal of the d.c. source supplies electrons [1] and prevents iron from losing electrons. [1]
(b) Zinc is more reactive than iron and would lose electrons in preference to iron. [1] Thus iron is prevented from forming $Fe^{2+}(aq)$ ions (and rusting). [1]
(c) The paint acts as a protective layer to iron [1] and keeps iron away from direct contact with air and moisture. [1]
(d) Grease acts as a protective layer to the moving iron parts [1] and keeps iron away from direct contact with air or water. [1]
(e) Plastic acts as a protective layer to iron [1] and keeps iron away from direct contact with air and moisture. [1]
##

|!|ELB031313008O|!|
Maria was given a piece of aluminium foil.

(a) Name an aluminium ore found in the Earth's crust.

(b) Suggest a method to extract aluminium from its ore.

(c) Maria claimed, 'aluminium is corrosion resistant as the position of aluminium is very low in the reactivity series.' Comment whether her statement is correct.

(d) Name a method that could further improve the corrosion resistance of aluminium.

(e) Suggest two daily uses of aluminium.

[8M]

##
(a) Bauxite [1]
(b) Aluminium could be extracted from its ore by electrolysis of molten aluminium oxide. [1]
(c) The statement is incorrect. [1] Aluminium is corrosion-resistant because the metal surface is coated with a thin but tough oxide layer which seals the metal surface. [1] Thus aluminium behaves to be less reactive than it really is. [1]
(d) Anodization [1]
(e) It is used to make soft drink cans [1] and window frames. [1]
##

|!|ELA031313009O|!|
Answer the following questions:

(a) The position of aluminium is even higher than iron in the reactivity series, yet unlike iron, it resists corrosion. Explain.

(b) If the surface of galvanized iron is scratched, what happens to the exposed iron? Explain.

(c) If the surface of tin-plate is scratched, what happens to the exposed iron? Explain.

(d) Iron cans, coated with tin, are used in the canning industry as 'tin cans' for

storing foodstuff. Can galvanized iron be used for such a purpose? Explain.

(e) By alloying with certain metals (such as chromium and nickel), steel can be turned into stainless steel which are corrosion resistant. Yet many iron objects are protected by various other methods. Explain.

[8M]

##

(a) Protective Al_2O_3 layer formed on surface by itself. [1]
(b) Exposed iron still protected from rusting; zinc, being more reactive, loses electrons to iron, preventing formation of Fe^{2+}(aq) ions (sacrificial protection). [2]
(c) Exposed iron is not protected and rusts even faster than no tin was plated. Iron, being more reactive, loses electrons to tin, thus encouraging formation of Fe^{2+} (aq) ions and speeding up rusting. [2]
(d) No, Zn^{2+} ions are poisonous. [2]
(e) Stainless steel is too expensive for making large objects. [1]

##

|!|ELA031313010O|!|

Nail	Treatment	Cost of treatment	Mass of nail + coating before exposure to air (in g)	Mass of nail + coating after exposure to air (in g)
A	Painted	Low	4.0	4.3
B	Greased	Low	4.0	4.2
C	Oiled	Low	4.0	3.3
D	Chromium plated	High	4.0	4.0
E	Untreated	——	4.0	4.9
F	Galvanized	Fairly high	4.0	4.1
G	Dipped in salt solution	Low	4.0	5.4

To investigate rusting of iron, six identical iron nails were treated in certain ways. One nail was left untreated. All seven nails were then left exposed to air for several weeks. The results of the experiments are given in the table above. There is an error in one of the results.

(a) Which nail was best protected against rusting?

(b) Which nail received a treatment which made the rusting worse than if it were untreated?

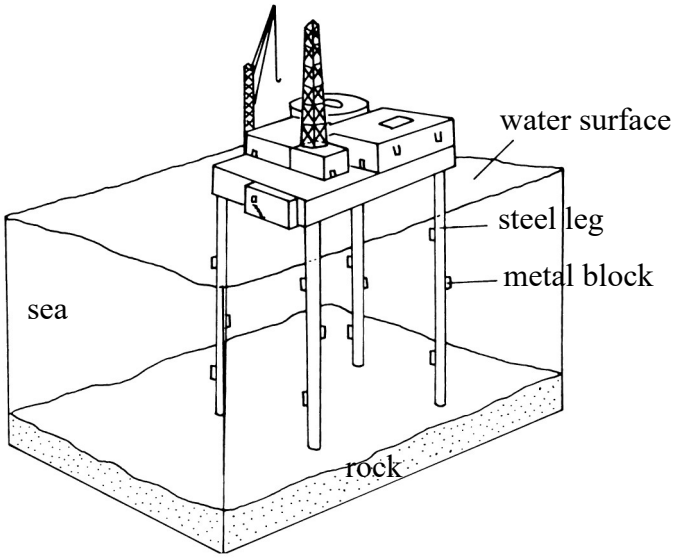
(c) In weighing the nail with its coating after the experiment, there was an obvious mistake. Which experiment is it?

(d) Which treatment would be most suitable to prevent dustbins from rusting?

[4M]

##
(a) *D*
(b) *G*
(c) *C*
(d) *F*
##

|!|ELA031313011O|!|
The following figure shows an off-shore oil platform.



(a) Would the steel legs of the oil platform rust faster or slower than when put in fresh water? Explain.

(b) To protect the steel legs from rusting, metal blocks could be attached to the steel legs. Suggest two metals which can be used for this purpose.

(c) Explain why the metal blocks mentioned in (b) can protect the steel legs from rusting.

(d) Give another method that can also be used to protect the steel legs from rusting.

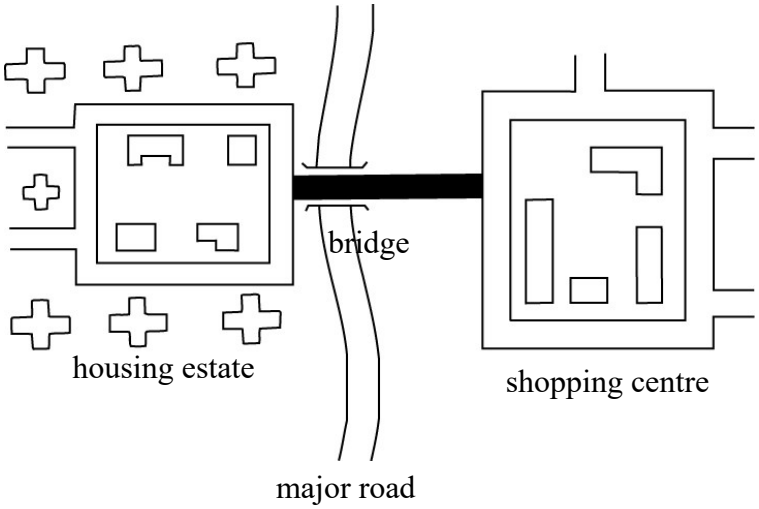
(e) Is it practical to use stainless steel to make the steel legs? Explain.

[7M]

##
(a) Slower. Fresh water contains much less salts than sea water. Salt solution speeds up rusting. [2]
(b) Zinc, magnesium. [1]

(c) Zinc or magnesium, being more reactive than iron, protects the iron from rusting by sacrificial protection. [1]
(d) Connect the steel legs to the negative terminal of a d.c. source. [1]
(e) No. Stainless steel is expensive and is usually only used for making small objects. [2]
##

|!|ELB031313012O|!|
The government plans to build a new bridge (fly-over) across a major road, to connect a housing estate and a neighbouring shopping centre:



The bridge is to be made of iron. It does not need to last longer than 17 years because after that time, there will be other new developments in that area.
The City Planning Unit has to make a choice among the following three options:
Option 1: To build the bridge with iron and paint it once and for all.
Option 2: To build the bridge with iron and paint it at regular intervals.
Option 3: To build the bridge with galvanized iron and paint it once and for all.
The table below shows the estimated cost (assuming no inflation) of the items involved, together with some remarks:

Item	Cost (in HK$)	Remarks
Building the bridge with iron	8 000 000 (cost does not include painting)	The bridge (with only initial painting) needs replacement after 12 years, as it would become unsafe at that time due to rusting.
Painting the bridge once	800 000	Repainting on iron is necessary every 3 years. There is no need for repainting on galvanized iron.
Building the bridge with galvanized iron	11 500 000 (cost does not include painting)	The bridge (with only initial painting) needs replacement after 20 years.

Suppose you are a city planning officer.

(a) For each option, work out the total cost.

(b) Which option would you choose? Explain.

[7M]

##

(a) Option 1: Another new bridge will need to be built after 12 years.

Minimum total cost

= ($ 8 000 000 + $ 800 000) × 2 [1]

= $ 17 600 000 [1]

Option 2: Six times of painting will be required.

Total cost

= $ 8 000 000 + $ 800 000 × 6 [1]

= $ 12 800 000 [1]

Option 3: Total cost= $ 11 500 000 + $ 800 000 [1]

= $ 12 300 000 [1]

(b) Option 3, which is the cheapest one. [1]

(Note: Assume there is no inflation and disregard any cost due to bank interest.)

##

Sections 13.6−13.7

|!|ELB031313013O|!|

XXX is a hot city located near the coast. Its air quality is poor due to overpopulation and intense industrial development. Her citizens found that the iron productsrust much faster than those in other cities.

(a) Explain this phenomenon.

(b) Suggest three ways to slow down iron rusting in the city.

(c) A man bought a new aluminium cooking pan. A few days later, he found that there was a thin white layer covering the pan surface. He scratched the layer off but it appeared again after a few days. He then scratched off the layer once it formed. After a period of time, the pan broke. Explain the phenomenon with appropriate chemical equation(s).

(d) Anodization is a well-grown industry in the city.
(i) State the main function of anodization.

(ii) Describe how anodization can be done in laboratory.

[16M]

##

(a) Air near the coast contains many electrolytes, such as sodium chloride, which can accelerate corrosion by providing a better conducting medium (for reaction of iron with water and oxygen). [1]
High temperature causes high reaction rate, making rusting goes faster. [1]
Overpopulation and intense industrial development produces many pollutants in the air. Common air pollutants are sulphur dioxide, nitrogen oxides and carbon monoxide. These air pollutants dissolve in rainwater to form acids, which provide hydrogen ions, and then corrodes iron. [1]

(b) Painting [1]
Electroplating [1]
Sacrificial protection [1] or any other correct methods

(c) When the new aluminium cooking pan was in use, the oxygen in air reacted with aluminium to form a white aluminium oxide layer covering the pan surface. [1]
$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$ [1]
After the layer was scratched off, the clean aluminium continued to react with oxygen and form oxide layer again. [1] The repeated scratching caused more aluminium reacting with oxygen and finally all aluminium had reacted and the pan broke. [1]

(d) (i) Anodization is to thicken the oxide layer on the surface of aluminium [1], and hence to enhance its resistance to corrosion. [1]
(ii) In a setup of electrolysis, the aluminium object to be anodized is placed at

the positive electrode [1], and the negative electrode [1] is an aluminium sheet, using dilute sulphuric acid as the electrolyte. [1] The oxygen evolved at the positive electrode reacts with aluminium to increase the thickness of the oxide layer. [1]

##

|!|ELA031313014O|!|

How would you protect the following from corrosion?

(a) An aluminium door frame

_____

(b) A saw blade

_____

(c) A bicycle handlebar

_____

(d) A bicycle chain

_____

(e) A bridge

_____

(f) Cutlery

_____

(g) The electrical contacts in a space capsule

_____

(h) A towel rail

_____

(i) An electric kettle

_____

[9M]

##

(a) Anodizing [1]
(b) Oiling [1]
(c) Chromium-plating [1]
(d) Oiling [1]
(e) Painting [1]
(f) Use of stainless steel [1]
(g) Use of gold electrical contacts [1]
(h) Chromium-plating [1]
(i) Chromium-plating [1]

##