Mastering Chemistry

- Book 1C
- Topic 3 Metals

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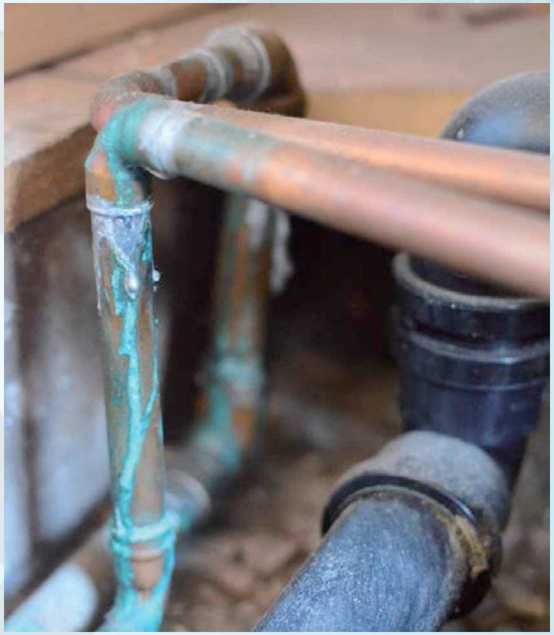
Content

13.1 What is corrosion (p.109)

- The deterioration of a metal caused by chemical interaction with oxygen, moisture or other substances in the environment is called **corrosion (腐蝕)**.

Black silver sulphide forms



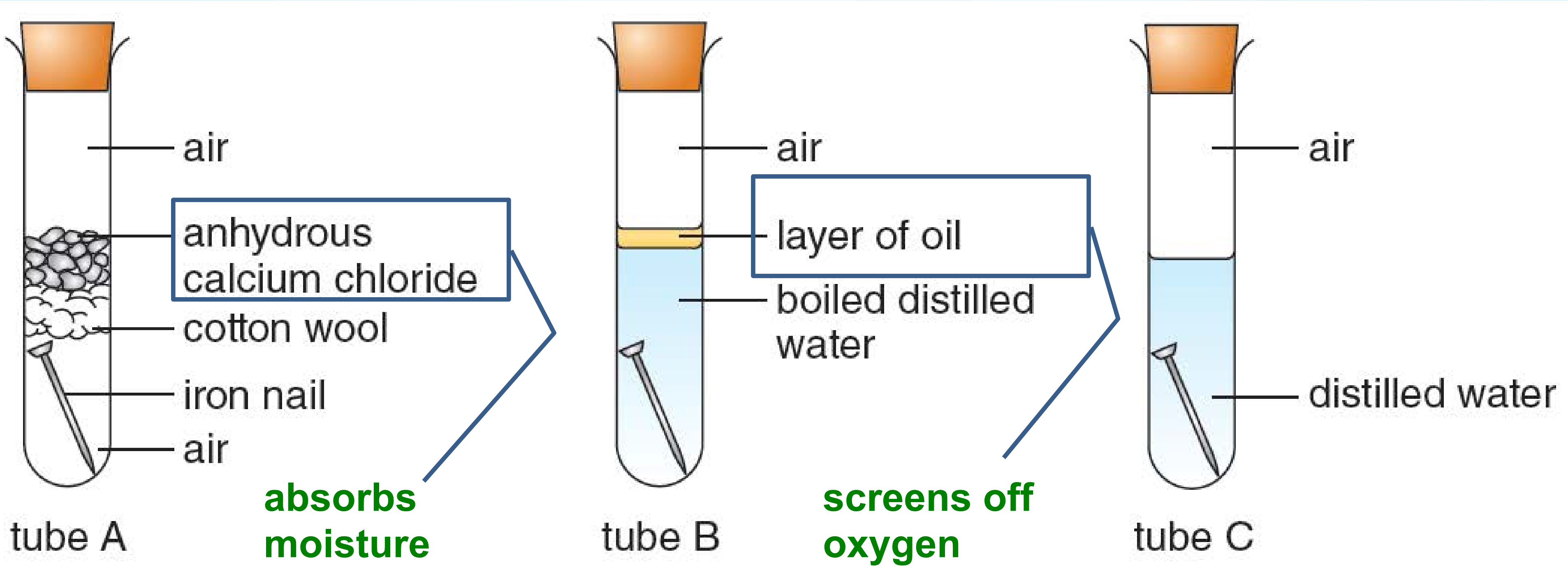
Green copper(II) carbonate forms

13.1 What is corrosion (p.109)

- The corrosion of iron is called **rusting (生銹)**.
- When iron is exposed to moist air for a long time, reddish brown, flaky rust, i.e. hydrated iron(III) oxide forms.
- Rusting continues until all the iron has corroded away.

13.2 Conditions for rusting to occur (p.110)

- Both air (oxygen) and water are needed for iron to rust.



Investigating the necessary conditions for rusting ***Ref.***

13.3 What happens during rusting (p.111)

- You can study how rust forms with a **rust indicator (鐵銹指示試劑)**—a mixture of $K_3Fe(CN)_6$ and phenolphthalein.

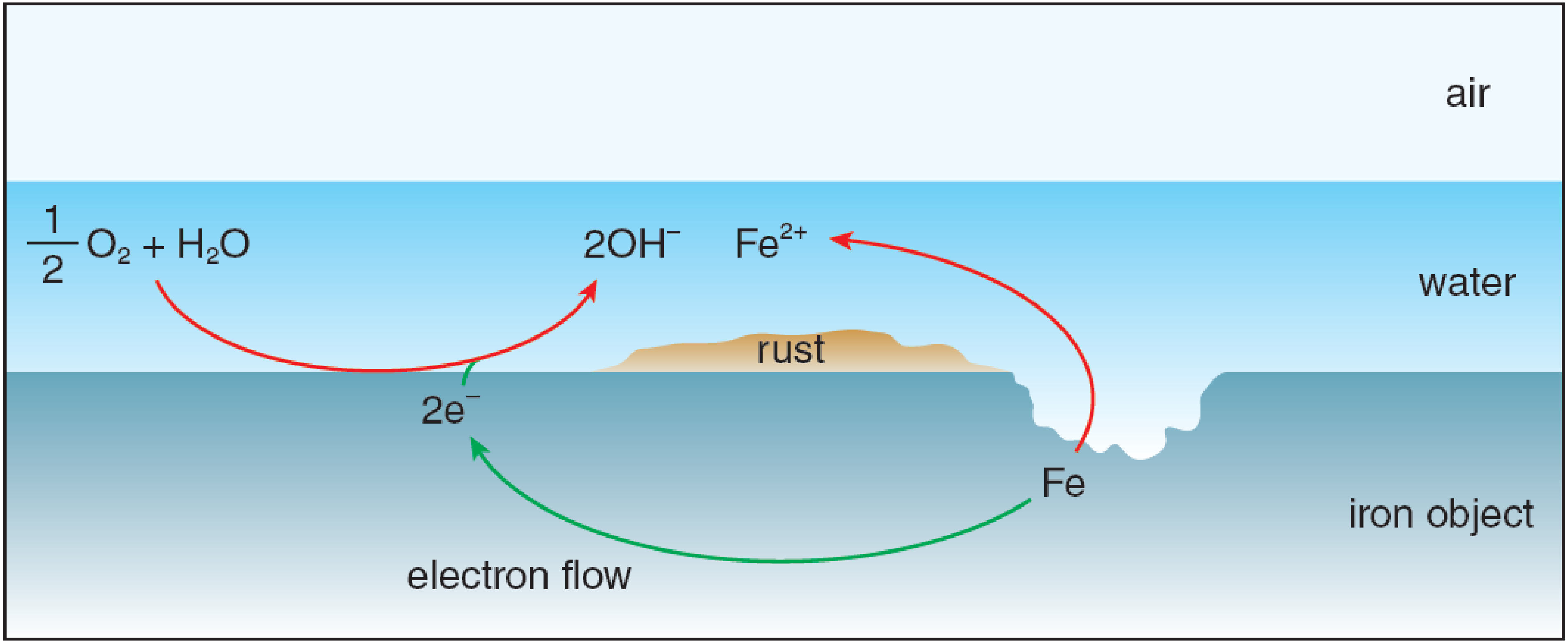
$K_3Fe(CN)_6$, potassium hexacyanoferrate(III), reacts with Fe^{2+} ions to give a blue product.

Phenolphthalein gives a pink colour in the presence of OH^- ions.

13.3 What happens during rusting (p.111)

$$4Fe(s) + 3O_2(g) + 2xH_2O(l) \longrightarrow 2Fe_2O_3 \bullet xH_2O(s)$$

rust



13.4 Factors that speed up the rusting process (p.112)

- A number of factors can speed up the rusting process.

  1 Presence of ionic substances (*e.g.* NaCl(aq))

  2 Presence of acidic pollutants (*e.g.* acidic gases)

  3 Higher temperature (*e.g.* car exhaust pipes)

  4 Scratching or bending (*e.g.* ends and bent regions of metals)

  5 Attachment to a less reactive metal (*e.g.* tin or copper)

Investigating factors that influence the speed of rusting of iron

13.5 Protecting iron from rusting (p.114)

- Corrosion of iron and steel can be dangerous. Some common protection methods are discussed below:

  1) protective coating on surface;

  2) sacrificial protection;

  3) impressed current cathodic protection; and

  4) use of stainless steel.

Investigating the effectiveness of various ways to prevent rusting

13.5 Protecting iron from rusting (p.114)

1) Protective coating on surface

Coating with paint

- cheap and simple
- for large iron and steel objects
- iron underneath can rust if surface is scratched

Coating with oil or grease

- moving parts cannot be painted
- oiled to keep out air and water
- oil must be applied regularly

13.5 Protecting iron from rusting (p.114)

Coating with plastic

- for small iron and steel objects
- to keep out air and water

Tin-plating

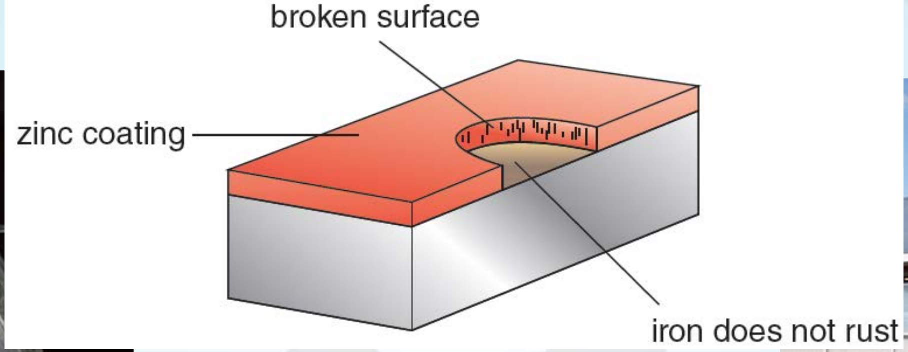
- **Tin-plating (鍍錫)**—coated with a thin layer of tin, which keeps out air and water, and non-poisonous

Electroplating

- **Electroplating (電鍍)**—plated with a thin layer (e.g. chromium) by electrolysis to give a decorative finish as well as protection
- higher cost

13.5 Protecting iron from rusting (p.114)

2) Sacrificial protection (犧牲性保護)



Galvinising

- **Galvinising (鍍鋅)**—coated with Zn (keeps out air and water; loses e^- first as a sacrificial metal)
- still protected even if the zinc layer is damaged

Protecting ships

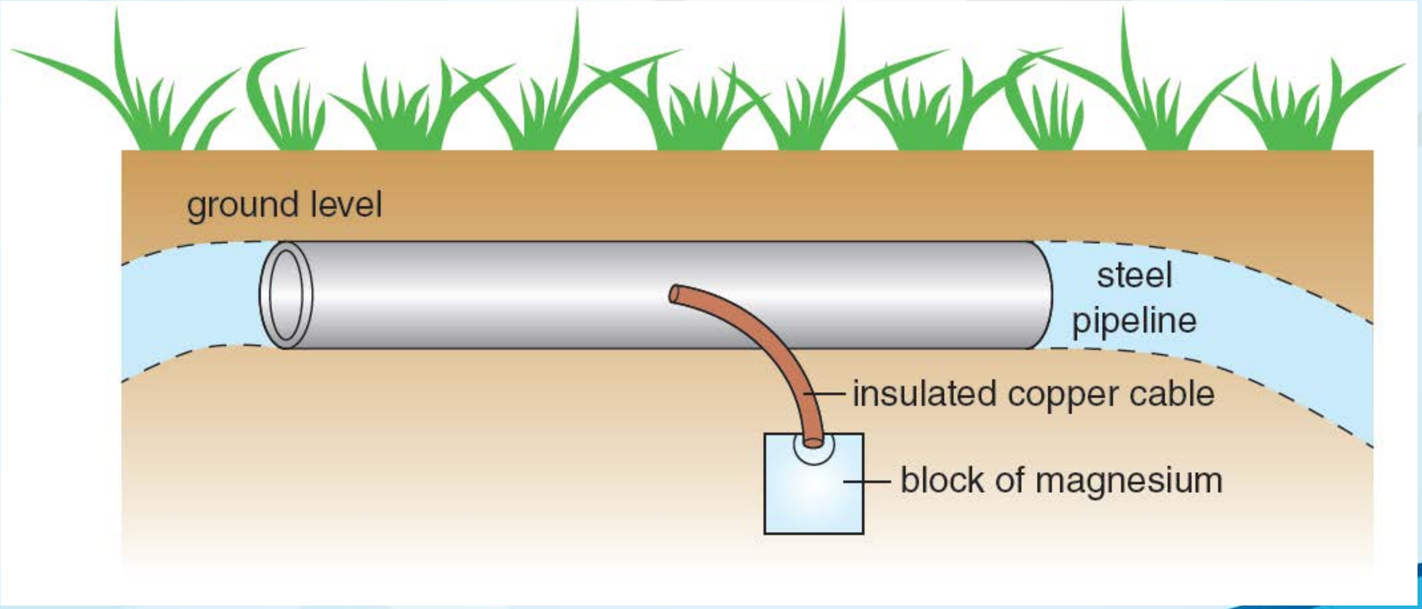
- with Zn or Mg blocks attached
- replaced regularly

13.5 Protecting iron from rusting (p.114)

2) Sacrificial protection

Protecting underground steel objects

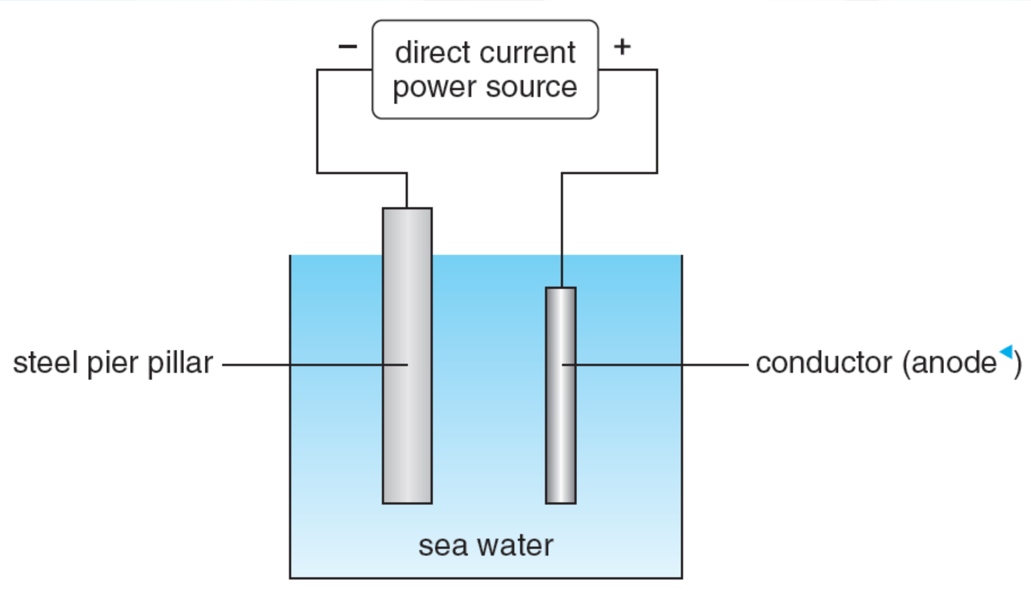
- connected to Mg or Zn blocks using insulated copper cables
- Mg or Zn corrodes slowly instead of steel



13.5 Protecting iron from rusting (p.114)

3) Impressed current cathodic protection

- **Impressed current cathodic protection (外加電流陰極保護)**—by making the iron the cathode of an electric circuit
- A d.c. power source supplies e^- to the cathode
- *e.g.* protecting a steel pier pillar



13.5 Protecting iron from rusting (p.114)

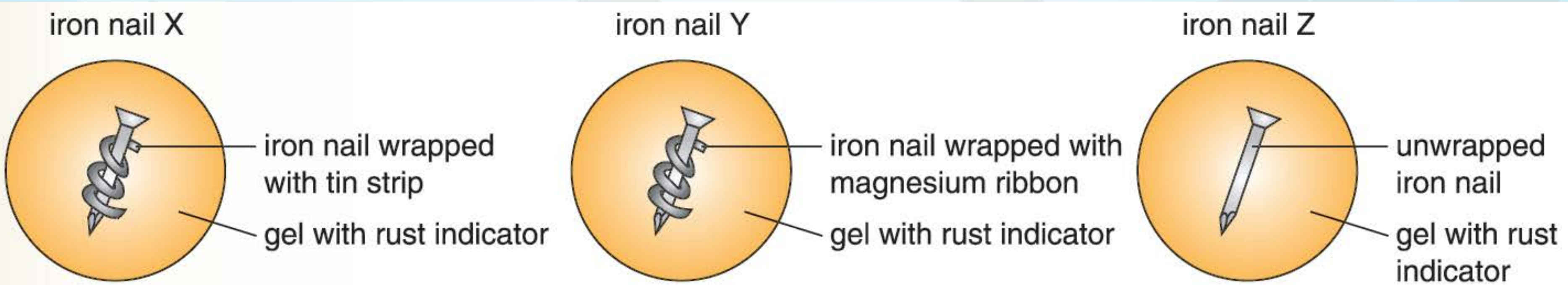
4) Use of stainless steel

- **Stainless steel (不銹鋼)**—iron + ~11% chromium + carbon (+ possibly nickel, magnesium and titanium)
- protective surface layer of oxide of chromium forms when the steel is exposed to oxygen
- most expensive way of preventing rusting (due to Cr, Ni)

13.5 Protecting iron from rusting (p.114)

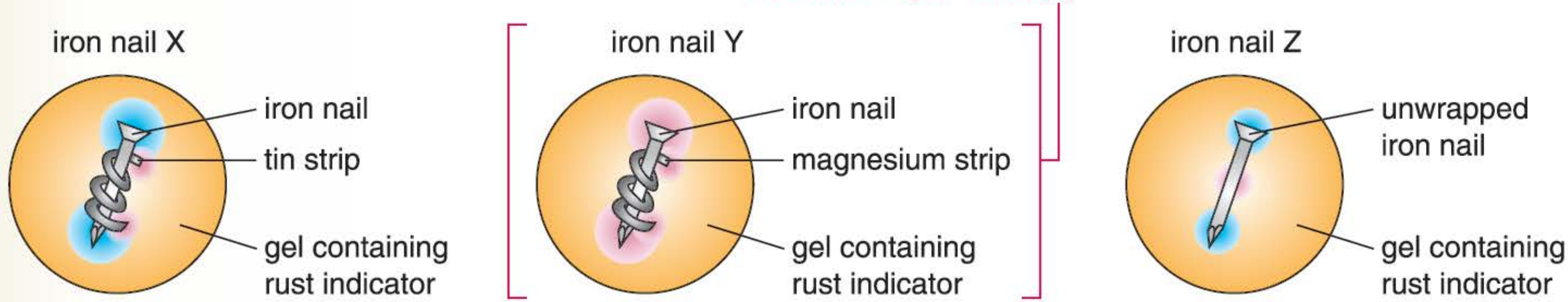
Q (Example 13.1)

Three iron nails are placed separately in gel with rust indictor containing potassium hexacyanoferrate(III) and phenolphthalein. The nails are left for a few days.



The experimental results are shown below.

DSE 2012 Paper 1B Q9(b)



13.5 Protecting iron from rusting (p.114)

a) The blue and pink regions are larger and deeper for nail X than for nail Z. Explain.

b) Explain why nail Y does not rust.

A

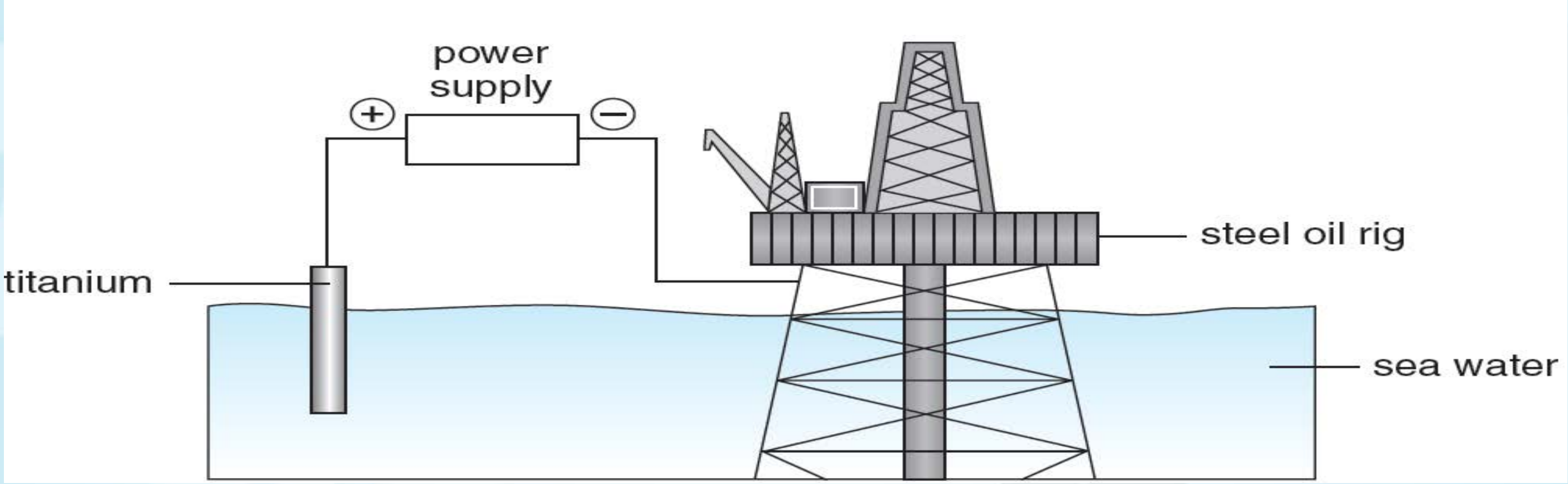
a) Tin is less reactive than iron. Iron acts as a sacrificial metal for tin and it rusts faster than normal.

b) Magnesium is more reactive than iron. Magnesium protects the iron nail from rusting by sacrificial protection.

13.5 Protecting iron from rusting (p.114)

Practice 13.1

Titanium is very resistant to corrosion. One of its uses is to serve as an electrode in the protection of steel oil rigs from rusting.

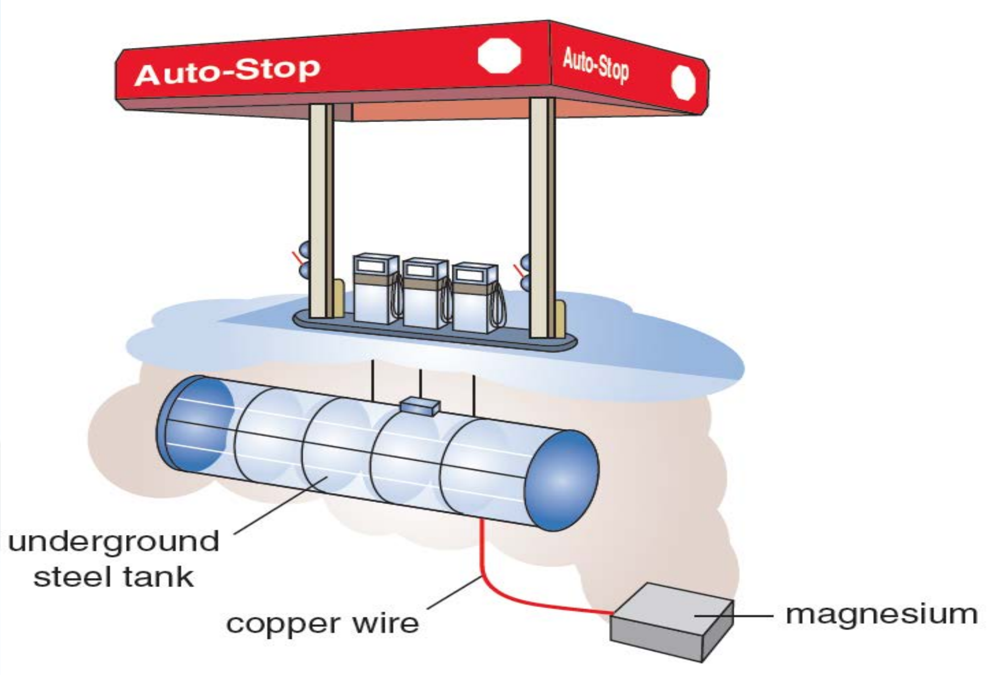


a) Name the protection method.
Impressed current cathodic protection

b) Explain why the oil rig does not rust.
The steel oil rig receives electrons from the direct current power source. Thus, the iron cannot lose electrons to form iron(II) ions.

13.5 Protecting iron from rusting (p.114)

c) The diagram below illustrates another protection method.



i) Explain why the underground steel tank does not rust.

Magnesium is more reactive than iron. It, instead of iron, corrodes.

ii) Give ONE difference between the two protection methods.

Any one of the following:

- The first method needs a power source while the second does not.
- The first method needs an inert electrode while the second method needs a more reactive metal.

13.6 Socioeconomic implications of rusting of iron (p.122)

Implications of rusting

Some consequences are economic and cause the following:

- replacement of rusted equipment;
- preventive maintenance, for example, painting;
- shutdown of equipment due to corrosion failure;
- contamination of a product;
- loss of valuable product, for example, from a container that has rusted through.

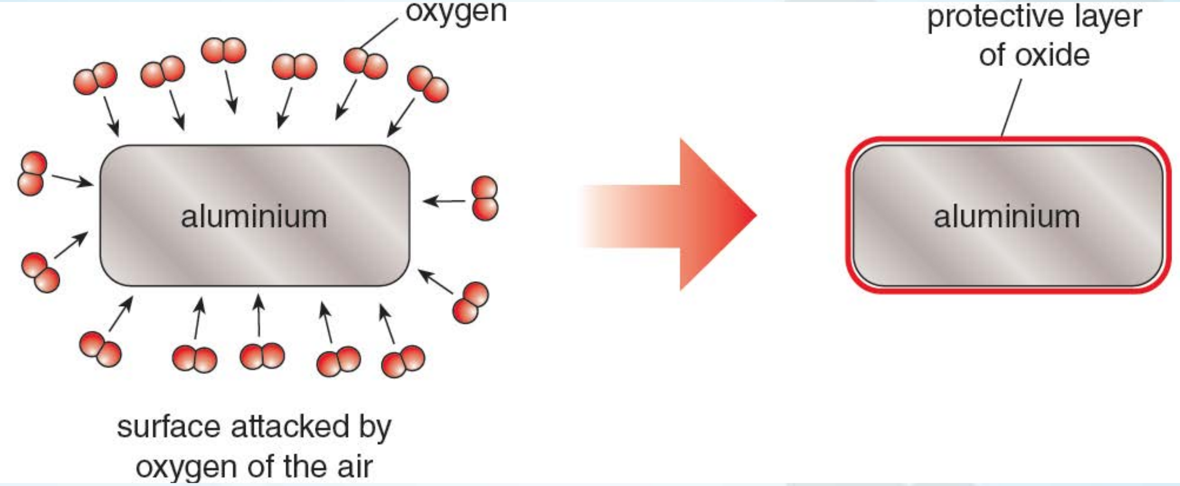
13.6 Socioeconomic implications of rusting of iron (p.122)

Other consequences are social and can involve the following issues:

- safety — for example, sudden failure can cause fire, release of toxic product and construction collapse;
- health — for example, pollution due to escaping product from rusted equipment;
- depletion of natural resources — including metals and the fuels used to manufacture them;
- appearance — rusted material is unpleasing to the eye.

13.7 Corrosion resistance of aluminium (p.124)

- Why is the corrosion of aluminium not an issue?
- A freshly cleaned surface of aluminium reacts with oxygen rapidly.

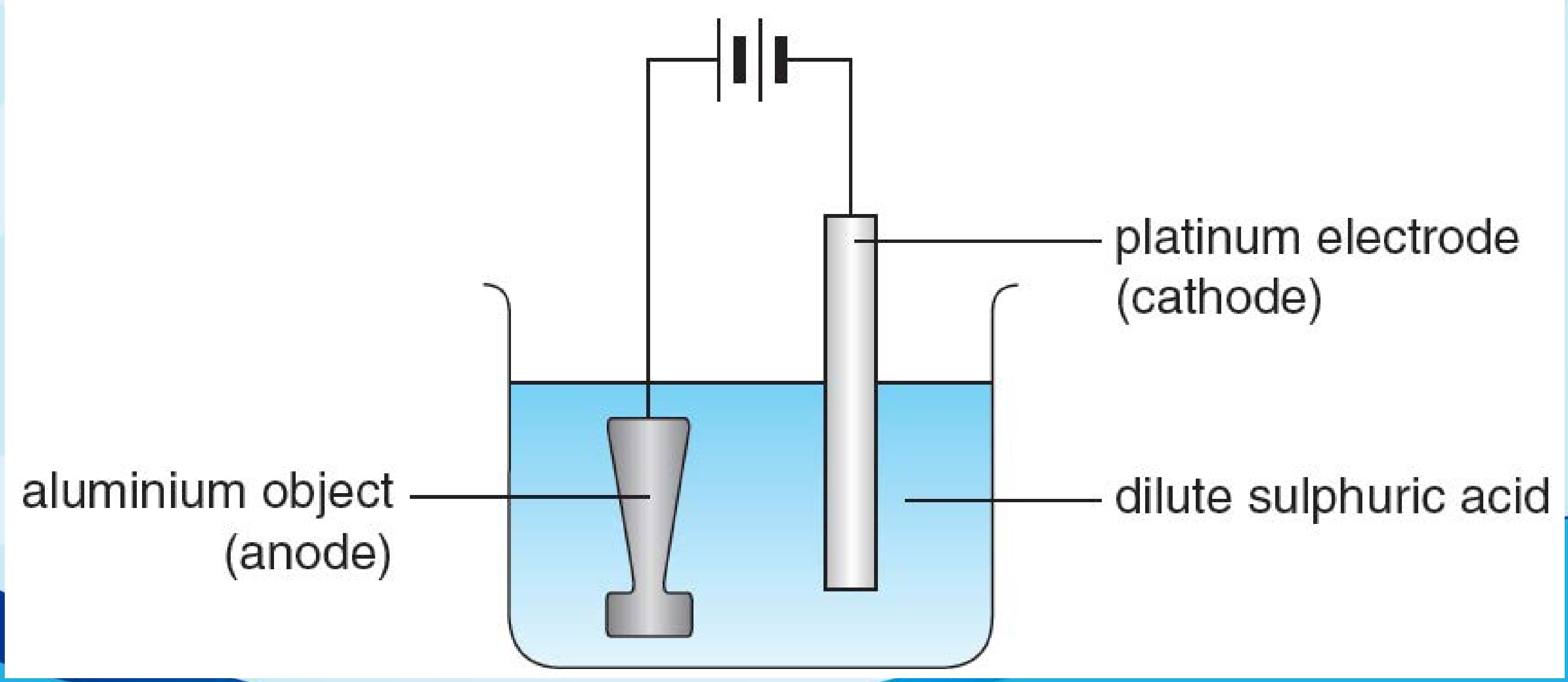


- The oxide layer formed is impermeable to oxygen and water.
- It protects the metal underneath from further attack.

13.7 Corrosion resistance of aluminium (p.124)

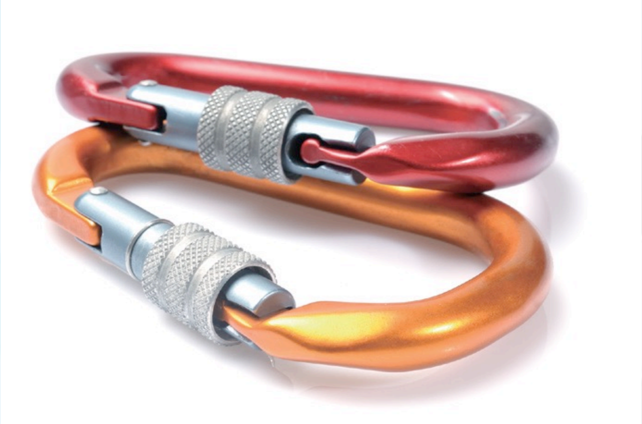
Aluminium anodisation

- The thickness of the oxide layer of the surface of aluminium can be increased by a process called **anodisation (陽極電鍍)**.
- This process gives the aluminium extra corrosion resistance.



13.7 Corrosion resistance of aluminium (p.124)

- Examples:



Key terms (p.126)

corrosion	腐蝕	sacrificial protection	犧牲性保護
rusting	生銹	galvanising	鍍鋅
rust indicator	鐵銹指示劑	impressed current cathodic protection	外加電流陰極保護
tin-plating	鍍錫	stainless steel	不銹鋼
electroplating	電鍍	anodisation	陽極電鍍

Summary (p.127)

1 The deterioration of a metal caused by chemical interaction with oxygen, moisture or other substances in the environment is called corrosion.

2 The corrosion of iron is called rusting. The chemical name of rust is hydrated iron(III) oxide ($Fe_2O_3 \cdot xH_2O$).

3 Both air (oxygen) and water are needed for iron to rust.

Summary (p.127)

4 Rusting can be studied using a rust indicator, a mixture of potassium hexacyanoferrate(III) ($K_3Fe(CN)_6$) and phenolphthalein.

Potassium hexacyanoferrate(III) reacts with iron(II) ions to give a blue product, and phenolphthalein gives a pink colour in the presence of hydroxide ions.

Summary (p.127)

5 Factors that speed up the rusting process include:
a) presence of ionic substances;
b) presence of acidic pollutants;
c) higher temperature;
d) scratching or bending; and
e) attachment to a less reactive metal.

Summary (p.127)

6 Methods to protect iron from rusting include:

a) protective coating on surface — coating with paint, coating with oil or grease, coating with plastic, tin-plating, electroplating;

b) sacrificial protection — galvanising;

c) impressed current cathodic protection; and

d) use of stainless steel.

Summary (p.127)

7 a) Aluminium oxide adheres tightly to the surface of the metal and is impermeable to oxygen andwater. Thus, aluminium does not further corrode.

b) The thickness of the oxide layer on the surface of aluminium can be increased by aluminium anodisation. This gives the aluminium extra corrosion resistance.

Unit Exercise (p.129)

Note: Questions are rated according to ascending level of difficulty (from 1 to 5):

 **question targeted at level 3 and above;**

 **question targeted at level 4 and above;**

 **question targeted at level 5.**

‘ * ’ indicates 1 mark is given for effective communication.

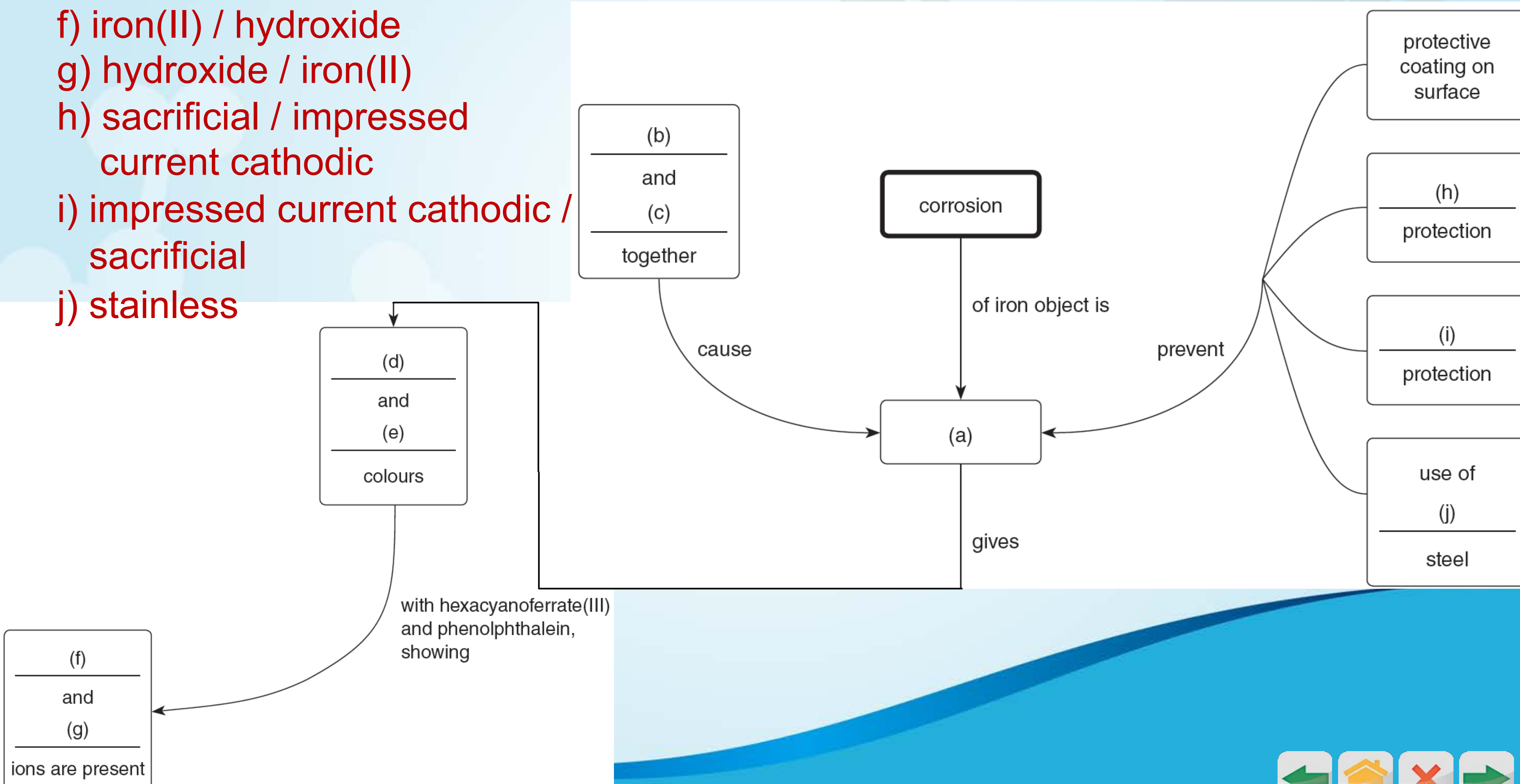
Unit Exercise (p.129)

a) rusting
b) air (oxygen) / water
c) water / air (oxygen)
d) blue / pink
e) pink / blue

PART I KNOWLEDGE AND UNDERSTANDING

1 Complete the following concept map.

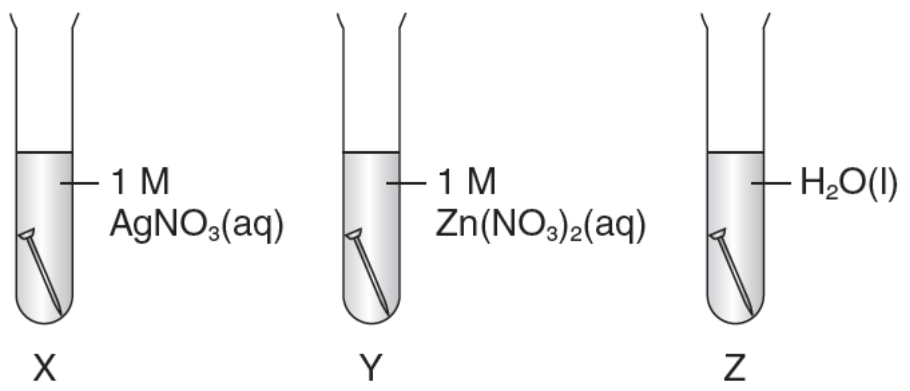
f) iron(II) / hydroxide
g) hydroxide / iron(II)
h) sacrificial / impressed current cathodic
i) impressed current cathodic / sacrificial
j) stainless



Unit Exercise (p.129)

PART II MULTIPLE CHOICE QUESTIONS

2 The diagram below shows three iron nails of the same size and shape each immersed in a liquid.



Which of the following arrangements represents the ascending order of rate of corrosion of the iron nails?

Answer: A

A Z < Y < X
B Y < Z < X
C Z < X < Y
D X < Z < Y

(HKDSE, Paper 1A, 2014, 3)

Unit Exercise (p.129)

3 A gel containing NaCl(aq), $K_3Fe(CN)_6$(aq) and phenolphthalein is yellow in colour. An iron nail is put into the gel and corrodes after a period of time.

Which of the following colours would NOT be observed in the gel after the iron nail corrodes?

A Blue
B Pink
C Grey
D Yellow

Answer: C

(HKDSE, Paper 1A, 2015, 5)

Unit Exercise (p.129)

4 Four steel paper clips are treated as described below, before being placed in a beaker of water.

Which paper clip rusts most quickly?

A Coated with grease
B Dipped in paint and allowed to dry
C Electroplated with zinc
D Washed with soap and rinsed

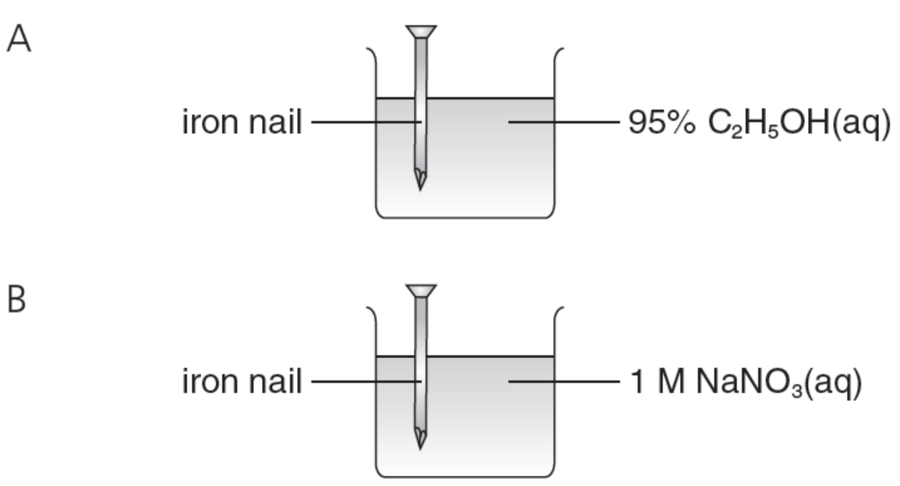
Answer: D

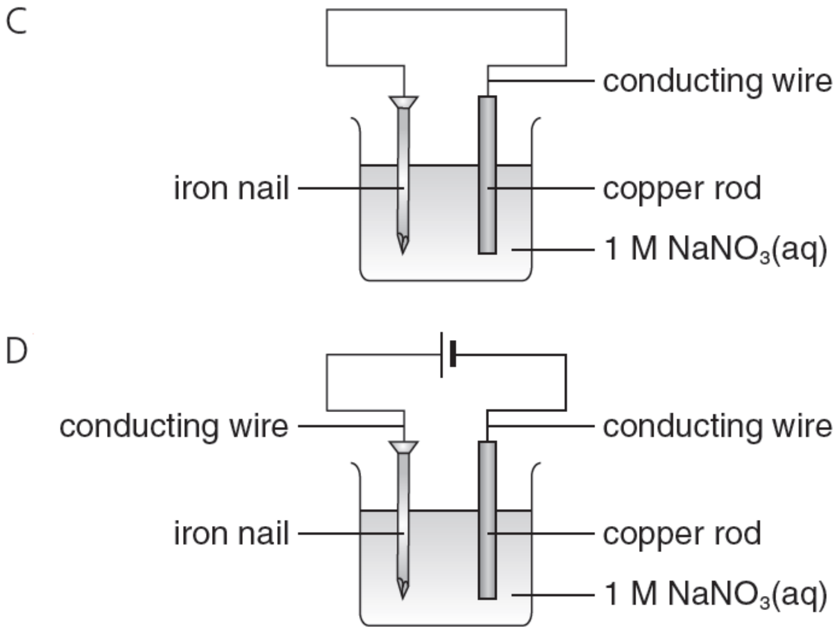
(Cambridge IGCSE, 0620/13, Paper 1, Jun. 2014, 33)

Unit Exercise (p.129)

Answer: D

5 In which of the following cases would the iron nail corrode fastest?





(HKDSE, Paper 1A, 2017, 13)

Unit Exercise (p.129)

6 Sacrificial protection is one of the methods to prevent corrosion. Which of the following metals CANNOT beused as a sacrificial metal to prevent iron from rusting?

A Aluminium
B Copper
C Magnesium
D Zinc

Answer: B

Explanation:
Copper is less reactive than iron and CANNOT be used as a sacrificial metal.

Unit Exercise (p.129)

7 Which of the following combinations is INCORRECT?

	Iron article	Method to prevent iron from rusting
A	Food can	galvanisation
B	Bath tap	chromium-plating
C	Fence	painting
D	Ship's hull	sacrifical protection

Answer: A

Explanation:
Zinc ions are poisonous and thus galvanisation is NOT used to prevent iron food can from rusting.

Unit Exercise (p.129)

8 The reactivity of aluminium is compared to zinc by observing their reactions with water and dilute hydrochloric acid. Aluminium has a lower rate of reaction as compared with zinc in both reactions. This is because

A aluminium is less reactive than zinc.
B aluminium has a coat of aluminium oxide.
C aluminium is an alkali metal while zinc is not.
D aluminium has three outermost shell electrons while zinc has two.

Answer: B

Unit Exercise (p.129)

9 Aluminium surfaces are often 'anodised'. This means the deposition of a layer of

A chromium oxide.
B aluminium oxide.
C nickel(II) oxide.
D zinc oxide.

Answer: B

Unit Exercise (p.129)

10 Which of the following ions are present when iron rusts?

(1) Fe^{2+}
(2) Fe^{3+}
(3) OH^-

A (1) and (2) only
B (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

Answer: D

Unit Exercise (p.129)

11 Which of the following are advantages of using anodised aluminium to make drink cans?

(1) The strength of the cans can be increased.
(2) The cans become more easily dyed.
(3) The corrosion resistance of the cans can be enhanced.

A (1) and (2) only
B (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

Answer: C

Explanation: (1) Anodisation CANNOT increase the strength of aluminium.

Unit Exercise (p.129)

PART III STRUCTURED QUESTIONS

12 Iron is a useful metal. One problem with using iron is that it can rust.

a) Name the compound present in rust. Hydrated iron(III) oxide (1)

b) Name TWO substances that iron reacts with when it rusts. Air (oxygen) (1) Water (1)

c) Explain, using chemical equations, how iron rusts.

Iron atoms lose electrons to form iron(II) ions. (1)

$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$ (1)

The electrons are gained by oxygen molecules dissolved in water. Hydroxide ions are formed. (1)

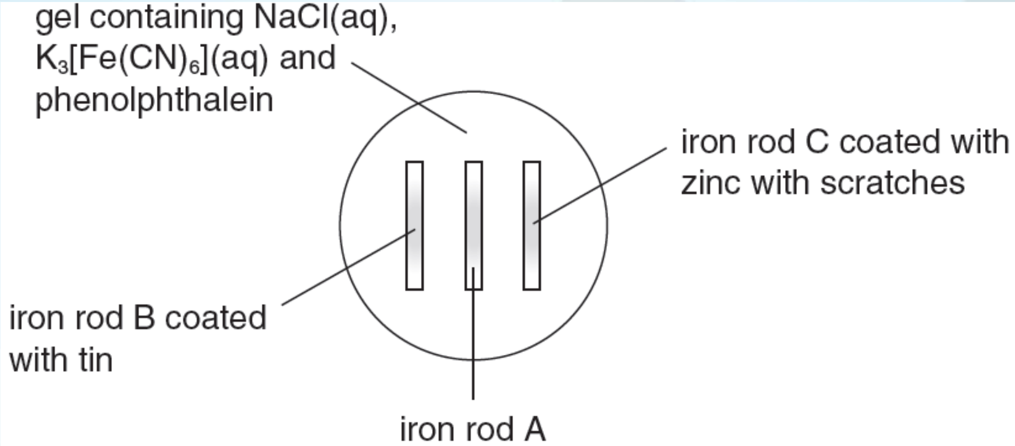
$\frac{1}{2}O^2(g) + H_2O(l) + 2e^- \rightarrow 2OH^-(aq)$ (1)

The iron(II) ions and hydroxide ions react to form iron(II) hydroxide. (1)

Iron(II) hydroxide then reacts with more oxygen and water to form hydrated iron(III) oxide.

Unit Exercise (p.129)

13 The diagram below shows an experimental set-up for investigating the factors affecting rusting. Blue and pink colours develop around iron rod A after one day.



a) Name the ion that gives a blue colour with the gel. Iron(II) ion (1)

b) Name the ion that gives a pink colour with the gel. Hydroxide ion (1)

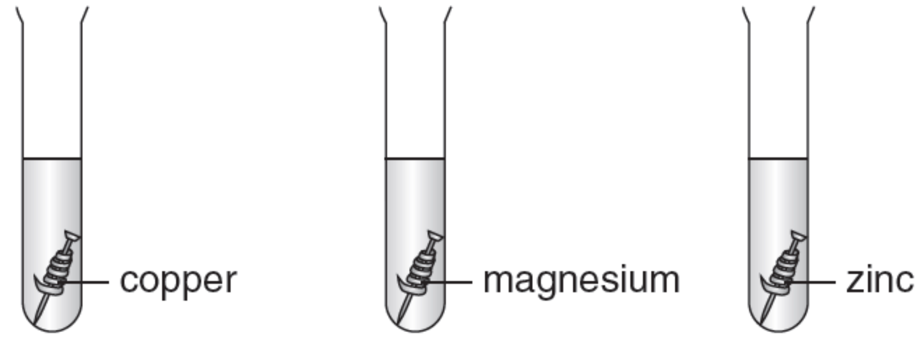
c) Both iron rods B and C do NOT rust after one day. Explain why.

The tin coating stops air and water reaching iron rod B. (1)

Zinc is more reactive than iron. It corrodes first and protects iron rod C from rusting. (1)

Unit Exercise (p.129)

14 The diagram below shows an experiment used to investigate the factors affecting rusting. Different metals were wrapped around iron nails and left in water for two days.



a) Suggest TWO ways in which you could ensure that this was a fair test.

Any two of the following:

- Use the same volume of water. (1)
- Use the same mass of metal. (1)
- Use nails of the same type and size. (1)
- Keep at the same temperature. (1)

b) Which of the iron nail(s) would NOT rust after two days. Explain your choice.

Iron nails wrapped with magnesium and zinc would NOT rust.
Magnesium and zinc are more reactive than iron.
They corrode instead of iron. (1)

Unit Exercise (p.129)

15 Iron fencing can be coated with zinc to prevent rusting.
State the name of this type of protection and explain how it works.

Galvanising / sacrificial protection (1)
Zinc is more reactive than iron. It corrodes instead of iron. (1)

Unit Exercise (p.129)

16 Outline the limitation(s) of using paint to protect ships that are in constant use.

- Paint must be constantly reapplied to maintain the ship due to scratches and other damages, and this might be very time consuming. (1)
- The ship must be checked regularly, otherwise the exposed iron can become pitted and eventually perforated. (1)
- The process requires the ship to be removed from the water. (1)

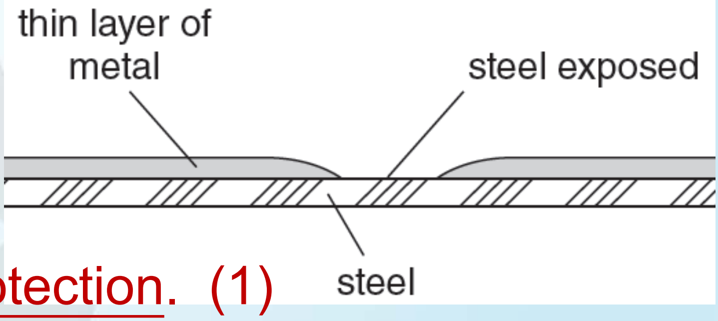
Unit Exercise (p.129)

17 In an experiment to investigate the rusting of steel, three pieces of steel were used. One piece of steel was coated with tin, the second piece was coated with zinc and the third piece was left uncoated. All three pieces were left in the laboratory.

a) The uncoated piece started to rust. Name the TWO substances which caused the steel to rust.

Air (oxygen) (1) Water (1)

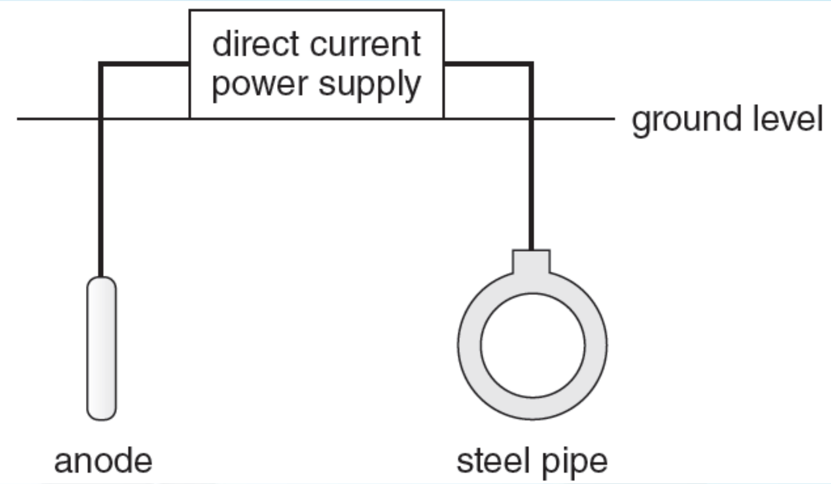
b) The coating on both of the other two pieces was scratched, exposing the steel. Suggest whether each piece of steel would rust. Explain your answer in each case.



The piece of steel coated with scratched zinc would NOT rust.
Zinc is more reactive than iron. (1)
Zinc protects the iron from rusting by sacrificial protection. (1)
The piece of steel coated with scratched tin would rust.
Tin is less reactive than iron. (1)
Iron acts as a sacrificial metal for tin and it rusts faster than normal. (1)

Unit Exercise (p.129)

18 The diagram illustrates one method of protecting a steel pipe.



a) Name this method. Impressed current cathodic protection (1)

b) Explain how this method works.

The steel pipe receives electrons from the direct current power supply. (1)

Thus, the iron cannot lose electrons to form iron(II) ions. (1)

c) Suggest ONE alternative method of protecting the steel pipe. Explain how this method works.

The pipe could also be protected by adding a sacrificial metal (e.g. zinc) in contact with the steel pipe. (1)

Zinc would corrode instead of iron. (1)

Unit Exercise (p.129)

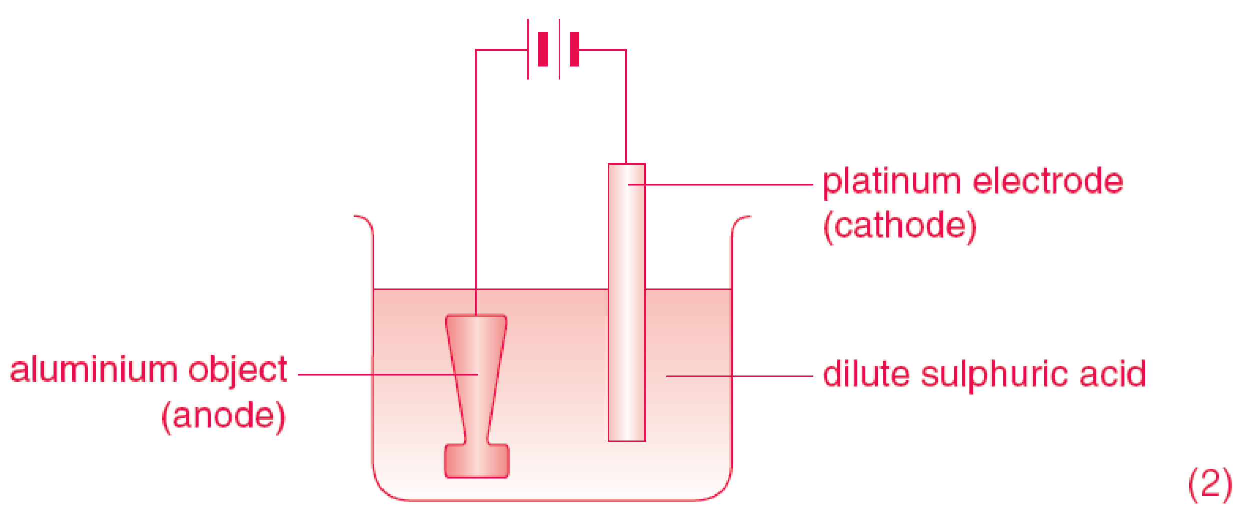
19 Aluminium is protected by an oxide layer on its surface.

a) Explain why an aluminium article coated with aluminium oxide is protected from further corrosion, but a steel article coated with rust continues to corrode.

The aluminium oxide layer is impermeable to oxygen and water. (1)

b) The thickness of the oxide layer on aluminium can be increased by anodising.

Draw a labelled diagram of the experimental set-up for the process, using dilute sulphuric acid as the electrolyte.



(2)

Topic Exercise (p.134)

Note: Questions are rated according to ascending level of difficulty (from 1 to 5):

 **question targeted at level 3 and above;**

 **question targeted at level 4 and above;**

 **question targeted at level 5.**

‘ * ’ indicates 1 mark is given for effective communication.

Topic Exercise (p.134)

PART I MULTIPLE CHOICE QUESTIONS

1 Which of the following metals can be extracted from its oxide by heat alone?

A Aluminium
B Iron
C Lead
D Mercury

Answer: D

Topic Exercise (p.134)

2 Stainless steel is an alloy of iron and other metals. It is strong and does not rust, but it costs much more than normal steel. What is NOT made from stainless steel?

Answer: C

A Cutlery
B Pipes in a chemical factory
C Railway lines
D Saucepans

(Cambridge IGCSE, 0620/13, Paper 1, Jun. 2017, 28)

Topic Exercise (p.134)

3 The metal beryllium does not react with cold water. It reacts with hydrochloric acid but cannot be extracted from its ore by using carbon. Where should it be placed in the reactivity series?

magnesium
A
zinc
B
iron
C
copper
D

Answer: A

(Cambridge IGCSE, 0620/13, Paper 1, Jun. 2014, 26)

Explanation:
Zinc can be extracted from its oxide by using carbon. Beryllium cannot be extracted from its ore by using carbon. Thus, beryllium should be more reactive than zinc.

Topic Exercise (p.134)

4 Consider the following information concening metals W, X, Y and Z:

(1) Heating oxide of W gives metal W.
(2) Heating metal X in steam gives a colourless gas.
(3) Putting metal Y in CH3CO2H(aq) gives a colourless gas.
(4) Putting metal Z in CuSO4(aq) gives a reddishbrown solid.

Which of these metals has the lowest reactivity?

Answer: A

A W
B X
C Y
D Z

(HKDSE, Paper 1A, 2015, 14)

Topic Exercise (p.134)

5 What is the number of atoms in 51.8 g of dinitrogen tetroxide (N_2O_4)?
(Relative atomic masses: N = 14.0, O = 16.0; Avogadro constant = 6.02×10^{23} mol^{-1})

Answer: C

A 3.39×10^{23}
B 5.42×10^{23}
C 2.03×10^{24}
D 2.87×10^{24}

Molar mass of N_2O_4 = $(2 \times 14.0 + 4 \times 16.0)$ g mol^{-1}
= 92.0 g mol^{-1}

Number of moles of N_2O_4 = $\frac{51.8 \text{ g}}{92.0 \text{ g mol}^{-1}}$
= 0.563 mol

Number of molecules = 0.563 mol × 6.02×10^{23} mol^{-1}
= 3.39×10^{23}

One N_2O_4 molecule contains 6 atoms.

Number of atoms = $6 \times 3.39 \times 10^{23}$
= 2.03×10^{24}

Topic Exercise (p.134)

6 How many moles of ammonia contain *y* hydrogen atoms? (L represents Avogadro constant)

Answer: C

A $\frac{y}{\text{L}}$

B $\frac{\text{L}}{y}$

C $\frac{y}{3\text{L}}$

D $\frac{3y}{\text{L}}$

Explanation:

$\frac{y}{3}$ moles of ammonia (NH_3) molecules contain *y* moles of hydrogen atoms.

$\therefore$ $\frac{y}{3\text{L}}$ moles of ammonia contain $\frac{y}{\text{L}}$ moles of hydrogen atoms (i.e. *y* hydrogen atoms).

Topic Exercise (p.134)

7 A sample of gas was prepared for use in helium-neon lasers. It contained 10.0 g of helium and 10.0 g of neon. What is ratio of helium atoms to neon atom in the sample? (Relative atomic masses: He = 4.0, Ne = 20.2)

Answer: C

A 1 : 1
B 2.5 : 1
C 5 : 1
D 10 : 1

$$\text{Number of moles of helium atoms} = \frac{\text{mass of He}}{\text{molar mass of He}} = \frac{10.0\text{ g}}{4.0\text{ g mol}^{-1}}$$

$$\text{Number of moles of neon atoms} = \frac{\text{mass of Ne}}{\text{molar mass of Ne}} = \frac{10.0\text{ g}}{20.2\text{ g mol}^{-1}}$$

$$\text{Ratio of helium atoms to neon atoms} = \frac{10.0}{4.0} : \frac{10.0}{20.2} = 5 : 1$$

Topic Exercise (p.134)

8 The percentage by mass of titanium in an oxide of titanium is 59.9%. What is the chemical formula of the oxide?
(Relative atomic masses: O = 16.0, Ti = 47.9)

Answer: B

A TiO
B TiO_2
C Ti_2O_3
D Ti_3O_4

Explanation:
Percentage of oxygen in oxide = (100 – 59.9)% = 40.1%
100.0 g of the oxide contain 59.9 g of titanium and 40.1 g of oxygen.

	Titanium	Oxygen
1 Mass of element	59.9 g	40.1 g
2 Number of moles of atoms	$\frac{59.9\ g}{47.9\ g\ mol^{-1}} = 1.25\ mol$	$\frac{40.1\ g}{16.0\ g\ mol^{-1}} = 2.51\ mol$
3 Mole ratio of atoms	$\frac{1.25}{1.25} = 1.00$	$\frac{2.51}{1.25} = 2.01$

∴ the chemical formula of the oxide is TiO_2.

Topic Exercise (p.134)

9 Element X forms an oxide X_2O_3 when heated in oxygen. In an experiment, 20.9 g of X give 23.3 g of X_2O_3 upon heating. What is the relative atomic mass of X? (Relative atomic mass: O = 16.0)

Answer: D

A 93
B 105
C 186
D 209

Let m be the relative atomic mass of X.

Mass of oxygen in X_2O_3 = (23.3 – 20.9) g
= 2.4 g

$$\frac{\text{Number of moles of X}}{\text{Number of moles of oxygen}} = \frac{2}{3} = \frac{\dfrac{20.9\ \text{g}}{m\ \text{g mol}^{-1}}}{\dfrac{2.4\ \text{g}}{16.0\ \text{g mol}^{-1}}}$$

$m = 209$

Topic Exercise (p.134)

10 A factory wanted to make 70.0 tonnes of zinc oxide by heating zinc carbonate: $ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$
What mass of zinc carbonate should be heated?
(Relative atomic masses: C = 12.0, O = 16.0, Zn = 65.4)

Answer: A

A 108 tonnes
B 127 tonnes
C 145 tonnes
D 190 tonnes

1 Molar mass of ZnO = (65.4 + 16.0) g mol^{-1} = 81.4 g mol^{-1}

$$\text{Number of moles of ZnO} = \frac{\text{mass of ZnO}}{\text{molar mass of ZnO}} = \frac{70.0 \times 10^6 \text{ g}}{81.4 \text{ g mol}^{-1}} = 860\ 000 \text{ mol}$$

2 According to the equation, 1 mole of $ZnCO_3$ gives 1 mole of ZnO when heated.

i.e. number of moles of $ZnCO_3$ = 860 000 mol

3 Molar mass of $ZnCO_3$ = (65.4 + 12.0 + 3 x 16.0) g mol^{-1} = 125.4 g mol^{-1}

Mass of $ZnCO_3$ = number of moles of $ZnCO_3$ x molar mass of $ZnCO_3$
= 860 000 mol x 125.4 g mol^{-1}
= 108 x 10^6 g
= 108 tonnes

Topic Exercise (p.134)

11 An impure sample of tin(IV) oxide of mass 24.0 g is reduced to tin by heating with carbon. 16.4 g of tin are obtained.
What is the percentage by mass of tin(IV) oxide in the sample?
(Relative atomic masses: O = 16.0, Sn = 118.7)

Answer: D

A 39.4%
B 68.3%
C 77.5%
D 86.7%

1 Number of moles of Sn $= \dfrac{\text{mass of Sn}}{\text{molar mass of Sn}}$

$= \dfrac{16.4\text{ g}}{118.7\text{ g mol}^{-1}}$

$= 0.138$ mol

2 1 mole of SnO_2 gives 1 mole of Sn when heated with carbon.

i.e. number of moles of SnO_2 = 0.138 mol

3 Molar mass of SnO_2 = (118.7 + 2 x 16.0) g mol^{-1} = 150.7 g mol^{-1}

Mass of SnO_2 in sample = number of moles of SnO_2 x molar mass of SnO_2
= 0.138 mol x 150.7 g mol^{-1}
= 20.8 g

Percentage by mass of SnO_2 in sample $= \dfrac{20.8\text{ g}}{24.0\text{ g}} \times 100\%$

= 86.7%

Topic Exercise (p.134)

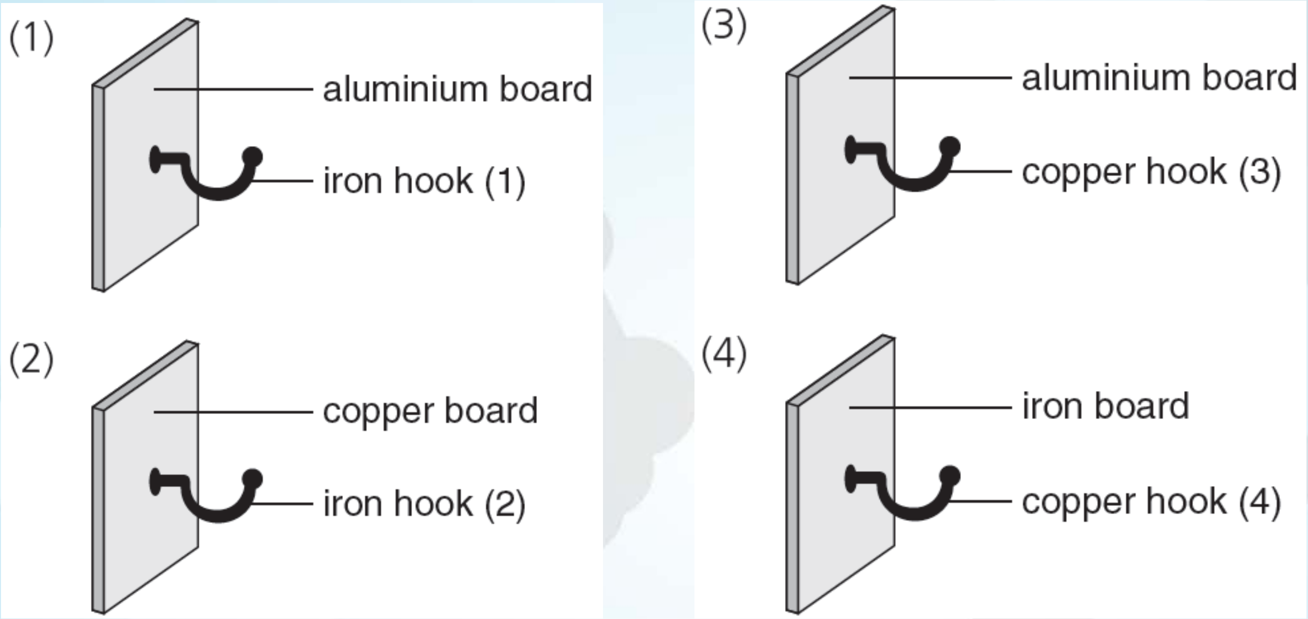
12 Which of the following iron objects is suitable for galvanising?

A Bicycle chain
B Bucket
C Car engine
D Drink can

Answer: B

Topic Exercise (p.134)

13 Consider the following set-ups:



Answer: B

Which hook would corrode first?

A Iron hook (1)
B Iron hook (2)
C Copper hook (3)
D Copper hook (4)

(HKDSE, Paper 1A, 2015, 7)

Topic Exercise (p.134)

14 Tin plating is used to prevent iron cans from rusting because

A tin provides sacrificial protection to iron.
B tin layer prevents iron from exposure to air.
C tin is higher than iron in the metal reactivity series.
D tin and iron form an alloy which does not corrode.

(HKDSE, Paper 1A, 2016, 5)

Answer: B

Topic Exercise (p.134)

15 Which of the following oxides can be reduced to the respective metal(s) by heating with carbon?

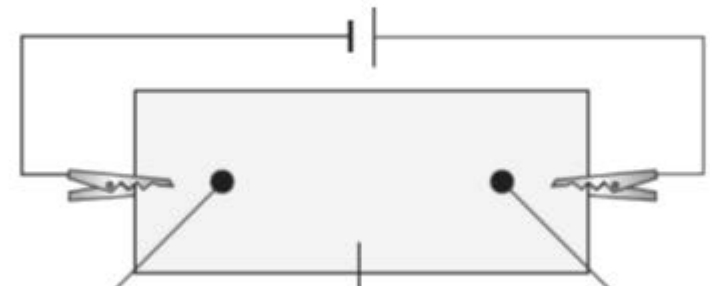
(1) Aluminium oxide
(2) Lead(II) oxide
(3) Zinc oxide

A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Answer: D

Topic Exercise (p.134)

16 The set-up of an experiment for studying the movement of ions is shown below.



Which of the following statements is / are correct?

(1) $FeSO_4(aq)$ is yellow-brown in colour.

(2) The filter paper is soaked with $K_2SO_4(aq)$ instead of water to increase the electrical conductivity of the filter paper.

(3) A blue colour appears around the middle of the filter paper.

A (1) only

B (2) only

C (1) and (3) only

D (2) and (3) only

Answer: B

Explanation: (1) $FeSO_4(aq)$ is light green in colour.

(3) $Fe^{2+}(aq)$ ions move towards the left. They do not meet the $Fe(CN)_6^{3-}(aq)$ ions. Hence no blue colour appears.

Topic Exercise (p.134)

17 Which of the following combinations is / are correct?

Object	Corresponding corrosion prevention method
(1) Aluminium window frames	cathodic protection
(2) Bicycle chain	greasing
(3) Tin-plated food cans	sacrificial protection

A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Answer: B

Explanation:
(1) Aluminium window frames are protected by anodisation.
(3) Tin is less reactive than iron. It CANNOT provide sacrificial protection to iron.

Topic Exercise (p.134)

Directions : Each question (Questions 18–20) consists of two separate statements. Decide whether each of the two statements is true or false; if both are true, then decide whether or not the second statement is a correct explanation of the first statement. Then select one option from A to D according to the following table :
A Both statements are true and the 2nd statement is a correct explanation of the 1st statement. B Both statements are true but the 2nd statement is NOT a correct explanation of the 1st statement. C The 1st statement is false but the 2nd statement is true. D Both statements are false.

Topic Exercise (p.134)

1st statement	2nd statement	
18 Potassium is more reactive than magnesium.	Potassium belongs to Period 4 of the Periodic Table while magnesium belongs to Period 3.	Answer: B
19 When a mixture of copper and zinc oxide is ignited, copper(II) oxide and zinc are produced.	Copper is less reactive than zinc.	Answer: C

Explanation: Copper is less reactive than zinc. NO reaction occurs between copper and zinc oxide.

20 Anodisation is a method used to increase the strength of aluminium.	By anodisation, the thickness of the oxide layer on the aluminium surface is increased.	Answer: C

Explanation: Anodisation CANNOT increase the strength of aluminium.

Topic Exercise (p.134)

PART II STRUCTURED QUESTIONS

21 The table gives some information about the properties of four metals.

Metal	Density (g cm^{-3})	Relative strength	Resistance to corrosion	Relative electrical conductivity	Melting point (°C)
Chromium	7.2	8	very good	8	1 857
Copper	8.9	30	good	60	1 283
Iron	7.9	21	poor	10	1 535
Titanium	4.5	23	very good	2	1 660

Which ONE of these metals is most suitable for making the frame of an aircraft?
Explain your answer using information from the table.

(Cambridge IGCSE, 0620/33, Paper 3, Nov. 2016, 1(b))

Titanium (1)
Lowest density (1), strong (1), resistant to corrosion (1)

Topic Exercise (p.134)

22 Antimony (Sb) is a solid element that is used in industry. It is extracted from low-grade ore and high-grade ore using different methods.

a) Antimony is extracted by reacting iron with low-grade ores containing antimony(III) sulphide (Sb_2S_3).

i) Write the chemical equation for the reaction between iron and antimony(III) sulphide to form antimony and iron(II) sulphide.

$3Fe(s) + Sb_2S_3(s) \rightarrow 3FeS(s) + 2Sb(s)$ (1)

ii) What does this reaction suggest about the reactivity of antimony compared to that of iron? Antimony is less reactive than iron. (1)

b) Antimony is extracted from high-grade ore containing antimony(III) sulphide in a two-step process.

Step 1 Antimony(III) sulphide is converted to antimony(III) oxide (Sb_2O_3).

Step 2 Antimony(III) oxide is reduced to antimony by carbon.

Write a chemical equation for the reaction involved in each step.

$2Sb_2S_3(s) + 9O_2(g) \rightarrow 2Sb_2O_3(s) + 6SO_2(g)$ (1)

$Sb_2O_3(s) + 3C(s) \rightarrow 2Sb(s) + 3CO(g)$ (1)

Topic Exercise (p.134)

23 Aluminium is obtained from aluminium oxide by electrolysis.

a) Aluminium oxide is obtained from the main ore of aluminium. Name this main ore.

Bauxite (1)

b) Describe the extraction of aluminium from aluminium oxide. Include the electrolyte, the electrodes and the products at the electrodes.

Aluminium oxide is dissolved in molten cryolite. (1)
Use cryolite to reduce the melting point of aluminium oxide.
Use carbon electrodes. (1)
Aluminium is formed at the negative electrode. (1)
Oxygen is formed at the positive electrode. (1)

Topic Exercise (p.134)

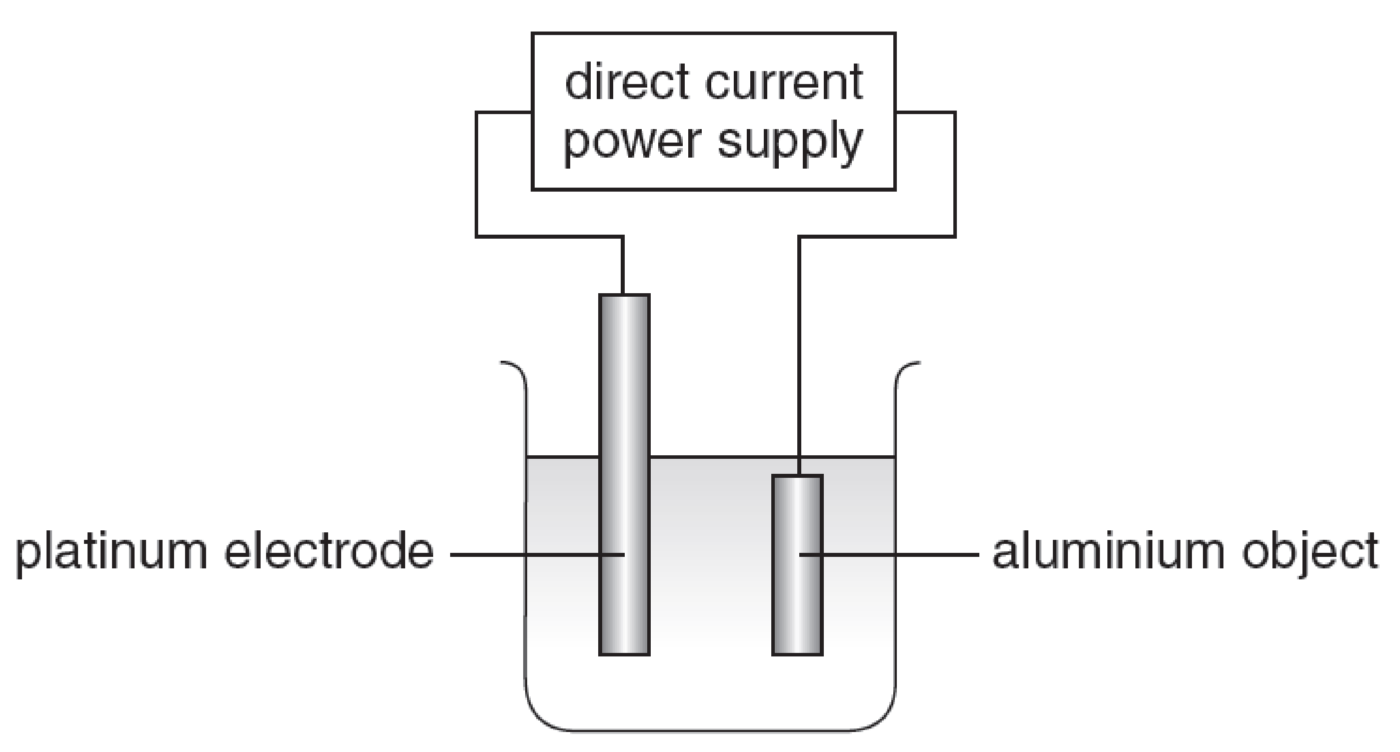
c) Aluminium is protected by an oxide layer on its surface. The thickness of this oxide layer can be increased via electrolysis.

i) Name the process involved.

Anodisation (1)

ii) The experimental set-up for the process is shown below.

Positive terminal (1)



Topic Exercise (p.134)

24) Iron in the form of steel, aluminium and copper are used to manufacture many useful articles.
These uses depend on their density, strength, electrical conductivity and resistance to corrosion.

Describe some uses of each of these metals in relation to their properties and the advantages of recycling these metals rather than extracting more of the metals from their ores.

(Edexcel GCSE (Higher Tier), C1, Jun. 2016, 5(c))

Topic Exercise (p.134)

Metal	Examples of uses	Examples of properties
Iron in the form of steel / stainless steel	bridges, cars, hulls of ships	strong, malleable
	cutlery, kitchen utensils, kitchen sinks	strong, malleable , resistant to corrosion
Aluminium	aeroplanes, bicycles, trains, window frames, ladders	low density, strong in the form of alloy, resistant to corrosion, malleable
	overhead power cables	low density, good conductor of electricity, resistant to corrosion
	foil, food packaging, cans, saucepans	low density, resistant to corrosion, malleable, non-toxic
Copper	electric wires	very good conductor of electricity, ductile, resistant to corrosion
	water pipes, roofing, coins, jewellery	resistant to corrosion, malleable
	cooking utensils	good conductor of heat, malleable, strong, resistant to corrosion, non-toxic

Topic Exercise (p.134)

Iron — any one use in relation to properties (1 + 1)
Aluminium — any one use in relation to properties (1 + 1)
Copper — any one use in relation to properties (1 + 1)

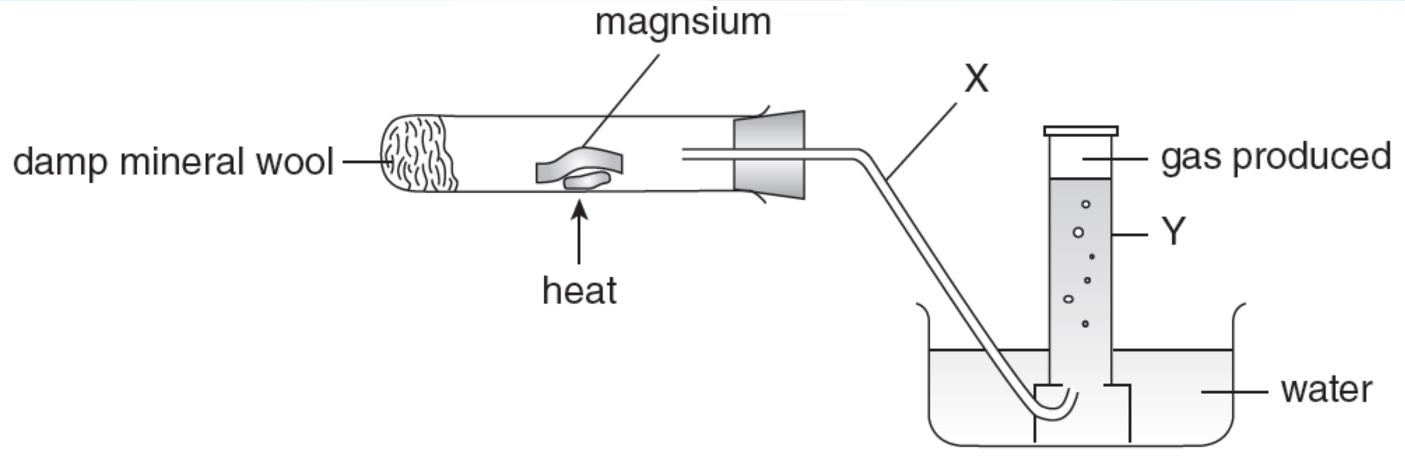
Advantages of recycling

- Natural reserves of metal ores will last longer. (1)
- The need to mine ores is reduced. Mining can damage the landscape as well as create noise and dust pollution. (1)
- Fewer pollutants may be produced. For example, sulphur dioxide is formed when some metals are extracted from metal sulphide ores. (1)
- Many metals need less energy to recycle them than to extract new metals from the ores. (1)
- Less waste metal ends up in landfill sites. (1)

Communication mark (1)

Topic Exercise (p.134)

25) The set-up shown below is used to study the reaction between magnesium and steam.



a) Name the apparatus labelled X and Y. X: delivery tube (1) Y: gas jar (1)

b) Explain why the damp mineral wool is heated. To generate steam. (1)

c) Write the chemical equation for the reaction between magnesium and steam. $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$ (1)

d) Name ONE metal which does not react when heated with steam.

Copper / silver / gold / platinum (1)

Topic Exercise (p.134)

26) An investigation was carried out to investigate how the following metals react with water and dilute hydrochloric acid:

calcium copper magnesium zinc

a) Name a metal, used in this experiment, that reacts with water at room temperature. Calcium (1)

b) Name the gas produced by the reaction of a metal with dilute hydrochloric acid. Hydrogen (1)

c) Name a metal, used in this experiment, that does NOT react with dilute hydrochloric acid. Copper (1)

d) List the metals used in this experiment in decreasing order of reactivity.

calcium > magnesium > zinc > copper (1)

Topic Exercise (p.134)

27) Water pipes used to carry drinking water are commonly made of copper instead of iron. Although lead-containing solder can be used to join these water pipes, such use is prohibited.

a) Suggest one chemical property of copper that makes it more suitable than iron for making water pipes. Explain your answer.

b) i) Suggest one reason of adding lead to soldering materials.

ii) Explain why lead-containing solder is prohibited in joining these water pipes.

(HKDSE, Paper 1B, 2017, 2(a)–(b))

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

Topic Exercise (p.134)

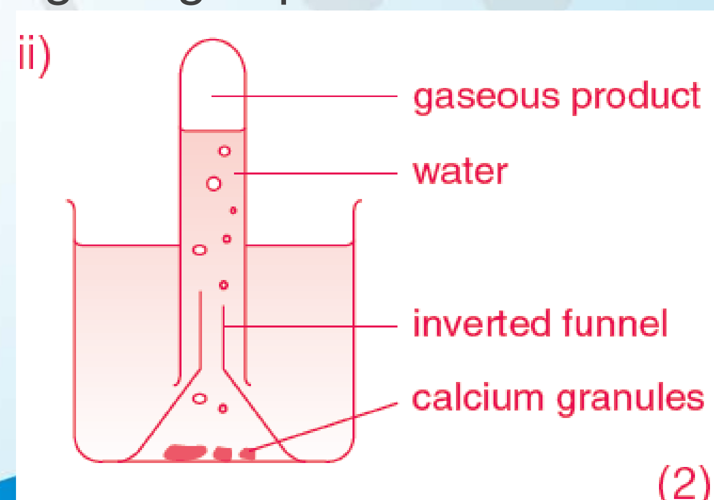
28) A student studied the reaction of water with two Group II metals, calcium and barium.

a) In the first experiment, 2.0 g of calcium granules reacted with water in a beaker.

i) Write the chemical equation for the reaction involved.

$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + H_2(g)$ (1)

ii) Draw a labelled diagram of an experimental set-up for carrying out this reaction in a beaker and collecting the gas produced.



iii) Suggest ONE potential hazard in performing the reaction.

Any one of the following:

- Hydrogen produced was flammable / can explode. (1)
- A lot of heat was released. (1)

Topic Exercise (p.134)

b) The student repeated the reaction using the same mass of barium. She noticed that the volume of gas collected, still at the same temperature and pressure, was less.

It was known that at constant temperature and pressure, the volume of a gas was proportional to the number of moles present.

Suggest why the volume of gas collected was less.

The number of moles of barium used was less. / The relative atomic mass of barium was larger. (1)

Topic Exercise (p.134)

29) The observations of some experiments with chromium and tin are summerised in the table below.

Experiment	Observation
1 Chromium was placed in tin(II) chloride solution.	Chromium became coated with a grey solid.
2 Chromium was placed in magnesium sulphate solution.	There was no observable change.
3 Tin was placed in copper(II) sulphate solution.	Tin became coated with a reddish brown solid.

Topic Exercise (p.134)

a) When tin was placed in copper(II) sulphate solution, a reddish brown solid formed and the solution turned pale blue.

i) Explain the reaction taking place. A displacement reaction occurs. (1)
Tin displaces copper from copper(II) sulphate solution. (1)
The solution turned pale blue as the concentration of copper(II) ions decreases. (1)

ii) Tin formed tin(II) ions (Sn^{2+}) in the reaction.
Write the ionic equation for the reaction.

$Sn(s) + Cu^{2+}(aq) \rightarrow Sn^{2+}(aq) + Cu(s)$ (1)

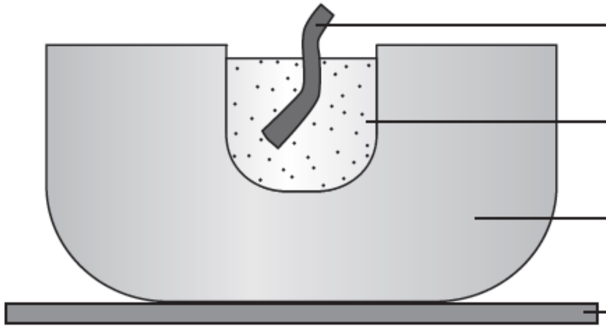
b) Arrange the metals chromium, copper, magnesium and tin in order of decreasing reactivity.

magnesium > chromium > tin > copper

c) Suggest the expected observations when excess chromium is placed in copper(II) sulphate solution. The chromium dissolves (1) with reddish brown deposits of copper formed. (1)
(The reaction that occurs is
$2Cr(s) + 3Cu^{2+}(aq)\ 2Cr^{3+}(aq) + 3Cu(s)$)

Topic Exercise (p.134)

30) The experimental set-up shown below is used to investigate the reaction between metals and metal oxides.



The results of the investigation are given in the table below.

Metal \ Metal oxide	Aluminium oxide	Barium oxide	Lead(II) oxide	Tin(IV) oxide
Aluminium	—	no reaction	reaction	reaction
Barium	reaction	—	reaction	reaction
Lead	no reaction	no reaction	—	no reaction
Tin	no reaction	no reaction	reaction	—

Topic Exercise (p.134)

a) Place the four metals in order of decreasing reactivity.

barium > aluminium > tin > lead (1)

b) Write the chemical equation for the reaction between barium and lead(II) oxide.

Ba(s) + PbO(s) → BaO(s) + Pb(s) (1)

c) Suggest what would be the result of using a mixture of barium and zinc oxide in such an experiment.

Barium is more reactive than aluminium, and aluminium is more reactive than zinc. Hence barium is more reactive than zinc.

In the reaction between barium and zinc oxide, barium competes with zinc for oxygen, and wins. (1)

Hence barium and zinc oxide react to give barium oxide and zinc. (1)

Topic Exercise (p.134)

31) Metal X is suspected to lie between zinc and copper in the reactivity series.
Describe, and explain, how you would show this was true using the following chemicals:
- copper granules, zinc granules and metal X;
- solutions of copper(II) nitrate, zinc nitrate and the nitrate of metal X.

Show that zinc displaces X from a solution of nitrate of X. (1)
Show that X displaces copper from a solution of copper(II) nitrate. (1)
A more reactive metal displaces a less reactive metal from a compound of the less reactive metal in a solution. (1)
Thus, it can be deduced from the experimental results that X is less reactive than zinc but more reactive than copper.
Communication mark (1)

Topic Exercise (p.134)

32) A sample of rust had the following composition:

51.85% of iron 22.22% of oxygen 16.67% of water

What is the chemical formula for this sample of rust?

(Relative atomic masses: H = 1.0, O = 16.0, Fe = 55.8)

100.0 g of the rust contain 51.85 g of iron, 22.22 g of oxygen and 16.67 g of water.

	Iron	Oxygen	Water	
1 Mass	51.85 g	22.22 g	16.67 g	
2 Number of moles	$\frac{51.85\text{ g}}{55.8\text{ g mol}^{-1}} = 0.929\text{ mol}$	$\frac{22.22\text{ g}}{16.0\text{ g mol}^{-1}} = 1.39\text{ mol}$	$\frac{16.67\text{ g}}{18.0\text{ g mol}^{-1}} = 0.926\text{ mol}$	(1)
3 Mole ratio	$\frac{0.929}{0.926} = 1.00$	$\frac{1.39}{0.926} = 1.50$	$\frac{0.926}{0.926} = 1.00$	(1)
4 Whole number mole ratio	2 x 1.00 = 2	2 x 1.50 = 3	2 x 1.00 = 2	(1)

∴ the chemical formula of rust is $Fe_2O_3 \bullet 2H_2O$.

Topic Exercise (p.134)

33) A compound of oxygen and fluorine has a relative molecular mass of 70.0 and contains 45.7% by mass of oxygen.
Calculate
a) the empirical formula;
b) the molecular formula of the compound.
(Relative atomic masses: O = 16.0, F = 19.0)

a) Percentage by mass of fluorine = (100 – 45.7)% = 54.3%
100.0 g of the compound contain 45.7 g of oxygen and 54.3 g of fluorine.

	Oxygen	Fluorine	
1 Mass of atoms	45.7 g	54.3 g	
2 Number of moles of atoms	$\frac{45.7\text{ g}}{16.0\text{ g mol}^{-1}} = 2.86\text{ mol}$	$\frac{54.3\text{ g}}{19.0\text{ g mol}^{-1}} = 2.86\text{ mol}$	(1)
3 Mole ratio of atoms	$\frac{2.86}{2.86} = 1.00$	$\frac{2.86}{2.86} = 1.00$	(1)

∴ the empirical formula of the compound is OF.

Topic Exercise (p.134)

b) Let $(OF)_n$ be the molecular formula of the compound.

Relative molecular mass = $n(16.0 + 19.0) = 35n$ (1)

$\therefore 35n = 70.0$

$n = 2$

$\therefore$ the molecular formula of the compound is O_2F_2.

Topic Exercise (p.134)

34) 10.000 g of hydrated sodium sulphate (Na2SO4•*n*H2O) yield 4.405 g of anhydrous sodium sulphate on heating. What is the value of *n*?
(Relative atomic masses: H = 1.0, O = 16.0, Na = 23.0, S = 32.1)

Mass of water in 10.000 g of hydrated sodium sulphate = (10.000 – 4.405) g = 5.595 g

	Na_2SO_4	H_2O	
1 Mass of compound	4.405 g	5.595 g	
2 Number of moles of compound	$\frac{4.405\text{ g}}{142.1\text{ g mol}^{-1}} = 0.0310\text{ mol}$	$\frac{5.595\text{ g}}{18.0\text{ g mol}^{-1}} = 0.311\text{ mol}$	(1)
3 Mole ratio of compound	$\frac{0.0310}{0.0310} = 1.00$	$\frac{0.311}{0.0310} = 10.0$	(1)

∴ the value of *n* is 10.

Topic Exercise (p.134)

35) Nitrogen reacts with fluorine to form nitrogen trifluoride.

a) Write the chemical equation for the reaction involved.

b) Calculate the mass of nitrogen trifluoride formed from the reaction of 7.00 g of nitrogen with excess fluroine.

(Relative atomic masses: N = 14.0, F = 19.0)

a) $N_2(g) + 3F_2(g) \rightarrow 2NF_3(g)$ (1)

Topic Exercise (p.134)

b) *Method 1*

1 Molar mass of N_2 = 2 x 14.0 g mol^{-1} = 28.0 g mol^{-1}

$$\text{Number of moles of } N_2 = \frac{\text{mass of } N_2}{\text{molar mass of } N_2}$$

$$= \frac{7.00 \text{ g}}{28.0 \text{ g mol}^{-1}}$$

$$= 0.250 \text{ mol}$$ (1)

2 According to the equation, 1 mole of N_2 can make 2 moles of NF_3.

i.e. number of moles of NF_3 = 2 x 0.250 mol
= 0.500 mol (1)

3 Molar mass of NF_3 = (14.0 + 3 x 19.0) g mol^{-1}
= 71.0 g mol^{-1}

Mass of NF_3 = number of moles of NF_3 x molar mass of NF_3
= 0.500 mol x 71.0 g mol^{-1}
= 35.5 g (1)

Topic Exercise (p.134)

Method 2

1 Molar mass of N_2 = 2 x 14.0 g mol^{-1} = 28.0 g mol^{-1}

Molar mass of NF_3 = (14.0 + 3 x 19.0) mol^{-1} = 71.0 g mol^{-1}

2 According to the equation, 1 mole of N_2 can make 2 moles of NF_3.

i.e. 28.0 g of N_2 can make 2 x 71.0 g of NF_3. (1)

3 Mass of NF_3 = 7.00 g x $\frac{2 \times 71.0\ g}{28.0\ g}$ (1)

= 35.5 g (1)

∴ 35.5 g of NF_3 are formed.

Topic Exercise (p.134)

36 Aluminium cookware is often referred to as 'anodised aluminium'. The anodising process puts a layer of aluminium oxide on the aluminium. Consider the reaction of 12.2 g of aluminium with 12.2 g of oxygen to form aluminium oxide.
(Relative atomic masses: O = 16.0, Al = 27.0)

a) Write the chemical equation for the reaction between aluminium and oxygen.
b) Identify the limiting reactant in the reaction.
c) What is the mass of product formed?

Topic Exercise (p.134)

a) $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

b) $\# \text{ of moles of Al} = \dfrac{\text{mass of Al}}{\text{molar mass of Al}} = \dfrac{12.2\text{ g}}{270\text{ g mol}^{-1}} = 0.452\text{ mol}$ (1)

$\# \text{ of moles of } O_2 = \dfrac{\text{mass of } O_2}{\text{molar mass of } O_2} = \dfrac{12.2\text{ g}}{2 \times 16.0\text{ g mol}^{-1}} = 0.381\text{ mol}$ (1)

According to the equation, 4 moles of Al react with 3 moles of O_2.
In this reaction, 0.452 mole of Al reacts with 0.339 mole of O_2.
Thus, O_2 is in excess. Al is the limiting reactant. (1)

Topic Exercise (p.134)

c)

The amount of Al_2O_3 formed is determined by the amount of Al.

Number of moles of Al_2O_3 = $\frac{2}{4}$ x number of moles of Al

= $\frac{2}{4}$ x 0.452 mol

= 0.226 mol (1)

Molar mass of Al_2O_3 = (2 x 27.0 + 3 x 16.0) g mol^{-1}

= 102.0 g mol^{-1}

Mass of Al_2O_3 = number of moles of Al_2O_3 x molar mass of Al_2O_3

= 0.226 mol x 102.0 g mol^{-1}

= 23.1 g (1)

∴ 23.1 g of Al_2O_3 are formed.

Topic Exercise (p.134)

37 Nitrogen can be prepared in the laboratory by the following reaction:

$$2NH_3(g) + 3CuO(s) \rightarrow N_2(g) + 3Cu(s) + 3H_2O(l)$$

204 kg of NH_3 are allowed to react with 1 360 kg of CuO.
What is the mass of nitrogen formed?
(Relative atomic masses: H = 1.0, N = 14.0, O = 16.0, Cu = 63.5)

$$\text{\# of moles of } NH_3 = \frac{\text{mass of } NH_3}{\text{molar mass of } NH_3} = \frac{204 \times 10^3 \text{ g}}{(14.0 + 3 \times 1.0)\ \text{g mol}^{-1}} = 12\,000 \text{ mol}$$

(1)

$$\text{\# of moles of CuO} = \frac{\text{mass of CuO}}{\text{molar mass of CuO}} = \frac{1\,360 \times 10^3 \text{ g}}{(63.5 + 16.0)\ \text{g mol}^{-1}} = 17\,100 \text{ mol}$$

(1)

According to the equation, 2 moles of NH_3 react with 3 moles of CuO.
In this reaction, 11 400 moles of NH_3 react with 17 100 moles of CuO.
Thus, NH_3 is in excess. CuO is the limiting reactant. (1)

Topic Exercise (p.134)

Number of moles of N_2 = $\frac{1}{3}$ x number of moles of CuO

= $\frac{1}{3}$ x 17 100 mol

= 5 700 mol (1)

Molar mass of N_2 = 2 x 14.0 g mol^{-1}

= 28.0 g mol^{-1}

Mass of N_2 = number of moles of N_2 x molar mass of N_2

= 5 700 mol x 28.0 g mol^{-1}

= 160 000 g

= 160 kg (1)

∴ 160 kg of N_2 are formed.

Topic Exercise (p.134)

38 A major use of aluminium is the manufacture of pots and pans. One reason for this is its resistance to corrosion. Explain why aluminium, a reactive metal, is resistant to corrosion.

Aluminium has an oxide layer that is impermeable to oxygen and water. (1)

Topic Exercise (p.134)

39 A violent reaction occurs when a mixture of chromium(III) oxide and aluminium is ignited.

a) Write the chemical equation for the reaction involved.

$Cr_2O_3(s) + 2Al(s) \rightarrow 2Cr(s) + Al_2O_3(s)$ (1)

b) Calculate the mass of aluminium needed to react with 274 g of chromium(III) oxide.

(Relative atomic masses: O = 16.0, Al = 27.0, Cr = 52.0)

Topic Exercise (p.134)

Method 1

1 Molar mass of Cr_2O_3 = $(2 \times 52.0 + 3 \times 16.0)$ g mol^{-1}
= 152.0 g mol^{-1}

Number of moles of Cr_2O_3 = $\dfrac{\text{mass of } Cr_2O_3}{\text{molar mass of } Cr_2O_3}$

= $\dfrac{274 \text{ g}}{152.0 \text{ g mol}^{-1}}$

= 1.80 mol (1)

2 According to the equation, 1 mole of Cr_2O_3 reacts with 2 moles of Al.

i.e. number of moles of Al = 2×1.80 mol
= 3.60 mol (1)

3 Mass of Al = number of moles of Al x molar mass of Al
= $3.60 \text{ mol} \times 27.0 \text{ g mol}^{-1}$
= 97.2 g (1)

Topic Exercise (p.134)

Method 2

1 Molar mass of Cr_2O_3 = (2 x 52.0 + 3 x 16.0) g mol^{-1}
= 152.0 g mol^{-1}

Molar mass of Al = 27.0 g mol^{-1}

2 According to the equation, 1 mole of Cr_2O_3 reacts with 2 moles of Al.

i.e. 152.0 g of Cr_2O_3 react with 2 x 27.0 g of Al. (1)

3 Mass of Al = 274 g x $\frac{2 \times 27.0 \text{ g}}{152.0 \text{ g}}$

= 97.3 g (1)

∴ 97.2 / 97.3 g of Al are needed. (1)

Topic Exercise (p.134)

40 Aluminium and iron are commonly used construction materials.

a) Suggest why iron was used earlier than aluminium in history.

b) A compound contains iron and oxygen only. In an experiment for determining the empirical formula of this compound, 2.31 g of the compound was heated with carbon monoxide. Upon complete reaction, carbon dioxide and 1.67 g of iron were formed.

i) Calculate the empirical formula of this compound.

ii) Write the chemical equation for the reaction involved in the experiment.

iii) As carbon monoxide is poisonous, suggest ONE necessary safety precaution in carrying out the experiment.

c) Explain why a galvanised iron object does not easily rust even if the zinc layer is broken.

d) Explain why anodisation can prevent aluminium objects from corrosion.

(HKDSE, Paper 1B, 2015, 3)

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

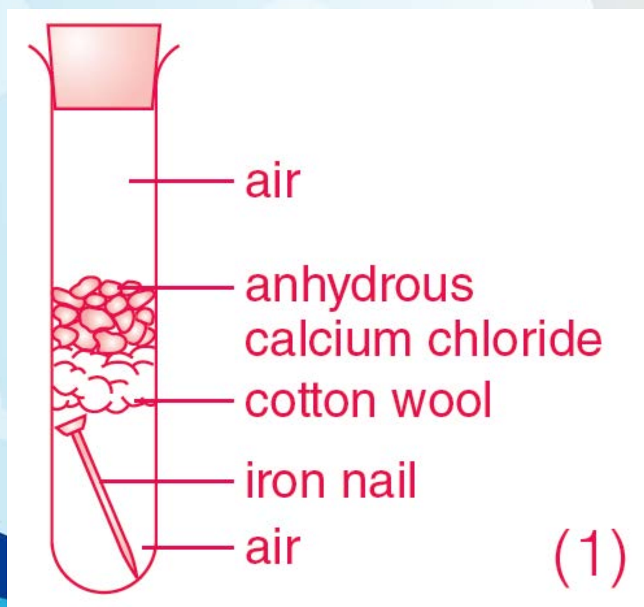
Topic Exercise (p.134)

41 Air and water are necessary for the corrosion of iron. Describe, with the aid of a labelled diagram, experiments to show that

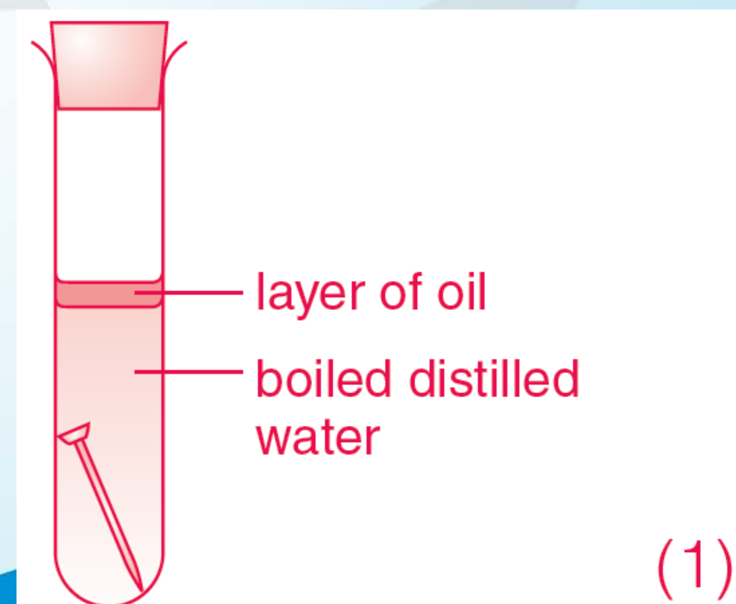
a) air alone will not lead to the rusting of iron;

b) water alone will not lead to the rusting of iron.

a) Nails with anhydrous calcium chloride in a sealed test tube will not rust. (1)

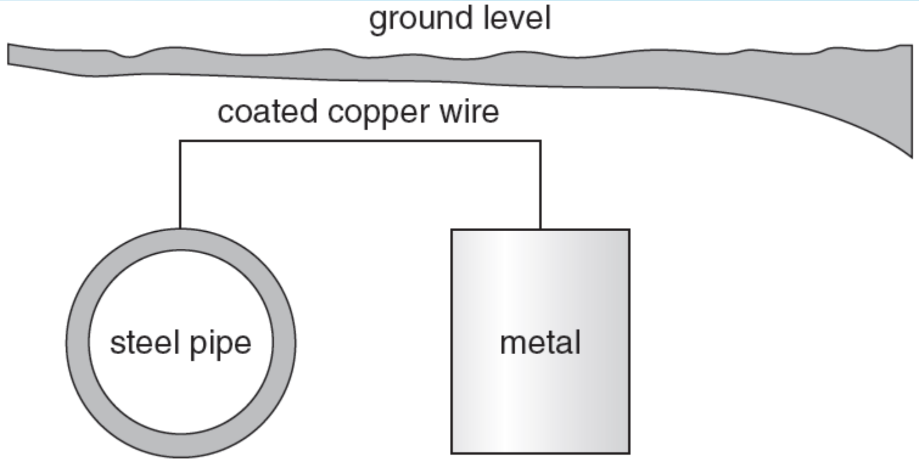


b) Nails in boiled distilled water which is covered with oil in a sealed test tube will not rust. (1)



Topic Exercise (p.134)

42 The diagram below shows one method of protecting a steel pipe.



a) Identify a suitable metal for protecting the steel pipe.

Magnesium / zinc (1)

b) Explain how the steel pipe is protected from rusting.

Magnesium / zinc is more reactive than iron. (1)

It protects iron from rusting by sacrificial protection. (1)

c) Suggest ONE other method that could be used to protect the pipe from rusting. Explain how the suggested method works.

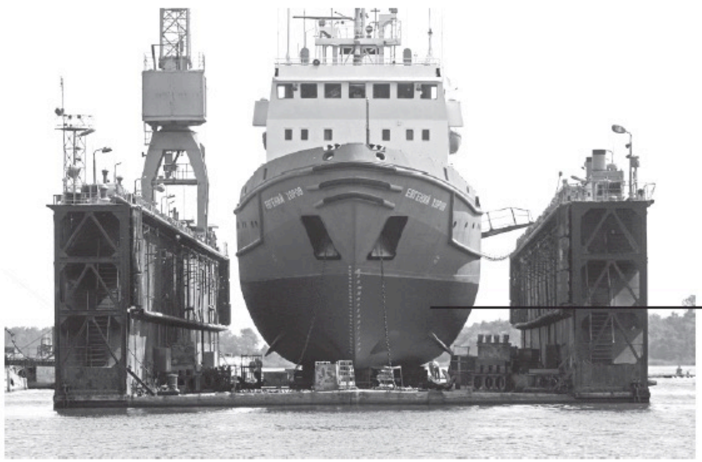
Impressed current cathodic protection (1)

The pipeline is connected to the negative terminal of a direct current power source while a conductor such as graphite is connected to the positive terminal. (1)

The pipeline receives electrons from the direct current power source. Hence the pipeline CANNOT lose electrons to form iron(II) ions. (1)

Topic Exercise (p.134)

43 Nick is investigating ways of preventing iron from rusting.
He wants to protect the bottom of a ship.
The bottom of the ship is made from iron.



He treats samples of iron in different ways.
He leaves them in a damp place and sees how long it takes for the first signs of rust to appear.

Look at Nick's results.

Topic Exercise (p.134)

Type of treatment	Time for rust to appear in days	Cost of treatment in £ per tonne of iron
Untreated iron (no treatment)	1	—
Painted iron	10	100
Iron mixed with chromium (alloying)	120	1 000
Iron with blocks of magnesium attached	50	500

Evaluate the advantages and disadvantages of each type of treatment for protecting the bottom of the ship from rusting.

Explain how attaching blocks of magnesium helps to prevent rusting.

(OCR GCSE Gateway Science, Chem B (Higher Tier), B742/02, Jun. 2015, 11)

Topic Exercise (p.134)

Evaluations

- Painting is cheap but does not last long. (1)
- Alloying is the best method of rust prevention but is the most expensive. (1)
- Alloying is difficult to do. (1)
- Attaching magnesium is expensive but lasts for a long time. (1)

How attaching blocks of magnesium helps to prevent rusting

- Magnesium is a sacrificial metal. (1)
- Magnesium is more reactive than iron and so it, instead of iron, corrodes. (1)

Communication mark (1)