Mastering Chemistry

- Book 2B
- Topic 5 Redox Reactions,
  Chemical Cells and Electrolysis

Content

Continued on next page

Content

19.1 Building a simple chemical cell (p.21)

- When a piece of zinc is put into copper(II) sulphate solution, a reaction occurs. The zinc becomes coated with copper and the blue colour of the copper(II) sulphate solution fades.
- The temperature of the reaction mixture rises. Energy is released in this reaction.

The reaction between zinc and copper(II) sulphate solution

3 **Building simple chemical cells** *Ref.*

19.1 Building a simple chemical cell (p.21)

- The overall reaction is:

  $Zn(s) + Cu^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Cu(s)$

- The reaction can be considered as the sum of two half reactions represented by the following two **half equations (半方程式)**:

  $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$

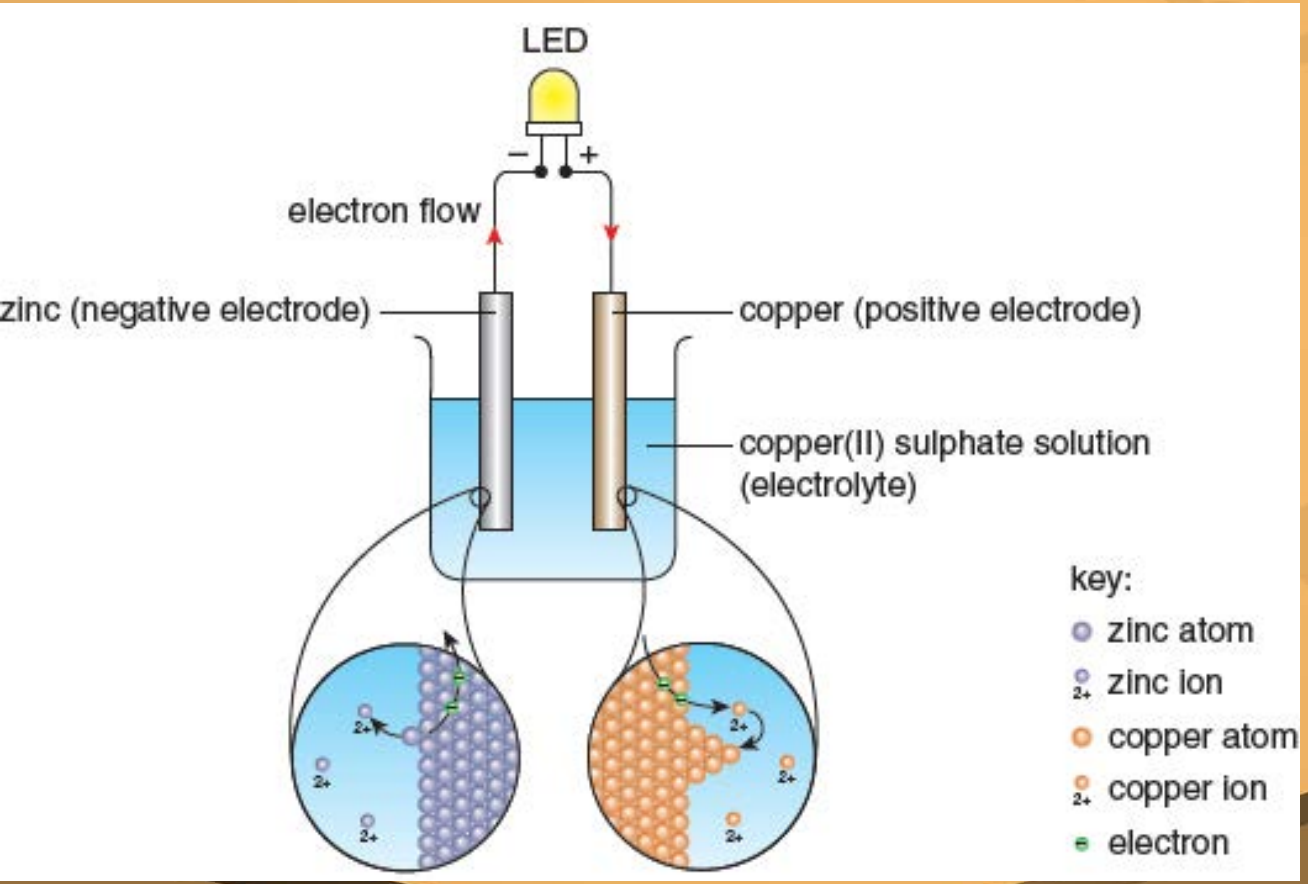
  $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

- A half equation shows the change that happens to one reactant in a reaction.

- The energy released in this reaction can be converted to electrical energy by using a simple chemical cell.

19.1 Building a simple chemical cell (p.21)

- Join strips of the two metals together by a conducting wire and dip them into copper(II) sulphate solution.



A zinc-copper chemical cell

19.1 Building a simple chemical cell (p.21)

- Zinc atoms in the zinc strip lose electrons to form zinc ions that enter the solution.

  $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$

- The electrons flow in the external circuit to the copper strip where they are gained by copper(II) ions to form copper atoms.

  $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

- The flow of electrons is an electric current. You can use the current to light a LED (light-emitting diode).

19.1 Building a simple chemical cell (p.21)

- The zinc strip is the negative electrode while the copper strip is the positive electrode. The copper(II) sulphate solution is the electrolyte.
- The overall equation for the reaction in the chemical cell is:

  $Zn(s) + Cu^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Cu(s)$
- The mass of the zinc strip decreases while that of the copper strip increases.

Electrons only flow in the external circuit while ions flow in the electrolyte.

19.1 Building a simple chemical cell (p.21)

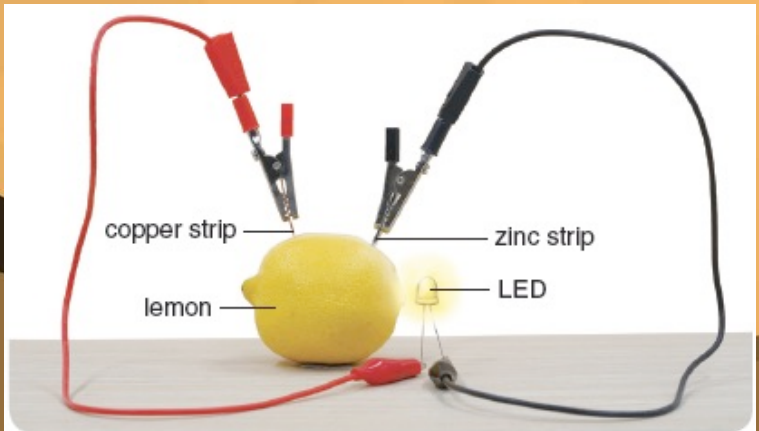
A lemon cell

- A lemon cell can be set up by using strips of zinc and copper. The lemon juice is the electrolyte of this cell.
- Zinc atoms in the zinc strip lose electrons to form zinc ions.

$$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$$

- The electrons flow in the external circuit to the copper strip where they are gained by hydrogen ions in the lemon juice to form hydrogen.

$$2H^+(aq) + 2e^- \longrightarrow H_2(g)$$

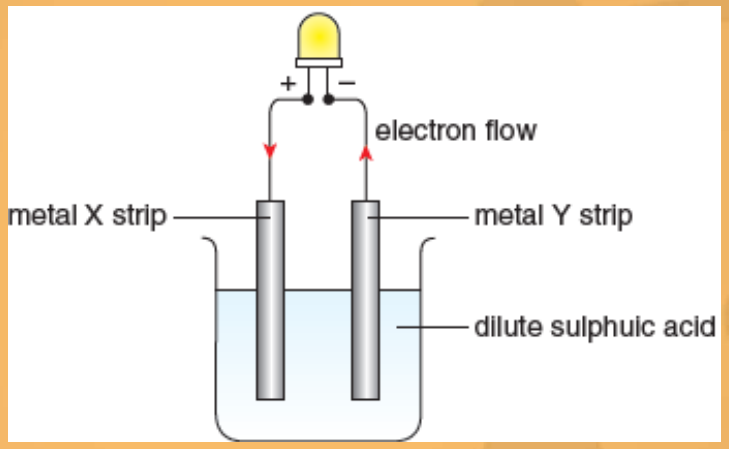


A lemon cell

19.1 Building a simple chemical cell (p.21)

Practice 19.1

A simple chemical cell is built by dipping two metal strips into dilute sulphuric acid. Electrons flow from the metal Y strip to the metal X strip in the external circuit. The LED lights up.



a) Identify the positive electrode of the chemical cell. Metal X strip

b) What would happen to the mass of the metal Y strip after some time? Explain your answer.
The mass of metal Y strip decreases.
Atoms of Y lose electrons to form ions.

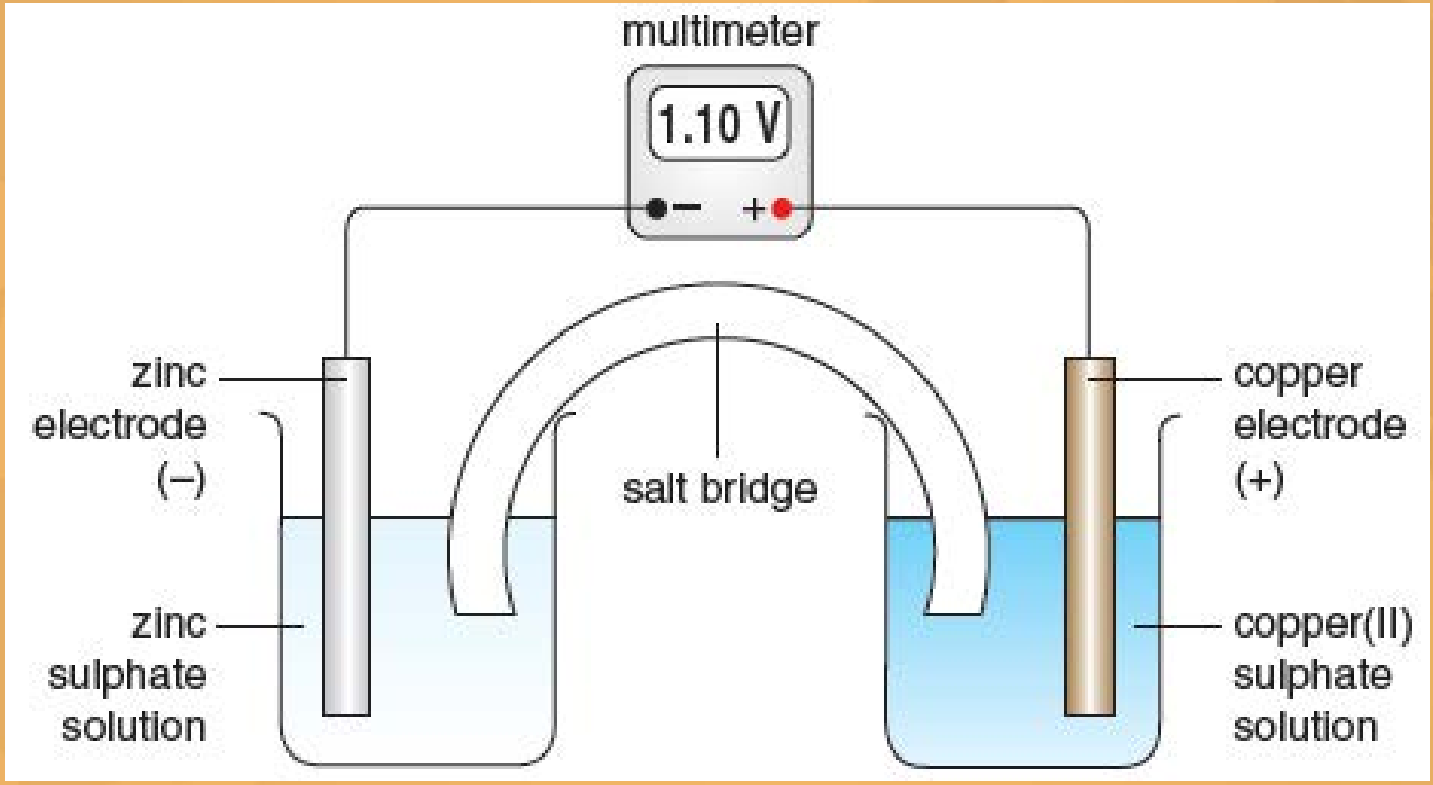
c) The sulphuric acid is now replaced by ethanol. What would happen? Explain your answer.
The LED would NOT light up.
Ethanol CANNOT conduct electricity.

19.2 Building a chemical cell from two cells (p.24)

- Place the zinc electrode and the copper electrode in separate compartments, called **half cells (半電池)**.
- Each half cell consists of a metal electrode dipped into a solution of its own ions.
- The electrodes of the half cells are connected by a conducting wire. The circuit is completed by a **salt bridge (鹽橋)** which is dipped into the two solutions.
- The chemical cell will function until either the zinc electrode or the copper(II) ion is completely used up.

Chemical cell with a salt bridge *Ref.*

19.2 Building a chemical cell from two cells (p.24)



Building a chemical cell from two half cells

19.2 Building a chemical cell from two cells (p.24)

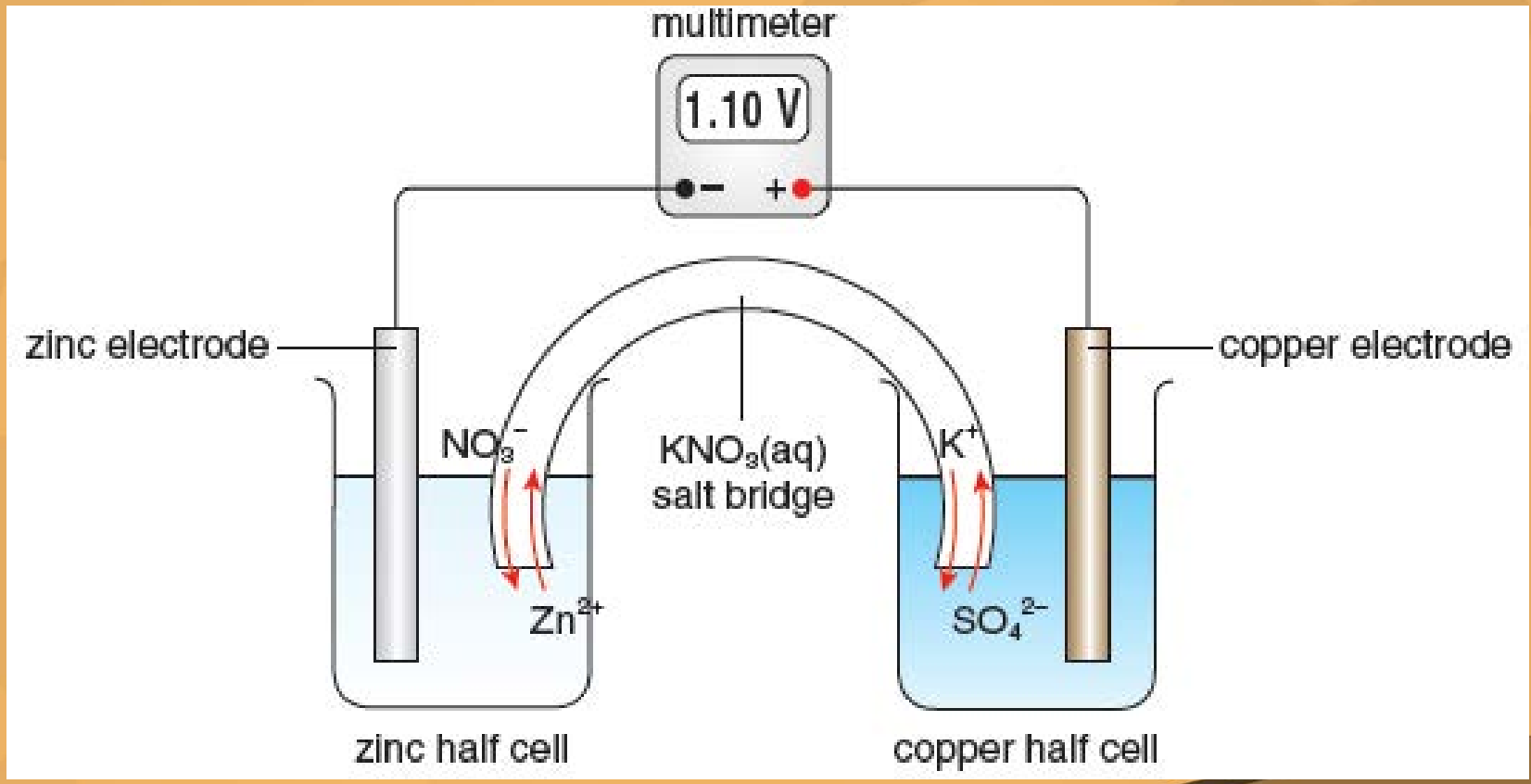
The role of a salt bridge

- A salt bridge is made from a strip of filter paper soaked in an electrolyte.
- The electrolyte is usually potassium nitrate solution. This is used because potassium ions and nitrate ions do not react with the other ions in the solutions or with the electrodes.
- The dissolution of zinc from the zinc electrode results in an increase in the concentration of zinc ions in the zinc sulphate solution. This leads to a build-up of positive charges in the zinc sulphate solution.

19.2 Building a chemical cell from two cells (p.24)

- The deposition of copper(II) ions from the copper(II) sulphate solution as copper atoms results in a decrease in the concentration of copper(II) ions in the copper(II) sulphate solution. This leads to a build-up of negative charges due to the sulphate ions that remain.
- The salt bridge contains ions that can flow out of the salt bridge into the individual half cells to prevent any build-up of charges.
- Similarly, any excess ions in the individual half cells can flow into the salt bridge to prevent the build-up of charges.

19.2 Building a chemical cell from two cells (p.24)



Ions flow into and out of the salt bridge to prevent any build-up of charges in the half cells

19.2 Building a chemical cell from two cells (p.24)

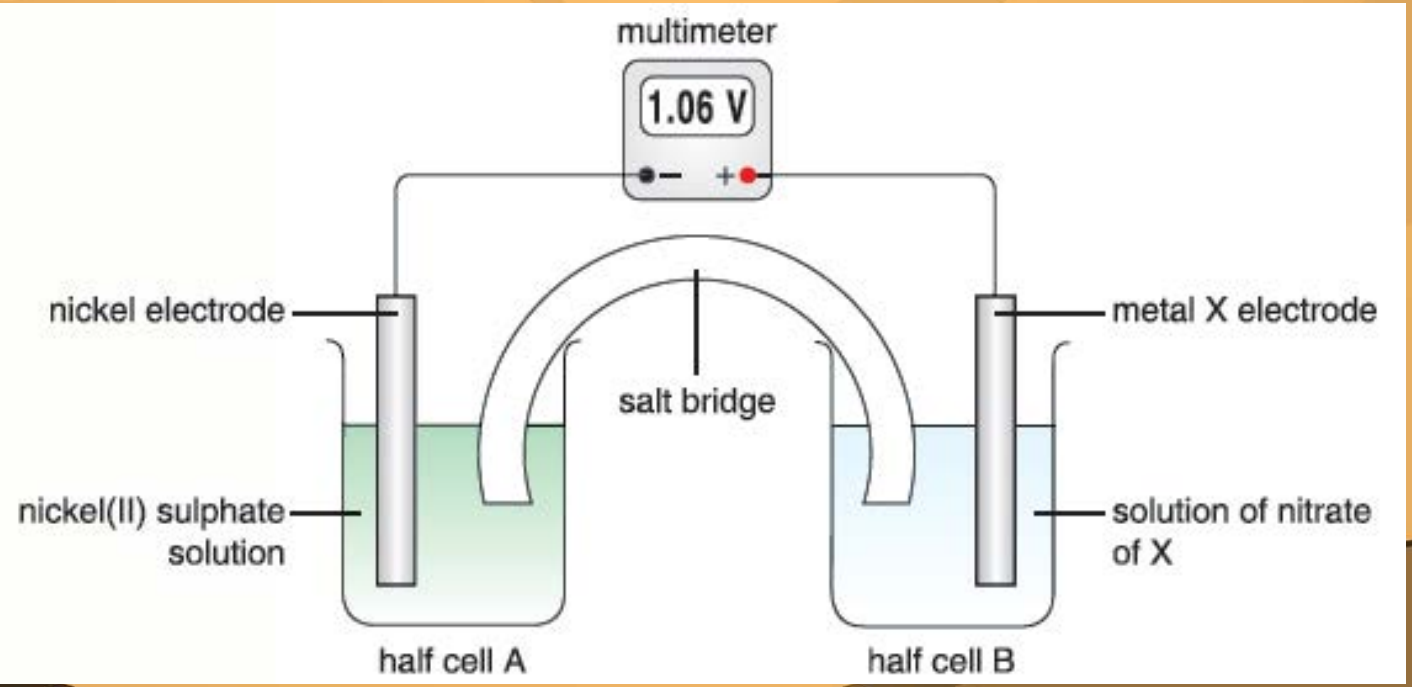
A salt bridge

- **allows the flow of ions between the two half cells to complete the circuit;**
- **allows ions to flow into or out of the half cells to balance the charges in the half cells.**

19.2 Building a chemical cell from two cells (p.24)

Q (Example 19.1)

Consider the chemical cell shown below. The voltage of the cell is +1.06 V. Half cell B is made by dipping a metal X electrode into a solution of nitrate of X ($XNO_3(aq)$).



19.2 Building a chemical cell from two cells (p.24)

Q (Example 19.1) (continued)

a) State, with explanation, the direction of electron flow in the external circuit.

b) Write a half equation for the change that occurs at each electrode.

c) Write the overall equation for the reaction in the chemical cell.

A

a) The multimeter gives a positive voltage when the negative electrode is connected to the negative terminal of the multimeter.
Hence the nickel electrode is the negative electrode.
Electrons flow from the nickel electrode to the metal X electrode in the external circuit.

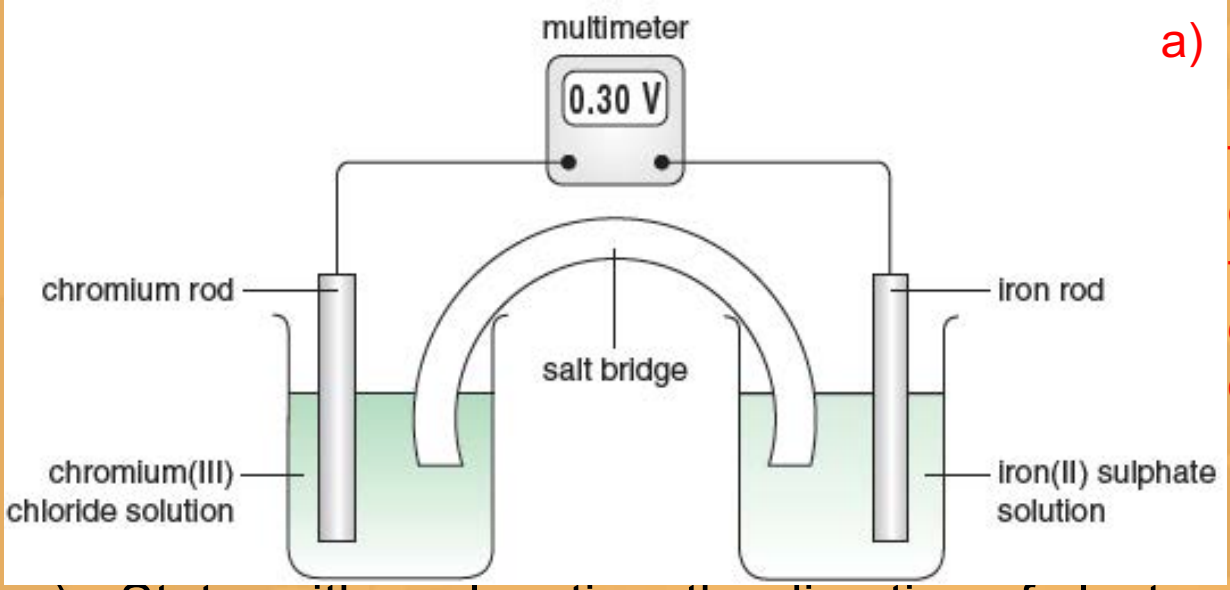
b) At the nickel electrode: $Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^-$
At the metal X electrode: $X^+(aq) + e^- \longrightarrow X(s)$

c) $Ni(s) + 2X^+(aq) \longrightarrow Ni^{2+}(aq) + 2X(s)$

19.2 Building a chemical cell from two cells (p.24)

Practice 19.2

Consider the chemical cell shown below. As time goes by, the colour of the iron(II) sulphate solution in the beaker gradually fades out.



a) From chromium rod to iron rod
Iron(II) ions gain electrons to form iron atoms. The concentration of iron(II) ions in the iron(II) sulphate solution decreases, and thus the colour of the solution fades out.

a) State, with explanation, the direction of electron flow in the external circuit.

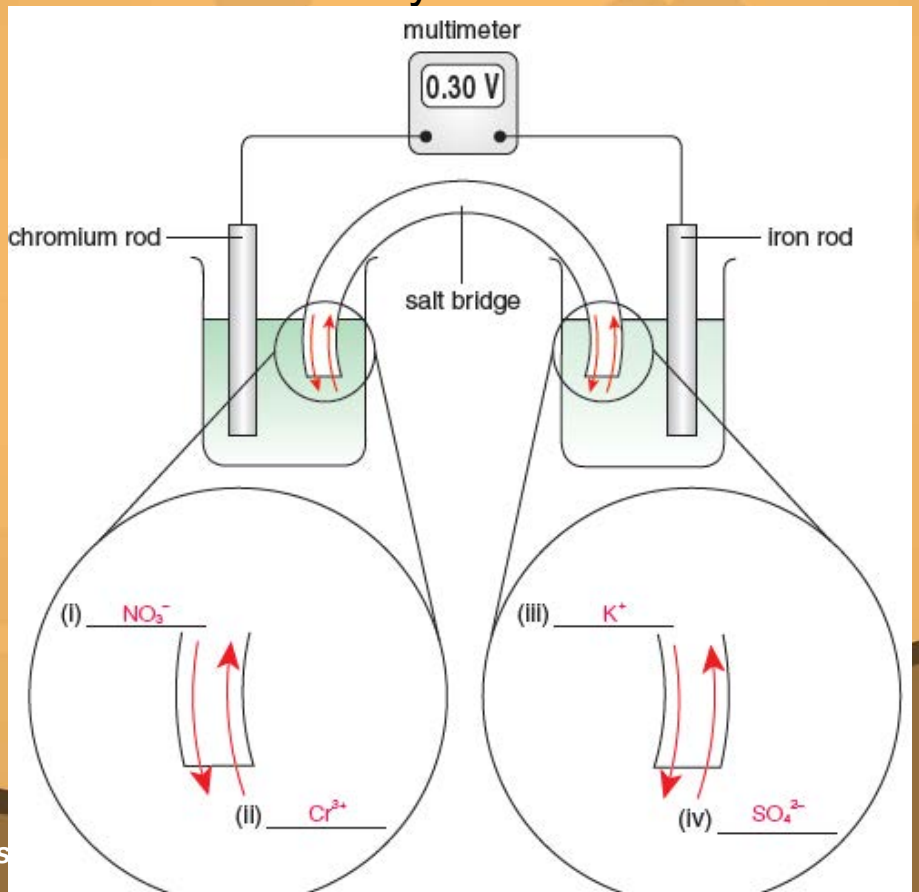
b) Write the half equation for the change that occurs at the chromium rod.

$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^-$

19.2 Building a chemical cell from two cells (p.24)

Practice 19.2 (continued)

c) The salt bridge is made from a strip of filter paper soaked in potassium nitrate solution.
Complete the diagram below to identify the ions that flow between the salt bridge and each half cell.



19.3 The Daniell cell (p.28)

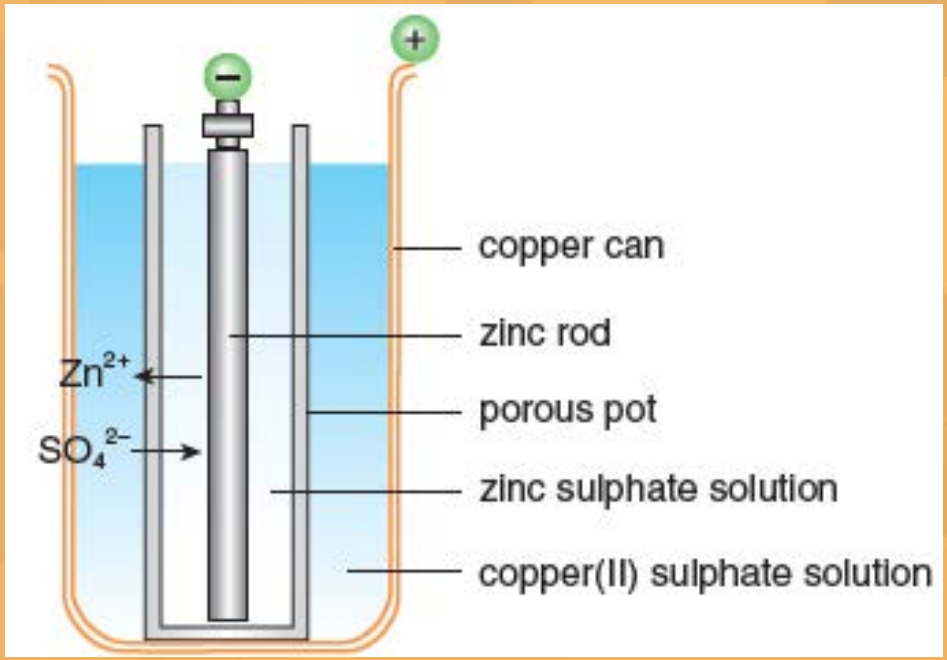
- In the **Daniell cell (丹聶爾電池)**, developed in 1836 by a British chemist John Frederic Daniell, a porous pot is used instead of a salt bridge between two half cells.
- The cell consists of a central zinc rod (negative electrode) dipped into a porous pot containing zinc sulphate solution.
- The porous pot is, in turn, immersed in copper(II) sulphate solution contained in a copper can, which acts as the positive electrode.

  At the zinc rod: $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$

  At the copper can: $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

19.3 The Daniell cell (p.28)

- The mass of the zinc rod decreases while that of the copper can increases after some time.
- The voltage of this cell is about 1.1 V.



A Daniell cell

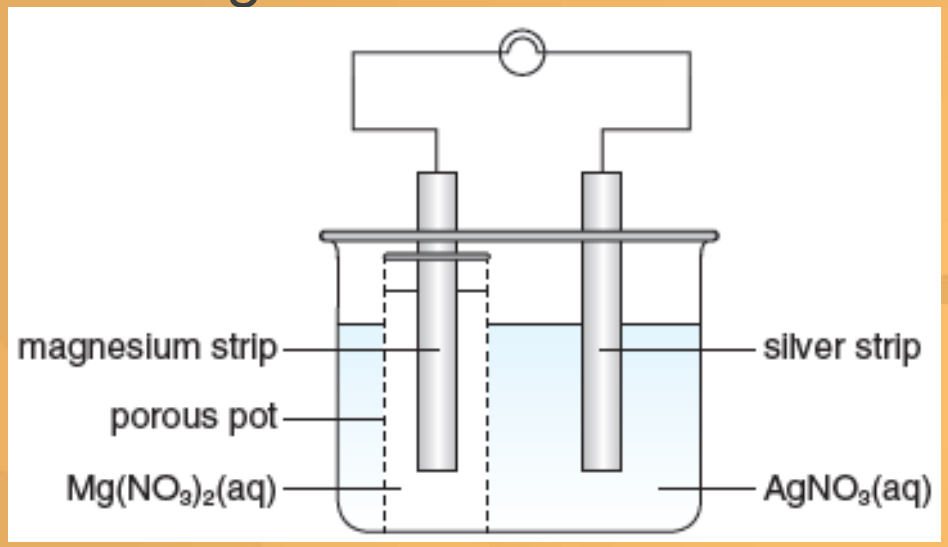
19.3 The Daniell cell (p.28)

- The porous pot
  - allows the flow of ions between the two solutions to complete the circuit;
  - separates the two solutions and hence prevents them from reacting with each other.
- The zinc ions and the sulphate ions migrate towards the copper can and the zinc rod respectively through the porous pot.

19.3 The Daniell cell (p.28)

Practice 19.3

The diagram below shows a set-up with the bulb lights up:



b) At magnesium strip:

$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^-$

At silver strip:

$Ag^+(aq) + e^- \longrightarrow Ag(s)$

a) What is the direction of electron flow in the external circuit?

From magnesium strip to silver strip

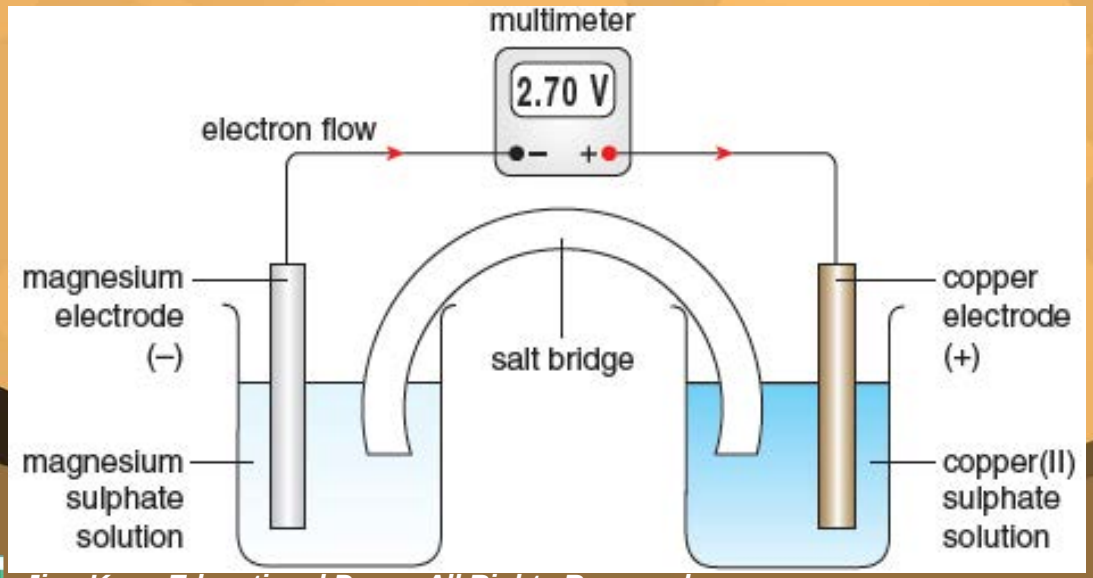
b) Write a half equation for the change that occurs at each electrode.

c) Identify the ion that migrates towards the porous pot.

Nitrate ions

19.4 Comparing the tendencies of metals to form ions (p.29)

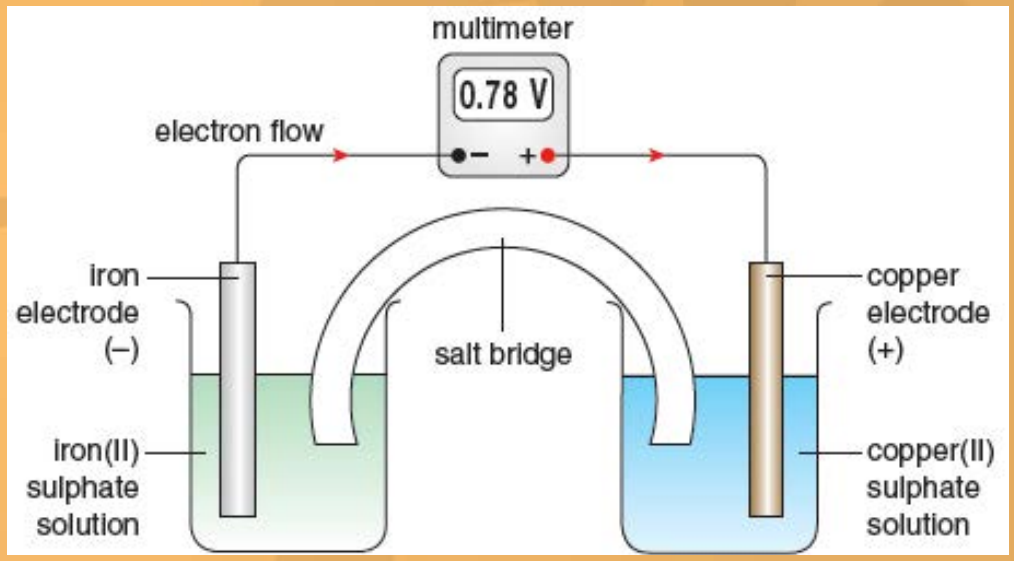
- The voltage of the cell shown in section 19.2 is 1.10 V. However, if the zinc electrode is replaced by a magnesium electrode and the zinc sulphate solution is replaced by magnesium sulphate solution, the voltage is much higher.
- This is because magnesium has a greater tendency than zinc of losing electrons to form ions.



A magnesium-copper chemical cell

19.4 Comparing the tendencies of metals to form ions (p.29)

- Build another half cell using iron and iron(II) sulphate solution. Combine this half cell with the copper half cell and measure the voltage.

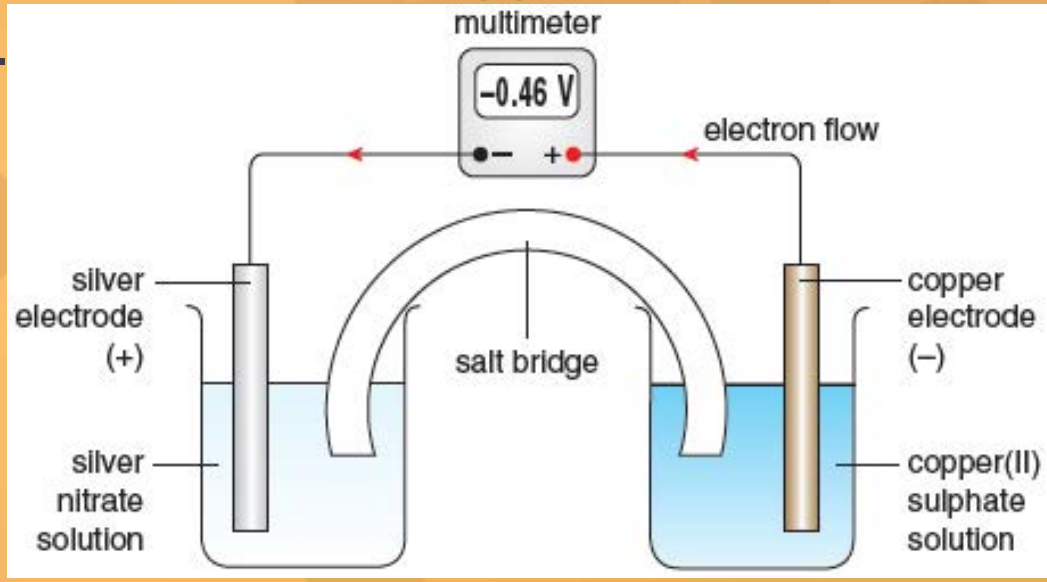


An iron-copper chemical cell

- The multimeter gives positive voltages in all the cases, showing that the copper electrode is the positive electrode in all the chemical cells.

19.4 Comparing the tendencies of metals to form ions (p.29)

- Build one more half cell using silver and silver nitrate solution. Combine this half cell with the copper half cell and measure the voltage.



A silver-copper chemical cell

- The multimeter gives a negative voltage, showing that the copper electrode is the negative electrode in this cell.

19.4 Comparing the tendencies of metals to form ions (p.29)

- The voltages of chemical cells built by combining different half cells with the copper half cell.

Chemical cell	Voltage (V)	Direction of electron flow in the external circuit
magnesium half cell – copper half cell	2.70	from magnesium to copper
zinc half cell – copper half cell	1.10	from zinc to copper
iron half cell – copper half cell	0.78	from iron to copper
silver half cell – copper half cell	–0.46	from copper to silver

- From the results, the tendencies of the metals to form ions are in the order of:

magnesium > zinc > iron > copper > silver

19.5 The electrochemical series of metals (p.31)

- Different metals have different tendencies to form ions. You can arrange the metals in the order of this tendency. This is called the **electrochemical series (電化序)** of metals.

Metal ion				Metal
$K^+(aq)$	+	e^-	⇌	K(s)
$Ca^{2+}(aq)$	+	$2e^-$	⇌	Ca(s)
$Na^+(aq)$	+	e^-	⇌	Na(s)
$Mg^{2+}(aq)$	+	$2e^-$	⇌	Mg(s)
$Al^{3+}(aq)$	+	$3e^-$	⇌	Al(s)
$Zn^{2+}(aq)$	+	$2e^-$	⇌	Zn(s)
$Fe^{2+}(aq)$	+	$2e^-$	⇌	Fe(s)
$Pb^{2+}(aq)$	+	$2e^-$	⇌	Pb(s)
$2H^+(aq)$	+	$2e^-$	⇌	$H_2(g)$
$Cu^{2+}(aq)$	+	$2e^-$	⇌	Cu(s)
$Ag^+(aq)$	+	e^-	⇌	Ag(s)
$Au^+(aq)$	+	e^-	⇌	Au(s)

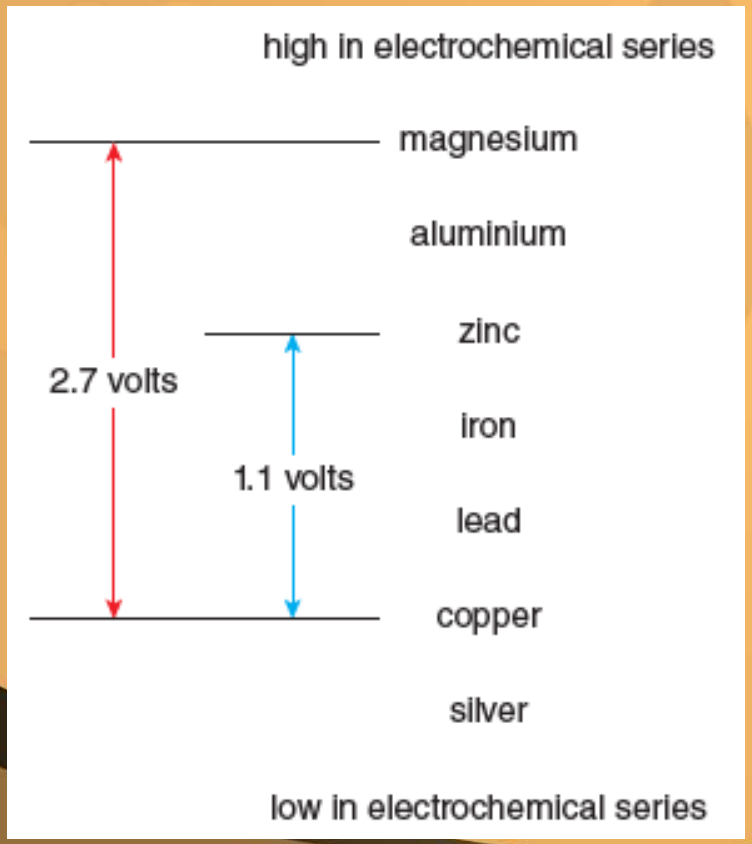
Increasing tendency to form ions

19.5 The electrochemical series of metals (p.31)

- Metals towards the top of the electrochemical series form ions more readily.
- In a simple chemical cell, electrons flow from the metal higher in the electrochemical series to the metal lower in the series.
- The voltage of the chemical cell is determined by the metals used. The further apart the two metals are in the series, the higher the voltage.

19.5 The electrochemical series of metals (p.31)

- For example, magnesium and copper are further apart than zinc and copper, so a magnesium-copper chemical cell has a higher voltage than a zinc-copper chemical cell.



The further apart between two metals in the electrochemical series, the higher the voltage of a chemical cell

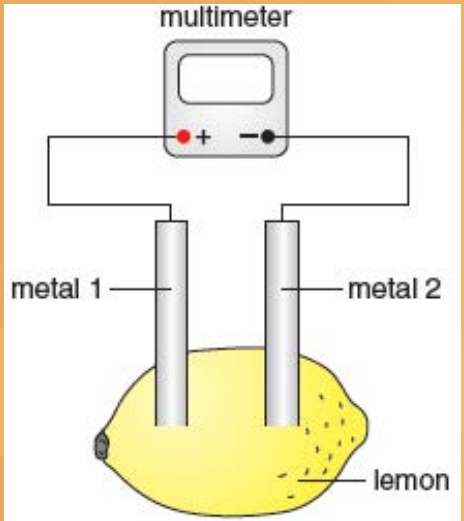
19.5 The electrochemical series of metals (p.31)

- Note that the electrochemical series is very similar to the reactivity series (except calcium). This is because a metal that loses electrons more readily to form ions is probably more reactive.

19.5 The electrochemical series of metals (p.31)

Practice 19.4

A student investigated lemon cells using the set-up shown below.



The student's results are shown in the table below.

Metal 1 \ Metal 2	Chromium	Copper	Iron	Tin	Zinc
Chromium	0.0 V	—	—	—	—
Copper	1.2 V	0.0 V	—	—	—
Iron	0.5 V	−0.8 V	0.0 V	—	—
Tin	0.8 V	−0.5 V	0.3 V	0.0 V	—
Zinc	0.2 V	−1.1 V	−0.3 V	−0.6 V	0.0 V

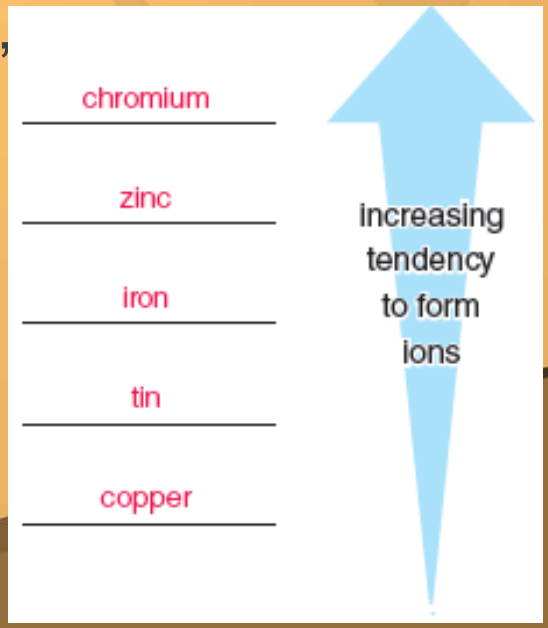
19.5 The electrochemical series of metals (p.31)

Practice 19.4 (continued)

a) What is the function of the lemons in these cells?
Lemon juice is the electrolyte of the cell.

b) Refer to the lemon cell made by using zinc and copper. Write a half equation for the change that occurs at each electrode. At zinc: $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$
At copper: $2H^+(aq) + 2e^- \longrightarrow H_2(g)$

c) Arrange the metals (chromium, copper, iron, tin and zinc) according to the ascending order of their tendencies to form ions.



Key terms (p.34)

half equation	半方程式	Daniell cell	丹聶爾電池
half cell	半電池	electrochemical series	電化序
salt bridge	鹽橋		

Summary (p.35)

1 In a simple chemical cell, electrons only flow in the external circuit while ions flow in the electrolyte.

2 To increase the efficiency of a simple chemical cell, the cell can be separated into two half cells connected by a salt bridge.

3 A salt bridge
- allows the flow of ions between the two half cells to complete the circuit;
- allows ions to flow into or out of the half cells to balance the charges in the half cells.

Summary (p.35)

4 In the Daniell cell, electrons flow from the zinc rod to the copper can in the external circuit.
At the zinc rod: $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$
At the copper can: $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

5 Metals can be arranged in order of their tendencies to form ions. This is called the electrochemical series of metals.

6 Metals towards the top of the electrochemical series form ions more readily. In a simple chemical cell, electrons flow from the metal higher in the electrochemical series to the metal lower in the series.

Unit Exercise (p.36)

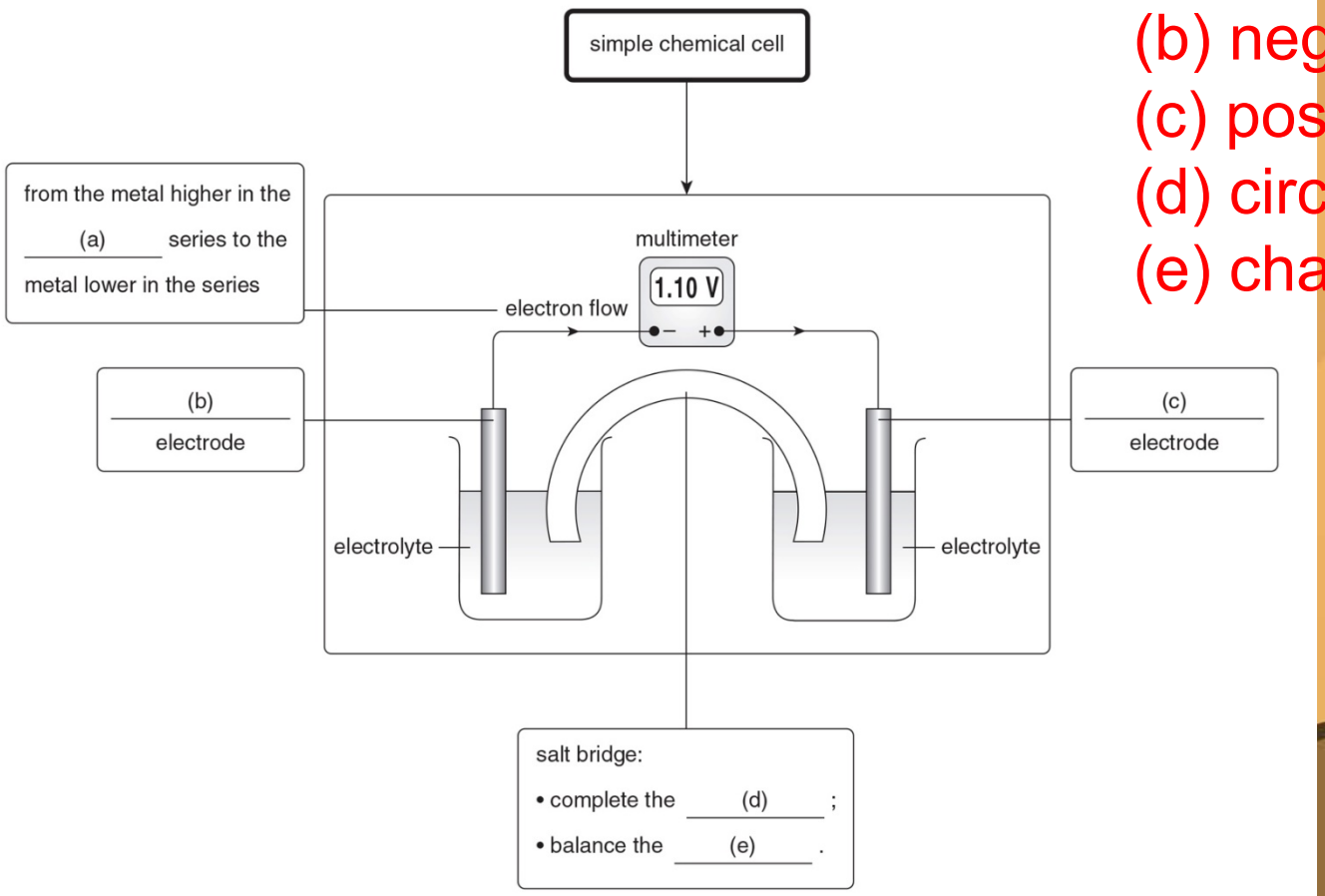
Note: Questions are rated according to ascending level of difficulty (from 1 to 5):

 **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.36)

PART I KNOWLEDGE AND UNDERSTANDING

1 Complete the following concept map.



(a) electrochemical
(b) negative
(c) positive
(d) circuit
(e) charges

Unit Exercise (p.36)

PART II MULTIPLE CHOICE QUESTIONS

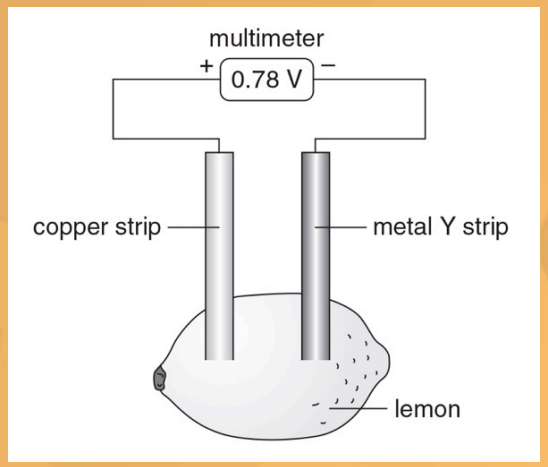
2 Which of the following pairs of metals will produce the highest voltage when used as electrodes in a simple chemical cell?

A Copper and silver
B Magnesium and silver
C Magnesium and zinc
D Zinc and copper

Answer: B

Unit Exercise (p.36)

3 Consider the lemon cell shown below. Y is a Group II metal.



Explanation:
Electrons flow through the external circuit, NOT the lemon juice.

Answer: C

Which of the following statements is INCORRECT?

A The metal Y strip is the negative electrode.

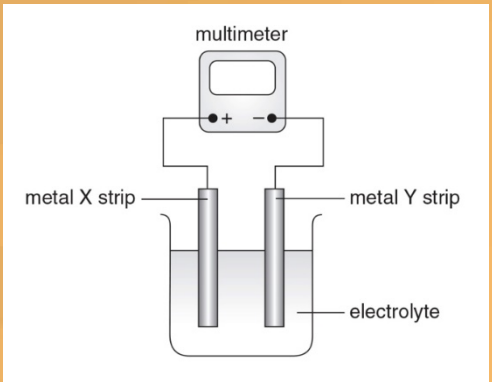
B $Y^{2+}(aq)$ ions are found in the lemon juice.

C Electrons flow from the metal Y strip to the copper strip through the lemon juice.

D A greater magnitude of voltage will be recorded if the copper strip is replaced by a silver strip.

Unit Exercise (p.36)

4 In the set-up shown below, metal X forms ions more readily than metal Y.



Explanation:
Option A — Electrons flow from metal X strip to metal Y strip in the external circuit. Thus, the multimeter gives a negative voltage reading.

Which of the following statements about the set-up is correct?

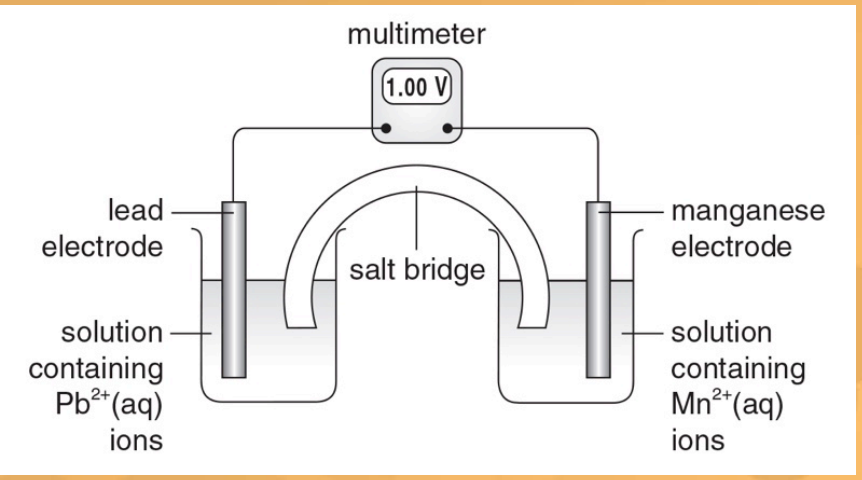
A The multimeter gives a positive voltage reading.
B The mass of metal X strip decreases.
C Metal Y strip is the negative electrode.
D Electrical energy is converted into chemical energy.

Answer: B

Unit Exercise (p.36)

5 The overall reaction in the chemical cell below is:

$Mn(s) + Pb^{2+}(aq) \longrightarrow Mn^{2+}(aq) + Pb(s)$



Explanation:
The dissolution of manganese from the manganese electrode results in an increase in the concentration of manganese(II) ions in the solution. This leads to a build-up of positive charges in the solution.
Anions in the salt bridge migrate towards the Mn half cell to prevent any build-up of charges.

Which of the following statements about the chemical cell is correct?

A The lead electrode is the negative electrode.

B The manganese electrode increases in mass.

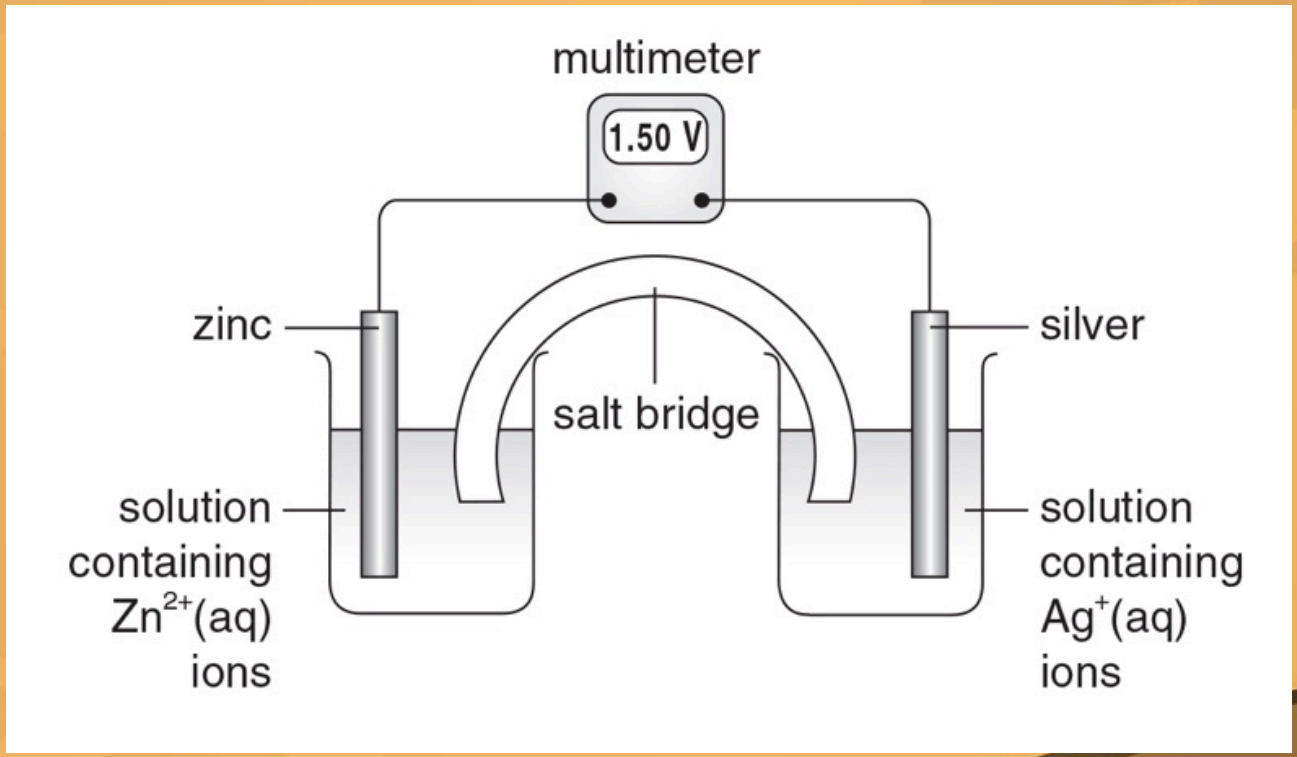
C Electrons flow from the lead electrode to the manganese electrode in the external circuit.

D Anions in the salt bridge migrate towards the Mn half cell.

Answer: D

Unit Exercise (p.36)

Directions: Questions 6 and 7 refer to the chemical cell shown below.



Unit Exercise (p.36)

6 Which of the following combinations is correct as the cell discharges?

	Electron flow	In the salt bridge
A	from zinc electrode to silver electrode	anions migrate to the Ag half cell
B	from silver electrode to zinc electrode	cations migrate to the Zn half cell
C	from silver electrode to zinc electrode	anions migrate to the Zn half cell
D	from zinc electrode to silver electrode	cations migrate to the Ag half cell

Explanation:
The deposition of silver ions from the solution as silver atoms results in a decrease in the concentration of silver ions in the solution. Cations in the salt bridge migrate to the Ag half cell to replace the positive charges of the silver ions consumed.

Answer: D

Unit Exercise (p.36)

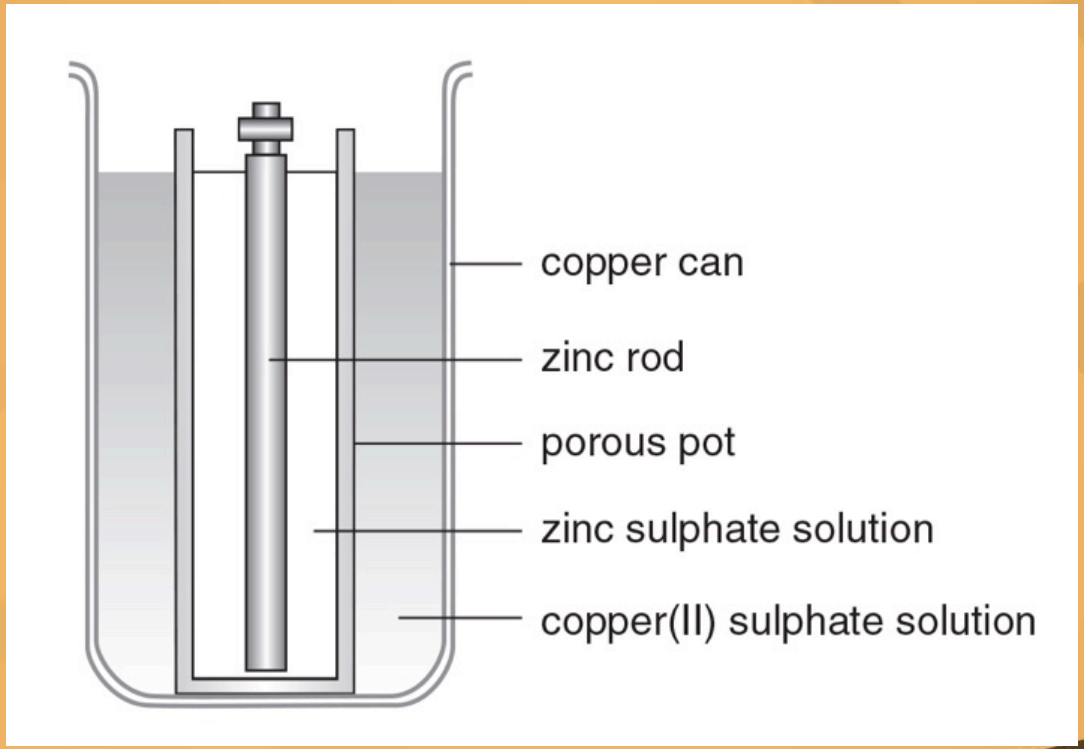
7 What is observed at the zinc electrode as the cell discharges?

A No change is observed.
B The electrode becomes thinner.
C Crystals are formed over the surface of the electrode.
D Gas bubbles are formed over the surface of the electrode.

Answer: B

Unit Exercise (p.36)

Directions: Questions 8 and 9 refer to the chemical cell shown below.



Unit Exercise (p.36)

8 Which of the following combinations about the changes at the electrodes is correct?

	Positive electrode	Negative electrode
A	$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$
B	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$	$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$
C	$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$
D	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$	$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

Answer: A

Unit Exercise (p.36)

9 Which of the following statements about the porous pot is / are correct?

(1) The porous pot allows electrons to move between the two solutions.
(2) Zinc ions migrate out of the porous pot.
(3) The porous pot provides ions to balance the excess charges in the two solutions.

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

Answer: B

Explanation:
(3) The porous pot CANNOT provide ions to balance the excess charges in the two solutions.

Unit Exercise (p.36)

10 A zinc half cell and a silver half cell are connected via a salt bridge. The two electrodes are connected by a conducting wire and a voltmeter.

Which of the following statements are correct?

(1) Electrons flow along the wire from the zinc electrode to the silver electrode.

(2) Electrons flow through the salt bridge to complete the circuit.

(3) If the salt bridge is lifted out of the solutions, the voltmeter will read zero volt.

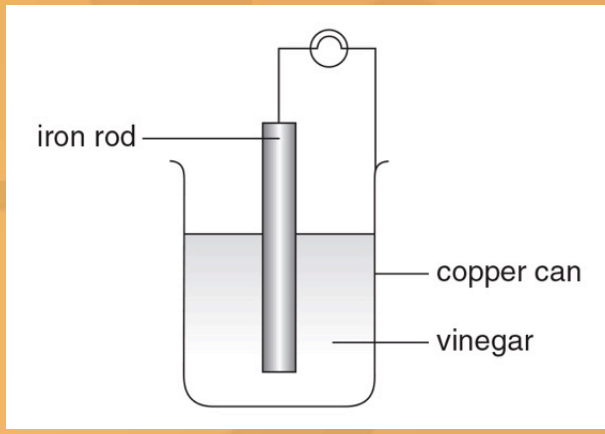
Answer: B

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

Explanation:
(2) Electrons flow through the external current, NOT the salt bridge.

Unit Exercise (p.36)

11 Consider the chemical cell shown below.



Which of the following statements about the chemical cell are correct?

(1) The iron dissolves gradually.
(2) Colourless gas bubbles are given out on the inner wall of the copper can.
(3) The vinegar turns blue gradually.

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

Answer: A

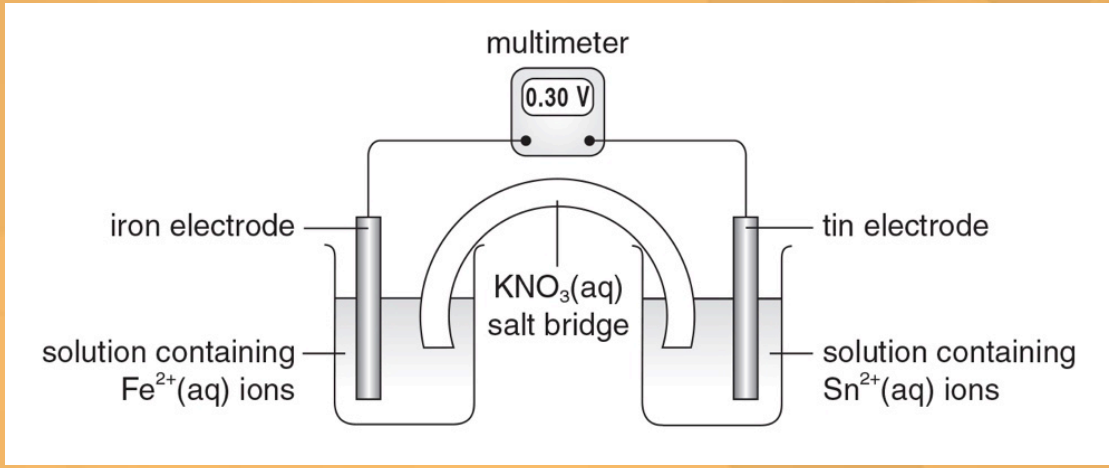
Explanation:
(2) Electrons flow from the iron rod to the copper can in the external circuit.
Hydrogen ions in the vinegar gain electrons to form hydrogen gas.
$2H^+(aq) + 2e^- \longrightarrow H_2(g)$

Unit Exercise (p.36)

PART III STRUCTURED QUESTIONS

12 The overall reaction in the chemical cell shown below is:

$Fe(s) + Sn^{2+}(aq) \longrightarrow Fe^{2+}(aq) + Sn(s)$ (Sn represents tin.)



a) Identify the direction of electron flow in the external circuit.

From the iron electrode to the tin electrode (1)

Unit Exercise (p.36)

12 (continued)

b) Give the half equation for the change that occurs at the positive electrode.

$Sn^{2+}(aq) + 2e^- \longrightarrow Sn(s)$ (1)

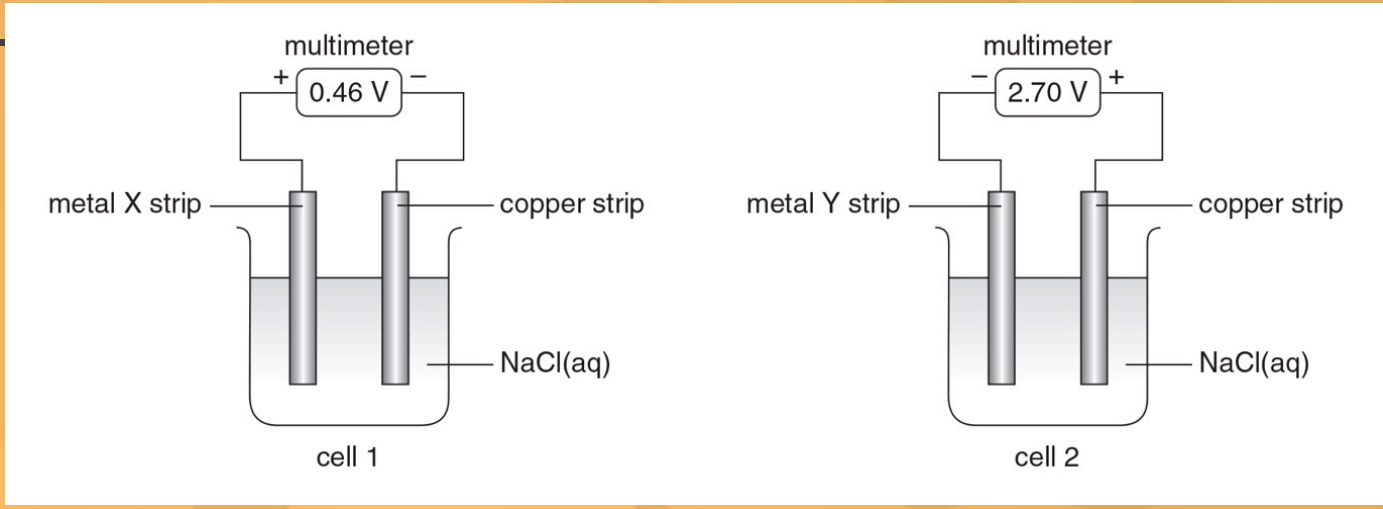
c) State and explain the direction of migration of $K^+(aq)$ ions in the salt bridge.

The deposition of $Sn^{2+}(aq)$ ions from the solution as Sn atoms results in a decrease in the concentration of $Sn^{2+}(aq)$ ions in the solution. (1)

Cations in the salt bridge migrate to the tin half cell to replace the positive charges of the $Sn^{2+}(aq)$ ions consumed. (1)

Unit Exercise (p.36)

13 Consider the information concerning the two chemical cells shown below.



a) Name the particles responsible for the passage of current

i) in the wires;

Electrons (1)

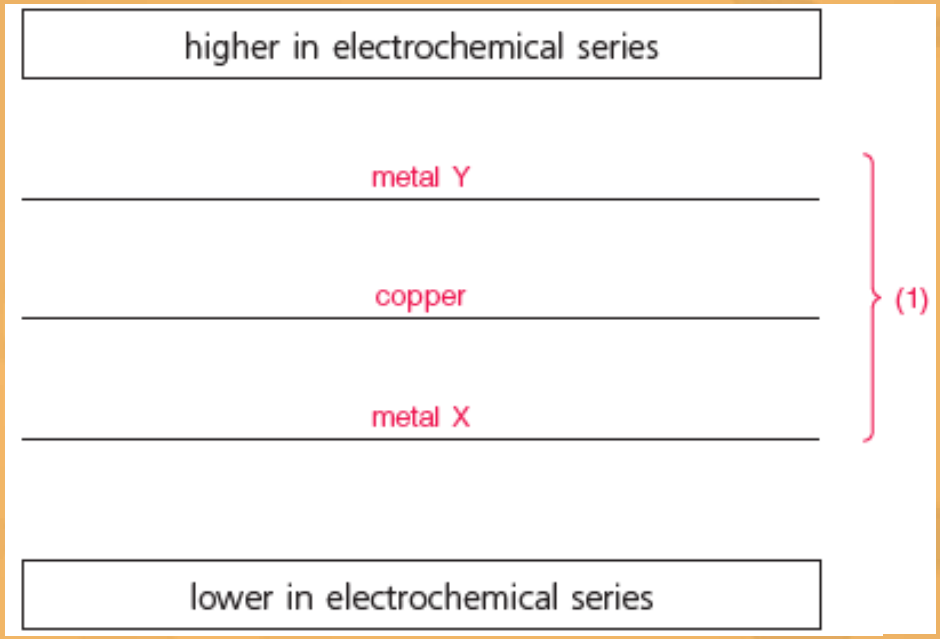
ii) in NaCl(aq).

Ions (1)

Unit Exercise (p.36)

13 (continued)

b) Arrange metal X, copper and metal Y in the electrochemical series.



c) For cell 1, write the half equation for the change that occurs at the copper strip.

$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$ (1)

Unit Exercise (p.36)

13 (continued)

d) For cell 1, if the copper strip is replaced by metal Y strip, what will happen to the magnitude of the voltage reading?

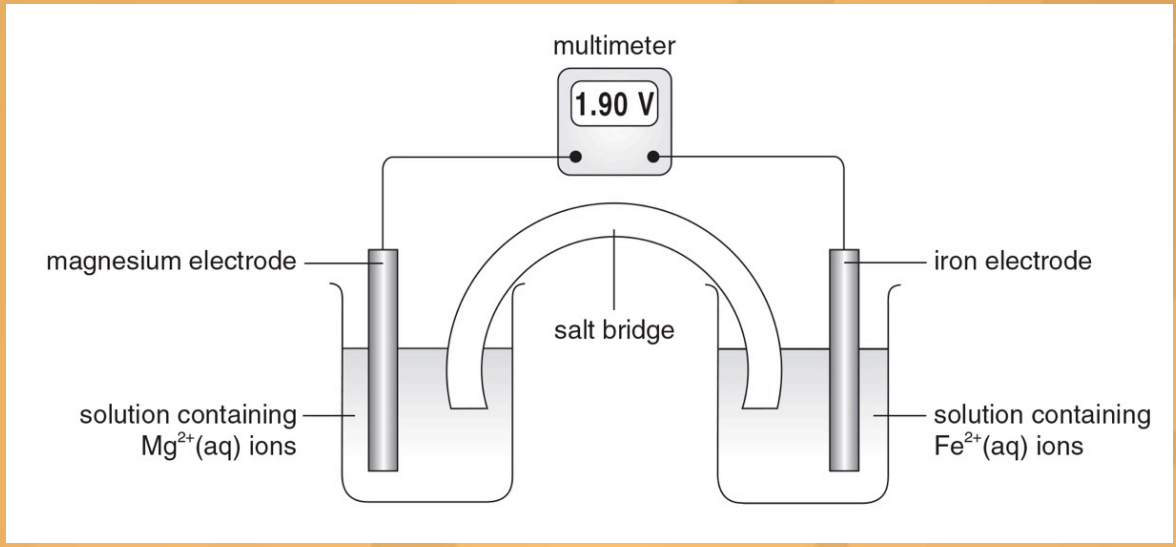
The magnitude of the voltage reading will increase. (1)

e) Predict, with reason, what would happen if the NaCl(aq) in cell 1 is replaced by ethanol.

The multimeter will read zero volt.
Ethanol CANNOT conduct electricity. NO electrons would flow through the external circuit. (1)

Unit Exercise (p.36)

14 Consider the chemical cell shown below.



It is found that the concentration of magnesium ions increases as the cell discharges.

a) Identify the direction of electron flow in the external circuit.

From the magnesium electrode to the iron electrode. (1)

Unit Exercise (p.36)

14 (continued)

b) Give the half equation for the change that occurs at the negative electrode.

$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^{-}$ (1)

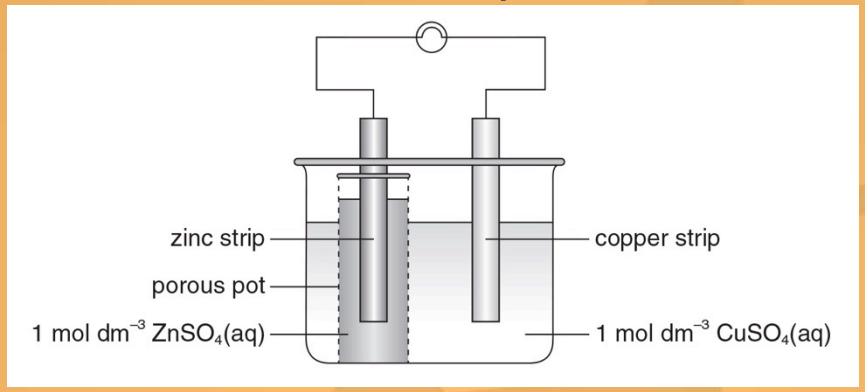
c) List TWO factors that need to be considered when choosing an appropriate substance for preparing the salt bridge.

The substance must be an ionic compound. (1)

The substance must NOT react with solutions in the half cells. (1)

Unit Exercise (p.36)

15 The diagram below shows a set-up with the bulb lights up.



a) Identify the direction of electron flow in the external circuit.

From the zinc strip to the copper strip (1)

b) Suggest TWO functions of the porous pot.

The porous pot

- allows the flow of ions between the two solutions to complete the circuit; (1)
- separates the two solutions and hence prevents them from reacting with each other. (1)

c) Identify the ion that migrates towards the porous pot.

Sulphate ion (1)

Unit Exercise (p.36)

16 A student carried out an investigation based on the systems shown below.

higher in electrochemical series

system 1 $Cr^{3+}(aq) + 3e^- \rightleftharpoons Cr(s)$

system 2 $Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$

system 3 $Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$

lower in electrochemical series

The student set up two chemical cells to measure the voltages.

- Cell A was based on systems 1 and 2;
- Cell B was based on systems 2 and 3.

Unit Exercise (p.36)

16 (continued)

a) Draw a labelled diagram to show how the student could have set up cell A to measure the voltage.

Diagram showing
- complete circuit with electrodes, multimeter and salt bridge between solutions;
- Cr electrode in Cr^{3+} half cell;
- Ni electrode in Ni^{2+} half cell. (2)

b) For each cell, what would be the polarity of the nickel electrode?

Cell A + (1)
Cell B – (1)

Unit Exercise (p.36)

16 (continued)

c) For each cell, the student weighed the nickel electrode before connecting the cell and after disconnecting the cell.

The student found that

- the nickel electrode in cell A gained mass;
- the nickel electrode in cell B lost mass.

Explain these observations. Include equations in your answers.

In cell A, ions of nickel gained electrons to form atoms of nickel. Hence the nickel electrode gained mass. (1)

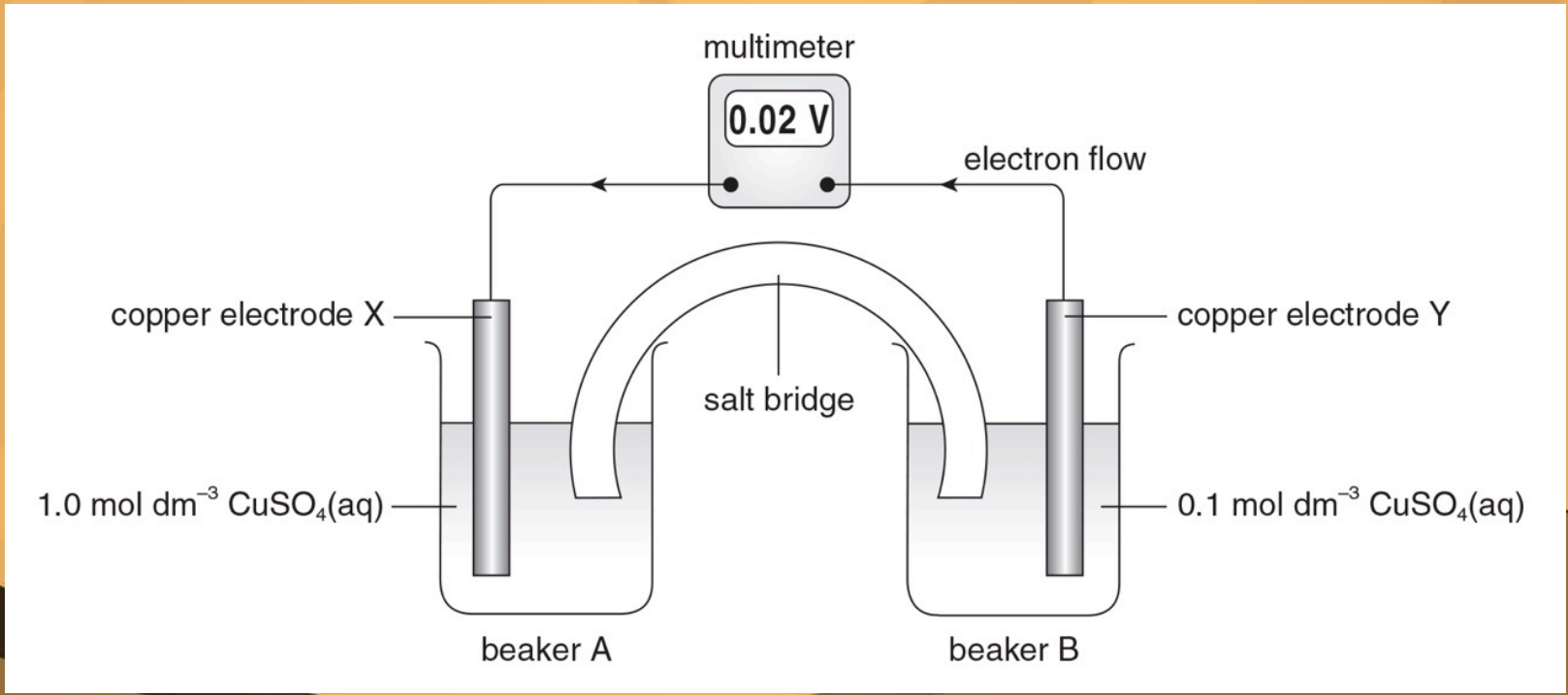
$2Cr(s) + 3Ni^{2+}(aq) \longrightarrow 2Cr^{3+}(aq) + 3Ni(s)$ (1)

In cell B, atoms of nickel lost electrons to form ions of nickel. Hence the nickel electrode lost mass. (1)

$Ni(s) + Pb^{2+}(aq) \longrightarrow Ni^{2+}(aq) + Pb(s)$ (1)

Unit Exercise (p.36)

17 A chemical cell is shown in the diagram below. In this cell, the amount of copper in the electrodes is much greater than the amount of copper(II) ions in the copper(II) sulphate solutions. Electrons flow from electrode Y to electrode X in the external circuit.



Unit Exercise (p.36)

17 (continued)

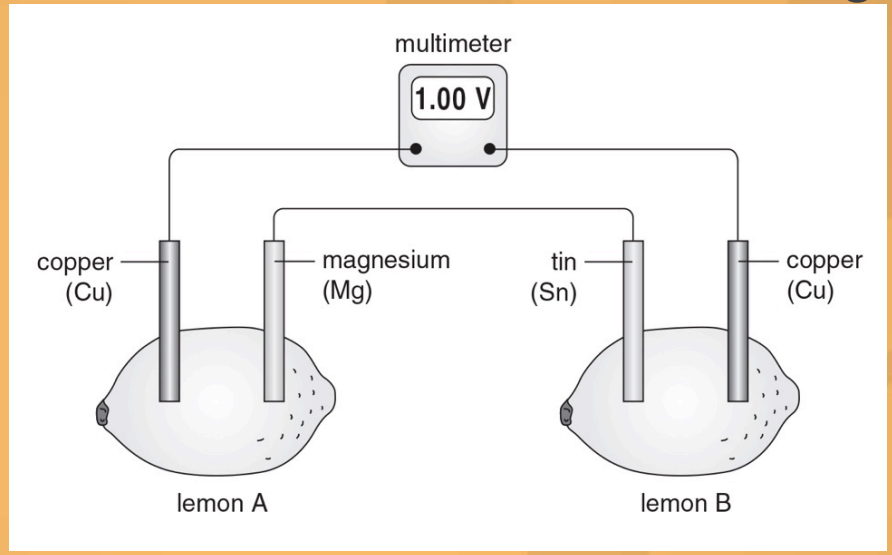
a) Explain how the salt bridge provides an electrical connection between the two electrodes.
It has mobile ions. (1)

b) Write the half equation for the change that occurs in beaker A.
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$ (1)

c) Explain why the current in the external circuit of this cell falls to zero after the cell has operated for some time.
Eventually, the $CuSO_4(aq)$ in each beaker will be at the same concentration. (1)

Unit Exercise (p.36)

18 The diagram below shows a set-up with metal strips inserted in fresh lemons. The multimeter reading in the set-up is +1.00 V.



Consider the relative positions of the three metals in the electrochemical series:

higher in electrochemical series

$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$

$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$

$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$

lower in electrochemical series

Unit Exercise (p.36)

18 (Continued)

a) State, with explanation, the direction of electron flow across the connecting wire between magnesium strip and tin strip.

Electron flow from magnesium strip to tin strip (1)
because magnesium loses electrons more easily than tin. (1)

b) For lemon A, write half equations for the changes that occur at:

i) copper strip;

$2H^+(aq) + 2e^- \longrightarrow H_2(g)$ (1)

ii) magnesium strip.

$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^-$ (1)

Unit Exercise (p.36)

18 (Continued)

c) Which two metal strips should be interchanged in order to increase the multimeter reading?

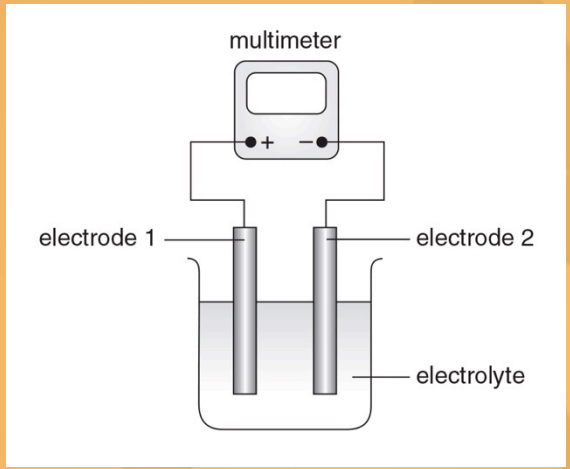
Interchange copper strip and tin strip in lemon B. (1)

d) Explain why fresh lemons should be used in the set-up.

Fresh lemons contain more juice so that the ions move more easily. (1)

Unit Exercise (p.36)

19 The tendencies of four metals (P, Q, R and S) to form ions can be compared using the set-up shown below.



Electrode 1 and electrode 2 are made from two different metals. The voltage of the chemical cell is recorded. The table below shows the results obtained.

Metal used as electrode 1	Metal used as electrode 2	Multimeter reading (V)
P	Q	+1.6
P	R	−1.1
P	S	−0.9
Q	R	−2.7
Q	S	−2.5
R	S	+0.2

Unit Exercise (p.36)

19 (Continued)

a) Which metal forms ions most readily?
Q (1)

b) Which metal forms ions least readily?
R (1)

c) Which two metals are the most similar in their tendencies to form ions?
R and S (1)