Gr. 12 Science: Redox reactions

R E D O X

- **Red**uction
- Gaining of electrons (e^-)
- The oxidizing agent undergoes reduction

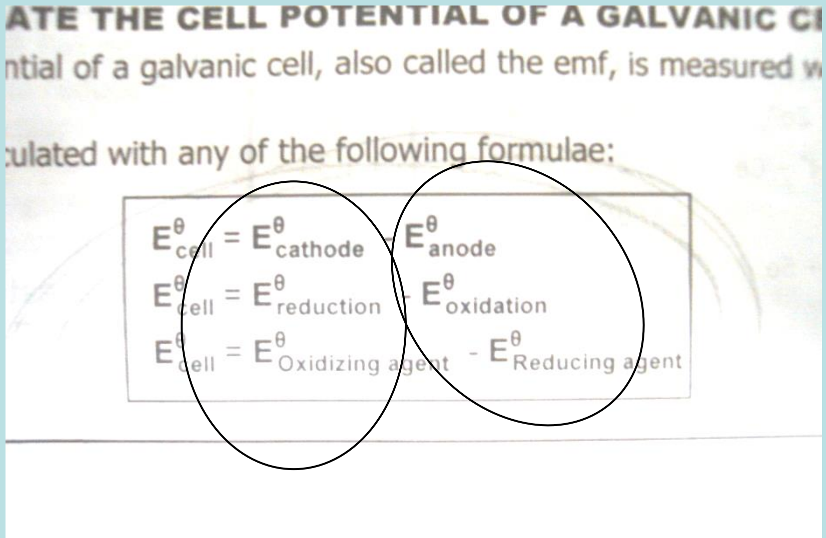
- **Ox**idation
- Loss of electrons (e^-)
- The reducing agent undergoes oxidation

- These two processes (reactions) will always take place simultaneously
- one substance must give e^- away (lose) and
- the other substance must take the e^- (gain)

p.228 (bottom)

The three equations are given in the exam.

They are forming a summary of the chapter:


ATE THE CELL POTENTIAL OF A GALVANIC CE

ntial of a galvanic cell, also called the emf, is measured w

culated with any of the following formulae:

$$E^{\theta}_{cell} = E^{\theta}_{cathode} - E^{\theta}_{anode}$$
$$E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$$
$$E^{\theta}_{cell} = E^{\theta}_{Oxidizing\ agent} - E^{\theta}_{Reducing\ agent}$$

Cathode=reduction=oxidizing agent

Anode=oxidation=reducing agent

I refer to "<u>positive gradient"</u> throughout the notes.

This simply refers to the orientation of the fingers for a <u>spontaneous</u> reaction and must NEVER be referred to in the exams.

In stead you MUST say:

The strong enough reducing agent (substance top right) can reduce the oxidising agent (substance bottom left)

OR

The strong enough oxidising agent (substance bottom left) can oxidise the reducing agent (substance top right)

Zn in HC*l*: open the half reaction table on p. 227
Remember this table only contains **REDUCTION** REACTIONS
(Regular mouse-clicking required)

TABLE 4B: STANDARD REDUCTION POTENTIALS
TABEL 4B: STANDAARD REDUKSIEPOTENSIALE

Increasing oxidising ability/*Toenemende oksiderende vermoë*

Increasing reducing ability/*Toenemende reduserende vermoë*

Half-reactions/*Halfreaksies*			E^θ (V)
$Li^+ + e^-$	$\rightleftharpoons$	Li	− 3,05
$K^+ + e^-$	$\rightleftharpoons$	K	− 2,93
$Cs^+ + e^-$	$\rightleftharpoons$	Cs	− 2,92
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	Ba	− 2,90
$Sr^{2+} + 2e^-$	$\rightleftharpoons$	Sr	− 2,89
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	Ca	− 2,87
$Na^+ + e^-$	$\rightleftharpoons$	Na	− 2,71
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	Mg	− 2,36
$A\ell^{3+} + 3e^-$	$\rightleftharpoons$	$A\ell$	− 1,66
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	Mn	− 1,18
$Cr^{2+} + 2e^-$	$\rightleftharpoons$	Cr	− 0,91
$2H_2O + 2e^-$	$\rightleftharpoons$	$H_2(g) + 2OH^-$	− 0,83
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	Zn	− 0,76
$Cr^{3+} + 3e^-$	$\rightleftharpoons$	Cr	− 0,74
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	Fe	− 0,44
$Cr^{3+} + e^-$	$\rightleftharpoons$	Cr^{2+}	− 0,41
$Cd^{2+} + 2e^-$	$\rightleftharpoons$	Cd	− 0,40
$Co^{2+} + 2e^-$	$\rightleftharpoons$	Co	− 0,28
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	Ni	− 0,27
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	Sn	− 0,14
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	Pb	− 0,13
$Fe^{3+} + 3e^-$	$\rightleftharpoons$	Fe	− 0,06
$2H^+ + 2e^-$	$\rightleftharpoons$	**$H_2(g)$**	**0,00**
$S + 2H^+ + 2e^-$	$\rightleftharpoons$	$H_2S(g)$	+ 0,14
$Sn^{4+} + 2e^-$	$\rightleftharpoons$	Sn^{2+}	+ 0,15
$Cu^{2+} + e^-$	$\rightleftharpoons$	Cu^+	+ 0,16
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(g) + 2H_2O$	+ 0,17
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	Cu	+ 0,34
$2H_2O + O_2 + 4e^-$	$\rightleftharpoons$	$4OH^-$	+ 0,40
$SO_2 + 4H^+ + 4e^-$	$\rightleftharpoons$	$S + 2H_2O$	+ 0,45
$Cu^+ + e^-$	$\rightleftharpoons$	Cu	+ 0,52
$I_2 + 2e^-$	$\rightleftharpoons$	$2I^-$	+ 0,54
$O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O_2	+ 0,68
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	+ 0,77
$NO_3^- + 2H^+ + e^-$	$\rightleftharpoons$	$NO_2(g) + H_2O$	+ 0,80
$Ag^+ + e^-$	$\rightleftharpoons$	Ag	+ 0,80
$Hg^{2+} + 2e^-$	$\rightleftharpoons$	$Hg(\ell)$	+ 0,85
$NO_3^- + 4H^+ + 3e^-$	$\rightleftharpoons$	$NO(g) + 2H_2O$	+ 0,96
$Br_2(\ell) + 2e^-$	$\rightleftharpoons$	$2Br^-$	+ 1,07
$Pt^{2+} + 2e^-$	$\rightleftharpoons$	Pt	+ 1,20
$MnO_2 + 4H^+ + 2e^-$	$\rightleftharpoons$	$Mn^{2+} + 2H_2O$	+ 1,23
$O_2(g) + 4H^+ + 4e^-$	$\rightleftharpoons$	$2H_2O$	+ 1,23
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons$	$2Cr^{3+} + 7H_2O$	+ 1,33
$C\ell_2(g) + 2e^-$	$\rightleftharpoons$	$2C\ell^-$	+ 1,36
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	+ 1,51
$H_2O_2 + 2H^+ + 2e^-$	$\rightleftharpoons$	$2H_2O$	+1,77
$Co^{3+} + e^-$	$\rightleftharpoons$	Co^{2+}	+ 1,81
$F_2(g) + 2e^-$	$\rightleftharpoons$	$2F^-$	+ 2,87

Put your fingers on the two reagents: Zn and H^+

Join the 2 points – if the line has a positive gradient, then the reaction is spontaneous

Write down the two half reactions (swop sides for the oxidation)

Red: $2H^+ + 2e^- \longrightarrow H_2$

Ox: $Zn \longrightarrow Zn^{2+} + 2e^-$

Nett ionic: $2H^+ + Zn \longrightarrow H_2 + Zn^{2+}$

Zn in $CuSO_4$: Keep open the half reaction table on p. 227 (Regular mouse-clicking required)

TABLE 4B: STANDARD REDUCTION POTENTIALS
TABEL 4B: STANDAARD REDUKSIEPOTENSIALE

Half-reactions/*Halfreaksies*			E^θ (V)
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$Na^+ + e^-$	$\rightleftharpoons$	Na	− 2,71
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$Al^{3+} + 3e^-$	$\rightleftharpoons$	Al	− 1,66
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	Mn	− 1,18
$Cr^{2+} + 2e^-$	$\rightleftharpoons$	Cr	− 0,91
$2H_2O + 2e^-$	$\rightleftharpoons$	$H_2(g) + 2OH^-$	− 0,83
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	Zn	− 0,76
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$Co^{2+} + 2e^-$	$\rightleftharpoons$	Co	− 0,28
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	Ni	− 0,27
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	Sn	− 0,14
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	Pb	− 0,13
$Fe^{3+} + 3e^-$	$\rightleftharpoons$	Fe	− 0,06
$\mathbf{2H^+ + 2e^-}$	$\rightleftharpoons$	$\mathbf{H_2(g)}$	**0,00**
$S + 2H^+ + 2e^-$	$\rightleftharpoons$	$H_2S(g)$	+ 0,14
$Sn^{4+} + 2e^-$	$\rightleftharpoons$	Sn^{2+}	+ 0,15
$Cu^{2+} + e^-$	$\rightleftharpoons$	Cu^+	+ 0,16
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(g) + 2H_2O$	+ 0,17
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$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	+ 0,77
$NO_3^- + 2H^+ + e^-$	$\rightleftharpoons$	$NO_2(g) + H_2O$	+ 0,80
$Ag^+ + e^-$	$\rightleftharpoons$	Ag	+ 0,80
$Hg^{2+} + 2e^-$	$\rightleftharpoons$	$Hg(l)$	+ 0,85
$NO_3^- + 4H^+ + 3e^-$	$\rightleftharpoons$	$NO(g) + 2H_2O$	+ 0,96
$Br_2(l) + 2e^-$	$\rightleftharpoons$	$2Br^-$	+ 1,07
$Pt^{2+} + 2e^-$	$\rightleftharpoons$	Pt	+ 1,20
$MnO_2 + 4H^+ + 2e^-$	$\rightleftharpoons$	$Mn^{2+} + 2H_2O$	+ 1,23
$O_2(g) + 4H^+ + 4e^-$	$\rightleftharpoons$	$2H_2O$	+ 1,23
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons$	$2Cr^{3+} + 7H_2O$	+ 1,33
$Cl_2(g) + 2e^-$	$\rightleftharpoons$	$2Cl^-$	+ 1,36
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	+ 1,51
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$Co^{3+} + e^-$	$\rightleftharpoons$	Co^{2+}	+ 1,81
$F_2(g) + 2e^-$	$\rightleftharpoons$	$2F^-$	+ 2,87

Increasing oxidising ability/*Toenemende oksiderende vermoë*

Increasing reducing ability/*Toenemende reduserende vermoë*

Put your fingers on the two reagents: Zn and Cu^{2+}

Join the 2 points – if the line has a positive gradient, then the reaction is spontaneous

Write down the two half reactions (swop sides for the oxidation)

Red: $Cu^{2+} + 2e^- \longrightarrow Cu$

Ox: $Zn \longrightarrow Zn^{2+} + 2e^-$

Nett ionic: $Cu^{2+} + Zn \longrightarrow Cu + Zn^{2+}$

Blue Colourless

Cu in $AgNO_3$: Keep open the half reaction table on p. 227
(Regular mouse-clicking required)

TABLE 4B: STANDARD REDUCTION POTENTIALS
TABEL 4B: STANDAARD REDUKSIEPOTENSIALE

Increasing oxidising ability/*Toenemende oksiderende vermoë*

Half-reactions/*Halfreaksies*	E^θ (V)
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$Ba^{2+} + 2e^- \rightleftharpoons Ba$	− 2,90
$Sr^{2+} + 2e^- \rightleftharpoons Sr$	− 2,89
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	− 2,87
$Na^+ + e^- \rightleftharpoons Na$	− 2,71
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	− 2,36
$Al^{3+} + 3e^- \rightleftharpoons Al$	− 1,66
$Mn^{2+} + 2e^- \rightleftharpoons Mn$	− 1,18
$Cr^{2+} + 2e^- \rightleftharpoons Cr$	− 0,91
$2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$	− 0,83
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	− 0,76
$Cr^{3+} + 3e^- \rightleftharpoons Cr$	− 0,74
$Fe^{2+} + 2e^- \rightleftharpoons Fe$	− 0,44
$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	− 0,41
$Cd^{2+} + 2e^- \rightleftharpoons Cd$	− 0,40
$Co^{2+} + 2e^- \rightleftharpoons Co$	− 0,28
$Ni^{2+} + 2e^- \rightleftharpoons Ni$	− 0,27
$Sn^{2+} + 2e^- \rightleftharpoons Sn$	− 0,14
$Pb^{2+} + 2e^- \rightleftharpoons Pb$	− 0,13
$Fe^{3+} + 3e^- \rightleftharpoons Fe$	− 0,06
$2H^+ + 2e^- \rightleftharpoons H_2(g)$	**0,00**
$S + 2H^+ + 2e^- \rightleftharpoons H_2S(g)$	+ 0,14
$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$	+ 0,15
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+ 0,16
$SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons SO_2(g) + 2H_2O$	+ 0,17
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+ 0,34
$2H_2O + O_2 + 4e^- \rightleftharpoons 4OH^-$	+ 0,40
$SO_2 + 4H^+ + 4e^- \rightleftharpoons S + 2H_2O$	+ 0,45
$Cu^+ + e^- \rightleftharpoons Cu$	+ 0,52
$I_2 + 2e^- \rightleftharpoons 2I^-$	+ 0,54
$O_2(g) + 2H^+ + 2e^- \rightleftharpoons H_2O_2$	+ 0,68
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+ 0,77
$NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2(g) + H_2O$	+ 0,80
$Ag^+ + e^- \rightleftharpoons Ag$	+ 0,80
$Hg^{2+} + 2e^- \rightleftharpoons Hg(l)$	+ 0,85
$NO_3^- + 4H^+ + 3e^- \rightleftharpoons NO(g) + 2H_2O$	+ 0,96
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-$	+ 1,07
$Pt^{2+} + 2e^- \rightleftharpoons Pt$	+ 1,20
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$Co^{3+} + e^- \rightleftharpoons Co^{2+}$	+ 1,81
$F_2(g) + 2e^- \rightleftharpoons 2F^-$	+ 2,87

Increasing reducing ability/*Toenemende reduserende vermoë*

Put your fingers on the two reagents: Ag^+ and Cu

Join the 2 points – if the line has a positive gradient, then the reaction is spontaneous

Write down the two half reactions (swop sides for the oxidation)

Ox: $Cu \longrightarrow Cu^{2+} + 2e-$

Red: $Ag^+ + e^- \longrightarrow Ag$

Nett ionic: $Ag^+ + Cu \longrightarrow Ag + Cu^{2+}$

Colourless Blue

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p215-224

The redox reaction between Copper (wire) and Silver nitrate.
(The silver tree experiment)

Take note: the blue solution that formed from a colourless solution,
Because of the Cu^{2+} ion that formed from Cu

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p215-224

Study p217 Example 1

Find the equations for Al and Cu^{2+} (-1,66 and +0,34)

(Be sure to see that there is a "positive gradient" between the two fingers)

p.218 : last section – **REDOX REACTIONS AND ELECTROCHEMICAL CELLS**

This far we looked at spontaneous reactions where no energy was added from outside.

Two types of **electrochemical** cells exist:

1. Galvanic (voltaic) cell: next chapter p 221 – 226.
   This cell converts chemical energy to electrical energy
2. Electrolytic cell: p 243 – 248.
   This cell converts electrical to chemical energy.

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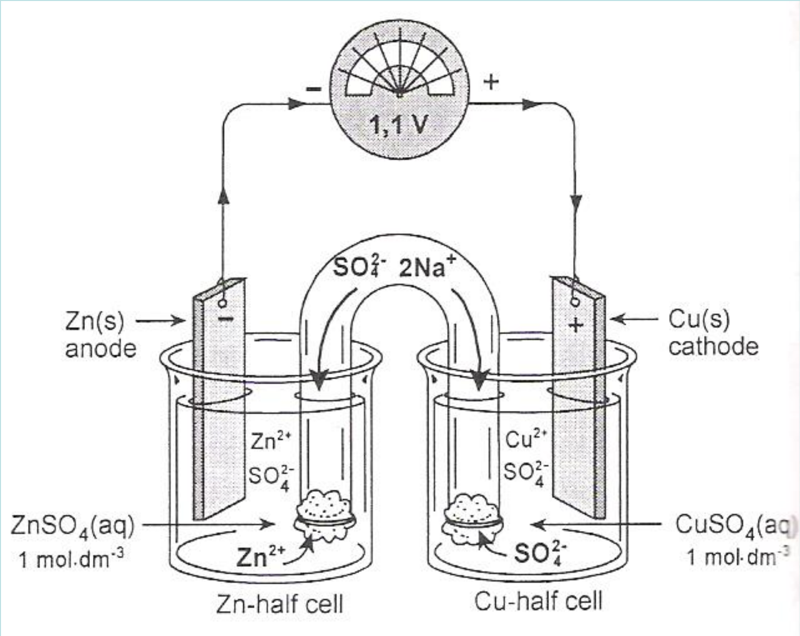
p215-224

The Zn-Cu galvanic/voltaic cell



- •Place your fingers on Cu and Zn – move the bottom finger to have "positive gradient"
- •Write down the reduction and oxidation reactions (see p 223 no.5)
- •Remember the electrons will flow towards the Cu^{2+} which is reduced to Cu and deposits onto the Cu electrode.
- •Electrons are given off from the Zn electrode.
- •Cell notation will be discussed now.

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The galvanic/voltaic cell

Salt bridge functions:

1. Pathway for **ions** (NOT electrons!! Electrons flow in a wire, ions move ('swim') in liquid)
2. Establishes charge neutrality in the solutions
3. Completes the circuit

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p215-224

The Zn-Cu galvanic/voltaic cell notation

•Cell notation is a very short way of writing down what the galvanic cell consists of:

•The order to follow:

anode | solution at anode || solution at cathode | cathode

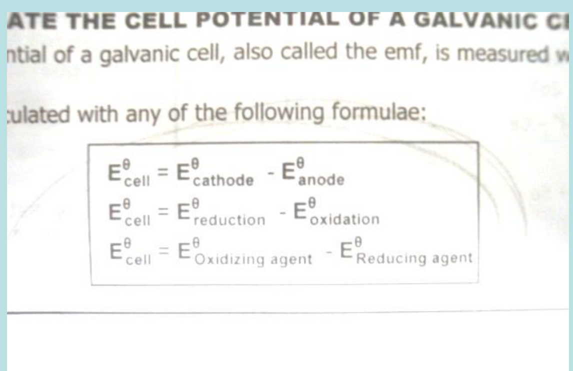
(the double lines in the middle represent the saltbridge)

REMEMBER: oxidation at ANODE

reduction at CATHODE

• $Zn(s)\ |Zn^{2+}(aq)\ (25^{o}C, 1\ mol.dm^{-3})\ ||\ Cu^{2+}\ (aq)\ (25^{o}C, 1mol.dm^{-3})\ |Cu\ (s)$

•Cell potential



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$$E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$$
$$E^{\theta}_{cell} = E^{\theta}_{Oxidizing\ agent} - E^{\theta}_{Reducing\ agent}$$

Electrolytic cells

Energy conversion:

Electrical $\longrightarrow$ Chemical

Study p 243

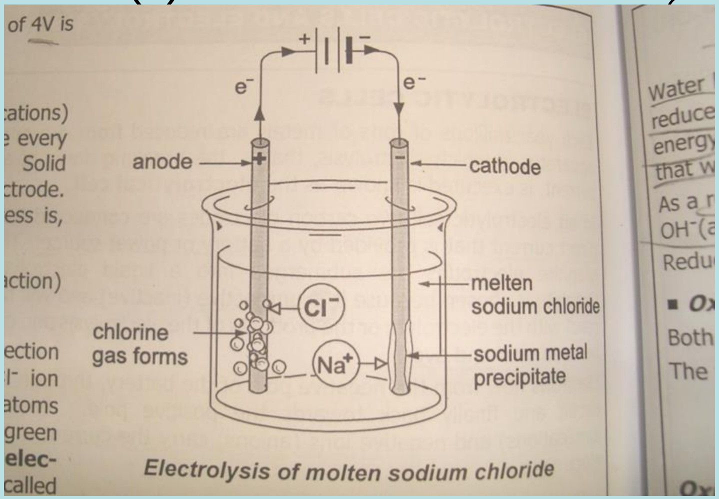
Sodium chloride cell p 244: Molten NaCl (table salt)

Identify the <u>ions</u>

Na+ and Cl^-

Attracted to negative electrode: Na^+ reduced to Na (s)

Attracted to positive electrode: Cl^- oxidised to Cl_2



Sodium chloride cell p 244-245: Dissolved NaCl (table salt in water)

Identify the <u>ions and H_2O</u> and find them on the half reaction table

Weakest oxidising angent

Strongest reducing agent

Half-reactions			E^θ (V)
$Li^+ + e^-$	⇌	Li	– 3,04
$K^+ + e^-$	⇌	K	– 2,92
$Ba^{2+} + 2e^-$	⇌	Ba	– 2,90
$Ca^{2+} + 2e^-$	⇌	Ca	– 2,87
$Na^+ + e^-$	⇌	Na	– 2,71
$Mg^{2+} + 2e^-$	⇌	Mg	– 2,37
$A\ell^{3+} + 3e^-$	⇌	$A\ell$	– 1,66
$Mn^{2+} + 2e^-$	⇌	Mn	– 1,18
$2H_2O + 2e^-$	⇌	$H_2(g) + 2OH^-$	– 0,83
$Zn^{2+} + 2e^-$	⇌	Zn	– 0,76
$Cr^{2+} + 2e^-$	⇌	Cr	– 0,74
$Cr^{3+} + 3e^-$	⇌	Cr	– 0,74
$Fe^{2+} + 2e^-$	⇌	Fe	– 0,44
$Cr^{3+} + e^-$	⇌	Cr^{2+}	– 0,41
$Cd^{2+} + 2e^-$	⇌	Cd	– 0,40
$Co^{2+} + 2e^-$	⇌	Co	– 0,28
$Ni^{2+} + 2e^-$	⇌	Ni	– 0,25
$Sn^{2+} + 2e^-$	⇌	Sn	– 0,14
$Pb^{2+} + 2e^-$	⇌	Pb	– 0,13
$Fe^{3+} + 3e^-$	⇌	Fe	– 0,04
$2H^+ + 2e^-$	⇌	$H_2(g)$	0,00
$S + 2H^+ + 2e^-$	⇌	$H_2S(g)$	+ 0,14
$Sn^{4+} + 2e^-$	⇌	Sn^{2+}	+ 0,15
$Cu^{2+} + e^-$	⇌	Cu^+	+ 0,16
$SO_4^{2-} + 4H^+ + 4e^-$	⇌	$SO_2(g) + 2H_2O$	+ 0,17
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$SO_2 + 4H^+ + 2e^-$	⇌	$S + 2H_2O$	+ 0,45
$Cu^+ + e^-$	⇌	Cu	+ 0,52
$I_2 + 2e^-$	⇌	$2I^-$	+ 0,54
$O_2(g) + 2H^+ + 2e^-$	⇌	H_2O_2	+ 0,68
$Fe^{3+} + e^-$	⇌	Fe^{2+}	+ 0,77
$NO_3^- + 2H^+ + e^-$	⇌	$NO_2(g) + H_2O$	+ 0,78
$Hg^{2+} + 2e^-$	⇌	$Hg(\ell)$	+ 0,78
$Ag^+ + e^-$	⇌	Ag	+ 0,80
$NO_3^- + 4H^+ + 3e^-$	⇌	$NO(g) + 2H_2O$	+ 0,96
$Br_2(\ell) + 2e^-$	⇌	$2Br^-$	+ 1,06
$O_2(g) + 4H^+ + 4e^-$	⇌	$2H_2O$	+ 1,23
$MnO_2 + 4H^+ + 2e^-$	⇌	$Mn^{2+} + 2H_2O$	+ 1,28
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇌	$2Cr^{3+} + 7H_2O$	+ 1,33
$C\ell_2(g) + 2e^-$	⇌	$2C\ell^-$	+ 1,36
$MnO_4^- + 8H^+ + 5e^-$	⇌	$Mn^{2+} + 4H_2O$	+ 1,52
$Co^{3+} + e^-$	⇌	Co^{2+}	+ 1,82
$F_2(g) + 2e^-$	⇌	$2F^-$	+ 2,87

Increasing oxdising ability

Increasing reducing ability

Strongest oxidising agent

Weakest reducing agent

H_2O has more positive value than Na^+. H_2O reduced easier. Na^+ not reduced to Na

H_2O has less positive value than Cl^-. H_2O oxidised easier. Cl^- also oxidised (since values are close)

Sodium chloride cell p 244: Dissolved NaCl (table salt)

Identify the ions

$Na+$ and Cl^- and H_2O

Not reduced

Attracted to positive electrode: Cl^- oxidised to Cl_2

H_2O reduced to H_2 and OH^- AND

H_2O oxidised to O_2 and $4H^+$

See the reactions on p. 245

The final products: Cl_2 gas, H_2 gas, OH^- ions (aq), Na^+ ions (aq).

Copper chloride cell p 246: Solution of $CuCl_2$

Identify the <u>ions</u>

Cu^{2+} and Cl^- and water

Attracted to negative electrode: Cu^{2+} reduced to Cu (s)

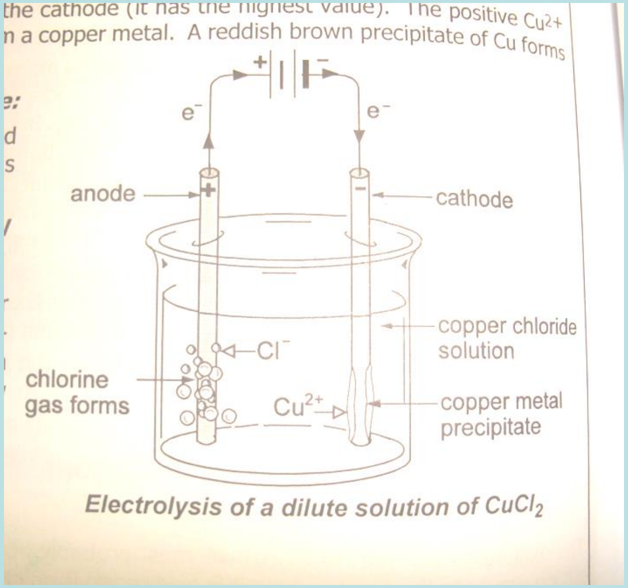
Attracted to positive electrode: Cl^- oxidised to Cl_2

Not reduced or oxidised

Cl^- has highest value: oxidised

Cu^{2+} has highest value: reduced

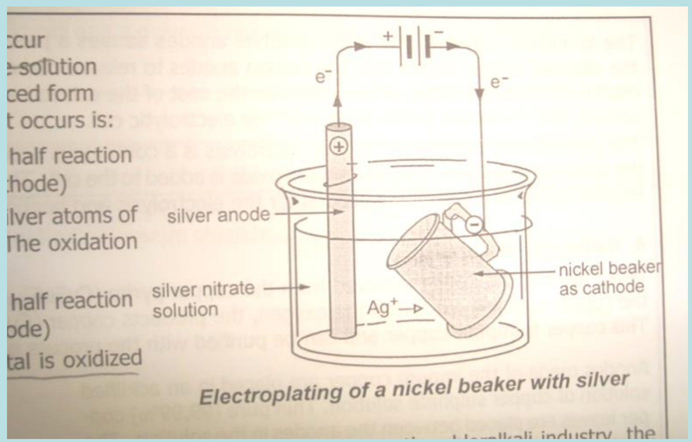
See explanations on p. 246.



Electroplating p. 246-7

Cheap metals are covered in more expensive metals:

The metal object to be "covered" becomes the cathode.



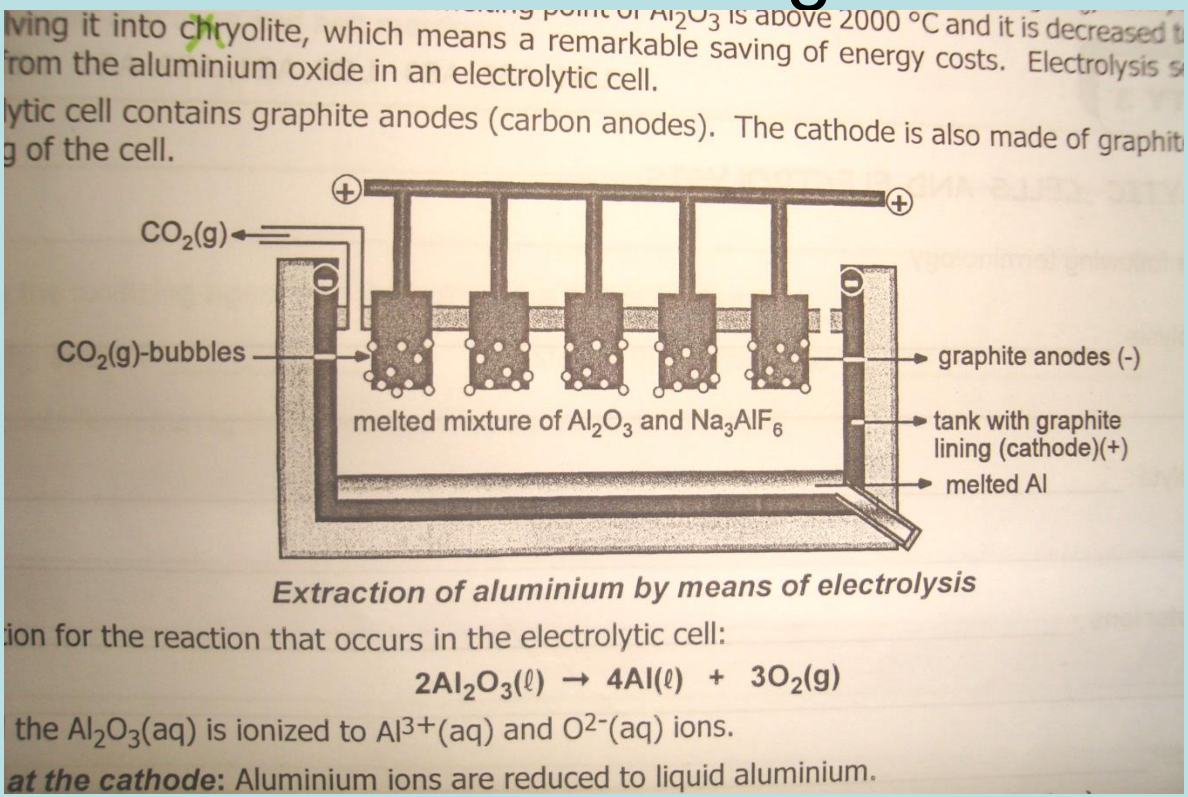
Electroplating of a nickel beaker with silver

- Note: the anode is silver, Ag oxidised to Ag^+
- The solution contains silver ions: Ag^+ reduced to Ag.
- The beaker(cathode) covered in Ag
- Oxidation and reduction occurs at <u>same rate</u>
- Concentration of Ag^+ remains constant

Preparation of chemicals p.247

Take note of no.2 on the page

Extraction of aluminium: read background


...elting point of Al_2O_3 is above 2000 °C and it is decreased t...
...lving it into chryolite, which means a remarkable saving of energy costs. Electrolysis s...
...from the aluminium oxide in an electrolytic cell.

...lytic cell contains graphite anodes (carbon anodes). The cathode is also made of graphit...
...g of the cell.

Extraction of aluminium by means of electrolysis

...ion for the reaction that occurs in the electrolytic cell:

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

... the $Al_2O_3(aq)$ is ionized to $Al^{3+}(aq)$ and $O^{2-}(aq)$ ions.

at the cathode: Aluminium ions are reduced to liquid aluminium.

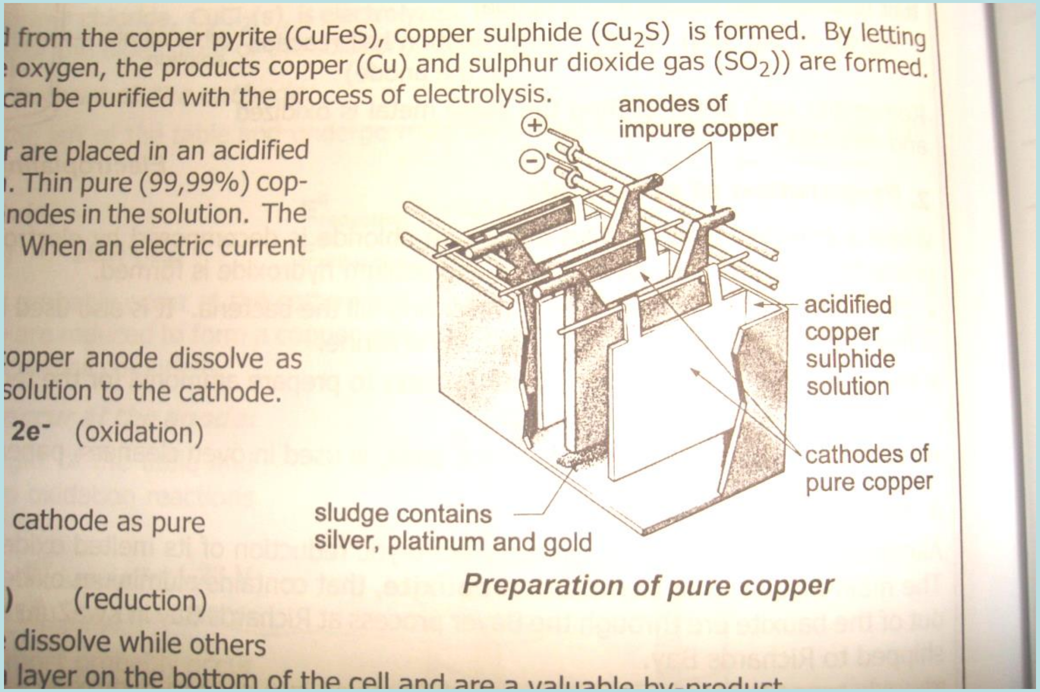
Al_2O_3 consists of Al^{3+} and O^{2-}

O^{2-} becomes oxidised to O_2 which reacts with electrodes at high temp. and gives off CO_2. (p.248)

Take note of ENVIRONMENTAL problems

Refinery of copper (p. 248)

Study this in textbook



d from the copper pyrite (CuFeS), copper sulphide (Cu_2S) is formed. By letting
e oxygen, the products copper (Cu) and sulphur dioxide gas (SO_2)) are formed.
can be purified with the process of electrolysis.

r are placed in an acidified
. Thin pure (99,99%) cop-
nodes in the solution. The
When an electric current

opper anode dissolve as
solution to the cathode.
2e⁻ (oxidation)

cathode as pure

) (reduction)
e dissolve while others
layer on the bottom of the cell and are a valuable by-product

Preparation of pure copper

Impure copper plates 'fall apart' and Cu oxidised to Cu^{2+}

The Cu^{2+} is reduced to Cu and deposits on the pure Cu plates (pure plates become thicker.

Do for class work:
p.249 no.4,6,8

These question are typical exam questions.

Answers displayed later

p.249 no.4,6,8

4.1 At cathode:
$K^+ + e^- \rightarrow K$ $E° = -2{,}92V$
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ $E° = -0{,}83V$
The reduction of water most likely to occur.
At Anode:
$2Br^- \rightarrow Br_2 + 2e$ $E° = 1{,}06V$
$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ $E° = 1{,}32V$
The oxidation of O_2 to H_2O would most likely occur.

4.2 At cathode:
$Ag^+ + e^- \rightarrow Ag$ $E° = 0{,}80V$
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ $E° = -0{,}83$
The reduction of H_2O is most likely to occur.
At anode:
$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ $E° = 1{,}32V$

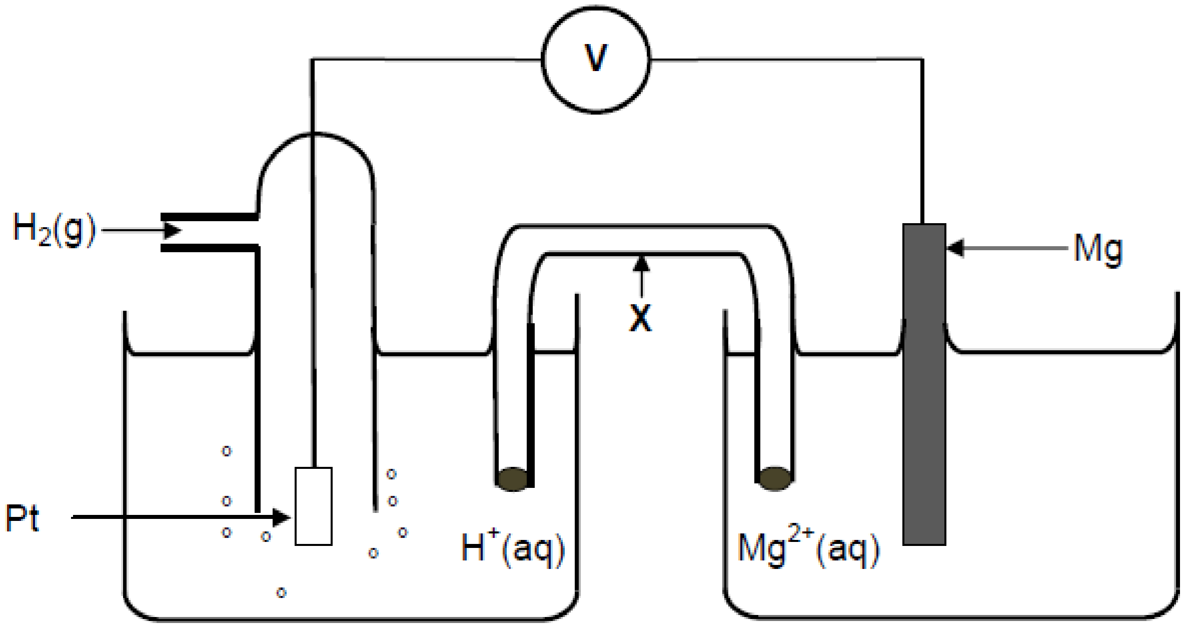
4.3 At cathode:
$Mg^{2+} + 2e^- \rightarrow Mg$ $E° = -2{,}37V$
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ $E° = -0{,}83$
The reduction of SO_4^{2-} is most likely to occur or $SO_4^{2-} + 4H^+ + 4e^- \rightarrow SO_2 + 2H_2O$
$E° = 0{,}17V$
At anode:
$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ $E° = 1{,}32V$

6.1 Bauxite mined in Australia – South Africa does not have this.
6.2 $A\ell_2O_3$
6.3 (cathode)
$A\ell^{3+} + 3e^- \rightarrow A\ell$
Anode: $2O^{2-} \rightarrow O_2 + 4e^-$
6.4 As the temperature increases the carbon reacts with O_2 to form CO_3 C-anode burns away.
6.5 Cooking ware , motor spares, windows, doors, etc.
6.6 + Electroplating: $Ag(s) \rightarrow Ag^+ + e^-$ is oxidised and then $Ag^+(aq) + e^- \rightarrow Ag(s)$ is reduced to form the solid on the metal being covered.
Refinery of copper: Impure copper is purified.

8.1 Positive
8.2 This is where oxidation occurs.
8.3 $Cu\ (s) \rightarrow Cu^{2+} + 2e^-$
8.4 A to B
8.5 It is often Ag, Pt or Au which is valuable.

Exam questions

The electrochemical cell represented below consists of a hydrogen half-cell and a magnesium half-cell at standard conditions.



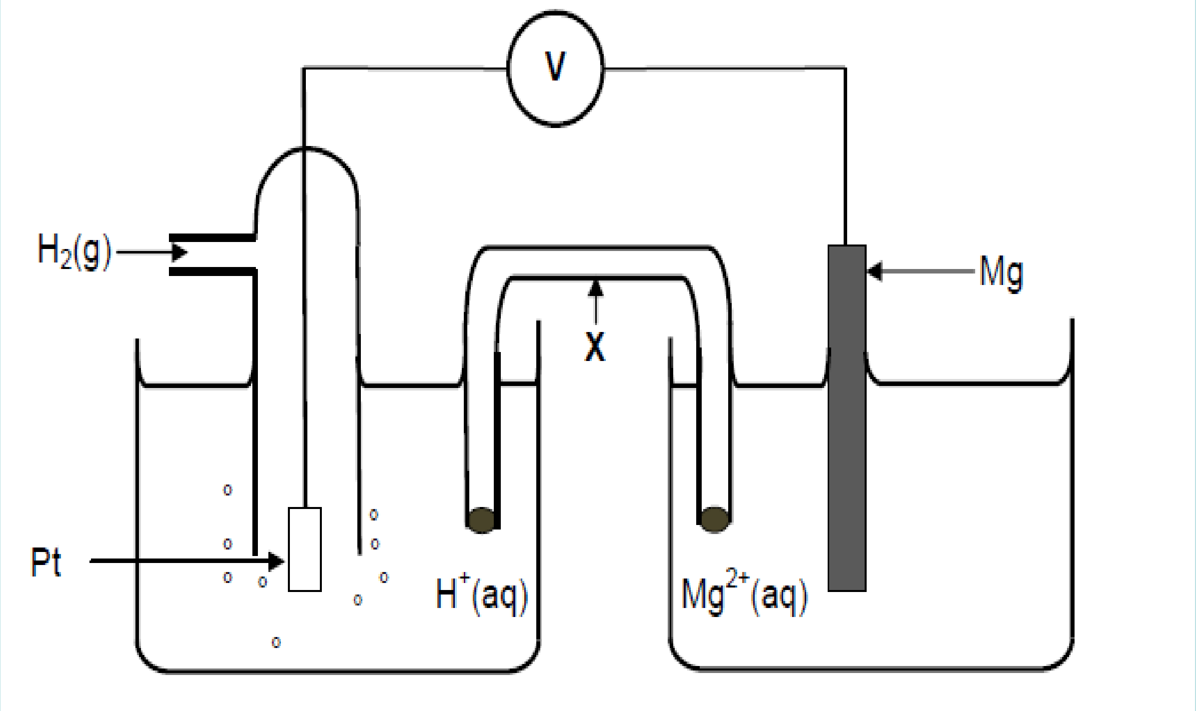
The reading on the voltmeter is 2,36 V.

8.1 Apart from concentration, write down TWO other conditions needed for the hydrogen half-cell to function at standard conditions. (2)

8.2 Write down the name of the item of apparatus labelled **X**. (1)

8.3 Is magnesium the ANODE or CATHODE in the cell above? Refer to the relative strengths of reducing agents to explain the answer. (4)

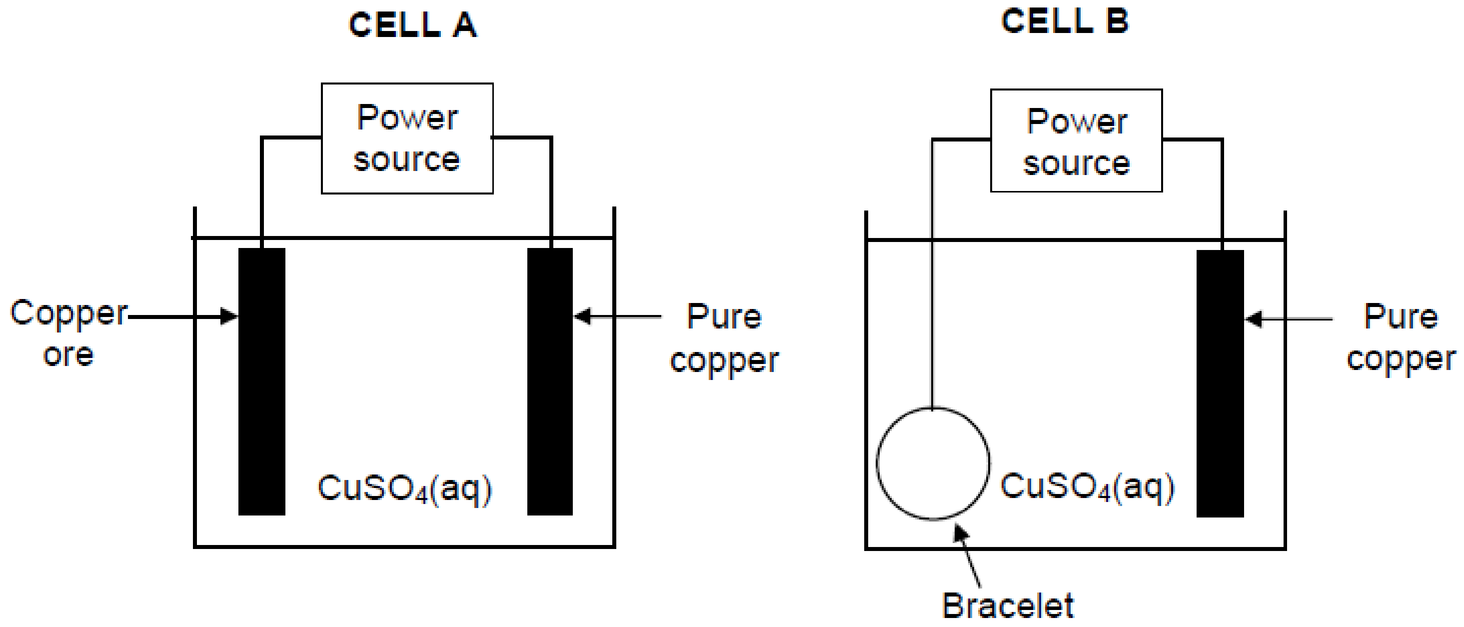
Exam questions



8.4	Write down the cell notation for this cell.	(3)
8.5	Calculate the standard reduction potential of the magnesium half-cell. Show ALL your working.	(4)
8.6	Write down the balanced NET (overall) cell reaction that takes place in this cell. No spectator ions are required.	(3)
		[17]

Exam questions

The simplified diagrams below represent two electrochemical cells, **A** and **B**, used in INDUSTRY. Cell **A** is used in the purification of copper ore containing silver and platinum impurities. Cell **B** is used to electroplate a bracelet with a layer of copper.



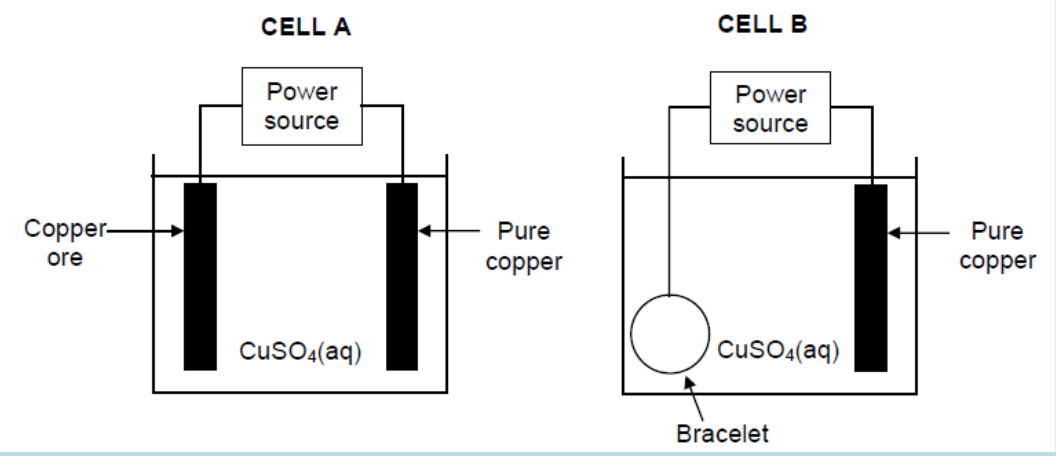
9.1 Write down the name of the type of electrochemical cell (ELECTROLYTIC or GALVANIC) of which the above two cells are examples. (1)

9.2 Pure copper is used as one of the electrodes in each of the cells above. In which cell (**A** or **B**) is the pure copper the:

9.2.1 Cathode (1)

9.2.2 Anode (1)

Exam questions



9.3 Consider cell **B**. Initially the $CuSO_4(aq)$ has a blue colour.

9.3.1 How will the intensity of the blue colour change whilst the cell is functioning? Write down INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (3)

9.3.2 Write down the half-reaction that takes place at the pure copper electrode. (2)

9.4 Consider cell **A**.

9.4.1 Give a reason why the sludge formed in this cell is of economic importance. (1)

9.4.2 Name ONE negative impact that the energy usage in this process has on the environment. (2)

[11]

Exam question: Memo

8.1 Pressure/*Druk*: 101,3 kPa ($1,013 \times 10^5$ Pa) ✓
Temperature/*Temperatuur*: 25 °C (298 K) ✓ (2)

8.2 Salt bridge/*Soutbrug* ✓ (1)

8.3 Anode ✓
It/ Mg is a stronger reducing agent ✓ than H_2. ✓
and (Mg) will be oxidised. ✓

OR/*OF*
Anode ✓
H_2 is a weaker reducing agent ✓ than Mg/ it. ✓
and Mg will be oxidised. ✓ (4)

8.4
$Mg(s) \mid Mg^{2+}(1\ mol{\cdot}dm^{-3}) \parallel H^+(1\ mol{\cdot}dm^{-3}) \mid H_2(g) \mid Pt(s)$ ✓✓✓

OR/*OF*

$Mg(s) \mid Mg^{2+}(aq) \parallel H^+(aq) \mid H_2(g) \mid Pt(s)$ ✓✓✓

OR/*OF*

$Mg \mid Mg^{2+} \parallel H^+ \mid H_2 \mid Pt$ ✓✓✓

Accept/*Aanvaar*:

$Mg \mid Mg^{2+} \parallel H^+ \mid H_2 , Pt$ (3)

8.5 **Option 1/*Opsie 1***
$E^\theta_{cell} = E^\theta_{cathode} - E^\theta_{anode}$ ✓
$2,36$ ✓ $= 0,00 - (E^\theta_{anode})$ ✓
$E^\theta_{anode} = -2,36$ V ✓

Option 2/*Opsie 2*

$$\checkmark\begin{cases} Mg \rightarrow Mg^{2+} + 2e^- & E° = +2,36 \\ 2H^+ + 2e^- \rightarrow H_2 & E° = 0,00 \checkmark \\ & E° = 2,36\ V \checkmark \end{cases}$$

Mg (red. pot.) = -2,36 V ✓

Notes/*Aantekeninge*
Accept any other correct formula from the data sheet.
Aanvaar enige ander korrekte formule vanaf gegewensblad.

Any other formula using unconventional abbreviations, e.g. $E°_{cell} = E°_{OA} - E°_{RA}$ followed by correct substitutions: $\frac{3}{4}$
Enige ander formule wat onkonvensionele afkortings gebruik bv. $E°_{sel} = E°_{OM} - E°_{RM}$

(4)

8.6 $Mg(s) + 2H^+(aq)$ ✓ $\rightarrow Mg^{2+}(aq) + H_2(g)$ ✓ Bal. ✓

Notes/*Aantekeninge*
• Reactants ✓ Products ✓ Balancing ✓ *Reaktanse* ✓ *Produkte* ✓ *Balansering* ✓
• Ignore if phases are omitted./*Ignoreer indien fases uitgelaat word.*
• Ignore/Ignoreer $\rightleftharpoons$
• Marking rule 3.9/*Nasienreël 3.9*
• Marking rule 3.4: One mark is forfeited when the charge of an ion is omitted per equation (not for the charge on an electron). *Nasienreël 3.4: Een punt word verbeur per vergelyking indien die lading op 'n ioon uitgelaat word (nie vir die lading op 'n elektron nie.)*

(3)

[17]

QUESTION 9/*VRAAG 9*

9.1 Electrolytic/*Elektrolities* ✓ (1)

9.2

9.2.1 A ✓ (1)

9.2.2 B ✓ (1)

9.3

9.3.1 Remains the same ✓
The <u>rate of oxidation</u> of copper at the anode is <u>equal</u> ✓
to the <u>rate of reduction</u> of copper(II) ions at the cathode. ✓

Bly dieselfde ✓
Die <u>tempo van oksidasie</u> van koper by die anode is <u>gelyk aan</u> ✓
Die <u>tempo van reduksie</u> van koper(II)-ione by die katode. ✓ (3)

9.3.2 $Cu \rightarrow Cu^{2+} + 2e^-$ ✓✓

Notes/*Aantekeninge*
$Cu \rightleftharpoons Cu^{2+} + 2e^-$ $(\frac{1}{2})$
$Cu^{2+} + 2e^- \rightarrow Cu$ $(\frac{0}{2})$
$Cu^{2+} + 2e^- \leftarrow Cu$ $(\frac{2}{2})$
$Cu^{2+} + 2e^- \rightleftharpoons Cu$ $(\frac{0}{2})$

(2)

9.4

9.4.1 It <u>contains precious metals</u>/valuable/expensive metals. ✓
Dit <u>bevat edelmetale</u>/waardevole/duur metale. ✓ (1)

9.4.2 Consumes <u>large amount of electricity</u>/energy. ✓
<u>Depletes coal resources.</u> **OR** Contributes to global warming. **OR** Habitats destroyed in mining of coal. **OR** Contributes to acid rain. ✓