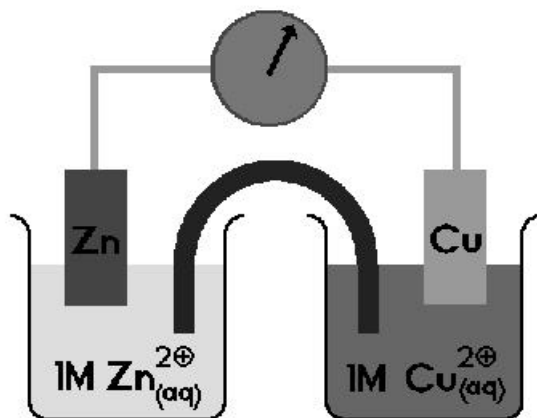


Teacher's Notes

REDOX



Duration: 30 Minutes

Years: 11-12

PROGRAM CONTENT

INTRODUCTION

Oxidation and Reduction are described in terms of losing and gaining electrons. The difference between spontaneous (electrochemical) and forced (electrolytic) redox reactions is emphasised.

SECTION 1: ORIGIN OF THE NAME, OXIDATION

- Combustion.
- Aerial (atmospheric) oxidation.
- Biochemical oxidation.
- Liquid oxygen (properties).
- Liquid oxygen (as a fuel).
- Oxygen bound in compounds.

SECTION 2: EVOLUTION OF THE DEFINITION

Written equations

- OXIDATION - "A gain of oxygen", or "A loss of hydrogen".
- REDUCTION - "A gain of hydrogen", or "a loss of oxygen".

SECTION 3: ELECTRONEGATIVITY

(Trends in the periodic table)

SECTION 4: OXIDATION NUMBER

(The rules and a sequential reduction of manganese.)

SECTION 5: HALF EQUATIONS

SECTION 6: HOW TO WRITE AND BALANCE REDOX EQUATIONS

SECTION 7: HALF CELLS

SECTION 8: STANDARD ELECTRODE REDUCTION POTENTIALS

- The "Daniel Cell" (Zn/Cu cell).
- Spontaneity from the cell voltage (E^\ominus).
- The rechargeable, lead-acid storage battery.

INTRODUCTION

Redox reactions are electron transfer reactions. The first example used is a copper strip placed in zinc sulphate. The equation for this reaction is written and balanced by observation. Balancing by observation should be practised:

eg.,

- Hydrogen gas evolves when magnesium metal is placed in hydrochloric acid. Write a balanced equation for this reaction.
- Ethanol is oxidised to acetic (ethanoic) acid by acidified potassium dichromate solution which loses its orange colour in the reaction. Write a balanced equation for this reaction.

Aluminium is produced by supplying electrons to a molten solution of aluminium oxide dissolved in cryolite (Na_2AlF_6). The electric current keeps the solution molten & reduces the aluminium to metal which sinks to the bottom. The reduction half reaction forced to proceed is:



SECTION 1: ORIGIN OF THE NAME, OXIDATION

(a) **Combustion:** Wood, coal, oil, the common and age old fuels are Carbon compounds. Wood is mostly cellulose. Balanced equations can be written if the exact formula of the fuel is known as the products are H_2O and CO_2 .

(b) **Aerial (atmospheric) oxidation:** Oxygen is the most abundant element, making up almost half of the material on Earth. The composition of the atmosphere is shown in the attached table. There are a number of straightforward demonstrations of aerial oxidation:-

"Tested Demonstrations in Chemistry", by Alyea & Dutton, 6th edition, p187.

"Colourful Chemistry", by Gipps & Friedmans, p6.

"Luminol", J Chem Ed 47, 519, 1977.

- (c) **Biochemical oxidation:** Respiration, Blood (oxygenation), Oxyhaemoglobin \ddot{O} Deoxyhaemoglobin.
- (d) **Liquid oxygen** (properties):
 O_2 (g) $\ddot{O} O_2$ (1) Boiling Point = $-183^\circ C$
 N_2 (g) $\ddot{O} N_2$ (1) Boiling Point = $-196^\circ C$
- (e) **Liquid oxygen** (as a fuel).
- (f) **Oxygen bound in compounds:** Gun powder, S, C, KNO_3 (fireworks).

Chromium trioxide and methanol: This illustrates an exothermic reaction where a change in oxidation state of a transition metal takes place.

SECTION 2: EVOLUTION OF THE DEFINITION

The different end users of a definition determine its evolution. The main point here is that oxygen and hydrogen are the most common reactants and products in their various atomic, molecular and ionic forms, so it was only natural to begin with loss or gain of these as a definition.

SECTION 3: ELECTRONEGATIVITY

(Trends in the periodic table)

When oxygen and/or hydrogen are gained or lost, electrons are transferred. Oxygen is electrophilic (loves electrons) - it has the second highest electronegativity. Tables of electronegativity are worth examining to confirm the trends shown in the video ("SI Chemical Data", Aylward & Findlay. Published by John Wiley & Sons Australia Pty Ltd).

SECTION 4: OXIDATION NUMBER

Redox reactions can be represented by complementary pairs of 'half equations'. A half-

reaction cannot occur by itself - it can only occur in conjunction with another complementary half-reaction.

SECTION 5: HALF EQUATIONS

Redox reactions can be represented by complementary pairs of 'half equations'. A half-reaction cannot occur by itself - it can only occur in conjunction with another complementary half-reaction.

SECTION 6: HOW TO WRITE AND BALANCE REDOX EQUATIONS

This is a matter of practice and familiarity.

Here are some examples:

- (a) $C_2H_5OH \Rightarrow CH_3COOH$ becomes
 $C_2H_5OH + H_2O \Rightarrow CH_3COOH + 4H^+ + 4e^-$
- (b) $Cr_2O_7^{2-} \Rightarrow Cr^{3+}$ becomes
 $Cr_2O_7^{2-} + 14H^+ + 6e^- \Rightarrow 2Cr^{3+} + 7H_2O$
- (c) $MnO_4^- \Rightarrow Mn^{2+}$ becomes
 $MnO_4^- + 14H^+ + 5e^- \Rightarrow Mn^{2+} + 4H_2O$

SECTION 7: HALF CELLS

Standard conditions need to be explained and the role of the standard hydrogen electrode emphasised. No current or reaction of any kind can take place in an isolated half cell. Cells need to be drawn up and the direction of electron motion and positive ions traced through the cell. Some sketches are provided for photocopying.

SECTION 8: STANDARD ELECTRODE REDUCTION POTENTIALS

Whether a reaction is electrochemical (spontaneous) or electrolytic (forced) is a vital difference. Understanding

this difference means understanding the processes involved in batteries, fuel cells, corrosion, electrolysis of brine, electroplating and the electrolytic purification of metals.

We have not used the terms "electrode", "cathode" or "anode". However, one way to remember the process and the electrode at which it takes place is:

Oxidation is a **LO**ss of electrons and always takes place at the **An**node? **O** and **A** are **both vowels**.

Reduction is a **GA**in of electrons and takes place at the **Ca**thode. **R** and **C** are **consonants**.

Credits

Produced & Directed by:

Peter Hicks

Teacher's Notes by:

Peter Hicks

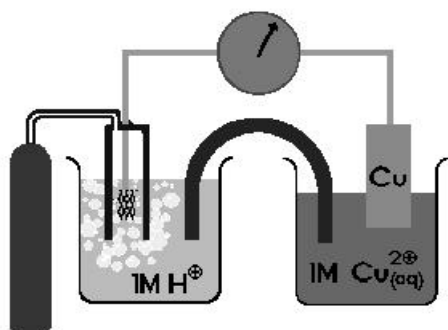
Computer Graphics & Animation by:

Graeme Whittle

Composition of clean air (at sea level)

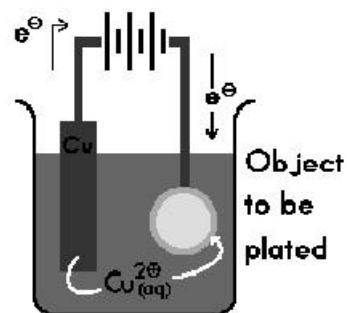
Component	Formula	Concentration
Nitrogen	N ₂	78.084%
Oxygen	O ₂	20.946%
Argon	Ar	0.934%
Water	H ₂ O	(9340 ppm) 1% to 0.1%
Carbon dioxide*	CO ₂	(10 000 to 1000ppm) 0.033%
Neon	Ne	(330 ppm) 18.2 ppm
Helium	He	5.2 ppm
Methane	CH ₄	2.0 ppm
Krypton	Kr	1.1 ppm
Hydrogen	H ₂	0.5 ppm
Nitrous oxide*	N ₂ O	0.5 ppm
Carbon monoxide*	CO	0.1 ppm
Xenon	Xe	0.09 ppm
Ozone*	O ₃	0.07 to 0.02 ppm
Ammonia*	NH ₃	0.01 ppm
Nitrogen dioxide*	NO ₂	0.001 ppm
Sulfur dioxide	SO ₃	0.0002 ppm

TITLE?



Label & indicate electron flow and ion movements.

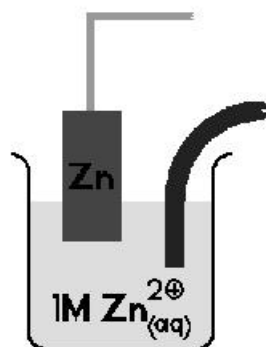
COPPER PLATING



1 1 H	THE FIRST 20 ELEMENTS OF THE PERIODIC TABLE						4 2 He
7 3 Li	9 4 Be	11 5 B	12 6 C	14 7 N	16 8 O	19 9 F	20 10 Ne
23 11 Na	24 12 Mg	27 13 Al	28 14 Si	31 15 P	32 16 S	35 17 Cl	40 18 Ar
39 19 K	40 20 Ca						
Mass Number				31 15 P	Electron Arrangement		
Atomic Number				15			

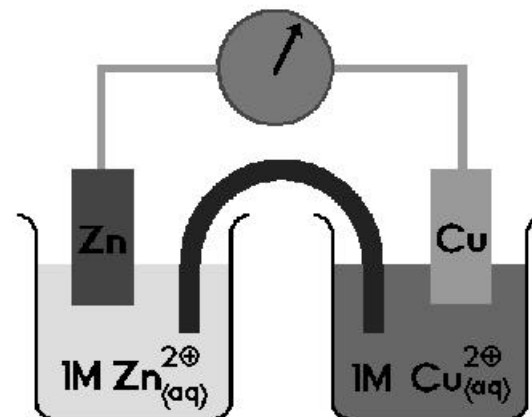
Show how Electronegativity increases.

TITLE?



Label

TITLE?



Label & indicate electron flow and ion movements.

Standard Reduction Potentials of some Transition Metal Species

Half-reaction	E^0 (volts)
$\text{Sc}^{3+} + 3\text{e}^-$ Sc	-2.12
$\text{Ti}^{2+} + 2\text{e}^-$ Ti	-1.63
$\text{V}^{2+} + 2\text{e}^-$ V	-1.18
$\text{Mn}^{2+} + 2\text{e}^-$ Mn	-1.18
$\text{V}^{3+} + 3\text{e}^-$ V	-0.87
$\text{Cr}^{3+} + 3\text{e}^-$ Cr	-0.74
$\text{Fe}^{2+} + 2\text{e}^-$ Fe	-0.44
$\text{Cr}^{3+} + \text{e}^-$ Cr^{2+}	-0.40
$\text{Ti}^{3+} + \text{e}^-$ Ti^{2+}	-0.37
$\text{Co}^{2+} + 2\text{e}^-$ Co	-0.28
$\text{Ni}^{2+} + 2\text{e}^-$ Ni	-0.23
$\text{Co}(\text{NH}_3)_6^{3+} + \text{e}^-$ $\text{Co}(\text{NH}_3)_6^{2+}$	+0.10
$\text{Cu}^{2+} + \text{e}^-$ Cu^+	+0.15
$\text{V}^{3+} + \text{e}^-$ V^{2+}	+0.26
$\text{Cu}^{2+} + 2\text{e}^-$ Cu	+0.34
$\text{Fe}(\text{CN})_6^{3-} + \text{e}^-$ $\text{Fe}(\text{CN})_6^{4-}$	+0.36
$\text{Cu}^+ + \text{e}^-$ Cu	+0.52
$\text{Fe}^{3+} + \text{e}^-$ Fe^{2+}	+0.77
$2\text{H}^+ + 2\text{e}^-$ H_2	+1.0
$\text{MnO}_2 + 4\text{H}^+ + \text{e}^-$ $\text{Mn}^{2+} + 2\text{H}_2\text{O}$	+1.23
$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^-$ $2\text{Cr}^{3+} + 7\text{H}_2\text{O}$	+1.33
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^-$ $\text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1.51
$\text{Mn}^{3+} + \text{e}^-$ Mn^{2+}	+1.51
$\text{MnO}_4^- + 4\text{H}^+ + 3\text{e}^-$ $\text{MnO}_2 + 2\text{H}_2\text{O}$	+1.70
$\text{Co}^{3+} + \text{e}^-$ Co^{2+}	+1.84
$\text{MnO}_4^{2-} + 4\text{H}^+ + 2\text{e}^-$ $\text{MnO}_2 + 2\text{H}_2\text{O}$	+2.26

Increasing oxidising strength

Strong
oxidising agentsStandard Reduction Potentials E^0 (volts)

$\text{K}^+ + \text{e}^-$ $\text{K}_{(\text{s})}$	-2.93
$\text{Ba}^{2+} + 2\text{e}^-$ $\text{Ba}_{(\text{s})}$	-2.90
$\text{Ca}^{2+} + 2\text{e}^-$ $\text{Ca}_{(\text{s})}$	-2.87
$\text{Na}^+ + \text{e}^-$ $\text{Na}_{(\text{s})}$	-2.71
$\text{Mg}^{2+} + 2\text{e}^-$ $\text{Mg}_{(\text{s})}$	-2.36
$\text{Al}^{3+} + 3\text{e}^-$ $\text{Al}_{(\text{s})}$	-1.66
$\text{Mn}^{2+} + 2\text{e}^-$ $\text{Mn}_{(\text{s})}$	-1.18
$\text{H}_2\text{O} + \text{e}^-$ $\frac{1}{2}\text{H}_{2(\text{g})} + \text{OH}_{(\text{aq})}$	-0.83
$\text{Zn}^{2+} + 2\text{e}^-$ $\text{Zn}_{(\text{s})}$	-0.44
$\text{Pb}^{2+} + 2\text{e}^-$ $\text{Pb}_{(\text{s})}$	-0.13
$\text{Fe}^{3+} + 3\text{e}^-$ $\text{Fe}_{(\text{s})}$	-0.02
$\text{H}^+_{(\text{aq})} + \text{e}^-$ $\frac{1}{2}\text{H}_{2(\text{g})}$	0.00
$\text{Cu}^{2+} + 2\text{e}^-$ $\text{Cu}_{(\text{s})}$	0.34
$\text{Cu}^+ + \text{e}^-$ $\text{Cu}_{(\text{s})}$	0.52
$\frac{1}{2}\text{I}_{2(\text{s})} + \text{e}^-$ I^-	0.54
$\frac{1}{2}\text{I}_{2(\text{aq})} + \text{e}^-$ I^-	0.62
$\text{Fe}^{3+} + \text{e}^-$ Fe^{2+}	0.77
$\text{Ag}^+ + \text{e}^-$ Ag	0.80
$\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^-$ $\text{NO}_{(\text{g})} + 2\text{H}_2\text{O}$	0.96
$\frac{1}{2}\text{Br}_{2(\text{l})} + \text{e}^-$ Br^-	1.07
$\frac{1}{2}\text{Br}_{2(\text{aq})} + \text{e}^-$ Br^-	1.09
$\text{O}_2 + 4\text{H}^+ + 4\text{e}^-$ $2\text{H}_2\text{O}$	1.23
$\frac{1}{2}\text{Cr}_2\text{O}_7^{2-} + 7\text{H}^+ + 3\text{e}^-$ $\text{Cr}^{3+} + \frac{7}{2}\text{H}_2\text{O}$	1.33
$\frac{1}{2}\text{Cl}_{2(\text{g})} + \text{e}^-$ Cl^-	1.36
$\frac{1}{2}\text{Cl}_{2(\text{aq})} + \text{e}^-$ Cl^-	1.40
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^-$ $\text{Mn}^{2+} + 4\text{H}_2\text{O}$	1.51
$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^-$ $2\text{H}_2\text{O}$	1.78
$\frac{1}{2}\text{F}_2 + \text{e}^-$ F^-	2.87

Strong
reducing agents

Increasing reducing strength

Batteries
Lead/Acid

E^0 (volts)
Anode (- terminal):
$\text{Pb} + \text{SO}_4^{2-} \rightarrow \text{PbSO}_4 + 2\text{e}^-$ +0.36
Cathode (+ terminal):
$\text{PbO}_2 + \text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \rightarrow \text{PbSO}_4 + 2\text{H}_2\text{O}$ +1.69
<u>$\text{Pb} + \text{PbO}_2 + 4\text{H}^+ + 2\text{SO}_4^{2-} \rightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O}$ +2.05</u>

The Dry Cell

E^0 (volts)
Anode (-):
$\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$ +0.76
Cathode (+):
$2\text{MnO}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow 2\text{MnO}(\text{OH})$ +0.50
<u>$\text{Zn} + 2\text{H}^+ + 2\text{MnO}_2 \rightarrow \text{Zn}^{2+} + 2\text{MnO}(\text{OH})$ +1.26</u>

The Nicad

E^0 (volts)
Anode (-):
$\text{Cd} + 2\text{OH}^- \rightarrow \text{Cd}(\text{OH})_2 + 2\text{e}^-$ +0.76
Cathode (+):
$\text{NiO}_2 + 2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{Ni}(\text{OH})_2 + 2\text{OH}^-$ +0.49
<u>$\text{Cd} + \text{NiO}_2 + 2\text{H}_2\text{O} \rightarrow \text{Cd}(\text{OH})_2 + \text{Ni}(\text{OH})_2$ +1.25</u>

Abundance and occurrence of major elements in Earth's crust

Elements	Abundance	Occurrence
Oxygen	49.5°	Water, atmosphere, rocks and minerals
Silicon	25.8°	Rocks and minerals (silicates)
Aluminium	7.5°	Alumina, feldspar
Iron	4.7°	Ores, minerals
Calcium	3.4°	Limestone, oceans, feldspars
Sodium	2.6°	Oceans
Potassium	2.4°	Oceans
Magnesium	1.9°	Oceans
Hydrogen	0.9°	Rutile
Others	0.7°	