Western Cape Government
Education

Directorate: Curriculum FET

TELEMATICS

GRADE 11

PHYSICAL SCIENCES CAPS

REVISION

Redox Reactions
Mining and Mineral Processing: Gold

October 2015

REDOX REACTIONS

UNIT 1: CONCEPTS (associated with Redox reactions)

Redox reactions are chemical reactions in which reduction and oxidation take place and the name REDOX is an abbreviation for RED<u>UCTION</u><u>OX</u>IDATION. During redox reactions electrons are transferred from one atom or group of atoms, to another atom or group of atoms. The example below illustrates the situation:

$Mg \rightarrow Mg^{2+} + 2\bar{e}$ … (I) [Mg LOSES two electrons and is OXIDISED to Mg^{2+}]

$C\ell_2 + 2\bar{e} \rightarrow 2C\ell^-$ … (II) [$C\ell_2$ GAINS two electrons and is REDUCED to $C\ell^-$]

$Mg + C\ell_2 \rightarrow Mg^{2+} + 2C\ell^-$ … (III) [Balanced (NET) OVERALL reaction]

Check in equations (I), (II) and (III) that: Total charge on LHS of "$\rightarrow$" = Total charge on RHS of "$\rightarrow$". We can now define concepts associated with redox reactions and provide examples to illustrate them. This is provided in the table below.

CONCEPT	DEFINITION	EXAMPLE
Redox reaction	A reaction in which oxidation and reduction occur	$Mg + C\ell_2 \rightarrow Mg^{2+} + 2C\ell^-$
Oxidation half reaction	The half reaction that shows a LOSS of electrons	$Mg \rightarrow Mg^{2+} + 2\bar{e}$
Reduction half reaction	The half reaction that shows a GAIN in electrons	$C\ell_2 + 2\bar{e} \rightarrow 2C\ell^-$
Oxidation	A LOSS of electrons (LEO)	Mg becomes Mg^{2+}
Reduction	A GAIN in electrons	$C\ell_2$ becomes $2C\ell^-$
Oxidizing agent	A substance that OXIDIZES another substance but it itself undergoes REDUCTION	$C\ell_2$. Because it oxidises Mg to Mg^{2+} but it itself is reduced to $C\ell^-$
Reducing agent	A substance that REDUCES another substance but it itself undergoes Oxidation.	Mg. Because it reduces $C\ell_2$ to $C\ell^-$ but it itself is oxidised Mg^{2+}

NOTES: Oxidation and reduction occur simultaneously.
An oxidizing agent and a reducing agent are always found on the LHS of the arrow "$\rightarrow$" in a redox reaction.

ACTIVITY 1

1.1 Which of the following reactions are redox reactions?
Give a reason for your answer in each case.

1.1.1 $K + Br_2 \rightarrow KBr_2$

1.1.2 $NaOH + HC\ell \rightarrow NaC\ell + H_2O$

1.1.3 $CuSO_4 + Zn \rightarrow ZnSO_4 + Cu$

1.1.4 $Cu + NO_3^- + 4H^+ \rightarrow Cu^{2+} + NO_2 + H_2O$

1.2 Consider the following redox reaction:
$2Na + C\ell_2 \rightarrow 2NaC\ell$

1.2.1 Write down a balanced chemical equation for the oxidation half reaction.

1.2.2 Write down the NAME of the substance that is the reducing agent.

1.2.3 Identify the substance that undergoes oxidation.

1.2.4 Write down a balanced chemical equation for the reduction half reaction.

1.2.5 Identify the oxidizing agent.

UNIT 2: OXIDATION NUMBER

In answering 1.1.4, it is possible to find the oxidation half reaction but it may not be possible to deduce that NO_3^- is the oxidizing agent with your present knowledge. A more reliable and far more accurate way to identify which substances undergo oxidation and reduction in redox reactions is to use OXIDATION NUMBER and to extend the existing definition of OXIDATION and REDUCTION.

Definition of oxidation number: The oxidation number of an element is the charge that an atom of the element would have in a compound if ALL BONDS WERE IONIC.

Definition of oxidation: An INCREASE in oxidation number.

Definition of reduction: A DECREASE in oxidation number.

OXIDATION: Increase in oxidation number

… -3 -2 -1 0 +1 +2 +3 …

REDUCTION: Decrease in oxidation number

NOTES:

- Oxidation numbers can be fractions as Fe is in Fe_3O_4
- A change in oxidation number from -4 to -1 is an INCREASE of 3.
- A change in oxidation number from -1 to -3 is a DECREASE of 2

RULES TO USE when allocating OXIDATION NUMBERS:

The oxidation number of an atom can be determined easily by using the following RULES:

RULE 1: *The oxidation number of a FREE element is 0*.

Hence the oxidation number of an atom in each of the following is 0:

- All diatomic molecules e.g. H_2 O_2 $C\ell_2$ etc.
- Elements in the Periodic Table e.g. Zn Cu Ag etc.
- P_4 and S_8

RULE 2: *The oxidation number of the H-atom = +1* in all compounds, except the hydrides where its oxidation number is -1 (In hydrides, the H-atom is bonded to a less electronegative atom)

- Group 1 metal hydrides e.g. LiH NaH KH etc.
- Group 2 metal hydrides e.g. BeH_2 MgH_2 CaH_2 etc.
- Group 13 metal hydrides e.g. AlH_3 BH_3 GaH_3 etc.
- Group 14 metal hydrides e.g. GeH_4 SnH_4 SiH_4 etc.

RULE 3: *The oxidation number of the O-atom = -2 in all compounds,* except:

The peroxides, in which case the oxidation number of the O-atom is -1.

The fluorides that are more electronegative than oxygen, in which the oxidation number of the O-atom is +2.

RULE 4: *The oxidation number of a simple monatomic ion is equal to its ionic charge.*

E.g.: The oxidation number of:

- Br in Br^- = -1
- Na in Na^+ = +1
- Mg in Mg^{2+} = +2
- S in S^{2-} = -2

RULE 5: *In the allocation of oxidation numbers charge is conserved.* This means that the SUM of the oxidation numbers in a:

- Neutral atom = 0
- Polyatomic ion = ionic charge

EXAMPLES

1. H_2SO_3

According to Rule 2, the oxidation number of each H-atom is +1.

According to Rule 3, the oxidation number of each O-atom is -2.

The oxidation number of the S-atom is determined as follows using Rule 5 (1st bullet):

2(oxidation number of H) + (oxidation number of S) + 3(oxidation number of O) = 0

i.e. 2(+1) + (oxidation number of S) + 3(-2) = 0 …. (a)

2 + (oxidation number of S) -6 = 0

∴The oxidation number of S = 0 +6 -2

= +4

CHECK YOUR ANSWER (Use equation (a)): 2 + 4 -6 = 0

2. SO_4^{2-}

According to Rule 3, the oxidation number of each O-atom is -2.

The oxidation number of the S-atom is determined as follows using Rule 5 (2nd bullet):

(Oxidation number of S) + 4(-2) = -2

∴The oxidation number of S = -2 + 8

= 6

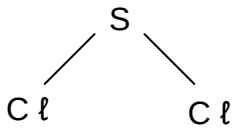
CHECK YOUR ANSWER: 6 -8 = -2

RULE 6: *The oxidation number of an atom in a covalent compound of known structure is equal to the charge that would remain on the atom if the shared electron pairs were allocated completely to the most electronegative atoms.*

EXAMPLE

(3) Determine the oxidation number of S in $SC\ell_2$.

The structure of $SC\ell_2$ is:



Each Cℓ-atom is more electronegative than S and therefore attracts the shared electron pair to itself.

According to Rule 6, the oxidation number of each Cℓ-atom = -1

According to Rule 5, the sum of the oxidation numbers of S and Cℓ in $SC\ell_2$ = 0

The oxidation number of the S-atom is determined as follows:

2(oxidation number of Cℓ) + (oxidation number of S) = 0

2(-1) + (oxidation number of S) = 0

∴Oxidation number of S = 0 +2

= +2

ACTIVITY 2

2.1 Write down the oxidation number of the atom underlined in each of the following:

2.1.1 $\underline{S}_8$ $\underline{S}O_3$ $H_2\underline{S}O_4$ $H\underline{S}^-$ $H\underline{S}O_3^-$ $\underline{S}Br_2$

2.1.2 $\underline{P}_2O_5$ $\underline{P}C\ell_3$ $\underline{P}_4$ $\underline{P}H_3$ $H_3\underline{P}O_4$ $H\underline{P}O_4^{2-}$

2.1.3 $\underline{N}_2$ $\underline{N}O_2^-$ $\underline{N}H_4\underline{N}O_3$ $\underline{N}_2O_4$ $H\underline{N}O_3$ $\underline{N}O$

2.1.4 $Na\underline{C\ell}$ $Na\underline{C\ell}O_4$ $NaO\underline{C\ell}$ $\underline{C\ell}_2$ $\underline{C\ell}F$ $C\underline{C\ell}_4$

2.1.5 $Na_2\underline{O}_2$ $H_2\underline{O}_2$ $\underline{O}F_2$

2.1.6 $\underline{Cr}_2O_7^{2-}$ $\underline{Cr}_2(SO_4)_3$ $\underline{Mn}O_4^-$ $\underline{Mn}O_2$ $\underline{Mn}^{+3}$

2.2 Identify which of the following reactions are redox reactions?

2.2.1 $N_2 + 3H_2 \rightarrow 2NH_3$

2.2.2 $2Na + 2H_2O \rightarrow 2NaOH + H_2$

2.2.3 $Zn + 2HC\ell \rightarrow ZnC\ell_2 + H_2$

2.2.4 $KOH + HC\ell \rightarrow KC\ell + H_2O$

2.2.5 $H_2SO_4 + Mg \rightarrow MgSO_4 + H_2$

2.2.6 $H_3O^+ + OH^- \rightarrow 2H_2O$

2.2.7 $CaCO_3 + 2HC\ell \rightarrow CaC\ell_2 + CO_2 + H_2O$

2.2.8 $MnO_4^- + Sn^{2+} \rightarrow Mn^{2+} + Sn^{4+}$

2.2.9 $C + H_2O \rightarrow CO + H_2O$

2.2.10 $CH_3COOH + H_2O \rightarrow CH_3COO^- + H_3O^+$

2.2.11 $2H_2O + O_2 \rightarrow 2H_2O_2$

2.3 Identify in each redox reaction in question 2.2:

2.3.1 The oxidising agent

2.3.2 The reducing agent

MINING AND MINERAL PROCESSING

UNIT 1: A BRIEF HISTORY OF GOLD

Historians believe that gold was the first metal known to man, possibly as long as 6000 years ago. It was love at first sight! Since then, man has desired gold for its sheer beauty, and for the ease in which he can make it into beautiful objects. Unlike other metals, gold does not perish and this makes gold artefacts a source of invaluable information about ancient civilizations. In such civilizations gold was used not only in jewellery. It gradually became a major symbol of wealth and power. It also became a standard of value, hence the expression: “as good as gold”.

ACTIVITY 1

1.1 Read the passage and answer the question below:

1.1.1 Why do people, both ancient and modern, love gold so much?

GOLD IN SOUTH AFRICA

UNIT 2: THE ORIGIN OF GOLD IN SOUTH AFRICA

About 250 million years ago a great inland sea covered the Highveld and the Free State. Rain water moved pebbles, sand and gold into this sea, and they sank to the bottom of the sea because of their density. This happened each year during the rainy season so that layers of sand containing gold were packed on top of one another forming sedimentary rock at the bottom of the sea. Today this sea has disappeared and what remained are the gold bearing layers of rock that are called gold reefs.

UNIT 3: LOCATION OF MINING ACTIVITIES IN SOUTH AFRICA

At present gold is mined over an arc, ± 500 km long and extending from Virginia in the Free State, through Klerksdorp in North West Province, Carletonville, Krugersdorp and Johannesburg in Gauteng to Kinross in Mpumalanga.

UNIT 4: HOW GOLD IS MINED IN SOUTH AFRICA

People who search for gold are called prospectors. They drill holes in rock in order to locate the gold reef. Where gold deposits are found a mine is developed. After head gear and other equipment are installed, a shaft is sunk to reach the gold bearing rock. Holes are drilled in the rock into which explosives are inserted and blasted out. Tunnels are made at various levels until they strike the gold reef. More tunnels are made along the plane of the gold reef. This is called reef development. The reef is mined by a process of drilling and blasting of the gold bearing rock called “stoping”. Rock is transported to tipping stations, dropped down a rock Shute, and hoisted up the shaft to the surface. The gold bearing ore is sent for processing to recover the gold in it.

UNIT 5: WHY IS GOLD WORTH MINING IN SOUTH AFRICA?

Au is a currency.
It is used to make expensive jewellery and coins.
Au is an excellent conductor of electricity. (2^{nd} only to Ag)
Au is used in the electronics industry to make tiny electrical contacts.
Au is used in dentistry as fillings.
Au has medicinal and healing properties – can be used in treating rheumatoid arthritis, chronic ulcers and TB (tuberculosis).
Au can be eaten.
Au is used in the construction of space shuttles.
It is easy to shape gold into useful objects.
Au is inert and can be stored for ages.
Au does not rust.
Au is a status symbol.
Au is a symbol of wealth.
Au is an attractive metal.
Au is an asset and an investment item.

UNIT 5 THE RECOVERY OF GOLD FROM ITS ORE

The following are methods used in South Africa to separate gold from its ore.

The Cyanidation Process:

Primary and secondary crushers break the ore into smaller pieces.
These pieces are milled to make a fine dust that exposes the gold.
A cyanide solution is added that dissolves the gold particles.
The reaction that takes place is:

$$4Au(s) + 8CN^-(aq) + O_2(g) + 2H_2O(\ell) \rightarrow 4[Au(CN)_2]^-(aq) + 4OH^-(aq)$$

Unwanted rock fines are filtered out of the solution that forms.
Zn dust is then added to the solution and the gold precipitates (falls) out of the solution.
The reaction that takes place is:

$$Zn(s) + 2[Au(CN)_2]^-(aq) \rightarrow [Zn(CN)_4]^{2-}(aq) + 2Au(s)$$

The gold is gathered in solid form and sent for smelting.

The carbon-in-pulp (CIP) method:

Primary and secondary crushers break the ore into smaller pieces.
These pieces are milled to make a fine dust that exposes the gold.
A cyanide solution is added that dissolves the gold particles.
(The solution is now processed using the CIP method in 3 stages.)

Stage 1: Absorption: The dissolved gold in pulp is loaded onto activated carbon.
Stage 2: Elution: Gold is then removed from the carbon by washing it with an alkaline cyanide solution
Stage 3: Electro-winning: Gold is removed from the alkaline cyanide solution by electrolysis and is deposited on steel wool electrodes.

ACTIVITY 2

2.1 Briefly describe how gold originated in South Africa.

2.2 Name four provinces where gold is currently mined in South Africa.

2.3 Consider the following list of terms associated with gold mining:

Cyanide solution	Bullion	Amalgamation
Cyanidation	Pyrometallurgy	Conglomerate
Gold reefs	Zn dust	Stoping

Choose a term from this list that is:

2.3.1 Gold in the form of bars
2.3.2 A method to recover gold using mercury
2.3.3 Used to dissolve gold
2.3.4 The final stage in gold recovery
2.3.5 Used to reduce Au^{+} to gold.
2.3.6 Excavations in the form of steps

2.4 South Africa is the world's largest gold producer. Describe the recovery of gold in South Africa by referring to:

2.4.1 Three uses of gold that make it worth mining.
2.4.2 The current location of the major mining activities in South Africa.
2.4.3 The major steps in the gold mining process.
2.4.4 Name of the process that is used to recover gold from its ore in South Africa
2.4.5 Provide one negative impact of the process in question 2.4.4 on humans. State the factor and then describe its impact on humans.