Electrochemistry

↳ Balancing Redox reactions using gain and loss of e^-

$$SO_{2(g)} + 2HNO_{2(g)} \longrightarrow H_2SO_{4(aq)} + 2NO_{(g)}$$ L = 2e⁻, G = 1e⁻

When there is an (aq) reactant or product, you can use OH^- or H^+ to balance the equation

Extremely Rare

8 OH⁻ $$S^{2-} + 4I_2 \longrightarrow SO_4^{2-} + 8I^- + 4H_2O$$

G = 8, L = 8

$2\,Ca(\overset{+5}{N}O_3)_2 \longrightarrow 2\,CaO + 4\,\overset{+4}{N}O_2 + O_2$

G: 2
L: 2

In Reaction Where a compound forms an element or vice versa, it is a Redox Reac^n.

$Cr_2O_7^{2-} + 14\,H^+ + 6\,I^- \longrightarrow 2\,Cr^{3+} + 7\,H_2O + 3\,I_2$

G: 1
L: 6

$6\,CuF_2 + 2\,NH_3 \longrightarrow 2\,Cu_3N + 6\,NH_4F + N_2$

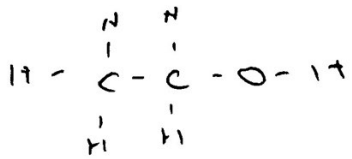
G: 1
L: 3

$12\,CuF_2 + 2\,NH_3 \longrightarrow Cu_3N + NH_4F + N_2$

G: 3 × 4
L: 6 × 2

$6\,CuF_2 + 16\,NH_3 \longrightarrow 2\,Cu_3N + 12\,NH_4F + N_2$

G: 3 × 2
L: 6



$$2\,Ca_3(PO_4)_2 + 6\,SiO_2 + 5C \rightarrow P_4 + 3\,CaSiO_3 + 5CO$$

G : 10 20
L : 2 2

MnO_4^{2-} ~~$MnO_4^- + H^+$~~

needs weak [O] agent → need strong [O] agent

Only methanoic acid and ethandioic acid can be further oxidized into CO_2

$$2\,MnO_4^- + 16\,H^+ + 5\,C_2O_4H_2 \rightarrow 2\,Mn^{2+} + 10\,CO_2 + 8\,H_2O$$

G : 5
L : 2

$$2\,Pb^{2+} + IO_3^- + 4\,OH^- \rightarrow 2\,PbO_2 + IO^- + 2\,H_2O$$

G : 4
L : 2

Electrolysis

- negative
- positive
- important

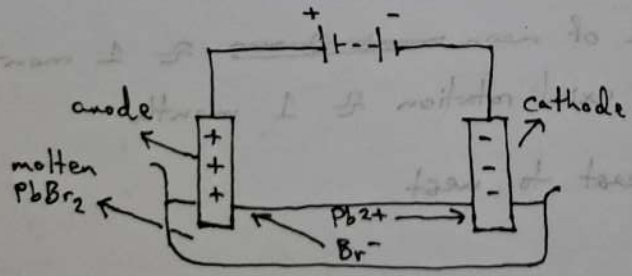
Electrolysis:

The decomposition of an ionic compound into its elements by passing electricity through it. In order to conduct electricity, the ionic compound must be in aqueous or molten state. An ionic compound in these forms is known as an electrolyte. Direct current in the form of a battery is always used as a power source. Two metals or carbon rods are connected to the power supply and immersed into the electrolyte. They are known as electrodes. The electrode that is connected to the positive terminal of the battery is called the anode, and the other electrode connected to the negative terminal is called ~~cathode~~ the cathode. Cations from the electrolyte will be attracted to the cathode, ~~Negatively charge~~ and anions will move towards the anode.

The cations will stick to the cathode and gain electrons from the negative terminal of the battery until it is neutral. This process of ~~neutra~~ neutralising the cation is called discharging.

The anions will stick to the anode and will lose electrons to the positive terminal of the battery until it is completely discharged.

Electrolysis of molten lead (II) bromide:



* In most cases, carbon or graphite ~~rods~~ rods are used
  - i) They are very good conductors of electricity
  - ii) They are inert

~~At cathode~~ At anode:

- $2Br^- \longrightarrow Br_2 + 2e^-$

Half ionic equations

- At anode, the anion always loses electrons to get discharged. This is called anodic oxidation.

At cathode:

- $Pb^{2+} + 2e^- \longrightarrow Pb$
- At cathode, cations always gain electrons. This is called cathodic reduction

Full ionic eqⁿ:

Reduction: $Pb^{2+} + 2e^- \longrightarrow Pb$

Oxidation: $2Br^- \longrightarrow Br_2 + 2e^-$

Redox: $Pb^{2+} + 2Br^- \longrightarrow Pb + Br_2$

Electrolysis of aqueous ionic compounds:

The problem associated with aqueous ionic compounds is that, other than the cations and anions of the ionic compound, other ions are also present. These ions are formed due to the ionisation of water, molecules. Normally, water has a very low degree of ionisation. However, when an ionic salt is dissolved in water, it causes high degree of ionisation of water molecules, resulting in formation of hydrogen ions (H^+) and hydroxide ions (OH^-). Thus we can conclude that, other than the ions of the ionic compound, H^+ ions and OH^- ions are always present in large quantity in any aqueous sol^n of ionic compounds.

Selective discharge of cations:

* The cations of less reactive metals have greater selective discharge than cations of more reactive metals. This is because the cations of less reactive metals can accept electrons more easily.

Selective discharge of anions:

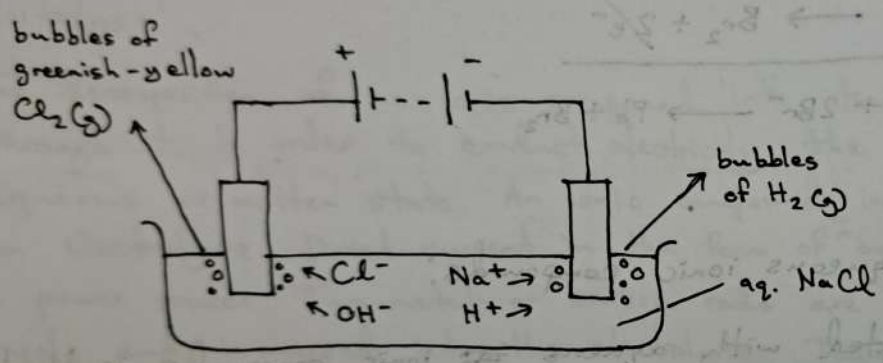
OH^-
Cl^-
Br^-
I^-

* SO_4^{2-} and NO_3^- will never discharge.

selective discharge (increases) / ease of losing electrons (increases)

* If the sol^n is in aqueous or concentrated form, then the selective discharge of the halide ion is greater than OH^- ion.
* For dilute aqueous sol^n, OH^- ions have a greater selective discharge than halide ions

Electrolysis of aqueous sodium chloride ($NaCl_{(aq)}$) soln:



Cation:
Na^+, H^+

Anion:
Cl^-, OH^-

At cathode:

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

At anode:

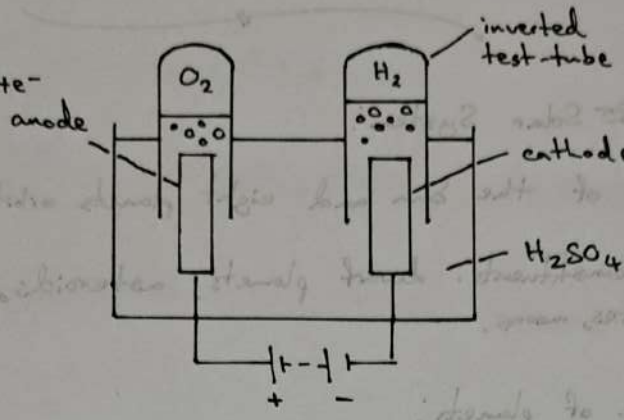
$2Cl^- \cancel{+2e^-} \longrightarrow Cl_2 + 2e^-$

Overall eqn: $2H^+ + 2Cl^- \longrightarrow H_2 + Cl_2$

Q. Outline the full method, including diagram, for the electrolysis of sulfuric acid. → NP

At anode:

$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$



At cathode:

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

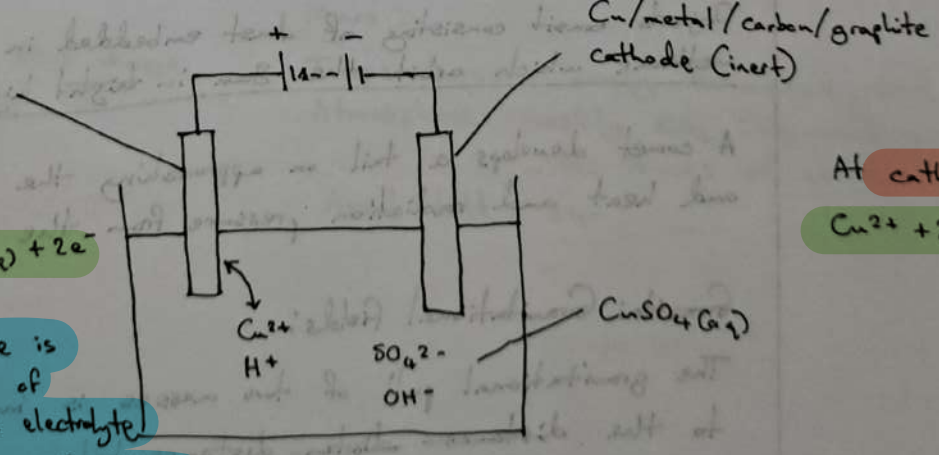
Overall eqⁿ: $4OH^- + 4H^+ \rightarrow 2H_2O + O_2 + 2H_2$

Active electrode:

The electrodes that itself chemically participates in electrolysis are called active electrodes. For an electrode to be active, the metal from which the electrode is made and the cation in the electrolyte must be from the same element.

* Only anodes behave actively

When the anode is active, instead of discharging anions from the electrolyte, it itself gets ionized to form cations.



At anode:

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

At cathode:

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

* When the anode is active, the conc. of the ions in the electrolyte does not change significantly.

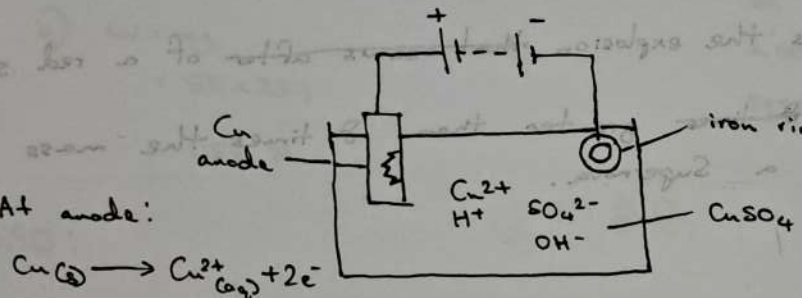
Chemistry (ART)

Applications of electrolysis:

~~Electroplating:~~

1. Electroplating

The object that is to be electroplated is used as cathode, and the metal ~~it is~~ which is electroplated onto the object is used as anode. The anode has to behave actively.



At anode:

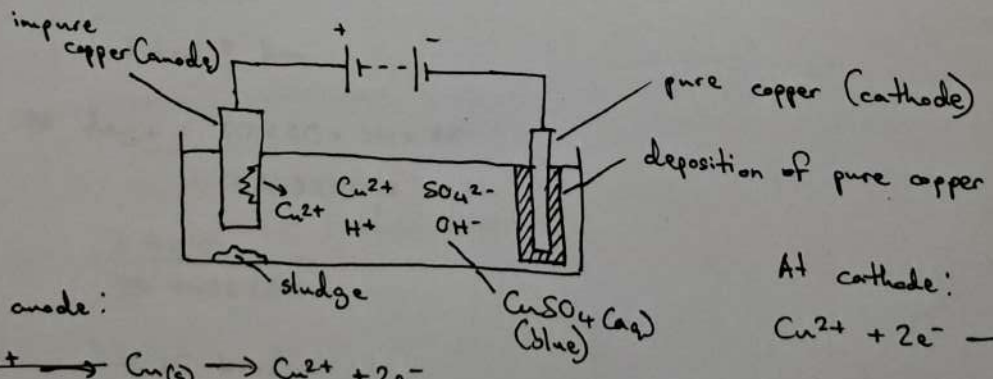
$Cu_{(s)} \longrightarrow Cu^{2+}_{(aq)} + 2e^-$

At cathode:

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

2. Purification of copper

The impure copper rod is used as anode and a very thin pure copper rod is used as cathode. The anode has to be active.



At anode:

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

At cathode:

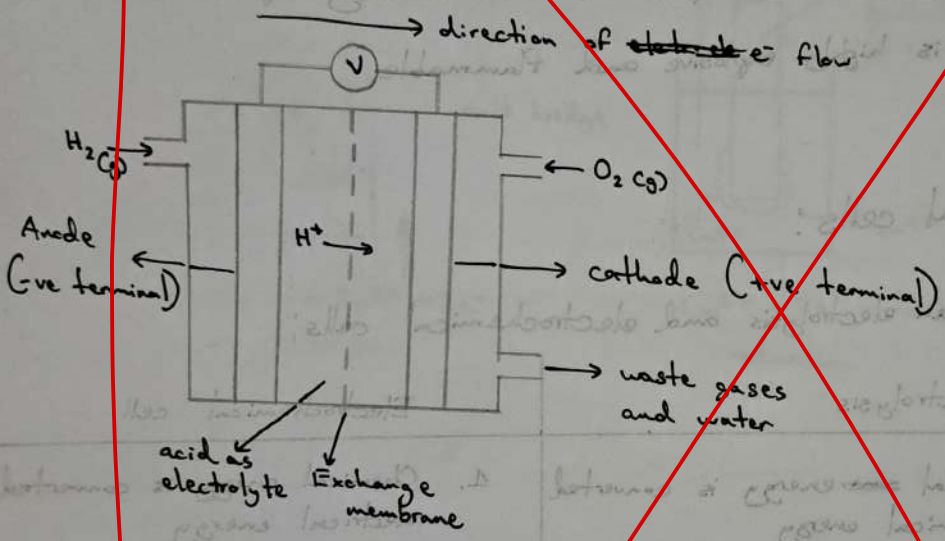
$Cu^{2+} + 2e^- \longrightarrow Cu_{(s)}$

* At the end the color of the electrolyte will remain constant as conc. of Cu^{2+} remains almost constant but becomes cloudy.

3. Hydrogen - oxygen fuel cell

The fuel cell is an electrochemical device that converts chemical energy of conventional fuels (e.g. H_2, CH_4) into electrical energy by oxidation with oxygen from the air. Fuel cells do not have the limited capacity of ordinary batteries, rather it has a continuous supply of reactant. A fuel cell can be made by using both acid and alkali as electrolyte.

Acidic Hydrogen - Oxygen Fuel Cell:



At anode:

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

At cathode:

$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$

Overall eqⁿ:

$2H_2 \longrightarrow 4H^+ + 4e^-$

$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$

$2H_2 + O_2 \longrightarrow 2H_2O$

Alkaline Hydrogen - Oxygen Fuel Cell:

OH^- ion migrates.

At anode:

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

At cathode:

$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

Overall eqⁿ:

$2H_2 \longrightarrow 4H^+ + 4e^-$

$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

$2H_2 + O_2 + 2H_2O \longrightarrow 4H^+ + 4OH^-$

$\Rightarrow 2H_2 + O_2 + 2H_2O \longrightarrow 4H_2O$

$\therefore 2H_2 + O_2 \longrightarrow 2H_2O$

Advantages of using hydrogen-oxygen fuel cells:

1. The only by-product produced is water, which is environmentally friendly.
2. Both H_2 and O_2 can be collected from renewable resources. (e.g. electrolysing water produces both H_2 and O_2).

Disadvantages of using hydrogen-oxygen fuel cells:

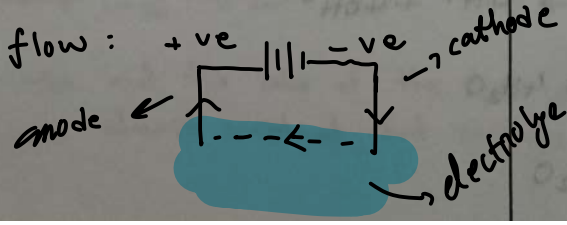
1. Hydrogen has to be kept ~~under large tanks in huge~~ in large tanks under ~~huge~~ huge pressure, which is very expensive.
2. Hydrogen is highly explosive and flammable.

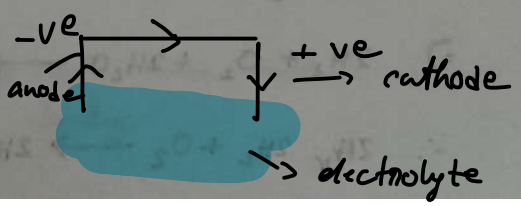
Electrochemical cells:

Difference between electrolysis and electrochemical cells:

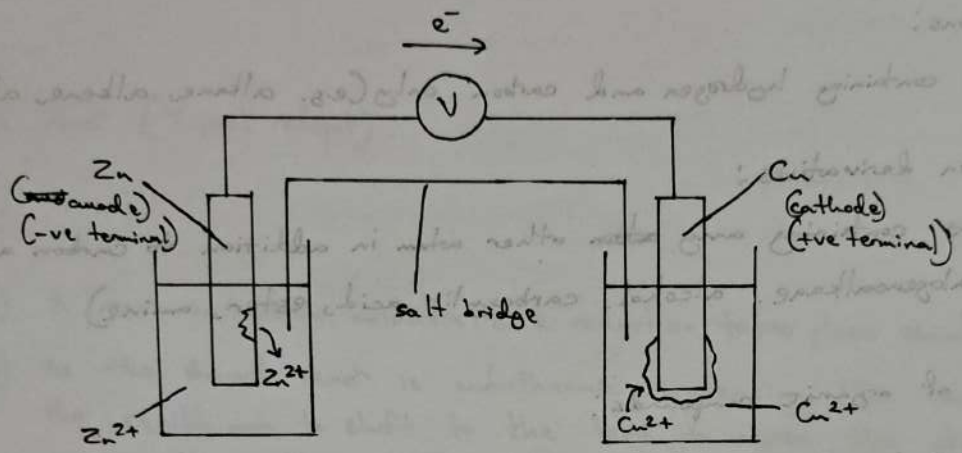
Electrolysis	Electrochemical cell
1. Electrical ~~energy~~ energy is converted to chemical energy	1. Chemical energy is converted to electrical energy
2. The metal rods connected to the terminals of the battery act as electrodes.	2. The metal rods ~~are~~ themselves behave as the terminal of the battery.
3. Electrodes are either active or inert.	3. Electrodes are always active.
4. Electrodes can be made of the same or different metals.	4. Electrodes are always made of different metals.
5. The electrode connected to the negative terminal of the battery is the cathode.	5. The electrode which will gain electrons is the cathode and will also act as the positive terminal of the battery.

6. e^- flow:





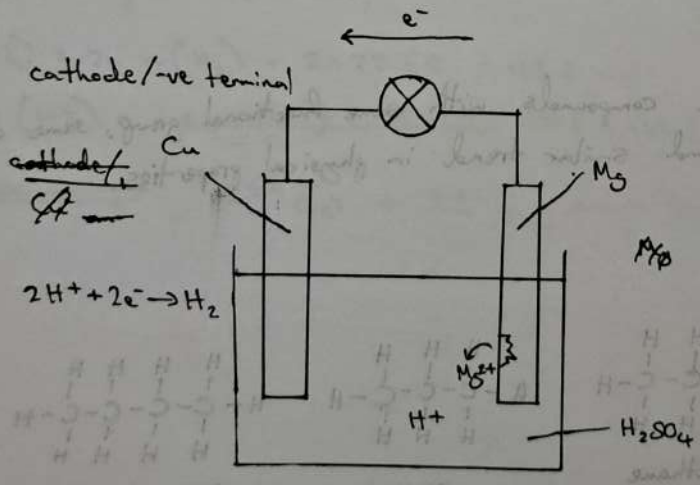
* In electrochemical cells, the electrode that is made of a more reactive metal always ~~made~~ behaves as the -ve terminal (anode). The ~~one~~ less reactive metal always acts as the +ve terminal of the battery (as cathode).



$Zn \longrightarrow Zn^{2+} + 2e^-$
oxidation

$Cu^{2+} + 2e^- \longrightarrow Cu$
reduction

* More reactive metals lose e^- more ~~eas~~ easily than less reactive ~~eta~~ metals
* Ions of less reactive metals gain electrons more easily than ions of ~~less~~ more reactive metals



~~Mg~~ $Mg \longrightarrow Mg^{2+} + 2e^-$
anode / +ve terminal

Misc. Notes

Oxidation State of Hydrogen is almost always +1 except in Metal Hydrides where it is -1.

Electrolysis+ Electrode Potentials & Cells 4

Brine is concentrated aqueous sodium chloride. Brine is electrolysed in a diaphragm cell.

What is the purpose of the diaphragm?

A to prevent Cl_2 reacting with H_2
B to prevent HCl reacting with Na
C to prevent NaOH reacting with Cl_2
D to prevent NaOH reacting with HCl

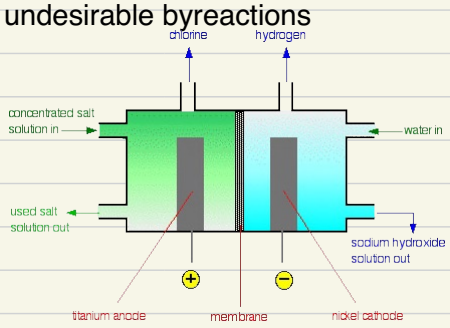
Paper 1 Variant 3 Summer 2015 I Q9

Answer:

C

Hide Answer

diaphragms have for their purpose to keep the products formed during the electrolysis separated -fromeach other and to prevent undesirable byreactions



Relative mass of an e^- is 1/1836 units

Electrolysis+ Electrode Potentials & Cells 9

Which row correctly describes the electrodes that can be used in a diaphragm cell for the production of chlorine, hydrogen and sodium hydroxide?

	anode	cathode
A	steel	graphite
B	steel	titanium
C	titanium	graphite
D	titanium	steel

Graphite cathode wears away thus it is not used.

ANODE IS ALWAYS TITANIUM

Paper 1 Variant 3 Winter 2015 I Q8

Answer:

D

Electrolysis+ Electrode Potentials & Cells 14

Which row correctly describes the electrodes used in the electrolysis cell for the production of aluminium?

	anode	cathode
A	carbon	carbon
B	carbon	steel
C	steel	carbon
D	steel	steel

Although the cathode are coated in steel, they ARE made of carbon.

Paper 1 Variant 2 Winter 2014 I Q10

Answer:

A

Redox 14

Xenon hexafluoride, XeF_6, reacts with water.

$$XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$$

Which statement is correct?

A Hydrogen is reduced in this reaction.

B Hydrogen is the only element oxidised in this reaction.

C The only element oxidised in this reaction is xenon.

D This is not a redox reaction.

Paper 1 Variant 3 Summer 2018 I Q8

Answer:

D

Hide Answer

Redox 21

Oxidation numbers should be used to answer this question.

A redox reaction takes place between hydroxylammonium ions, $[NH_3OH]^+$, and acidified iron(III) ions, Fe^{3+}. The products are iron(II) ions, Fe^{2+}, H^+ ions, water and a compound of nitrogen.

The mole ratio of reacting hydroxylammonium ions to reacting iron(III) ions is 1 : 2.

Which nitrogen-containing compound could be formed in the reaction?

A NH_3 **B** N_2O **C** NO **D** NO_2

Paper 1 Variant 1 Summer 2018 I Q9

Answer:

B

Hide Answer

→ Just use gain and loss of e^-. Each N atom needs to lose 2 e^-. The rest will balance automatically

21)

$$2NH_3OH^+ + 4Fe^{3+} \rightarrow 4Fe^{2+} + H^+ + H_2O + N_2O$$

(-1 → +1)

G : 4

L : 4 (each N atom losing 2e)

★ → Thermal decomposition of Group-2 Nitrates IS a redox reaction

Precipitation reac^n, Thermal decomposition and Neutralization reac^n are NOT redox reactions

Salt of a weak acid and strong base will be basic
" " " strong " " weak " " " acidic
" " " strong " " strong " " " neutral

All displacement reac^n are REDOX
↳ Reactions where a compound forms from an element or vice versa are all redox reactions.

O$_2$ is formed

Redox 25

Chlorine reacts with **hot** aqueous sodium hydroxide.

Which oxidation states does chlorine show in the products of this reaction?

1 –1
2 +3
3 +1

Paper 1 Variant 2 March 2018 I Q35

Answer:

D

28 Which pair of reagents react together in a redox reaction?

A $CH_3CHCH_2 + Br_2$ ✓ element to compound ★

B $CH_3CH_2CH_2OH$ + concentrated H_3PO_4 ??

C $CH_3COCH_3 + HCN$

D $HCO_2C_2H_5$ + dilute H_2SO_4

Redox 26

Ammonia and chlorine react together in the gas phase.

$$8NH_3 + 3Cl_2 \rightarrow N_2 + 6NH_4Cl$$

Which statements are correct?

1 Ammonia behaves as a reducing agent.

2 Ammonia behaves as a base.

3 The oxidation number of hydrogen changes.

Paper 1 Variant 2 March 2018 I Q33

Answer:

B

When K_2MnO_4 is dissolved in water, the following reaction occurs.

$$a\,MnO_4^{2-}(aq) + b\,H_2O(l) \rightarrow c\,MnO_4^{-}(aq) + d\,MnO_2(s) + e\,OH^{-}(aq)$$

What are the values of *a* and *c* in the balanced chemical equation?

	a	*c*
A	2	1
B	3	2
C	4	3
D	5	4

Paper 1 Variant 1 Summer 2017 I Q9

Answer:

B

Answer:

B

40) $3\,MnO_4^{2-} + 2H_2O \longrightarrow 2\,MnO_4^{-} + MnO_2 + 4OH^{-}$

Cr : 2

L : 1

Just balance Gain and loss from the right side when there are 2 products of the same element, both of which are part of the gain loss equation

Oxidising agent : (Species) that gains e^- // e^- acceptor —ng

Must memorise the following Half equations for balancing:

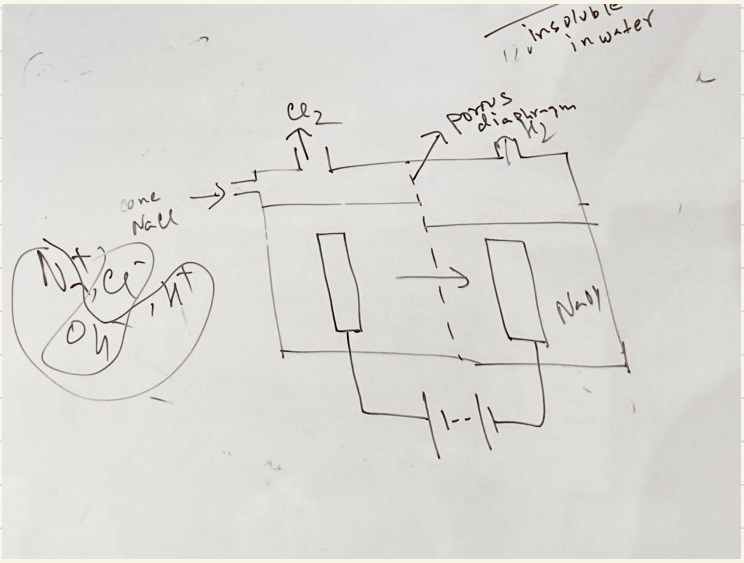
i) $Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$

ii) $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

↳ # H^+ ions are from the acidified solution and are added to balance the charges on both sides.

↳ The e^- in the equation are the same as the gain-loss of e^- we use in balancing. → We actually use gain-loss in balancing because the e^- in the half equations cancel out and the overall equation has no e^-.

In MCQs when a question is given that asks you to identify element // compound X from a reaction of X, the way to do it is by matching gain and loss of e^- and NOT just balancing the equation


insoluble in water
Cl_2
Porous diaphragm
H_2
Conc NaCl
Na^+, Cl^-
OH^-, H^+
NaOH