

Chemical Behaviours



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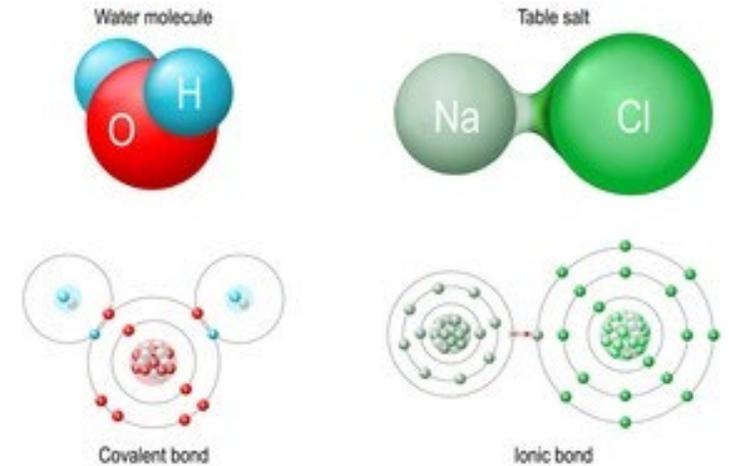
**UNIVERSITY
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Atomic Structure (Refresher)

- All materials are made from atoms.
- An atom contains:
 - Protons (positive charge)
 - Neutrons (no charge)
 - Electrons (negative charge)
- The arrangement of electrons determines how a substance behaves chemically.
- An ion forms when an atom gains or loses electrons.
 - Loss of electrons → Positive ion (cation)
 - Gain of electrons → Negative ion (anion)
- Ions are essential in:
 - Electrolytes
 - Batteries
 - Corrosion reactions

Types of Bonding (Refresher)

- **Ionic Bonding** - Electron transfer between atoms
 - Forms positive and negative ions
 - Strong electrostatic attraction
 - Example: Sodium chloride (NaCl)
- **Covalent Bonding** - Atoms share electrons
 - Often form gases or low melting point substances
 - Example: Water (H₂O)
- **Metallic Bonding** - Positive metal ions in a “sea” of delocalised electrons
 - Allows electrical and thermal conductivity
 - Gives metals ductility and malleability



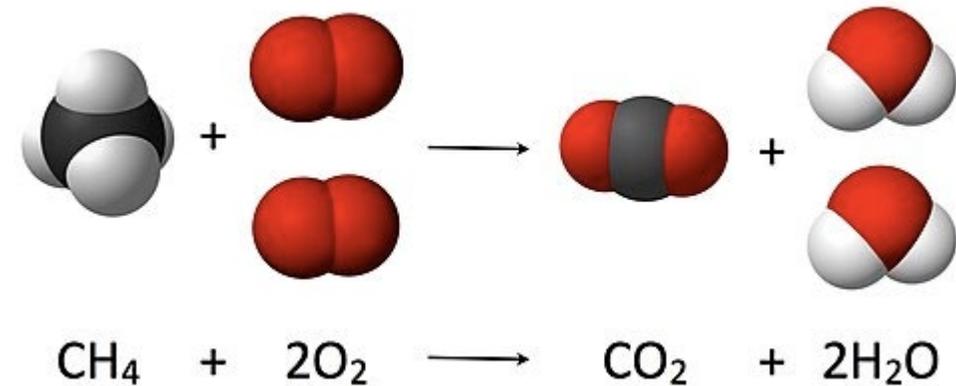
What is Chemical Behaviour

- Chemical behaviour describes how a substance reacts, changes, or interacts with other substances due to its atomic structure and bonding.
- It explains:
 - Whether a material will react
 - How fast it reacts
 - What products are formed
 - How much energy is absorbed or released



What is a chemical reaction?

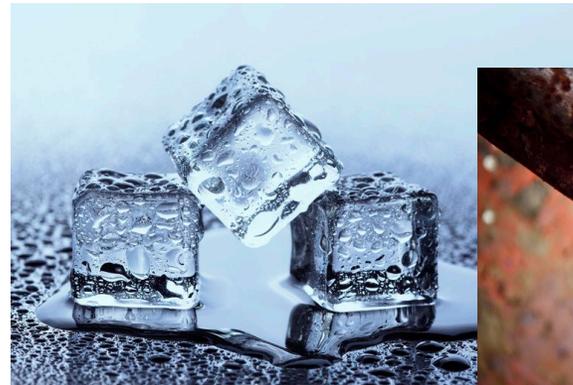
- A Chemical Reaction is a process that occurs when two or more molecules interact to form a new product(s).
- Compounds that interact to produce new compounds are called reactants whereas the newly formed compounds are called products.
- Chemical reactions play an integral role in different industries, customs and even in our daily life. They are continuously happening in our general surroundings; for example, rusting of iron, pottery, fermentation of wine and so on.
- A reaction can take place between two atoms or ions or molecules, and they form a new bond and no atom is destroyed or created but a new product is formed from reactants.



Physical vs Chemical Change

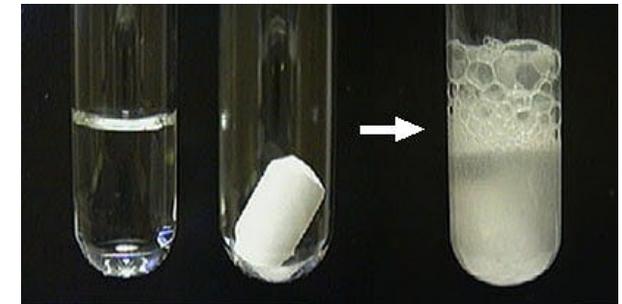
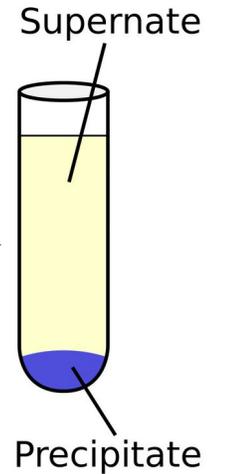
Physical Change	Chemical Change
No new substance formed	New substance formed
Often reversible	Usually irreversible
Change in state only	Change in composition

- Examples:
 - Melting ice → physical
 - Rusting steel → chemical



Indicators of a Chemical Reaction

- A chemical change is often identified by:
 - Colour change
 - Gas formation (bubbles)
 - Temperature change
 - Light emission
 - Formation of a precipitate

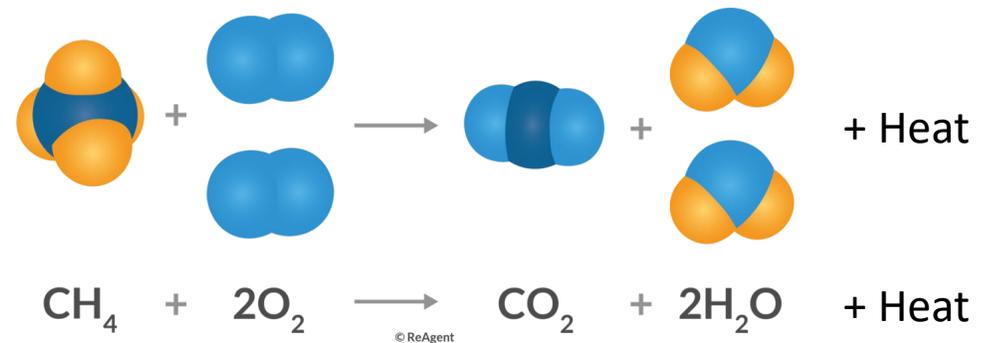


Types of Chemical Reactions

- **Combustion Reaction**

- A combustion reaction is a reaction with a combustible material with an oxidizer to give an oxidized product. An oxidizer is a chemical a fuel requires to burn, generally oxygen.

- For example the methane reaction on this slide in which methane reacts with oxygen to produce carbon dioxide, water and heat.

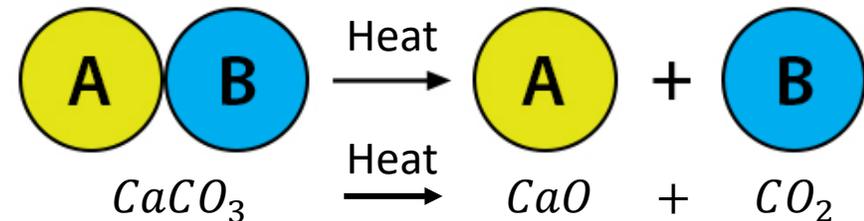


Types of Chemical Reactions

- **Decomposition Reaction**

- A decomposition reaction is a reaction in which a single component breaks down into multiple products. Certain changes in energy in the environment must be made like heat, light or electricity breaking bonds of the compound.

- For example calcium carbonate when heated breaks down into calcium oxide and carbon dioxide.

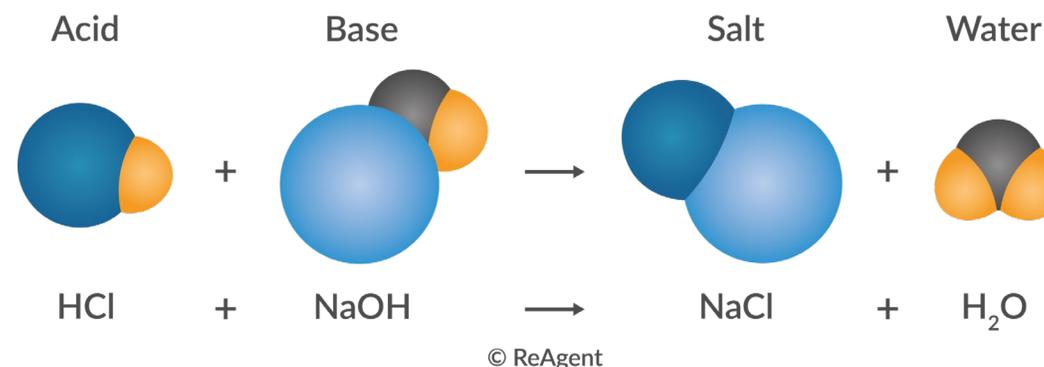


Types of Chemical Reactions

- **Neutralisation Reaction**

- A Neutralisation reaction is basically the reaction between an acid and a base giving salt and water as the products. The water molecule formed is by the combination of OH⁻ ions and H⁺ ions. The overall pH of the products when a strong acid and a strong base undergo a neutralization reaction will be 7.

- For example the hydrochloric acid and sodium hydroxide reaction on this slide result in a neutralization reaction producing Sodium Chloride(Common Salt) and water as the products.



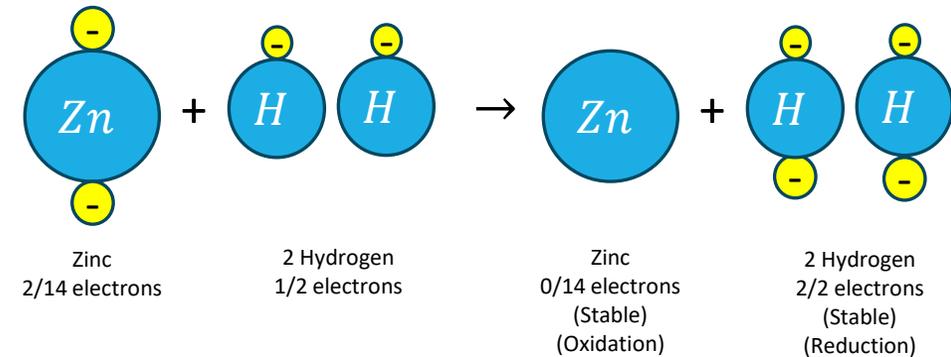
Types of Chemical Reactions

- **Redox Reaction**

- A redox reaction is a reaction between two chemicals resulting in the production of ions due to the transfer of electrons between reactants. It is the main link between electrochemical link.

- For example, when zinc reacts with hydrogen the zinc loses 2 electrons making it positively charged and the hydrogen atoms each gain an electron becoming stable.

- Oxidation → Loss of electrons
- Reduction → Gain of electrons



Note this diagram only shows valence shells

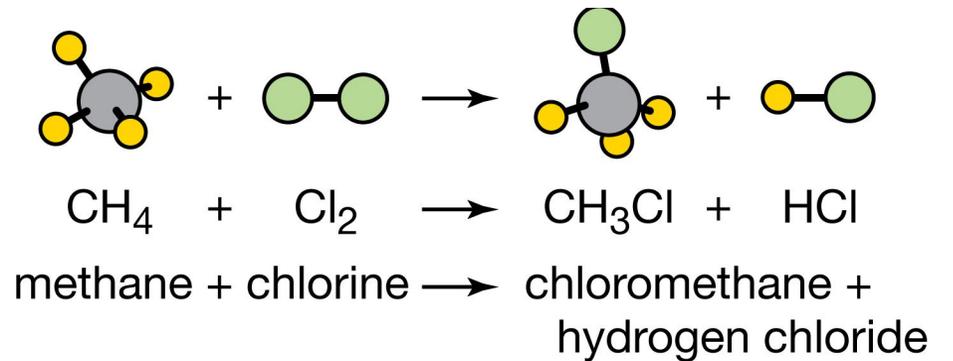
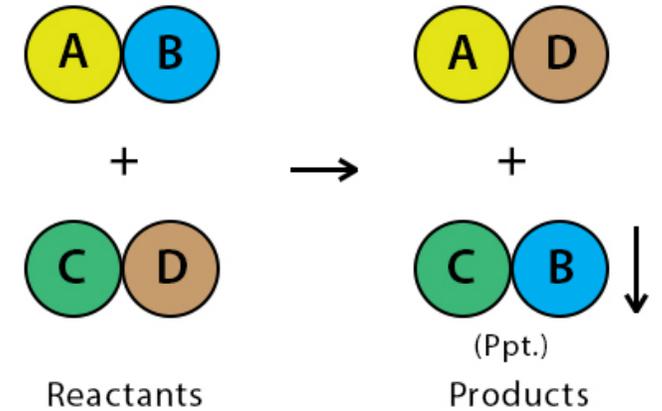
Memory tip: Remember OIL RIG
Oxidation Is Loss
Reduction Is Gain

Types of Chemical Reactions

- **Precipitation or Double-Displacement Reaction**

- Precipitation reaction is a type of displacement reaction in which two compounds react and consequently, their anions and cations switch places forming two new products.

- For example, when chlorine and methane react one of the chlorine atoms swaps with one of the hydrogen atoms

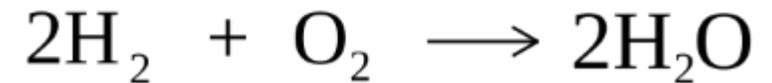
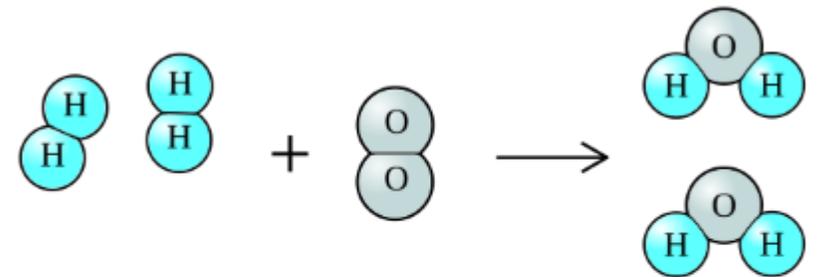


Types of Chemical Reactions

- **Synthesis Reaction**

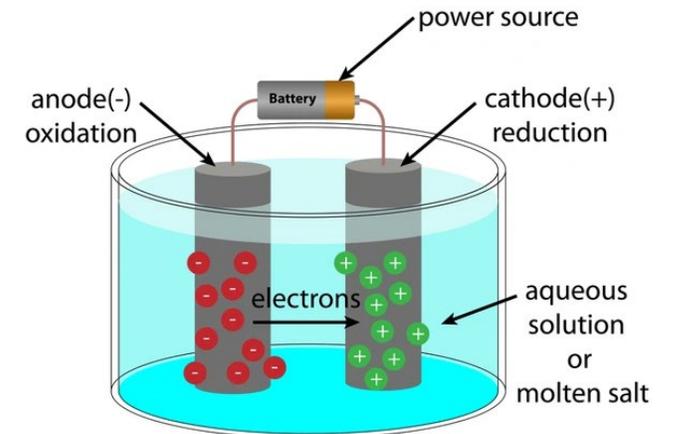
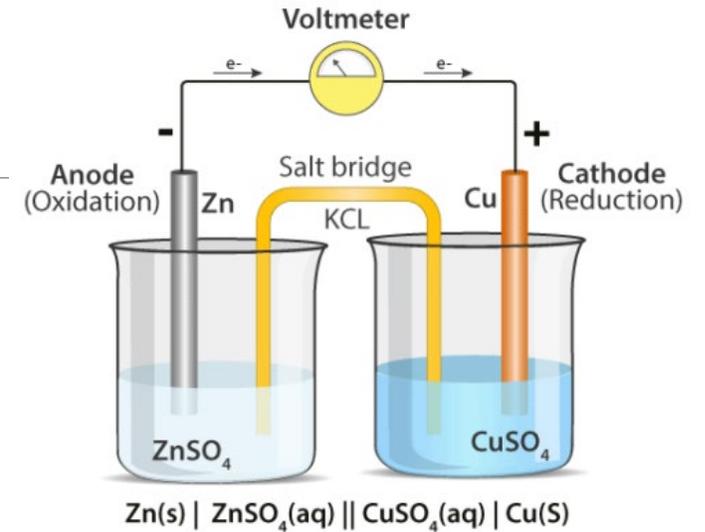
- A Synthesis reaction is one of the most basic types of reaction wherein multiple simple compounds combine under certain physical conditions giving out a complex product. The product will always be a compound.

- For example, when hydrogen and oxygen combine to produce hydrogen dioxide (water)



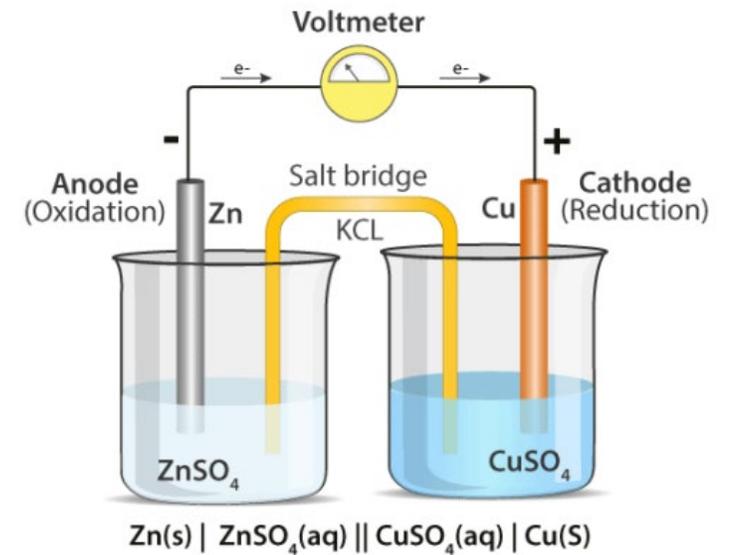
What is a Chemical Cell?

- Chemical cells are electrochemical components which rely on redox reactions to convert chemical to electrical energy.
- There are two main types of chemical cells:
 - **Galvanic Cell** - Converts chemical energy into electrical energy
 - **Electrolytic Cell** - Converts electrical energy to chemical energy



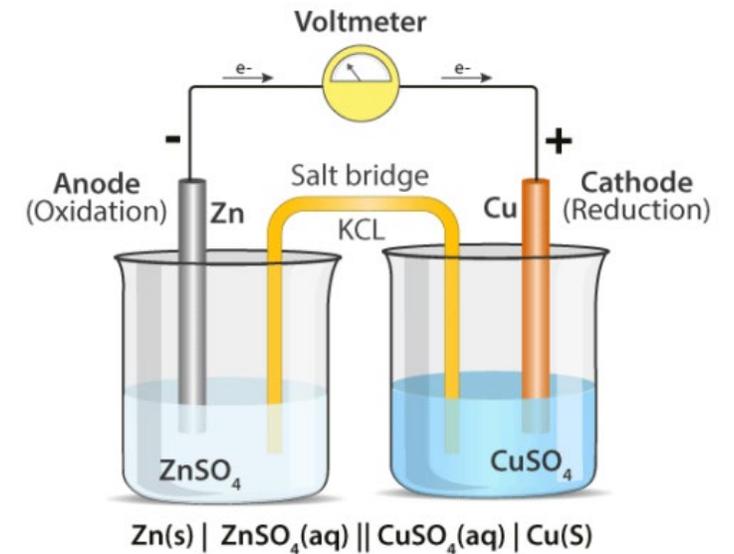
What is a Galvanic Cell?

- The galvanic cell consists of two separate half-cells. Each dedicated to the anode or the cathode
- Each of these half cells contain an electrolyte solution and a conductor acting as an electrode.
- It works because:
 - One material loses electrons
 - Another material gains electrons
 - The movement of electrons produces current



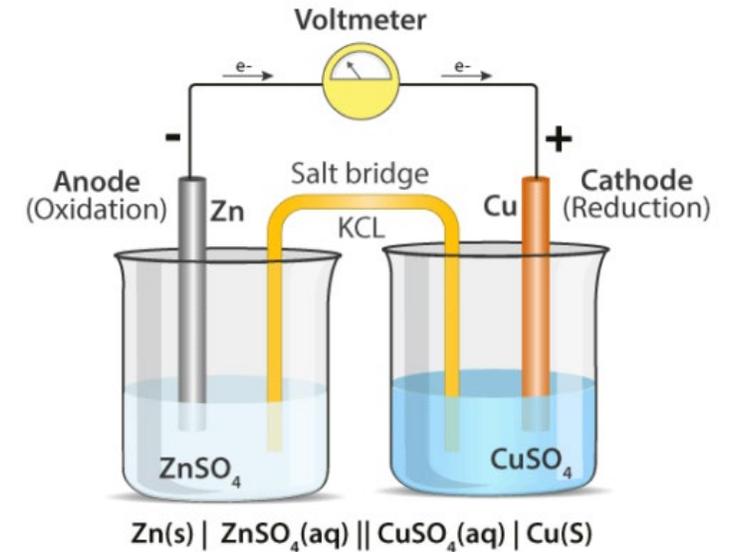
What is a Galvanic Cell?

- The salt bridge is typically an inverted U-tube.
- It is filled with a concentrated solution of an inert electrolyte.
- It often contains a gel mixed with electrolytes such as KNO_3 or K_2SO_4 .
- Its purpose is to complete the circuit by allowing ions to flow between half-cells.
- It maintains electrical neutrality in the cell.
- Negative ions move toward the anode. (-)
- Positive ions move toward the cathode. (+)
- This ion movement prevents charge build-up and allows the cell to continue functioning.



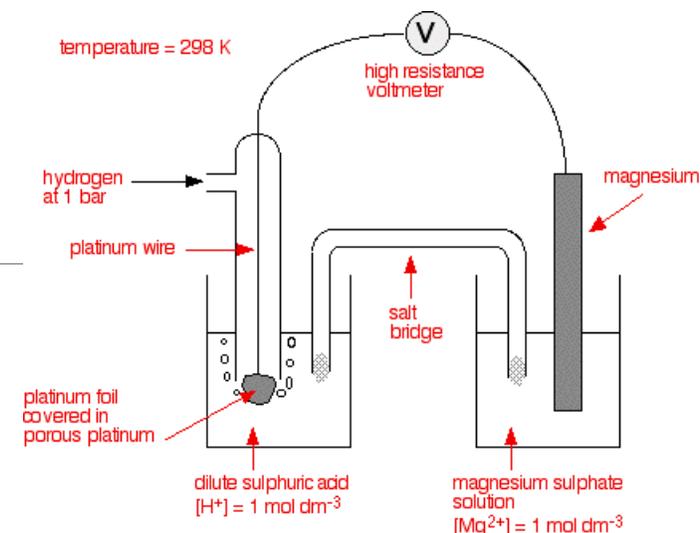
What is a Galvanic Cell?

- In a galvanic cell, when two-electrode are dipped in their respective ion
- There is a tendency for:
 - one of the electrodes (anode (-)) to undergo oxidation (lose electrons)
 - the other electrode (cathode (+)) to undergo reduction (gain electrons)
- This tendency of losing of electrons (oxidation) or gaining of electrons (reduction) is called electrode potential.



What is a Galvanic Cell?

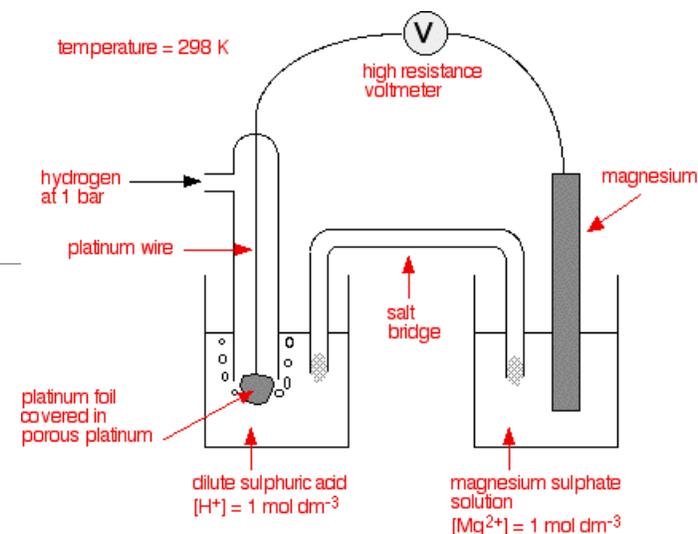
- Standard electrode potential is defined as the electrode potential of an electrode relative to a standard hydrogen electrode under standard conditions.
- The standard conditions taken are as follows:
 - 1 molar concentration of each ion in the solution.
 - A temperature of 298 K.
 - 1 bar pressure.
- We can then form an electrochemical series which tells us the relative potential of various elements
- The positive values are oxidising agents, the bottom is the reduction agents



$F_2(g) + 2e^-$	\rightarrow	$2F^-(aq)$	+2.87
$Au^+(aq) + e^-$	\rightarrow	$Au(s)$	+1.68
$Cl_2(g) + 2e^-$	\rightarrow	$2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^-$	\rightarrow	$2H_2O(l)$	+1.23
$Ag^+(aq) + e^-$	\rightarrow	$Ag(s)$	+0.80
$Fe^{3+}(aq) + e^-$	\rightarrow	$Fe^{2+}(aq)$	+0.77
$I_2(s) + 2e^-$	\rightarrow	$2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^-$	\rightarrow	$4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^-$	\rightarrow	$Cu(s)$	+0.34
$2H^+(aq) + 2e^-$	\rightarrow	$H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^-$	\rightarrow	$Pb(s)$	-0.13
$Sn^{2+}(aq) + 2e^-$	\rightarrow	$Sn(s)$	-0.14
$Ni^{2+}(aq) + 2e^-$	\rightarrow	$Ni(s)$	-0.23
$Co^{2+}(aq) + 2e^-$	\rightarrow	$Co(s)$	-0.28
$Fe^{2+}(aq) + 2e^-$	\rightarrow	$Fe(s)$	-0.44
$Zn^{2+}(aq) + 2e^-$	\rightarrow	$Zn(s)$	-0.76
$2H_2O(l) + 2e^-$	\rightarrow	$H_2(g) + 2OH^-(aq)$	-0.83
$Al^{3+}(aq) + 3e^-$	\rightarrow	$Al(s)$	-1.67
$Mg^{2+}(aq) + 2e^-$	\rightarrow	$Mg(s)$	-2.34
$Na^+(aq) + e^-$	\rightarrow	$Na(s)$	-2.71
$Ca^{2+}(aq) + 2e^-$	\rightarrow	$Ca(s)$	-2.87
$K^+(aq) + e^-$	\rightarrow	$K(s)$	-2.93

What is a Galvanic Cell?

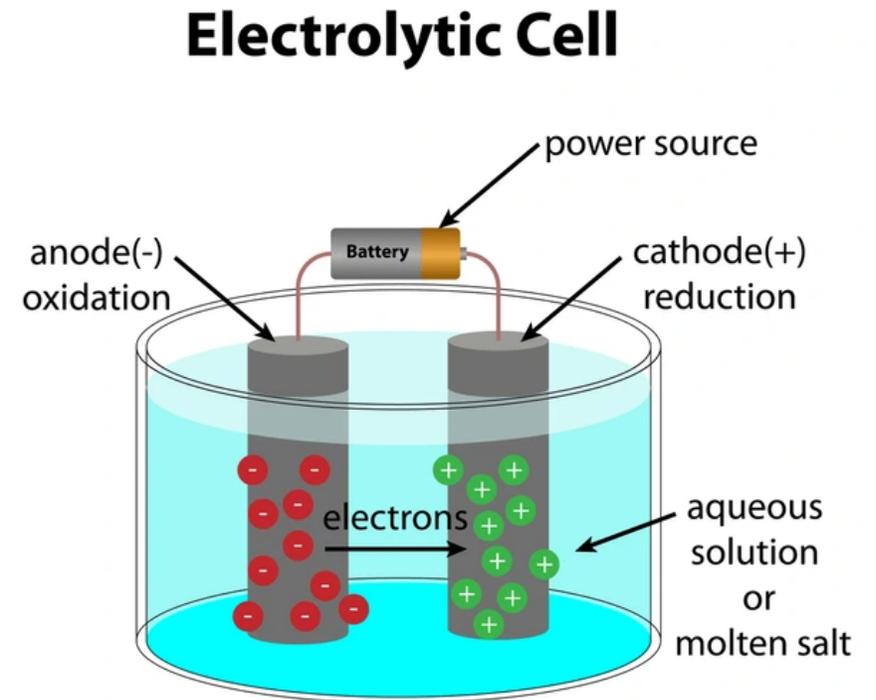
- We can tell whether a cell is feasible based on the electrode potential
- We do this by working out the cell potential (cell emf)
- To do this we use this formula: $E_{\text{cell}}^{\circ} = E_{\text{Cathode}} - E_{\text{anode}}$
- If E_{cell}° is positive the reaction is feasible
- If E_{cell}° is negative the reaction is not feasible



$\text{F}_2(\text{g}) + 2\text{e}^-$	\rightarrow	$2\text{F}^-(\text{aq})$	+2.87
$\text{Au}^+(\text{aq}) + \text{e}^-$	\rightarrow	$\text{Au}(\text{s})$	+1.68
$\text{Cl}_2(\text{g}) + 2\text{e}^-$	\rightarrow	$2\text{Cl}^-(\text{aq})$	+1.36
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^-$	\rightarrow	$2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{Ag}^+(\text{aq}) + \text{e}^-$	\rightarrow	$\text{Ag}(\text{s})$	+0.80
$\text{Fe}^{3+}(\text{aq}) + \text{e}^-$	\rightarrow	$\text{Fe}^{2+}(\text{aq})$	+0.77
$\text{I}_2(\text{s}) + 2\text{e}^-$	\rightarrow	$2\text{I}^-(\text{aq})$	+0.54
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^-$	\rightarrow	$4\text{OH}^-(\text{aq})$	+0.40
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$	\rightarrow	$\text{Cu}(\text{s})$	+0.34
$2\text{H}^+(\text{aq}) + 2\text{e}^-$	\rightarrow	$\text{H}_2(\text{g})$	0.00
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^-$	\rightarrow	$\text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^-$	\rightarrow	$\text{Sn}(\text{s})$	-0.14
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^-$	\rightarrow	$\text{Ni}(\text{s})$	-0.23
$\text{Co}^{2+}(\text{aq}) + 2\text{e}^-$	\rightarrow	$\text{Co}(\text{s})$	-0.28
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^-$	\rightarrow	$\text{Fe}(\text{s})$	-0.44
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^-$	\rightarrow	$\text{Zn}(\text{s})$	-0.76
$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^-$	\rightarrow	$\text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^-$	\rightarrow	$\text{Al}(\text{s})$	-1.67
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$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^-$	\rightarrow	$\text{Ca}(\text{s})$	-2.87
$\text{K}^+(\text{aq}) + \text{e}^-$	\rightarrow	$\text{K}(\text{s})$	-2.93

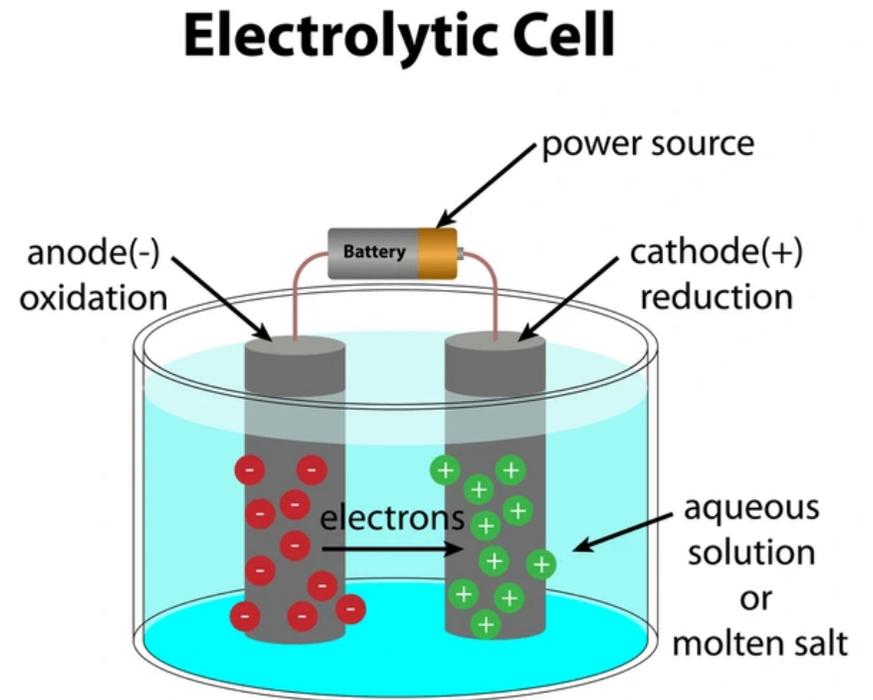
What is an Electrolytic Cell

- An electrolytic cell converts electrical energy into chemical energy
- Electrodes are dipped in an electrolytic solution containing cations and anions.
- On supplying current, the ions move towards electrodes of opposite polarity, and simultaneous reduction and oxidation take place.



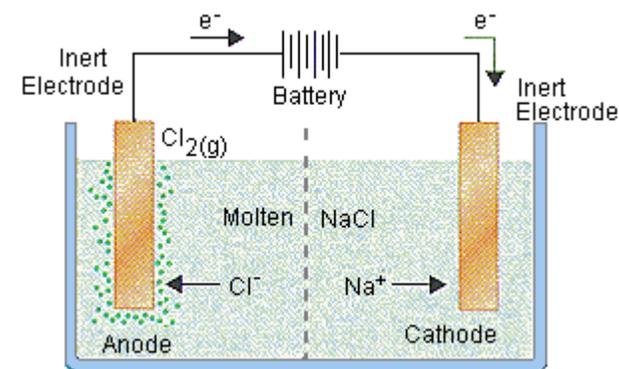
What is an Electrolytic Cell

- The electrodes are connected to an external DC power supply.
- The power supply makes the electrode connected to its positive terminal the anode, and the electrode connected to its negative terminal the cathode.
- The supply forces electrons to move from the power source into the cathode and pulls electrons away from the anode.
- This drives a chemical reaction that would not occur naturally.
- Electrical energy from the battery is converted into chemical potential energy stored in the products.



What is an Electrolytic Cell

- For example, in the electrolysis of molten sodium chloride, sodium chloride is melted (above 801°C)
- Two electrodes are inserted into the melt, and an electric current is passed through the molten salt. The chemical reaction that takes place at the electrodes is as follows:
 - Sodium-ion migrates to the cathode, where sodium ion gains one electron and reduces to sodium metal. ($\text{Na}^+ + \text{e}^- \rightarrow \text{Na}$)
 - Chloride ions migrate towards the anode, where it loses one electron and gets oxidised to chlorine gas. ($\text{Cl}^- \rightarrow \frac{1}{2}\text{Cl}_2 + \text{e}^-$)
 - The overall reaction is the breakdown of sodium chloride into its elements ($2\text{NaCl} \rightarrow 2\text{Na} + \text{Cl}_2$)



Electrolytic vs Galvanic

- A spontaneous reaction releases energy naturally, this happens in a galvanic cell
- A non-spontaneous reaction requires energy to be put in, this happens in an electrolytic cell

Feature	Spontaneous	Non-Spontaneous
External Power Needed?	No	Yes
Energy Conversion	Chemical → Electrical	Electrical → Chemical
ΔG	Negative	Positive
E°_{cell}	Positive	Negative
Common Name	Galvanic / Voltaic	Electrolytic