SC10-13: Electrolysis, metals, reversible reactions, transition metals, alloys and corrosion

Sequence

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1. Electrolysis

Electrolysis	Using direct current to break compounds down into their elements.
Electrolyte	Liquid used for electrolysis because ions can move – either molten or dissolved ionic compounds
Electrolysis of solids	Does not work as ions can't move.
Electrodes	Conducting rods placed in electrolyte, connected to power supply.
Cathode	Negative electrode where cations (positive ions) are discharged.
Anode	Positive electrode where anions (negative ions) are discharged.
OIL	Oxidation Is Loss of electrons (OIL)
RIG	Reduction Is Gain of electrons (RIG)
AnOx	Anode is for *ox*idation
CaRe	Cathode is for reduction

2. Half-equations (HT)

Half-equations	An equation that shows what happens to just one of the ions during chemical reaction. Two half-equations combine to give the overall ionic equation
Half-equations in electrolysis	Show electron transfer: Cathode (reduction): $M^+ + e^- \rightarrow M$ Anode (oxidation): $X^- \rightarrow X + e^-$
Electrons in half equations	Cations will gain the same number of electrons as their charge. Anions will lose the same number of electrons as their charge.
Non-metals in half-equations	Most non-metals will form molecules: O_2, F_2, Cl_2, Br_2, I_2 etc – you will need two of them in the half-equation.

3. Products of electrolysis

Discharged	When an ion loses its charge to become an atom
Electrolysis of molten salts	Cathode: metal Anode: non-metal
Ions in salt solutions	Metal, non-metal and H^+ and OH^- because water partially ionises.
Hydrogen half-equation	$2H^+(g) + 2e^- \rightarrow H_2(g)$
Electrolysis of salt solutions - cathode	Metal, unless reactive metal such as K, Na, Li, Mg, Ca in which case hydrogen.
Electrolysis of salt solutions - anode	Non-metal, unless sulphate salt in which case oxygen.
Electrolysis of sulfuric acid	Cathode: hydrogen Anode: oxygen
Purifying copper - setup	Anode: impure copper Cathode: pure copper Electrolyte: copper sulfate solution
Purifying copper - explanation	Copper atoms leave the anode ($Cu \rightarrow Cu^{2+} + 2e^-$), travel through solution to the cathode ($Cu^{2+} + 2e^- \rightarrow Cu$). Impure atoms on the anode fall to the bottom as sludge.

4. Core practical – electrolysis of copper sulfate solution (CP10)

CP10 - aim	To see how the changing the current affects the rate of electrolysis.
CP10 – Prepare electrodes	Clean two copper electrodes, label one anode and one cathode, weigh each and record mass.
CP10 - Setup	Connect a variable resistor to the negative terminal of a power supply then connect this to the cathode. Connect an ammeter to the positive terminal then connect this to the anode. Place both electrodes in a beaker of copper sulfate solution
CP10 – Run the experiment	Switch the power supply on, adjust the variable resistor so the ammeter reads 0.2 A and leave for 20 minutes.
CP10 – Record results	Carefully remove each electrode, rinse them with water and then with propanone. Re-weigh each and record.
CP10 – Variations	Repeat the experiment with a current of 0.3 A, 0.4 A and 0.5 A.
CP10 - Results	The anode loses mass whilst the cathode gains mass. The higher the current the greater the mass change.

potassium	most reactive	K
sodium	↑	Na
calcium		Ca
magnesium		Mg
aluminium		Al
carbon		C
zinc		Zn
iron		Fe
tin		Sn
lead		Pb
hydrogen		H
copper		Cu
silver		Ag
gold	↓	Au
platinum	least reactive	Pt

5. Reactivity

Reactivity series (most to least)	Potassium, sodium, calcium, magnesium, aluminium, zinc, iron, copper, silver, gold.
Forming cations	The more reactive metals more easily lose electrons to form cations.
Reaction with cold water ($H_2O(l)$)	Metal + water → metal hydroxide + hydrogen - Potassium – violently - Sodium – very quickly - Calcium – slowly
Reaction only with steam ($H_2O(g)$)	Metal + water → metal oxide + hydrogen Magnesium, zinc, iron
No reaction with water or steam	Copper, silver, gold
Reaction with acid	Metal + acid → salt + hydrogen Sodium, potassium – violent Calcium, magnesium, zinc, iron – steady Copper, silver, gold – no reaction

6. Displacement reactions

Displacement reactions	Reactions in which a more reactive metal displaces a less reactive metal from a salt eg: *copper sulfate + zinc →* *zinc sulfate + copper* Does not work backwards as copper is less reactive than zinc.
Redox reactions	Reactions in which an oxidation and reduction happen at the same time, such as displacement reactions.
Redox during displacement	The more reactive metal is oxidised, eg: $Zn \rightarrow Zn^{2+} + 2e^-$ The less reactive metal is reduced, eg: $Cu^{2+} + 2e^- \rightarrow Cu$
Spectator ion	An ion that does not change during a chemical reaction.

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7. Extracting metals from their ores

Native state	When metals are found in their pure form, e.g. silver and gold.
Ore	Rock containing enough of a metal compound to extract for profit. Normally oxides or sulphides of the metal.
Extracting metals by heating with carbon	For extracting less reactive metals such as zinc, iron, copper. Works because carbon is more reactive, e.g.: iron oxide + carbon → carbon dioxide + iron
Extracting metals by electrolysis	Done with metals more reactive than carbon e.g. potassium, sodium, calcium, magnesium, aluminium, e.g.: Aluminium oxide → aluminium + oxygen
Bioextraction	Using living organisms to extract metals.
Bioleaching	Growing bacteria on poor quality copper ore. The bacteria produce a solution of copper sulfate from which copper can be extracted by electrolysis.
Phytoextraction	Plants are grown that absorb metal ions as they grow. The plants are then burnt to produce ash rich in metal compounds.

Process	Advantages	Disadvantages
both bioleaching and phytoextraction	no harmful gases (e.g. sulfur dioxide) are produced causes less damage to the landscape than mining conserves supplies of higher grade ores	very slow
bioleaching	does not require high temperatures	toxic substances and sulfuric acid can be produced by the process, and damage the environment
phytoextraction	can extract metals from contaminated soils	more expensive than mining some ores growing plants is dependent on weather conditions

8. Oxidation and reduction

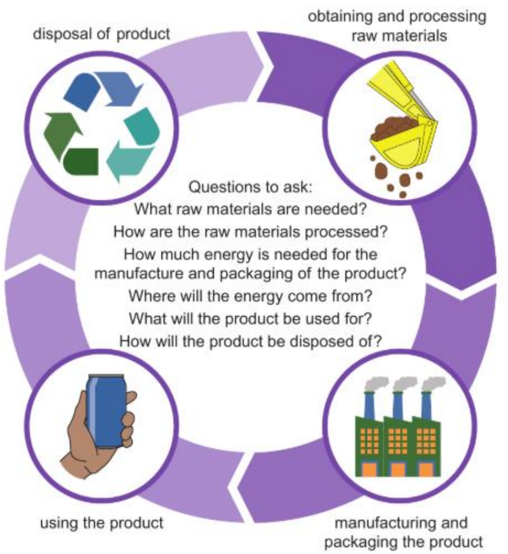
Oxidation	Gaining oxygen or losing electrons
Reduction	Losing oxygen or gaining electrons
Redox	When reduction and oxidation reactions happen together.
Reduction of iron	Iron produced from iron oxide by heating with carbon: *iron oxide + carbon → carbon dioxide + iron* Iron is reduced, carbon is oxidised.
Reduction of aluminium ore	Aluminium is produced from aluminium oxide by electrolysis: *Aluminium oxide → aluminium + oxygen* Aluminium is reduced, oxygen is oxidised
Corrosion	When metals slowly react with oxygen, making them weaker.
Rates of corrosion	More reactive metals corrode more quickly.
Tarnish	A protective layer of oxide that stops the layers below from corroding.

9. Life-cycle assessment and recycling

Recycling	Converting old waste metal into new metal that can be reused
Advantages of recycling	- Natural reserves last longer - Less pollution from mining - Less pollution from processing - Less waste in landfill - Often less energy used
Disadvantages of recycling	- Can be expensive - Can use a lot of energy in transporting, collecting, sorting
Life-cycle assessment (LCA)	Looks at environmental impact of all stages of a product's lifecycle. We should aim to reduce all damage.
LCA stages	- Obtaining and processing raw materials - Making/packaging the product - Using the product - Disposal or recycling of product

10. Dynamic equilibrium

Reversible reaction	Reactions that can go forwards as well as backwards (with products turning back into reactants)
⇋	Used to show reversible reactions.
Dynamic equilibrium	The point at which the rate of the forwards reaction and backwards reaction are equal, so the concentrations of reactants and products stops changing.
Closed systems	Nothing can escape, so dynamic equilibrium can be reached.
Open systems	Gases can escape so dynamic equilibrium can't be reached.
Equation for making ammonia	Nitrogen + hydrogen ⇋ ammonia $N_2 + 3H_2 \rightleftharpoons 2NH_3$ Exothermic ⇋ Endothermic
Haber process	For making ammonia industrially: - 200 atm pressure – equilibrium shifts right, yield increases - 450ºC – equilibrium shifts left, lower yield but MUCH faster reaction - Catalyst – increases reaction rate



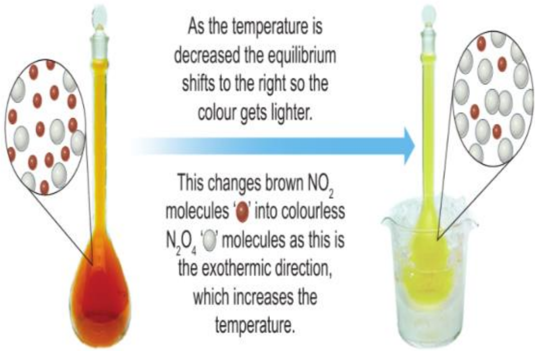
11. Changes to equilibrium systems (HT)

Effect on equilibrium of increasing temperature	Exothermic reaction – equilibrium shifts left, yield decreases Endothermic reaction – equilibrium shifts right, yield increases
Effect on equilibrium of decreasing temperature	Exothermic reaction – equilibrium shifts right, yield increases Endothermic reaction – equilibrium shifts left, yield decreases
Effect on equilibrium of increasing gas pressure	Equilibrium shifts to side with fewer gas molecules
Effect on equilibrium of decreasing gas pressure	Equilibrium shifts to side with more gas molecules
Effect on equilibrium of increasing concentration…	…of products – equilibrium shifts left, yield decreases …of reactants – equilibrium shifts right, yield increases
Effect on equilibrium of decreasing concentration	…of products – equilibrium shifts right, yield increases …of products – equilibrium shifts left, yield decreases

Photo D shows how the equilibrium position of a mixture of nitrogen dioxide and dinitrogen tetroxide depends on temperature.

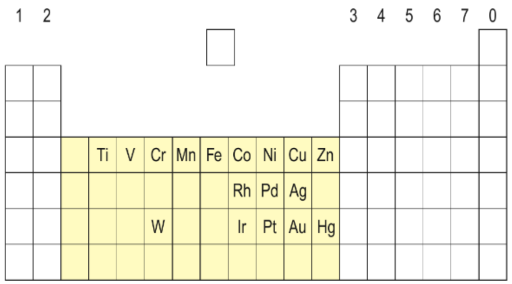
$2NO_2(g) \rightleftharpoons N_2O_4(g)$ (forward reaction is exothermic)

nitrogen dioxide (brown) dinitrogen tetroxide (colourless)



12. Transition metals

Transition metals	Metal elements placed in the block between groups 2 and 3 in the periodic table. These metals trend to have the properties associated with typical metals.
Malleable	A substance that can be hammered or rolled into shape without shattering.
Ductile	A substance that can be stretched out to make wires.
Colourful compounds	The transition metals form colourful compounds, in contrast to groups 1, 2 and 3 which tend to form white compounds.
Catalysts	The transition metals are used to catalyse a number of different chemical reactions.
Catalytic convertor	A device fitted to the exhaust system of cars/lorries which reduces the amount of harmful carbon monoxide, nitrous oxides and unburnt hydrocarbons they release. Platinum, rhodium and palladium are all used as catalysts to speed up these reactions.



B the transition metals, with some common examples identified

E Pure beryl is a colourless mineral. Iron impurities turn it into aquamarine, a blue gemstone.

13. Corrosion

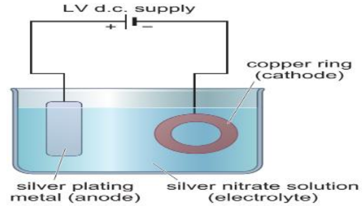
Oxidise	A reaction in which oxygen is added to another substance. It can also mean the loss of an electron from an atom.
Tarnish	A thin layer that appears on the surface of a metal due to oxidation. A metal is also said to tarnish as this layer forms.
Rusting	The corrosion of **iron or steel** in the presence of both oxygen and water.
Corrosion	The gradual deterioration of a substance when it reacts with substances in the environment, for example when a metal oxidises in air.
Sacrificial protection	Using a more reactive metal to protect a less reactive metal from corrosion, through the transfer of electrons from the more reactive metal, which is oxidised, to the less reactive metal, which is reduced.
Desiccant powder	A substance that absorbs water preventing the rusting of iron or steel.
Hydrazine	A substance that reacts with oxygen preventing the oxygen from reacting with, and corroding, metals.

A The Statue of Liberty consists of 27 tonnes of copper sheeting over a steel frame. Its green colour is due to a natural layer of copper salts that forms when copper tarnishes.

D blocks of sacrificial metal bolted onto a ship's hull

14. Electroplating

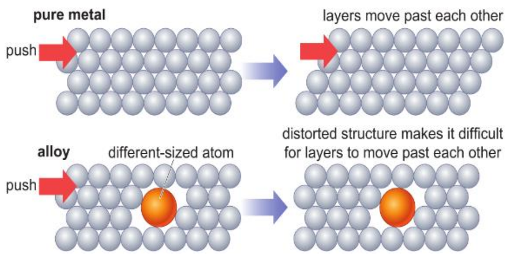
Electroplating	Using electricity to coat one metal with a thin layer of another, to improve its appearance, corrosion resistance or to make it appear more valuable.
Galvanising	Coating iron or steel with a thin layer of zinc to improve its resistance to rusting.
Tin plating	Coating the inside of steel cans with a thin layer of tin, which prevents the contents reacting with steel. Tin cans actually only contain this thin layer, as tin is an expensive metal.



C electroplating silver onto a copper ring

15. Alloying

Alloy	A mixture of two or more metals, which results in improved properties such as lower density or improved strength.
Alloying	The process of mixing metals to form an alloy
Steel alloys	Iron with other elements deliberately added to it to make an alloy.
Stainless steel	A steel alloy containing elements such as chromium to improve its resistance to rusting.
Pure metals	A single metallic element forming a regular metallic lattice.



16. Uses of metals and their alloys

Chemical properties	How a chemical reacts with other substances.
Physical properties	A description of how a material behaves and responds to forces and energy. For example a materials ability to conduct electricity or heat.
Aluminium	A lightweight metal that resists corrosion and is relatively strong, making it suitable for making aeroplane parts and the outer parts of overhead power cables.
Copper	A dense metal that is a good conductor of electricity and highly resistant to corrosion, making it suitable for making electrical circuitry, wires and water pipes.
Gold	A highly dense, soft metal that is an excellent conductor of electricity and is highly expensive. These properties make it suitable for use in microprocessors, where the speed of electricity conduction is vital and jewellery to show someone's status or due its appearance.
Brass	An alloy of copper and zinc which is stronger than copper alone, making it suitable for door fixtures, statues and screws/hinges/padlocks.
Magnalium	Magnalium is an alloy that contains 95% aluminium and 5% magnesium. It is used as an engineering alloy to make aircraft parts and scientific instruments. Magnalium is less dense and almost four times stronger than aluminium alone. Although it is denser than magnesium, magnalium is twice as strong and has better resistance to corrosion.
Density (g/cm^3)	The mass of an object divided by its volume, which shows us whether a substance will be heavier than another.
Relative strength	The strength of one material compared to that of another.