Combined Science - Chemistry

CC10-12 Knowledge organiser

C10-12: Electrolysis, metals and reversible reactions

Sequence

1. Electrolysis
2. Half-equations (HT)
3. Products of electrolysis
4. Core practical – electrolysis of copper sulfate solution (CP10)
5. Reactivity
6. Displacement reactions
7. Extracting metals from their ores
8. Oxidation and reduction
9. Life-cycle assessment and recycling
10. Dynamic equilibrium
11. Changes to equilibrium systems (HT)

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 (+) are discharged.
Anode	Positive electrode where anions (-) are discharged.
OIL	Oxidation Is Loss of electrons (OIL)
RIG	Reduction Is Gain of electrons (RIG)
AnOx	<u>An</u>ode is for ***ox***idation
CaRe	<u>Ca</u>thode is for <u>re</u>duction

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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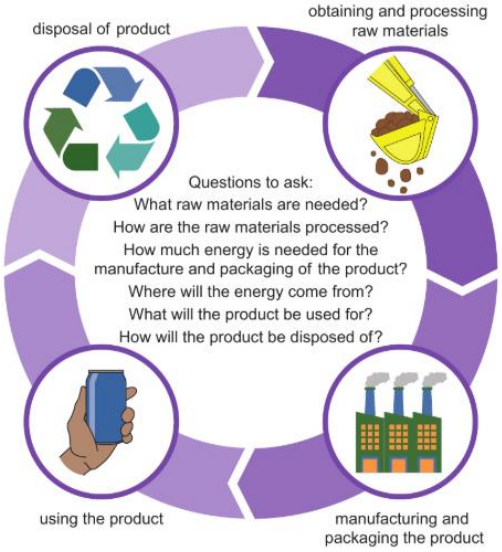
7. Extracting metals from their ores	
Native state	When metals are found in their pure form, e.g. silver and gold.
Ore	Rock containing enough of a metal compound to extract for profit. Normally oxides or sulphides of the metal.
Extracting metals by heating with carbon	For extracting less reactive metals 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
Reduction	Losing oxygen
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.

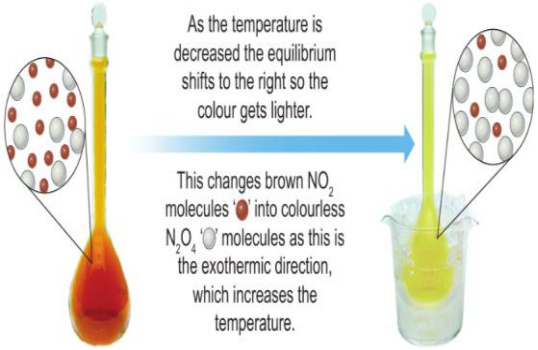
9. Life-cycle assessment and recycling	
Recycling	Converting old waste metal into new metal that can be reused
Advantages of recycling	- Natural reserves last longer - Less pollution from mining - Less pollution from processing - Less waste in landfill - Often less energy used
Disadvantages of recycling	- 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 - 450°C – 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)