Electrolysis:

1. Describe electrolysis as the conduction of electricity by an ionic compound (electrolyte), when molten or dissolved in water, leading to the chemical decomposition of the electrolyte

- Electrolyte: compound in solution or a molten compound which conducts electricity and is decomposed by it in the process
    - Strong electrolyte: able to conduct large currents due to high percentage of ionization
    - Weak electrolyte: does not ionize completely and does not readily conduct electricity
    - Non-electrolytes: does not ionize or conduct electricity
- Battery: an electrical source that is required to drive the flow of electrons in the set up
    - Note: direct current must be used, since alternating current results in a continuous change in polarity or charge on the electrode (so switching of anode and cathode prevents the discharge of ions)
- Electrodes: conductors by which an electric current enters or leaves the electrolyte
    - Metal conductor: conducts electricity in solid or liquid states by movement of electrons
    - Electrolyte: relies on the movement of ions in the electrolyte (not a metal conductor)
- Cathode: **negative electrode that is connected to the negative terminal of a battery** or electrical source (cations migrate to the cathode to be reduced)
    - **Reduction** occurs at the cathode and where electrons enter the electrolyte
- Anode: **positive electrode** that is connected to the positive terminal of a battery (anions migrate to the anode to be oxidized)
    - **Oxidation occurs** at the cathode and where electrons leave the electrolyte
- Certain products are formed or discharged at each electrode
    - Cathode: usually hydrogen gas or metal is produced
    - Anode: non-metals are produced (oxygen, chlorine)
- There are often more than two types of ions in the electrolyte
    - Water (in aqueous solution) can gain electrons to form H+ and OH- ions
- Electrolytic reactions are **redox reactions** since they involve the transfer of electrons

2. Describe electrolysis as evidence for the existence of ions which area held in a lattice when solid but which are free to move when molten or in solution

- Ionic Theory: presence of freely moving charged particles called ions in the electrolytes that allows for electrolysis to occur
    - When ionic solids (NaCl) dissolves in water, the ions which were fixed in position in the solid can now move freely
    - When covalent compounds (HCl) dissolve in water, their polar molecules ionize and dissociate to produce freely-moving ions
    - Direct current that passes through the electrolyte results in the free ions losing their random movement, so positive ions are attracted to the negative electrode (and negative ions to positive electrode)
- Electrolyte must be in the aqueous or molten state in order for electrolysis to occur
    - Does not happen when the electrolyte is solid
    - Ions are held in a lattice structure and prevents mobile charge carriers from moving about

3. Predict the identity of the substance liberated during electrolysis from the state of electrolyte (molten or aqueous), position in the electrochemical series and concentration, using inert electrodes (with focus on the electrolysis of aqueous sodium chloride, aqueous copper sulfate, dilute sulfuric acid, and aqueous potassium iodide)

Factors Affecting Electrolysis:

i. Ease of positive ion in gaining electron

a. The electrochemical series provides the information

i. K+ to Au+ shows a trend of increasing preferential discharge (whereby Au+ is more likely to gain electrons than K+)
ii. F-, SO42-, NO3-, Cl-, Br-, I-, OH- of increasing preferential discharge (where OH- loses electrons more readily than F-)
1. There is a huge gap between Cl- and OH-

b. Note: preferential discharge does not warrant marks, explain the loss/gain of electrons

ii. Concentration effect of the ions in the electrolyte

a. **Increasing the concentration of a given ion promotes its discharge from a solution**
b. Order of discharge in electrochemical series can be reversed by concentration effect
c. Usually only effective when the two compared ions are closely positioned in the series

Electrolyte	Product at Anode	Explanation	Product at Cathode	Explanation
Dilute NaCl solution (Na+, Cl-, H+, OH-)	Oxygen	OH- loses electrons more readily than Cl-, thus OH- is preferentially oxidized	Hydrogen	H+ gains electrons more readily than Na+, thus H+ is preferentially reduced
Concentrated NaCl solution	Chlorine	Concentration of Cl- is high enough for the concentration effect to take place, due to the *closeness of OH- and Cl- in the electrochemical series*, Cl- is preferentially oxidized	Hydrogen	Although the concentration of Na+ is high*, the distance between the positions of Na+ and Cl- in the electrochemical series is too great*, H+ is still preferentially reduced

iii. Nature of the electrode

a. Electrodes which take no part in the electrolytic reaction are **inert** (platinum and carbon graphite are usually inert electrodes)
i. Note: platinum is attacked by liberated chlorine and carbon by liberated oxygen
b. Some electrodes participate in redox process or have strong affinity for certain ions and these are **active electrodes** (copper and silver)
i. Aqueous copper (II) sulfate and copper anode whereby no product is collected at the anode but the copper anode dissolves (instead of OH- losing electrons, Cu atoms of the anode loses electrons)
ii. Aqueous sodium chloride and mercury cathode where sodium metal is produced instead of hydrogen gas (mercury associates with sodium to form sodium amalgam so the discharge of Na+ requires less energy)

4. <u>Construct ionic equations for the reactions occurring at the electrodes during electrolysis</u>

5. <u>Describe electrolysis of aqueous copper (II) sulfate with copper electrodes as a means of purifying copper</u>

- Experimental process:
  - Impure copper is made the anode and the piece of pure copper is used as the cathode
  - Electrolyte must be a solution of copper salt
  - Copper atoms of the anode loses electrons and the copper (II) ions formed dissolves in the electrolyte (to replenish the copper (II) ions in the electrolyte)
  - Copper (II) ions migrate to the cathode to gain electrons and copper atoms are deposited
  - Anode becomes smaller while cathode becomes larger (while electrolyte is unchanged)
  - Impurities are left on the anode and fall off to collect below the anode

6. <u>Describe the electroplating process</u>

- Refers to coating the surface of one metal with another metal

- Used to give objects an attractive appearance, a good decorative finish and for protection against corrosion (copper plating, tin plating for food cans, silver and gold plating)
    - Objects to be electroplated are at the cathode, while metal used to plate is the anode, electrolyte contains metal ions found in the metal of the anode
    - Anode dissolves and the ions migrate to the cathode where they are discharged and deposited as a layer on the object (evenly deposited) and the electrolyte remains unchanged in concentration
    - To electroplate a non-conducting material, the material is sprayed with metallic paint or coated with graphite powder

7. State the manufacture of aluminium through electrolysis of pure aluminium oxide

- Aluminium is extracted from bauxite ore, which contains aluminium oxide, mixed with impurities
- Bauxite is purified to obtain pure aluminium oxide (electrolysis yields aluminium)
- Pure aluminium oxide has a high melting point (2045 degrees Celsius) and is mixed with cryolite (Na_3AlF_6) to form a mixture that melts at lower temperature of 950 degrees Celsius
    - Cathode reaction: $Al^{3+} + 3e^- \rightarrow Al$
    - Anode reaction: $2O^{2-} \rightarrow O_2 + 4e^-$
- Oxygen gas attacks the carbon anodes at high temperature to form carbon dioxide, and the anodes burn away so they must be replaced regularly

Extra Notes:

- Electrolysis of acidified water (dilute sulfuric acid)
    - Ions present: H^+, OH^- and SO_4^{2-} (H^+ and OH^- will be preferentially discharged)
    - Therefore, the water becomes more concentrated with sulfuric acid (lower pH value)
    - Acidification of water increases the conductivity of the water during electrolysis
    - Volume of oxygen gas collected is less than half of hydrogen gas (since oxygen is more soluble than hydrogen in water, thus some of the oxygen dissolves in electrolyte)
- Electrolysis of aqueous potassium iodide
    - Phenolphthalein will turn pink, since hydrogen ions discharged at the cathode leaves behind excess OH^- ions which gives alkalinity
- Anodizing
    - Making the layer of oxide on the surface of aluminium even thicker
    - Aluminium object is the anode and the cathode is copper/lead/aluminium
    - Electrolyte is usually dilute sulfuric acid (oxygen gas evolved at anode combines with the aluminium at the anode, making the oxide layer even thicker)