The content on this sheet is assessed on paper 1 only.

Electrolysis

3.22—Electrolytes

An electrolyte is an ionic compound which is either molten or in solution. Thus, the ions are free to move.

3.23—Electrolysis

Electrolysis is a process by which a direct current (DC) is used to break down electrolytes into elements.

3.24a—Movement of cations

Cations are ions with a positive charge. During electrolysis, they move to the cathode, which is the electrode with a negative charge. They do this because opposite charges attract.

3.24b—Movement of anions

Anions are ions with a negative charge. During electrolysis, they move to the anode, which is the electrode with a positive charge. They do this because opposite charges attract.

3.25a—Explain the formation of products from copper (II) chloride solution

In the electrolysis of copper (II) chloride, copper forms at the cathode. This is because the positively charged copper ions are attracted to the negatively charged electrode. At the cathode, the copper (II) ions, Cu^{2+}, are changed into copper atoms, Cu.

Chlorine forms at the anode. The negatively charged chloride ions are attracted to the positively charged electrode. At the anode, the chloride ions, Cl^-, are changed into chlorine molecules Cl_2.

3.25b—Explain the formation of products from sodium chloride solution

In the electrolysis of sodium chloride, hydrogen forms at the cathode. As well as the Na^+ ions, the water also produces hydrogen ions, H^+. The H^+ ions are less stable, and so form hydrogen gas at this electrode.

At the anode, chlorine gas molecules, Cl_2, are formed from the chloride ions, similarly to the copper chloride electrolysis.

3.25c—Explain the formation of products from sodium sulfate solution

As in the electrolysis of sodium chloride, hydrogen gas molecules, H_2, form at the cathode from the H^+ ions. At the anode, oxygen gas molecules, O_2, are formed. This is due to the breakdown of hydroxide ions, OH^-, produced from the water. *The hydroxide ions are less stable than the sulfate ions, and O_2 gas is formed.*

3.25d—Explain the formation of products from water acidified by sulfuric acid

At the cathode, hydrogen gas molecules, H_2, are formed, as only hydrogen ions, H^+, are present in the solution.

At the anode, oxygen gas molecules, O_2, form. The sulfuric acid produces sulfate ions, SO_4^{2-}, and the water produces hydroxide ions, OH^-. As with the electrolysis of sodium sulfate, the hydroxide ions are less stable, and so are broken down at the anode.

3.25e—Electrolysis of molten lead bromide

Unlike solutions, only the ions from the molten compound are in the electrolyte. Therefore, at the cathode, lead atoms will form from the lead ions, Pb^{2+}. At the anode, the bromide ions, Br^-, form bromine molecules, Br_2.

3.26—Products of electrolysis of molten binary ionic compounds*

Predict what forms at each anode in the electrolysis of the following molten compounds.

Molten compound	Formed at cathode (+)	Formed at anode (-)
Sodium chloride	Chlorine, Cl_2	Sodium, Na
Aluminium oxide	Oxygen, O_2	Aluminium, Al
Silver bromide	Bromine, Br_2	Silver, Ag
Titanium chloride	Chlorine, Cl_2	Titanium, Ti
Lithium iodide	Iodine, I_2	Lithium, Li
Calcium bromide	Bromine, Br_2	Calcium, Ca
Tin oxide	Oxygen, O_2	Tin, Sn

3.27—Writing half equations* (HT only)

Half equations are used in electrolysis to show the movement of electrons between ions and atoms.

For example, for the electrolysis of copper chloride solution, the two half equations would be as follows:

For the copper ions: Cu^{2+} (aq) + $2e^-$ —> Cu (s)

Here, each copper ion gains 2 electrons to end up as a copper atom with an overall charge of 0.

For the chloride ions: $2Cl^-$ (aq) —> Cl_2 + 2 e^-

Here, **two** chloride ions are required, as Cl_2 forms. Two chloride ions lose 1 electron to end up as chlorine molecules.

Write half equations for:

The conversion of H^+ ions to H_2 atoms.

2 H^+ + 2 e^- —> H_2

The conversion of Br^- ions to Br_2 molecules.

2 Br^- —> Br_2 + 2 e^-

The conversion of Al^{3+} ions to Al atoms.

Al^{3+} + 3 e^- —> Al

The conversion of O^{2-} ions to O_2 molecules.

2 O^{2-} —> O_2 + 4 e^-

N.B. you may be expected to include state symbols: use the information in the question to work out what state of matter the ions are in.

3.28—Reduction & oxidation (HT only)

In terms of electrons:

Reduction is gain of electrons.

Oxidation is loss of electrons.

We can use the acronym O I L R I G to help us remember this.

3.29—Reduction & oxidation at the electrodes (HT only)

Reduction occurs at the cathode (negative electrode). This is because the positive ions gain electrons to form atoms or molecules.

Oxidation occurs at the anode (positive electrode). This is because the negative ions lose electrons to form atoms or molecules.

3.30—Electrolysis of copper sulfate with graphite electrodes and copper electrodes

Copper electrodes:

The use of copper electrodes causes a different reaction to occur.

At the anode (made of impure copper), Cu atoms are converted into copper (II) ions, Cu^{2+}, as the atoms lose electrons . These ions enter the copper sulfate solution. Any impurities collect under the anode.

At the cathode (made of pure copper), the copper (II) ions, Cu^{2+}, are changed into copper atoms, Cu.

This process can be used to purify copper as the impurities are removed, and pure copper builds up on the cathode.

3.31—CP3—Electrolysis of copper sulfate with graphite electrodes and copper electrodes

Graphite electrodes:

This follows the same theory as discussed in section 3.25, hence:

At the cathode, the copper ions, Cu^{2+}, are changed into copper atoms, Cu.

At the anode, oxygen gas molecules, O_2, are formed. This is due to the breakdown of hydroxide ions, OH^-, produced from the water.

Copper electrodes:

See above (3.30)

Describe how you can measure the mass of pure copper that forms in these reactions.

Measure the mass of the cathode at the start; carry out the electrolysis; measure the mass of the cathode at the end; calculate the difference.

Suggest the safety precautions needed to undertake this practical safely.

Ensure that there are no unprotected wires, as these could cause electric shocks.