**Electrolysis Calculations**

Charge transferred

The amount of charge transferred during electrolysis can be calculated from the mean current used and the time taken:

charge, Q = current, I × time, t

(coulombs, C) (amperes, A) (seconds, s)

**Example 1a:** Calculate the amount of charge transferred when a 5 A current is used for 2 minutes during electrolysis.

2 minutes = 2 × 60 = 120 s

Charge = current × time

Charge = 5 × 120 = 600 C

**The faraday**

One faraday represents one mole of electrons. It is equal to 96,500 coulombs. The use of the faraday lets us work out how many moles of a substance is produced during electrolysis, provided we know the total charge transferred.

**Example 1b:** Calculate the mass of silver deposited at the cathode during the electrolysis of silver nitrate solution if you use a current of 0.10 amps for 10 minutes.

F = 9.65 x 104 C mol-1 (or 96500 C mol-1 if you prefer). Ar of Ag = 108.

The first thing to do is to work out how many coulombs of electricity flowed during the electrolysis.

Number of coulombs = current in amps x time in seconds

Number of coulombs = 0.10 x 10 x 60 = 60

Now look at the equation for the reaction at the cathode:

Ag+ + e– = Ag

Just as with any other calculation from an equation, write down the essential bits in words:

1 mol of electrons gives 1 mol of silver, Ag.

Now put the numbers in. 1 mol of electrons is 1 faraday.

96500 coulombs give 108 g of silver.

So, if 96500 coulombs give 108 g of silver, all you have to do is to work out what mass of silver would be produced by 60 coulombs.

Mass of silver = 60/96500 x 108 g = 0.067 g

Note:  If you can't follow the last bit of the calculation:

If 2 x 96500 coulombs give 24 dm3 H2, then 1 coulomb would give 24 divided by 2 x 96500 dm3. 900 coulombs would produce 900 times this amount.

In other words, you are working out 24/(2 x 96500) and then multiplying by 900. It is a different order from the way it is shown in the simple proportion sum shown above, but the answer is still exactly the same.

In addition, if you feel happier working out the value of 2 x 96500 before you do anything else, that's what you should do. As long as you get the answer right, nobody is interested in the exact way you handle the sums.

**Example 1c:**

This example shows you what to do if the question is reversed.

How long would it take to deposit 0.635 g of copper at the cathode during the electrolysis of copper(II) sulphate solution if you use a current of 0.200 amp.

F = 9.65 x 104 C mol-1 (or 96500 C mol-1). Ar of Cu = 63.5.

This time you can't start by working out the number of coulombs, because you don't know the time. As with any other calculation, just start from what you know most about. In this case, that's the copper, so start with the electrode equation.

Write down the important bits of this in words:

Cu2+ + 2e– = Cu

2 mol of electrons give 1 mol of copper, Cu.

Now put the numbers in. 1 mol of electrons is 1 faraday.

2 x 96500 coulombs give 63.5 g of copper.

You need to work out how many coulombs give 0.635 g of copper.

Number of coulombs = 0.635/ 63.5 x 2 x 96500 = 1930 g

**Example 2a:** Sodium and chlorine are produced during the electrolysis of molten sodium chloride:

Na+ + e– = Na

2Cl– = Cl2 + 2e–

9,650 coulombs of charge pass. Calculate the amount of sodium and chlorine produced. Remember that 1 F (faraday) = 96,500 C.

Number of moles of electrons = 9,650 ÷ 96,500 = 0.1 mol

1 mol of electrons are needed to produce 1 mol of sodium - so 0.1 mol of sodium is produced.

2 mol of electrons are needed to produce 1 mol of chlorine - so 0.05 mol (0.1 ÷ 2) of chlorine is produced.

**Calculating masses**

The mass of a substance produced during electrolysis can be calculated from the charge transferred, the faraday, and the relative atomic mass (Ar) or relative formula mass (Mr) of the substance.

**Example 2b:** This example shows you how to do the calculation if the product you are interested in is a gas.

Calculate the volume of hydrogen produced (measured at room temperature and pressure - rtp) during the electrolysis of dilute sulphuric acid if you use a current of 1.0 amp for 15 minutes.

F = 9.65 x 104 C mol-1 (or 96500 C mol-1). The molar volume of a gas at rtp = 24 dm3 mol-1.

Start by working out how many coulombs of electricity flowed during the electrolysis.

Number of coulombs = current in amps x time in seconds

Number of coulombs = 1.0 x 15 x 60 = 900

Now look at the equation for the reaction at the cathode:

**2H+ + 2e - = H2**

Write down the essential bits in words:

2 mol of electrons give 1 mol of hydrogen, H2.

Now put the numbers in. Two moles of electrons is 2 faradays.

2 x 96500 coulombs give 24 dm3 H2 at rtp.

So, if 2 x 96500 coulombs give 24 dm3 H2, work out what volume of hydrogen would be produced by 900 coulombs.

Volume of hydrogen = 900/(2 x 96500) x 24 dm3 = 0.11 dm3

Don't quote your answer beyond 2 decimal places. The current and the molar volume are only quoted to that degree of accuracy.

**Example 3a:**

Bromine is produced during the electrolysis of molten lead(II) bromide:

**2Br– = Br2 + 2e–**

A current of 13.4 A was used for 0.5 hours. Calculate the mass of bromine produced. 1 F = 96,500 C. Ar of Br2 = 160.

Remember: charge = current × time

Charge = 13.4 × 1,800 = 24,120 C

Remember: One faraday represents one mole of electrons. It is equal to 96,500 coulombs.

Number of moles of electrons = 24,120 ÷ 96,500 = 0.25 mol

Amount of bromine produced = 0.25 ÷ 2 = 0.125 mol

Mass of bromine produced = Ar × mol = 0.125 × 160 = 20 g

**Calculating volumes**The volume of a gas produced during electrolysis can be calculated from the charge transferred and the faraday. You also need to know the molar volume of a gas. This is the same for any gas at room temperature and pressure (rtp) and is 24 dm3 or 24,000 cm3.

**Example 4a:**

During electrolysis of molten sodium chloride, 0.125 mol of chlorine gas was produced. Calculate the volume of chlorine at rtp.

Volume = amount of gas × molar volume

Volume of chlorine = 0.125 × 24 = 3 dm3 (or 3,000 cm3)

**Example 4b:**

Another gas example:

Calculate the volume of oxygen produced (measured at room temperature and pressure - rtp) during the electrolysis of sodium sulphate solution if you use a current of 0.50 amp for 30 minutes.

F = 9.65 x 104 C mol-1 (or 96500 C mol-1). The molar volume of a gas at rtp = 24 dm3 mol-1.

Start by working out how many coulombs of electricity flowed during the electrolysis.

Number of coulombs = current in amps x time in seconds

Number of coulombs = 0.50 x 30 x 60 = 900

Now we need to look at the equation for the reaction at the anode. Unfortunately, there are two ways of looking at this, and you may come across either of them.

The first one releases oxygen from water molecules:

2H2O = O2 + 4H + 4e-

The alternative way releases oxygen from hydroxide ions from the ionisation of the water:

4OH- = 2H2O + O2 + 4e-

Write down the essential bits in words. Both ways of looking at it say the same thing:

Releasing 1 mol of oxygen, O2, involves 4 mol of electrons.

Now put the numbers in. Four moles of electrons is 4 faradays.

4 x 96500 coulombs give 24 dm3 O2 at rtp.

So, if 4 x 96500 coulombs give 24 dm3 O2, work out what volume of oxygen would be produced by 900 coulombs.

Volume of oxygen = 900/(4 x 96500) x 24 dm3 = 0.056 dm3

Don't quote your answer beyond 2 decimal places. The current and the molar volume are only quoted to that degree of accuracy**.**

**Purifying copper by electrolysis**

Copper is purified by electrolysis. Electricity is passed through solutions containing copper compounds, such as copper(II) sulfate. The anode (positive electrode) is made from impure copper and the cathode (negative electrode) is made from pure copper.

Pure copper forms on the cathode. The slideshow shows how this works:

**Diagrams:**

**Purifying copper by electrolysis**

1. A beaker with pure and impure copper rods dipped into copper(II) sulfate solution

During electrolysis, the anode loses mass as copper dissolves, and the cathode gains mass as copper is deposited.

The slideshow shows what happens during the purification of copper by electrolysis:

**Diagram:**

**The purification of copper by electrolysis**

1. Four Cu ions are attached to the rod on the right, and four Cu²+ ions are floating in the space between the rods

A half-equation shows what happens at one of the electrodes during electrolysis. Electrons are shown as e-.

These are the half-equations:

anode: Cu = Cu2+ + 2e- (oxidation)

cathode: Cu2+ + 2e- = Cu (reduction)

Oxidation happens at the anode because electrons are lost. Reduction happens at the cathode because electrons are gained.

One way to remember this is by using the mnemonic OIL RIG:

Oxidation Is Loss of electrons, Reduction Is Gain of electrons.

**Electroplating**

Electrolysis is used to electroplate objects (coat them with a thin layer or metal). This is useful for coating a cheaper metal with a more expensive one, such as copper or silver.

**How it works**

The negative electrode should be the object to be electroplated.

The positive electrode should be the metal that you want to coat the object with.

The electrolyte should be a solution of the coating metal, such as its metal nitrate or sulfate.

Here are two examples:

**Electroplating with silver**

The object to be plated, such as a metal spoon, is connected to the negative terminal of the power supply. A piece of silver is connected to the positive terminal. The electrolyte is silver nitrate solution.

**Electroplating with copper**

The object to be plated, such as a metal pan, is connected to the negative terminal of the power supply. A piece of copper is connected to the positive terminal. The electrolyte is copper sulfate solution.