BBC Bitesize - Chemistry

Episode 8 – Electrolysis of aqueous solutions

SUNAYANA: I'm Dr Sunayana Bhargava, a scientist and poet.

TULELA: And I'm Tulela Pea, a science communicator and podcaster.

SUNAYANA: And this is Bitesize Chemistry.

TULELA: This is the final episode of an eight-part series on chemical changes. In this episode, we're going to look at electrolysis of aqueous solutions.

SUNAYANA: As always, it might be handy to write some notes or diagrams along the way. So hit pause when you need to. Don't worry, we'll wait for you to hit play again.

TULELA: And also hit rewind if you need to go over some of those key facts. And remember to head over to BBC Bitesize on the web for more useful information and diagrams.

SUNAYANA: We've looked at electrolysis in the previous two episodes. In episode 6, we looked at how ions in a molten ionic compound can be separated into atoms.

TULELA: Remembering that a molten ionic compound is simply one that is melted into its liquid state. And then it's used as the electrolyte that an electric current can flow through.

SUNAYANA: And in episode 7 we looked at the extraction of metal using electrolysis.

TULELA: And we saw that this is a process used where the metal we want to extract from its ore is more reactive – or higher in the reactivity series – than carbon.

SUNAYANA: Again, we use the molten metal ore as the electrolyte.

TULELA: Have a relisten to both those episodes or visit the Bitesize website if you need a reminder.

SUNAYANA: This time we're going to look at electrolysis not of a molten solution, but an aqueous solution. That is, one where an ionic compound has been dissolved in water.

TULELA: Does this make it more complicated, Sunayana?

SUNAYANA: Not complicated, just more exciting! So grab a pen and paper to write down the key facts and diagrams along the way and hit pause and rewind whenever you need to.

TULELA: Let's get going with the excitement then! The difference when we do electrolysis of an aqueous solution rather than a molten solution is that, as well as the ions of the ionic compound, we also have to take into account the presence of ions in the water itself.

SUNAYANA: This happens because in the aqueous solution water molecules break down producing hydrogen H-plus ions and hydroxide OH-minus ions.

TULELA: As before when we add our electrodes…

SUNAYANA: …cathode negative, anode positive…

TULELA: …and connect them to a power supply, an electric current flows through the electrolyte.

SUNAYANA: This time, two positive ions are attracted to the negative cathode where they compete for electrons. The hydrogen ion from the water and the metal ion from the compound. To determine which substance is made at the cathode, we use the reactivity series.

TULELA: If the metal is more reactive than hydrogen, then hydrogen will be produced at the cathode. If the metal is less reactive than hydrogen, then the metal is produced at the cathode.

SUNAYANA: So if the metal is more reactive, we get hydrogen. And if the metal is less reactive, we get the metal. Similarly two negative ions are attracted to the positive anode. The hydroxide ions from the water and the negative ions from the dissolved compound.

TULELA: If the negative ion is a halide – which you'll remember is from a group 7 element, chlorine, bromine or iodine, then the equivalent halogen gas will form at the anode. So bromide ions form bromine gas and chloride ions form chlorine gas. If the negative ion from the ionic compound isn't a halide then oxygen will be formed.

SUNAYANA: Sounds like we need to go through a kind of decision tree or flow chart to work out what is formed at each of the electrodes. Perhaps NNICK can help us here. Hi NNICK! Can you summarise what forms at each electrode in the electrolysis of an aqueous solution?

NNICK: Nothing could be easier. Except falling off a log while mambo dancing. Believe me, I've tried it.

SONG

What's produced at the cathode?
That's easy, you see
Because the key
Is reactivity.

If the m-m-m-metal is least reactive
The m-m-m-metal is what we get.
If h-h-h-hydrogen's least reactive
Then h-h-h-hydrogen's what we get.

What's produced at the anode?
That's easy to decide
Because it can't be denied
It's all about the halide.

If a h-h-h-halide happens to be present

A h-h-h-halogen's what we get.

O-o-o-o-o-o-o-o-o-otherwise

o-o-o-oxygen's what we get.

SUNAYANA: Thanks NNICK! Nice singing. That helps, but perhaps an example or two might help us more.

TULELA: OK, let's take our good friend sodium chloride NaCl. We dissolve it in water – the aqueous solution – add our electrodes and connect to a power supply. What happens next?

SUNAYANA: It can be handy to write out all the ions present in the solution. In this case the positive ions are hydrogen H-plus from the water, and sodium Na-plus from the compound.

TULELA: And the negative ions are hydroxide OH-minus from the water, and chloride Cl-minus from the compound.

SUNAYANA: The positive H and Na ions are attracted to the cathode and compete for electrons. We see that in this case sodium is a more reactive element than hydrogen – so it is hydrogen that gains those electrons and become neutral hydrogen gas. And indeed we see bubbles of hydrogen at the cathode. So what about the anode?

TULELA: The hydroxide OH-minus from the water and the chloride Cl-minus from the compound are attracted to the anode. Is there a halide present? Yes – the chloride ions. So in this case, at the anode the chloride loses electrons to become chlorine gas. And again this is what we see.

SUNAYANA: Another example, Tulela?

TULELA: How about we give our dear podcast listening friends a chance to do this before we work through the answer?

SUNAYANA: Good shout.

TULELA: Let's go with an aqueous solution of copper sulfate, $CuSO_4$. Hit pause, write out the ions present and work out what we see at each electrode.

SUNAYANA: And in the meantime we'll look at picture of cats on social media…. Ahhhh!

TULELA: Ahhh!

SUNAYANA: Enough cats! How did you get on with that aqueous solution of copper sulfate?

TULELA: The positive ions present are the hydrogen H-plus from the water and Copper Cu 2-plus from the compound. And the negative ions are the hydroxide OH-minus from the water and the sulfate SO_4 2-minus from the compound.

SUNAYANA: At the cathode the hydrogen and copper ions compete for electrons. We compare their reactivity in the reactivity series and see that copper is less reactive than hydrogen. So it will be copper that forms at the cathode. And indeed we'll see a coating of copper on the cathode.

TULELA: At the anode, the hydroxide and sulfate ions are present. There is no halide ion present. So it will be oxygen that forms at the anode which we'll see as bubbles of oxygen.

SUNAYANA: Correct! Hope you got that. There are more of these examples on the Bitesize webpages, the more you practise the easier it is and you'll be doing them in your sleep.

TULELA: So why do we need to know about this anyway, Sunayana? Let's look at some real-world examples of electrolysis of an aqueous solution.

SUNAYANA: Well, as with everything in this series, the chemistry knowledge that we've revised isn't there just to pass exams. It's the foundation of really useful and important processes that help in our daily life. So, for example, electrolysis of aqueous solutions is a process used to produce hydrogen gas which can be used instead of fossil fuels.

TULELA: And that helps us to develop green and renewable energy sources.

SUNAYANA: Also, maybe some of the jewellery that you're wearing has been electroplated to protect it and make it look shiny. You may have also copper-plated a key in the class by using your key as the cathode with a copper sulfate electrolyte.

TULELA: Also done by electrolysis in an aqueous solution?

SUNAYANA: Correct! And it's also an important process in the treatment of wastewater, production of chlorine and refining of metals.

TULELA: Chemistry saves the day yet again.

SUNAYANA: Final summary of the series, Tulela? You start.

TULELA: In the electrolysis of an aqueous solution, we need to take account of the hydrogen and hydroxide ions as well as the ions from the ionic compound.

SUNAYANA: If the metal in the compound is more reactive than hydrogen, then hydrogen will form at the cathode.

TULELA: And if the metal is less reactive than hydrogen, then the metal will form at the cathode.

SUNAYANA: If there are halide ions in the compound then the equivalent halogen gas will form at the anode.

TULELA: If there are no halide ions in the compound, then oxygen will form at the anode.

SUNAYANA: Remember there's loads more hints and tips and revision aids on the Bitesize webpages.

TULELA: And you can listen on BBC Sounds for loads of other Bitesize series in this subject and many others.

SUNAYANA: Thanks so much for listening to us and good luck with your chemistry exams.

TULELA: We should thank NNICK also. Thanks NNICK!

NNICK: Please, don't mention it! Oh, too late, you already have. Never mind. Bye!

SUNAYANA: Bye from me, Sunayana…

TULELA: …and me, Tulela.

TOGETHER: Bye!