B8 · Electrolytic cells

Student notes - complete the underlined spaces | Notes 1/3

Explain how an electrolytic cell uses electrical energy to drive a reaction that is not spontaneous, label its parts, write its reactions and compare it with a voltaic cell.

Name: _____ Date: _____

1. A power source drives the reaction

A reaction that does not go by itself

Look at $Cu + Zn^{2+} \rightarrow Cu^{2+} + Zn$. Zn^{2+} is reduced at the cathode (−0.76 V) and copper is oxidized at the anode (+0.34 V).

E°cell = −0.76 − (+0.34) = _____. A negative value means the reaction is _____ as written, so it will not go by itself.

But a power source can push it, like pushing a ball uphill. A cell that uses _____ energy to drive a reaction that is not spontaneous is an electrolytic cell.

The source must supply more than _____. We ignore the sign, because the size of the negative value is the minimum push needed.

On the diploma: give a minimum voltage as a positive number. A negative one is a common wrong choice.

Watch: A reaction that is not spontaneous (Tyler DeWitt, “Electrolysis”, 3:58)

Watch: Splitting water needs electrical energy (Alberta Chemistry Teacher, “Chemistry 30 - Predicting redox reaction from species in the reduction table”, 20:04)

Watch: Why the battery must push the electrons (Tyler DeWitt, “Introduction to Electrochemistry”, 13:46)

Anode and cathode

In every cell, _____ happens at the cathode and _____ happens at the anode. Those names come from the chemical change, not from a plus or minus sign.

In an electrolytic cell, the power source sets the signs. A terminal is where a wire joins the source. The negative terminal pushes electrons out, and they arrive at the electrode joined to it.

Electrons arriving means that electrode gains electrons, which is reduction. So the cathode is joined to the _____ terminal and the anode to the _____ terminal.

Cations (positive ions) move toward the _____. Anions (negative ions) move toward the _____.

Electrons move only in the _____. In the liquid, the moving ions carry the charge. Both electrodes sit in one container, so no salt bridge is needed. In a drawing, a power source in the wire means electrolytic, and a voltmeter means voltaic.

On the diploma: a diagram may show only the power source. Label the terminals first, then the electrodes. The wrong option usually swaps the two electrodes.

Watch: Anode and cathode in an electrolytic cell (Tyler DeWitt, “Electrolysis”, 8:02)

Watch: A way to remember anode and cathode (Tyler DeWitt, “Introduction to Electrochemistry”, 10:44)

Cathode joins the _____ terminal; anode joins the _____ terminal.

Cathode (reduction): _____

Anode (oxidation): _____

E°cell = −2.71 − 1.36 = _____; source must exceed _____

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Student notes - complete the underlined spaces | Notes 2/3

2. Molten salts

Molten sodium chloride

Molten NaCl is the ionic solid heated until it melts, so its ions can move. It has only Na^+ and Cl^- ions and no water.

Na^+ is attracted to the negative _____ and gains one electron: $Na^+ + e^- \rightarrow$ _____.

Cl^- goes to the positive anode. Cl_2 has two atoms, so two chloride ions each give up one electron: $2Cl^- \rightarrow$ _____ + $2e^-$.

The anode gives 2 electrons and the cathode takes only 1, so double the cathode half. The cell reaction is $2Na^+ + 2Cl^- \rightarrow$ _____.

$E°cell = -2.71 - (+1.36) =$ _____, so the source must supply more than _____. We do not double E° when we double a half-reaction.

On the diploma: list the ions first, then send the cation to the cathode. Doubling E° with the half-reaction is a common wrong choice.

Watch: Splitting sodium chloride (Tyler DeWitt, “Electrolysis”, 0:46)

Watch: A battery forces the reaction (Tyler DeWitt, “Electrolysis”, 4:46)

Watch: Why the salt must be molten (Tyler DeWitt, “Electrolysis”, 7:10)

Watch: The two half-reactions (Tyler DeWitt, “Electrolysis”, 11:56)

Watch: The final equation (Tyler DeWitt, “Electrolysis”, 14:19)

Molten zinc bromide

$ZnBr_2(l)$ has only Zn^{2+} and Br^-. Zn^{2+} goes to the _____: $Zn^{2+} + 2e^- \rightarrow Zn$. Br^- goes to the _____: $2Br^- \rightarrow Br_2 + 2e^-$.

Both halves move two electrons, so they cancel when we add them. The cell reaction is $Zn^{2+} + 2Br^- \rightarrow$ _____.

$E°cell = -0.76 - (+1.07) =$ _____. A negative value shows that a power _____ is needed, one that supplies more than 1.83 V.

On the diploma: reporting +1.83 V would suggest the cell runs by itself. Check the electrode order before you subtract, and give the sign.

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Student notes - complete the underlined spaces | Notes 3/3

3. Compare cells, plating and refining

Side by side

The same two half-cells can run either way. In the Zn / Cu voltaic cell, zinc is oxidized and E°cell is +1.10 V. In the electrolytic cell, copper is oxidized and E°cell is −1.10 V for the forced reaction.

Voltaic cell: _____ energy to electrical energy, E°cell _____, anode _____. It needs a _____ or porous barrier.

Electrolytic cell: electrical energy to _____ energy, E°cell for the forced reaction _____, anode _____. It _____ need a salt bridge.

The voltaic anode is negative because that cell makes electrons there. The electrolytic anode is positive because it is joined to the positive terminal.

On the diploma: many wrong choices copy the voltaic sign onto an electrolytic cell. Check which cell type the question describes.

Watch: Electrolytic cell versus voltaic cell (Tyler DeWitt, “Introduction to Electrochemistry”, 11:30)

Plating and refining

To plate a spoon with silver, make the spoon the _____. Reduction deposits metal there: $Ag^+ + e^- \rightarrow$ _____, so the spoon gains mass.

A silver anode _____ mass as $Ag \rightarrow Ag^+ + e^-$. It replaces the Ag^+ the cathode used up, so the ion concentration stays nearly constant. A carbon anode would not dissolve.

To refine copper, impure copper is the anode and a thin pure sheet is the cathode. Pure metal builds up on the _____. Impurities above copper on the table, like silver and gold, fall as solid. Those below it dissolve.

Two electrodes of the same metal in its own ion give E°cell = _____, because the same half-reaction is reversed at the anode. Only a small voltage is needed, plus a little extra to beat resistance.

On the diploma: the electrode that gains mass is where ions are reduced, the cathode. Same metal at both electrodes means E°cell = 0.00 V.

Watch: Plating a copper ring with silver (Tyler DeWitt, “Electroplating”, 1:30)

Watch: Which terminal the object connects to (Tyler DeWitt, “Electroplating”, 3:00)

Watch: Half-reaction at the ring (Tyler DeWitt, “Electroplating Part 2”, 1:27)

Watch: Half-reaction at the silver (Tyler DeWitt, “Electroplating Part 2”, 2:36)

Watch: Anode and cathode in electroplating (Tyler DeWitt, “Electroplating Part 2”, 6:23)

B8 · Practice

Electrolytic cells | Questions 1-3 of 12

State symbols: (s) solid, (aq) dissolved in water, (l) liquid, (g) gas. Use the supplied reaction and conditions. B4 values name the Alberta Chemistry 30 Data Booklet table where used.

B8-P01 · Easy · Given $Ni^{2+} + 2e^- \rightarrow Ni$ (−0.26 V) and $Cu^{2+} + 2e^- \rightarrow Cu$ (+0.34 V). A power source is used to drive $Cu + Ni^{2+} \rightarrow Cu^{2+} + Ni$. Calculate E°cell and state the smallest voltage that the source must exceed.

B8-P02 · Easy · In an electrolytic cell, which electrode is joined to the negative terminal of the power source? Name the process there and give the direction in which cations move.

B8-P03 · Easy · Explain why electrons do not travel through the electrolyte, and why an electrolytic cell does not need a salt bridge.

B8 · Practice

Electrolytic cells | Questions 4-6 of 12

B8-P04 · Easy · Write the half-reactions, the cell reaction and the product at each electrode for the electrolysis of molten NaCl.

B8-P05 · Medium · Given molten $ZnBr_2(l)$ with inert electrodes (Zn^{2+}/Zn −0.76 V; Br_2/Br^- +1.07 V). Write the cell reaction and calculate E°cell.

B8-P06 · Medium · Given molten $MgCl_2$ with inert electrodes (Mg^{2+}/Mg −2.37 V; Cl_2/Cl^- +1.36 V). Write the cell reaction and calculate the smallest voltage that the source must exceed.

B8 · Practice

Electrolytic cells | Questions 7-9 of 12

B8-P07 · Medium · Compare a voltaic cell and an electrolytic cell for the Zn / Cu pair. Use the energy change, the sign of the cell value for the reaction that runs, and the sign of the anode.

B8-P08 · Medium · A student says the anode in an electrolytic cell is negative because it is negative in a voltaic cell. Explain the error.

B8-P09 · Challenging · A silver spoon is plated in $AgNO_3(aq)$ with a silver bar. Say which is the cathode, write the half-reaction at each electrode and predict the mass change of each.

B8 · Practice

Electrolytic cells | Questions 10-12 of 12

B8-P10 · Challenging · Describe a cell for refining impure copper and name the electrode that gains mass.

B8-P11 · Challenging · Silver electrodes are placed in silver nitrate solution and connected to a power source. Calculate E°cell for the reaction in this cell and say how much voltage is needed in principle.

B8-P12 · Challenging · A student says that a negative E°cell means a reaction cannot happen at all. Use the idea of an electrolytic cell to correct this.