B6 · Voltaic cells

Student notes - follow the slides, fill the blanks, work the questions

Goals: Explain why a voltaic cell separates the half-reactions and needs a salt bridge. Identify the anode and cathode, and write cell notation and half-reactions. Predict observations and calculate the standard cell potential.

Name: _____ Date: _____

Slide 1 of 9 · Why separate the halves?

Zinc atoms give up electrons and Cu^{2+} ions take them, so zinc in copper(II) sulfate solution is a _____ reaction.

When zinc touches the ions, electrons jump straight across the surface and the energy spreads out as _____.

To get useful work, keep the two halves _____ and let the electrons travel only through a _____.

A cell that turns chemical energy into electrical energy is a _____ cell (also called a galvanic cell). One electrode plus its solution is a _____.

Example. Zinc placed in copper(II) sulfate solution slowly becomes coated with copper, and the solution warms. How could we use that electron transfer to run a device? Sketch the cell.

Work:

Answer: _____

Try it. Zinc metal is placed directly in $Cu^{2+}(aq)$. What happens to the energy released? Name the energy change when the same reaction runs in a voltaic cell.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 2 of 9 · Which electrode is which?

The ion with the _____ table value is the stronger oxidizing agent, so it is reduced. The metal in the other row is oxidized.

The _____ is where oxidation happens. The _____ is where reduction happens. Memory aid: AN OX (anode, oxidation) and RED CAT (reduction, cathode).

In a voltaic cell the anode is _____ and the cathode is _____.

Electrons leave the anode, travel through the _____ and are used up at the cathode. Ions carry the charge in the _____.

Example. Given $E°(Zn^{2+}/Zn) = -0.76$ V and $E°(Cu^{2+}/Cu) = +0.34$ V. A voltaic cell joins the two half-cells. Which metal is oxidized? Name the anode and cathode, give their signs, and say which way the electrons travel.

Work:

Answer: _____

Try it. Given $E°(Mg^{2+}/Mg) = -2.37$ V and $E°(Zn^{2+}/Zn) = -0.76$ V. A voltaic cell joins the two half-cells. Which metal is the anode, which electrode is positive, and which way do the electrons travel?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 9 · The salt bridge keeps charge balanced

At the anode, Zn atoms make Zn^{2+} ions, so that beaker gains _____ charge. At the cathode, Cu^{2+} ions leave, so extra _____ ions (anions) remain.

The charge build-up pushes back on the electrons, and the voltmeter reading falls to _____.

A salt bridge holds unreactive ions, such as sodium nitrate. It joins the two solutions and carries _____ but no electrons. A porous barrier does the same job.

Anions move toward the _____ beaker, which gains positive charge. Cations move toward the _____ beaker, which loses positive charge.

Example. A Zn / Cu cell is joined with wires only. After a short time the voltmeter reading falls to zero. What stops the cell, and how does a salt bridge fix it?

Work:

Answer: _____

Try it. In the Zn / Cu cell, the salt bridge contains $NaNO_3(aq)$. Toward which beaker do the Na^+ ions move, and why?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 4 of 9 · Cell notation

In cell notation, the _____ goes on the far left and the _____ goes on the far right.

Each half is written from the _____ metal to its ion. A single line | separates two different _____.

The double line || stands for the _____ or porous barrier. Always include _____ such as (s) and (aq).

To write the overall reaction, take the left half as _____ and the right half as reduction. Match the electrons, add the halves and cancel them.

Example. In a Zn / Cu cell, zinc is the anode and copper is the cathode. Write the cell notation and the overall reaction.

Work:

Answer: _____

Try it. Given the cell notation Mg(s) | Mg^{2+}(aq) || Ag^{+}(aq) | Ag(s). Write the oxidation half-reaction, the reduction half-reaction and the overall reaction.

Work:

Answer: _____

Slide 5 of 9 · Your turn: copper and silver

Compare the table values first. Ag^+/Ag is _____ V and Cu^{2+}/Cu is +0.34 V, so silver ions are reduced at the _____.

Each Ag^+ takes _____ electron but the copper anode gives _____. Multiply the silver half by 2: $2Ag^+ + 2e^- \rightarrow$ _____.

E° is _____ multiplied by a coefficient. The doubled silver half still has the value +0.80 V. Overall: $Cu + 2Ag^+ \rightarrow$ _____.

Notation: Cu(s) | Cu^{2+}(aq) _____ Ag^+(aq) | Ag(s). Cell notation has no _____.

Example. Given $Cu^{2+} + 2e^- \rightarrow Cu$ (+0.34 V) and $Ag^+ + e^- \rightarrow Ag$ (+0.80 V). A cell has a copper electrode in Cu^{2+}(aq), a silver electrode in Ag^+(aq), a wire and a salt bridge. Name the anode, write the half-reactions and overall reaction, and write the cell notation.

Work:

Answer: _____

Try it. Given $Al^{3+} + 3e^- \rightarrow Al$ (−1.66 V) and $Cu^{2+} + 2e^- \rightarrow Cu$ (+0.34 V). A cell has an aluminium electrode in Al^{3+}(aq), a copper electrode in Cu^{2+}(aq) and a salt bridge. Name the anode, write the overall reaction and write the cell notation.

Work:

Answer: _____

Slide 6 of 9 · Predict what you would observe

Every prediction comes from a _____. Ask what is made and what is used up at each electrode.

At the copper anode, $Cu \rightarrow Cu^{2+} + 2e^-$, so the electrode _____ mass and the Cu^{2+} concentration goes _____. The Data Booklet lists Cu^{2+} as blue (p. 11), so the blue gets deeper.

At the silver cathode, $2Ag^+ + 2e^- \rightarrow 2Ag$, so the electrode _____ mass and the Ag^+ concentration goes _____.

Ag^+ is _____ in water, so there is no colour change at the cathode. A metal anode loses mass and a metal cathode gains mass.

Example. The Cu / Ag cell $Cu(s) \mid Cu^{2+}(aq) \parallel Ag^+(aq) \mid Ag(s)$ is running. Predict what happens to each electrode and each solution as the cell operates.

Work:

Answer: _____

Try it. The Zn / Cu cell $Zn(s) \mid Zn^{2+}(aq) \parallel Cu^{2+}(aq) \mid Cu(s)$ is running. Predict the mass change of each electrode and the change in the blue colour of the copper solution.

Work:

Answer: _____

Slide 7 of 9 · Cell potential

Standard conditions mean _____ mol/L solutions, 25.00 °C (298.15 K) and _____ kPa for gases.

E°cell = E°_____ − E°_____. Use each table value as printed, even for the anode.

For the Zn / Cu cell, E°cell = 0.34 − (−0.76) = _____ V. Subtracting a negative number _____.

A positive E°cell means the cell reaction runs as _____. A negative value warns that the anode and cathode are _____. Never multiply E° by a coefficient.

Example. Given E°(Zn^{2+}/Zn) = −0.76 V and E°(Cu^{2+}/Cu) = +0.34 V. Zinc is the anode and copper is the cathode. Calculate E°cell. Then swap the electrodes and say what the sign tells you.

Work:

Answer: _____

Try it. Given E°(Fe^{2+}/Fe) = −0.45 V and E°(Ag^{+}/Ag) = +0.80 V. Iron is the anode and silver is the cathode. Calculate E°cell and say whether the cell reaction runs as written.

Work:

Answer: _____

Slide 8 of 9 · Method: how to describe a voltaic cell

Step 1. Write the two _____. Oxidation happens at the _____. Reduction happens at the cathode.

Step 2. Trace the _____. They travel through the wire from the anode to the cathode.

Step 3. Place the salt bridge ions. _____ move toward the anode. Cations move toward the cathode.

Step 4. Write the cell _____, with the anode on the left and the cathode on the right.

Step 5. $E°_{cell} = E°$_____ $- E°_{anode}$.

Step 6. Predict what you would see. Check: $E°_{cell}$ is _____ for a working cell.

Example. Use the method on a cell with Cu in $Cu^{2+}(aq)$ and Ag in $Ag^{+}(aq)$. $E°(Cu^{2+}/Cu) = +0.34$ V and $E°(Ag^{+}/Ag) = +0.80$ V. Describe the cell.

Work:

Answer: _____

Try it. Use the method on a cell with Zn in $Zn^{2+}(aq)$ and Cu in $Cu^{2+}(aq)$. $E°(Zn^{2+}/Zn) = -0.76$ V and $E°(Cu^{2+}/Cu) = +0.34$ V. Find the anode, the notation and $E°_{cell}$.

Work:

Answer: _____

Slide 9 of 9 · A cell drawn the other way

Where an electrode is drawn does _____ show which one is the anode. Use the table values.

$E°(Ag^+/Ag) = +0.80$ V is higher than $E°(Zn^{2+}/Zn) =$ _____ V, so silver is the _____ and zinc is the anode.

If the anode is drawn on the right, the electrons travel through the wire from _____ to left.

In cell notation the anode is always on the _____. $E°_{cell} = E°_{cathode} - E°_{anode} =$ _____ V, and redrawing the cell does not change it.

Example. Given $E°(Zn^{2+}/Zn) = -0.76$ V and $E°(Ag^+/Ag) = +0.80$ V. A drawing shows the silver half-cell on the left and the zinc half-cell on the right. Find the anode, write the cell notation and find $E°_{cell}$.

Work:

Answer: _____

Try it. Given $E°(Cu^{2+}/Cu) = +0.34$ V and $E°(Mg^{2+}/Mg) = -2.37$ V. A drawing shows the copper half-cell on the left and the magnesium half-cell on the right. Find the anode, write the cell notation and find $E°_{cell}$.

Work:

Answer: _____

B6 · Practice

Voltaic cells | Questions 1-2 of 7

1. Given the Data Booklet table values $E°(Zn^{2+}/Zn) = -0.76$ V and $E°(Ag^{+}/Ag) = +0.80$ V. A cell has a zinc electrode in $Zn^{2+}(aq)$ and a silver electrode in $Ag^{+}(aq)$. Name the anode and the cathode, and state the direction of electron flow in the wire.

Work:

Final answer (with unit): _____

2. Given a cell in which Mg(s) is oxidized and $Cu^{2+}(aq)$ is reduced, with a salt bridge. Write the cell notation.

Work:

Final answer (with unit): _____

B6 · Practice

Voltaic cells | Questions 3-4 of 7

3. Given the Cu / Ag cell, Cu(s) | $Cu^{2+}(aq)$ || $Ag^{+}(aq)$ | Ag(s), with a salt bridge containing $NaNO_3(aq)$. Toward which beaker do the NO_3^- ions move, and why?

Work:

Final answer (with unit): _____

4. Given the Cu / Ag cell, Cu(s) | $Cu^{2+}(aq)$ || $Ag^{+}(aq)$ | Ag(s), running. Predict the change in mass of each electrode and the change in the blue colour of the copper solution.

Work:

Final answer (with unit): _____

B6 · Practice

Voltaic cells | Questions 5-6 of 7

5. A student builds the Zn / Cu cell with wires but no salt bridge or porous barrier. The voltmeter reading drops to zero after a moment. Explain why.

Work:

Final answer (with unit): _____

6. Given the Data Booklet table values $E°(Zn^{2+}/Zn) = -0.76$ V and $E°(Ag^{+}/Ag) = +0.80$ V. Find $E°_{cell}$ for the cell with zinc as the anode and silver as the cathode.

Work:

Final answer (with unit): _____

B6 · Practice

Voltaic cells | Questions 7-7 of 7

7. Challenge: Given the Data Booklet table values $E°(Al^{3+}/Al) = -1.66$ V and $E°(Ni^{2+}/Ni) = -0.26$ V. Both values are negative. A voltaic cell is built from these two half-cells. Name the anode, write the cell notation and the net equation, and find $E°_{cell}$ in volts.

Work:

Final answer (with unit): _____