

XI) The Electrochemical Cell

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What is another name for an electrochemical cell? **Battery**
 What is the point of an electrochemical cell? **to get e⁻ moving through an external circuit, creating electricity.**
 How does an electrochemical cell work?

aqueous solutions (specifications)
electron flow Anode → cathode
1.10 V Voltmeter - measure voltage (charge difference)
aqueous solution $\text{Cu}(\text{NO}_3)_2$ $\text{Cu}^{2+}(\text{aq}) + \text{NO}_3^{-}(\text{aq})$
oxidation rxn takes place. Zinc metal
 • anode metal will lose mass (smaller) b/c e⁻ leave and $\text{Zn}^{2+}(\text{aq})$ is released into solution
Half-Rxns:
 $\text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^{-}$ oxidation
 $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cu}(\text{s})$ reduction
AN OX CARED
 anode oxidation cathode reduction
Reduction @ Cathode "RED CAT"
Oxidation @ Anode "AN OX"
 1) e⁻ travel in this direction b/c e⁻ feel an attraction/pull towards Cu^{2+}
 2) cations anions
 3) charge builds on $\text{Cu}(\text{s})$
 4) $\text{Cu}^{2+}(\text{aq})$ attracted to the metal strip b/c of $\ominus \text{e}^{-}$ arriving through wire
 5) reduction rxn occurs $\text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu}(\text{s})$ Cu metal will gain mass as more $\text{Cu}(\text{s})$ is produced.
 Salt Bridge (ionic) NO_3^{-} moves to balance (exchange) build up.
 bal. Na⁺ + Exchange
 solution (lost Cu^{2+})
 solution (due to Zn^{2+})

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Description of the Electrochemical Cell on the Previous Page

Oxidation takes place at the anode, as Zn metal atoms lose two electrons to become Zn^{2+} cations ($\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^{-}$) which then dissolve in the $\text{Zn}(\text{NO}_3)_2(\text{aq})$ solution. The electrons travel up the Zn electrode and through the wire to the cathode Cu electrode where they are used to reduce Cu^{2+} cations to Cu metal atoms ($\text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu}$). The electrons travel from the oxidation to the reduction half-cell because they feel the 'pull' for electrons from the Cu^{2+} ions (similar to how we feel the 'pull' from gravity). The Cu^{2+} ions are attracted to the cathode (Cu metal strip) by the electrons that are arriving through the wire. The anode Zn electrode loses mass (as Zn atoms make Zn^{2+} ions that dissolve in solution) and the cathode Cu electrode gains mass (as Cu^{2+} ions make Cu atoms). The point of the whole process is to get electrons moving through the wire. Then you can hook up and electrically power a device such as a light bulb. To balance the positive charge build-up in the solution at the Zn anode (due to production of Zn^{2+}), NO_3^{-} anions from the salt bridge migrate into the anode solution and Zn^{2+} cations migrate out of the anode solution into the salt bridge. To avoid negative charge build-up at the Cu cathode (due to loss of Cu^{2+}), Na^{+} cations from the salt bridge migrate into the cathode solution and NO_3^{-} anions migrate out of the cathode solution into the salt bridge. If there is no salt bridge, the cell would cease to operate due to the resistance by build-up of like charges.

Key Terms

Electrode

a conductor at which a half-rxn occurs. eg. Zn electrode was the $\text{Zn}(\text{s})$ metal

"An Ox"

Anode

- electrode where oxidation occurs
- supplying the e⁻ to the substance being reduced
- anions (from salt bridge) travel towards it

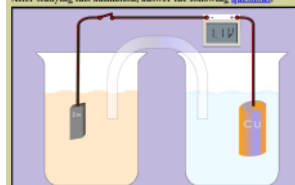
<http://www.chemistry.uoguelph.ca/educmat/chm19105/galvanic/galvanic1.htm>

Electrochemical Cells

Move the cursor over the components of the cell to see their labels. Click on the arrow at the bottom right for the definitions of each component and to observe the cell in its operational mode. Write down and explain your observations.

Now, to see what happens in each compartment on a molecular basis, click on **anode** or **cathode**.

After studying this animation, answer the following questions.



There are four important observations to make regarding the operation of this cell: 1) the anode became smaller; 2) the cathode became larger; 3) the colour of the solution in the cathode half-cell faded; and 4) the voltmeter registered a reading of 1.1 volts. This voltage is the cell potential - a measure of the ability of a cell reaction to force electrons through a circuit.

http://www.physics-chemistry-interactive-flash-animation.com/chemistry_interactive/daniell_cell.htm

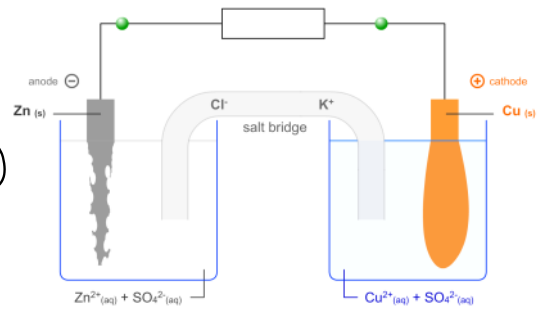
"An Ox" Anode: electrode where oxidation occurs
 • supplying the e^- to the substance being reduced
 • anions (from salt bridge) travel towards it.

"Red Cat" Cathode: electrode where reduction occurs
 • receives e^- from the substance being oxidized.
 • cations (from salt bridge) travel towards it.

Wire: e^- travel through from ANODE → CATHODE

Voltmeter: measures the voltage of the cell (E_{cell} - potential difference)

Salt bridge: made up of spectator ions (don't want any ppt.)
 (KNO_3 , $NaNO_3$, Na_2SO_4)
 ions from the salt bridge help to maintain neutral charge in both half cells.
 (combat the \oplus and \ominus charge buildup)



anode cell ← → cathode cell.

anode 1/2 cell and cathode 1/2 cell

If the half-cells were not separated, what would happen?
 • The redox reaction between $Zn(s)$ and $Cu^{2+}(aq)$ would occur directly in solution (Cu^{2+} ions would be right beside Zn atoms, so the Cu^{2+} would directly take e^-)
 • e^- will flow in solution, not through the wire.

Determining what redox reaction is occurring in an electrochemical cell:
 Electrochemical cells are **spontaneous** (as opposed to electrolytic cells), therefore the reduction half-reaction is **higher** on the table than the oxidation half-reaction.
 To determine which electrode is the **cathode (site of reduction)**, look for the substance in either of the half-cells that is **best at reducing (strongest oxidizing agent)**.

non-spontaneous (require energy input)
 (top left) → FWD rxn.

Example: In an Mg/Pb electrochemical cell, which is the cathode? The anode? What half-reactions are occurring?
 Pb 1/2 rxn is higher on the table (ie: Pb^{2+} is a stronger oxidizing agent than Mg^{2+})
 Reduction: $Pb^{2+} + 2e^- \rightarrow Pb(s)$ (@ Cathode)
 Oxidation: $Mg(s) \rightarrow Mg^{2+} + 2e^-$ (@ anode)

e^- move

Half-Reactions

Any two half-reactions from the redox table can be put together to create an electrochemical cell. However, **not all half-reactions include a metal**. How can these reactions be set up in a half-cell? Sketch and explain an Mg/F₂ electrochemical cell:

Reduction: $F_2(g) + 2e^- \rightarrow 2F^-(aq)$
 Oxidation: $Mg(s) \rightarrow 2e^- + Mg^{2+}(aq)$

non-metals require the use of an **inert electrode**:
 i.e. C, Pt, Au
 Cathode (reduction)

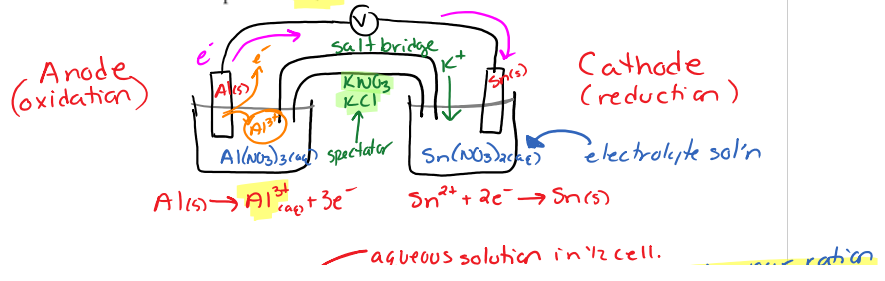
$F_2(g)$ introduced to cell via tube
 Bubbles in cathode if reactant is a gas.

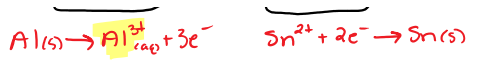
$Mg(s) \rightarrow 2e^- + Mg^{2+}$
 $F_2(g) + 2e^- \rightarrow 2F^-(aq)$

pumped in via tube
 from Pt electrode that is \ominus charged

Practice Questions:

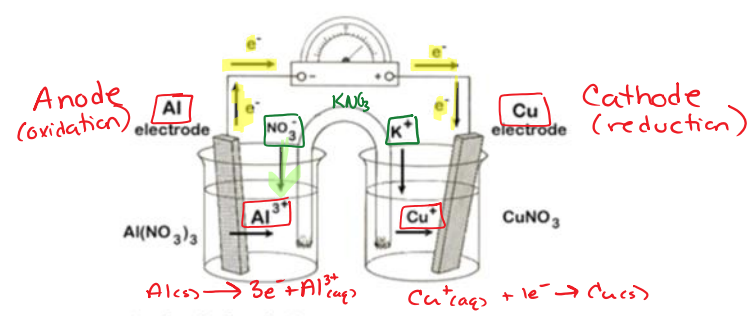
1. Draw and label all parts of a Sn/Al electrochemical cell.





- a) Identify a suitable electrolyte for the Al half cell. aqueous solution in 1/2 cell. $\text{Al}(\text{NO}_3)_3$ ← pair your cation from 1/2 rxn with a spectator ion.
- b) In which direction will electrons flow in the wire? (Al) anode → cathode (Sn)
- c) Which electrode will lose mass? Al(s) is oxidized (lose mass) Al^{3+} sol'n
- d) Toward which half cell will the K⁺ in the salt bridge migrate? Towards Sn 1/2 cell to balance ⊖ charge.
- e) Write the half-reaction occurring at the anode. $\text{Al}(s) \rightarrow \text{Al}^{3+}_{(aq)} + 3e^-$
- f) Identify the cathode. reduction (Sn(s))
- g) What happens to the [Al³⁺] in the aluminum half cell? [Al³⁺] will increase; but then some ions will flow through salt bridge ↓ [Al³⁺]
- h) Write the net redox equation.
- $$\begin{aligned} \text{reduction: } & (\text{Sn}^{2+}_{(aq)} + 2e^- \rightarrow 3\text{Sn}(s)) \times 3 \\ \text{oxidation: } & (\text{Al}(s) \rightarrow 3e^- + \text{Al}^{3+}_{(aq)}) \times 2 \quad * \text{cancel } e^- \\ \hline \text{Net Redox: } & 2\text{Al}(s) + 3\text{Sn}^{2+}_{(aq)} \rightarrow 3\text{Sn}(s) + 2\text{Al}^{3+}_{(aq)} \end{aligned}$$

2. Examine the following diagram of an electrochemical cell.



- a) Identify the cathode. Cu(s)
- b) What happens to the [NO₃⁻] in the Al half-cell as the cell is operating? (from salt bridge) ↑ [NO₃⁻] to balance the ⊕ in [Al³⁺]
- c) What happens to the [Cu⁺] in the copper half-cell as the cell is operating? ↓ [Cu⁺] as it is reduced.
- d) What is the role of K⁺ from the salt bridge? K⁺ move in Cu 1/2 cell to bal. charge.
- e) Write the net redox reaction.

Assignment 10:

- Draw an electrochemical cell with Mn and Pb electrodes and solutions of MnCl₂ and Pb(NO₃)₂ with a KNO₃ salt bridge.
 - Identify the anode.
 - Write the oxidation half-reaction.
 - Write the half-reaction occurring at the cathode.
 - Toward which electrode do the K⁺ ions in the salt bridge migrate?
 - Toward which electrode do the electrons travel in the wire?
 - What will happen to the mass of the Pb electrode?