Redox, Ohm's Law, and Power

Investigation 3 Benchmark Lesson

Redox reactions

We built batteries. What did we learn?

Redox reactions: Half-Reactions

To predict E^0:

1. Identify elements
2. Balance electrons (by integer multiplication)
3. Multiply the E^0s by the same integer
4. Flip one of the equations (probably the one with a negative E^0)
5. Multiply that E^0 by -1
6. Add the equations and cancel out the electrons
7. Add the E^0s

Half-Reaction	E^o_{red}
$K^+ + e^- \rightleftharpoons K$	-2.924
$Ba^{2+} + 2\ e^- \rightleftharpoons Ba$	-2.90
$Ca^{2+} + 2\ e^- \rightleftharpoons Ca$	-2.76
$Na^+ + e^- \rightleftharpoons Na$	-2.7109
$Mg^{2+} + 2\ e^- \rightleftharpoons Mg$	-2.375
$H_2 + 2\ e^- \rightleftharpoons 2\ H^-$	-2.23
$Al^{3+} + 3\ e^- \rightleftharpoons Al$	-1.706
$Mn^{2+} + 2\ e^- \rightleftharpoons Mn$	-1.04
$Zn^{2+} + 2\ e^- \rightleftharpoons Zn$	-0.7628
$Cr^{3+} + 3\ e^- \rightleftharpoons Cr$	-0.74
$S + 2\ e^- \rightleftharpoons S^{2-}$	-0.508
$2\ CO_2 + 2\ H^+ + 2\ e^- \rightleftharpoons H_2C_2O_4$	-0.49
$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	-0.41
$Fe^{2+} + 2\ e^- \rightleftharpoons Fe$	-0.409
$Co^{2+} + 2\ e^- \rightleftharpoons Co$	-0.28
$Ni^{2+} + 2\ e^- \rightleftharpoons Ni$	-0.23
$Sn^{2+} + 2\ e^- \rightleftharpoons Sn$	-0.1364
$Pb^{2+} + 2\ e^- \rightleftharpoons Pb$	-0.1263
$Fe^{3+} + 3\ e^- \rightleftharpoons Fe$	-0.036
$2\ H^+ + 2\ e^- \rightleftharpoons H_2$	0.0000...
$S_4O_6^{2-} + 2\ e^- \rightleftharpoons 2\ S_2O_3^{2-}$	0.0895
$Sn^{4+} + 2\ e^- \rightleftharpoons Sn^{2+}$	0.15
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	0.158
$Cu^{2+} + 2\ e^- \rightleftharpoons Cu$	0.3402

Redox reactions: Half-Reactions

Ex: Copper-Zinc battery:

1. Identify elements (Cu, Zn)
2. Balance electrons (by integer multiplication) (1 Cu, 1 Zn)
3. Multiply the E^0s by the same integer (0.3402, -0.7628)
4. Flip one of the equations (probably the one with a negative E^0) (1 Cu, -1 Zn)
5. Multiply that E^0 by -1 (0.3402, 0.7628)
6. Add the equations and cancel out the electrons (Cu^{2+} + Zn = Cu + Zn^{2+})
7. Add the E^0s (1.0030)

So, a Copper-Zinc battery will have a voltage of 1.0030 V

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$Na^+ + e^- \rightleftharpoons Na$	-2.7109
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$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$	0.15
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	0.158
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	0.3402

Redox reactions: Half-Reactions

Ex: Do a Nickel-Cadmium battery on your own

(These are the most common disposable battery type)

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$Ca^{2+} + 2\ e^{-} \rightleftharpoons Ca$	-2.76
$Na^{+} + e^{-} \rightleftharpoons Na$	-2.7109
$Mg^{2+} + 2\ e^{-} \rightleftharpoons Mg$	-2.375
$H_2 + 2\ e^{-} \rightleftharpoons 2\ H^{-}$	-2.23
$Al^{3+} + 3\ e^{-} \rightleftharpoons Al$	-1.706
$Mn^{2+} + 2\ e^{-} \rightleftharpoons Mn$	-1.04
$Zn^{2+} + 2\ e^{-} \rightleftharpoons Zn$	-0.7628
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$S + 2\ e^{-} \rightleftharpoons S^{2-}$	-0.508
$2\ CO_2 + 2\ H^{+} + 2\ e^{-} \rightleftharpoons H_2C_2O_4$	-0.49
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Redox reactions: Half-Reactions

Bonus: If I have a battery one Chromium electrode and a voltage of 0.79 V, what's the other electrode?

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$Na^+ + e^- \rightleftharpoons Na$	-2.7109
$Mg^{2+} + 2\ e^- \rightleftharpoons Mg$	-2.375
$H_2 + 2\ e^- \rightleftharpoons 2\ H^-$	-2.23
$Al^{3+} + 3\ e^- \rightleftharpoons Al$	-1.706
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$Zn^{2+} + 2\ e^- \rightleftharpoons Zn$	-0.7628
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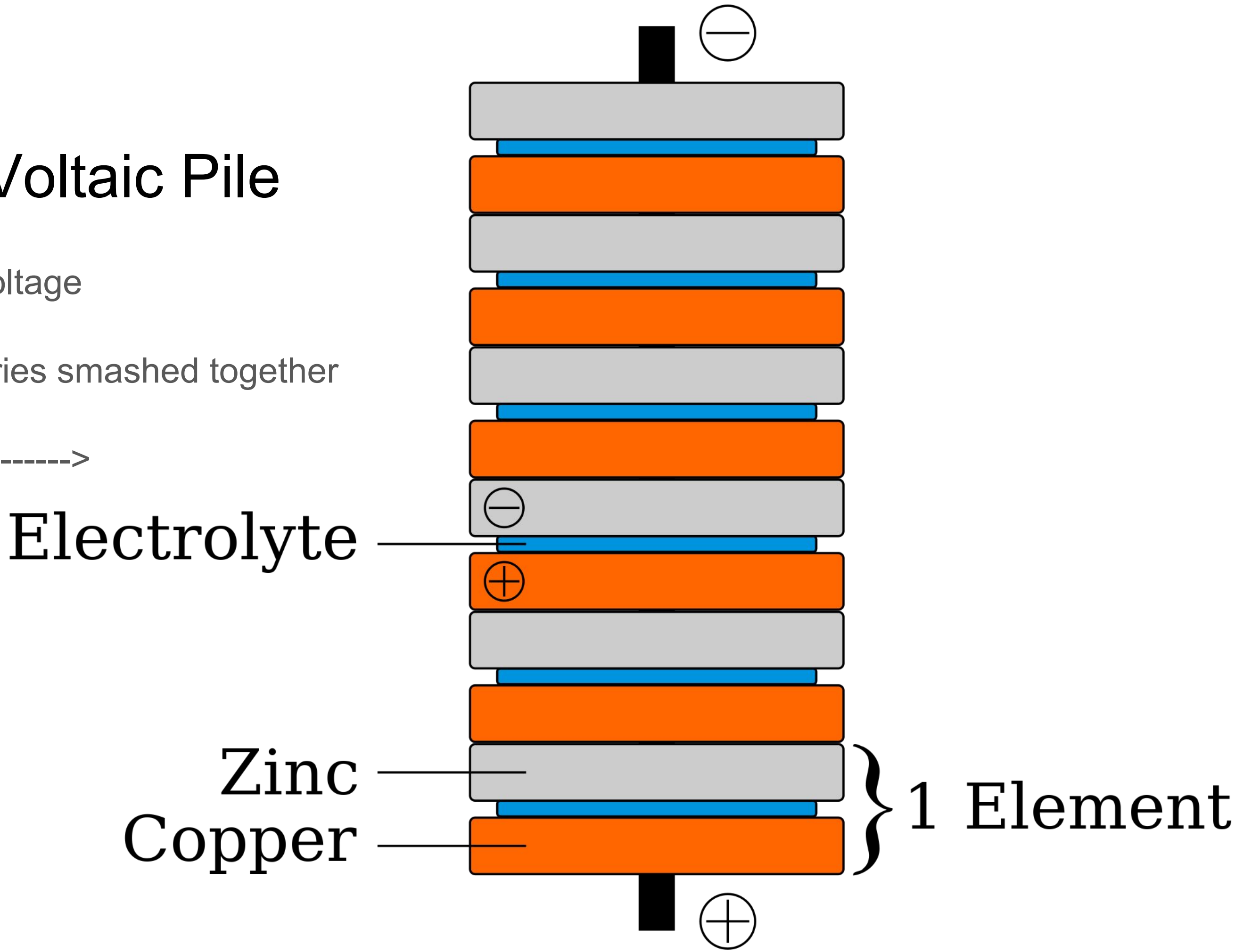
Redox reactions: Voltaic Pile

Stacking metal multiplies the voltage

Think of it like a bunch of batteries smashed together

Ex: What’s the voltage of that? ------>



Ohm's Law

We simulated resistive circuits. What did we learn?

Ohm's Law

Can do more than predict current:

How much of the electric potential is used by the electrons trying to move through the resistor? This is called the voltage drop

Ex: A 2000 Ω resistor has a 0.004 A current running through it. What is the voltage drop on the resistor?

Ohm’s Law and Series/Parallel Resistors

You observed resistors in series and in parallel. What did we learn?

Ohm's Law and Series/Parallel Resistors

Resistors in series (arithmetic sum):

$R_{eff} = \Sigma_i R_i$

Just more resistor for electrons to flow through

Resistors in parallel (harmonic sum):

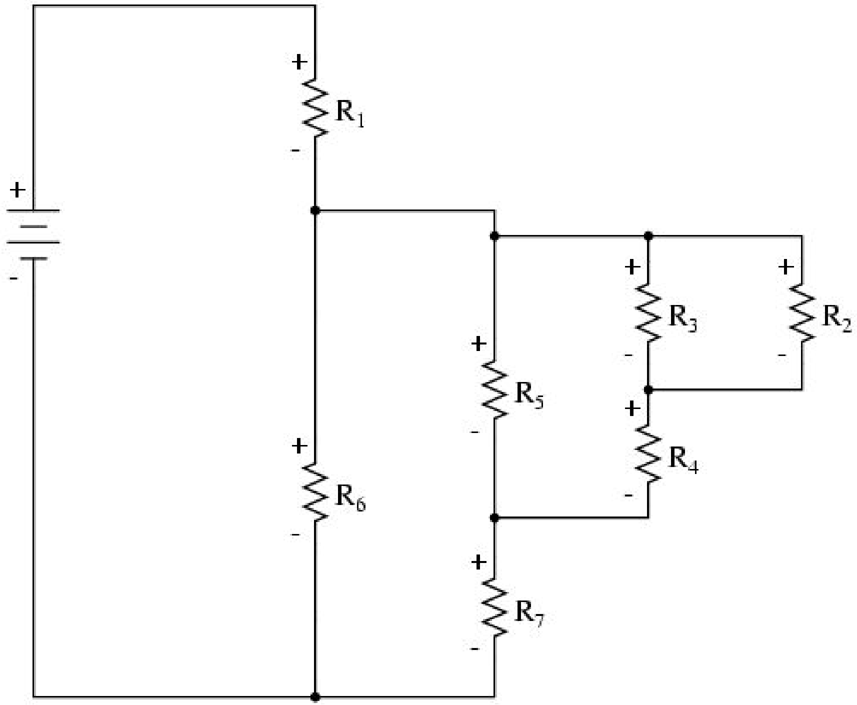
$R_{eff} = (\Sigma_i (R_i)^{-1})^{-1}$

Electrons have more options, and tend to flow on the path of least resistance

Large resistive systems can be reduced to just one effective resistance.

Ohm's Law and Series/Parallel Resistors

Ex: What's the effective resistance of this circuit? (Hint: break it up into components in parallel and components in series)



Ohm's Law and Power Loss

Resistors dissipate electrical energy as barely-usable heat, so we want to know how much energy is being used up by an electrical device.

(Power loss) = (Voltage)(Current) $P=IV$

If we are looking at a particular resistor and know the current traveling through it, we can find power loss through that resistor. Or, knowing the voltage drop and resistance:

$$P = IV = I^2R = V^2/R$$

Reducing the system to one effective resistance can give us the power loss through the whole system!

Ohm’s Law and Power Loss

Now, Energy is just Power multiplied by Time, or E=PT. (Technically, power is defined as energy per unit time, or P = E/T)

In SI units, power is watts, time is seconds, and energy is joules. (Energy consumption for your house is given by kilowatt-hours, not joules)

Ex: I have a toaster whose effective resistance is 5000 Ω, and I apply a 9V DC power source to it. If I run that toaster for 5 minutes, how much energy have I used (in joules)?