

Electrochemistry
CHEM 212

1. Define the following variables and units

variable	definition	Units
q	electric charge charge per $e^- = 1.602 \times 10^{-19} \frac{C}{e^-}$	coulombs (C)
n	mols	mol
F	coulombs per mol $9.649 \times 10^4 \frac{C}{mol e^-}$	$\frac{C}{mol e^-}$
W	work $1J = 1 \text{coulomb charge moves } 1V$	Joule (J)
E	potential difference	$1V = \frac{1J}{1C}$
ΔG	free energy	
I	current	Amperes (A) = $\frac{V}{R} = \frac{C}{Sec}$ 1 amp flows 1V if resistance is 1 Ω
R	Resistant	ohms (Ω)
P	Power = $\frac{\text{work}}{\text{Second}}$	Watts (w) = $\frac{J}{S}$

2. What are the 5 primary relationships between the relationships above?

$$q = nF$$

$$W = E \cdot q$$

$$\Delta G = -\text{work} = -nFE$$

$$E = IR \quad \text{Ohm's Law}$$

$$P = E \cdot I$$

3. Reduction-oxidation (redox) reactions are concerned with electron transfers between species. The **species that gets reduced gains electrons**. The **species that gets oxidized loses electrons**. There are a lot of mnemonic devices to remember this- what's yours?

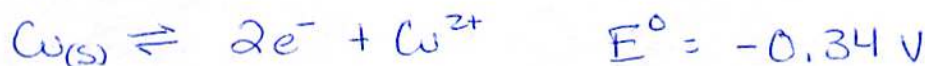
Leo goes Ger lose electron → oxidation
 gain electron → reduction

4. The reactions for oxidation and reduction are generally written separately, called half reactions. These reactions occur at **specific voltage potentials, E^0 for standard conditions**. What are these standard conditions?

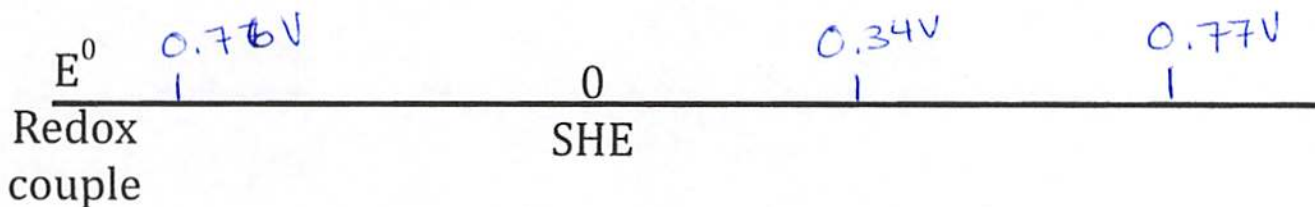
solids, pure liquids, solvents $A=0$
 aqueous solns $A=1$ (1M)
 gas $A=1$ bar

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5. Redox half reactions are tabulated as reductions. In order to convert it to an oxidation reaction, you simply flip the reaction and change the sign on E^0 . Write the following reaction as an oxidation.

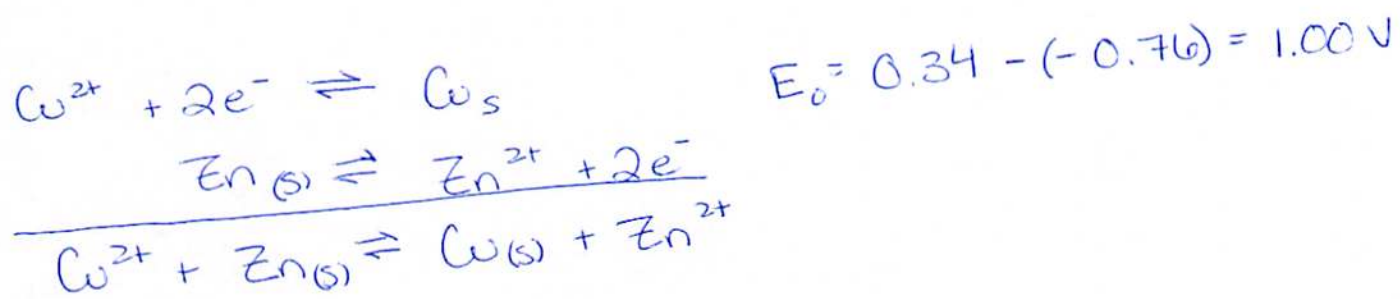
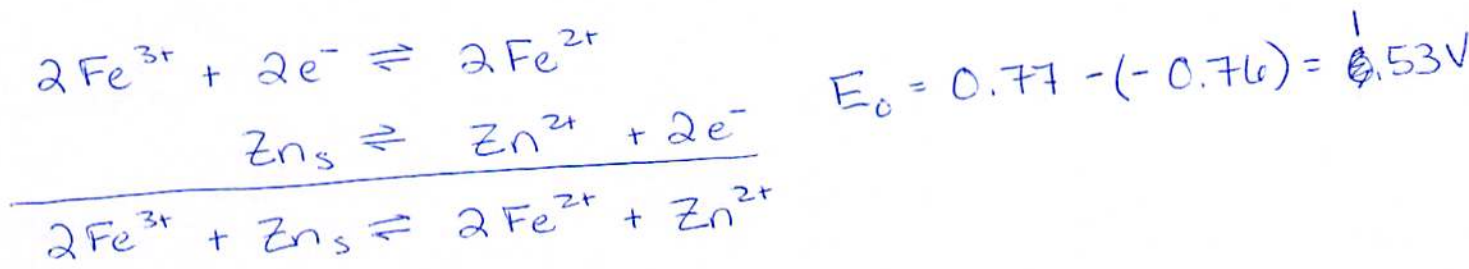
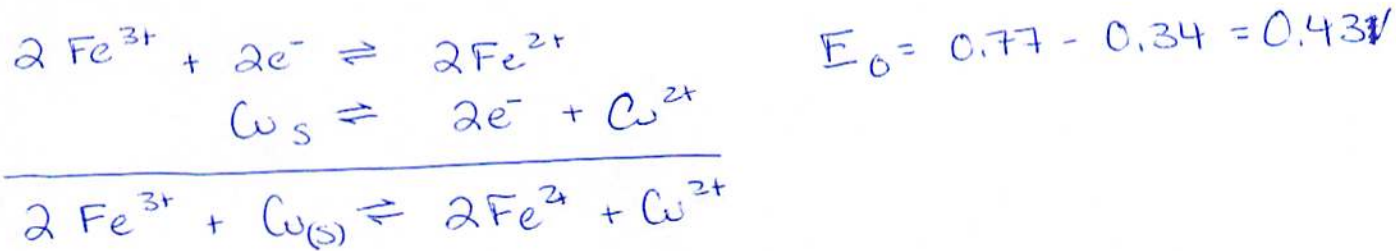


6. In a redox reaction, one of the reduction reactions must get flipped, but which one? For this class, **E^0 for a cell will always be positive**. Place the reactions shown below on the line and show the three potentials between them.



The more positive will always "go as written" and remain a reduction reaction. The less positive reaction will be flipped and become an oxidation reaction. E^0 for the complete cell is the potential difference between the two redox couples.

7. Write the balanced half reactions and full reaction for each redox pair in the previous problem. Then calculate E^0 for each cell.



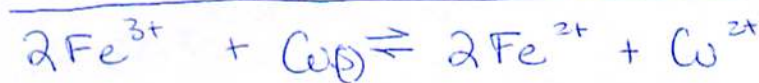
Nonstandard Conditions- Nerst Equation

11. Write the Nerst Equation @ 25°C

$$E = E^{\circ} - \frac{0.05916V}{n} \log \frac{A^b}{A^a} \quad aA + ne^- \rightleftharpoons bB$$

$$E^{\circ} = \frac{0.05916}{n} \log K$$

12. Calculate E and K for the cell if $[Fe^{2+}] = 0.034 M$, $[Fe^{3+}] = 0.005 M$, $[Cu^{2+}] = 0.012 M$



$$E^{\circ} = 0.43V$$

$$K = 3.44 \times 10^{14}$$

$K > Q$ \therefore reaction proceeds to the ~~left~~ right
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$$E = E^{\circ} - \frac{0.05916V}{n} \log \frac{[Fe^{2+}]^2 [Cu^{2+}]}{[Fe^{3+}]^2}$$

$$E = 0.43V - \frac{0.05916V}{2} \log \frac{(0.034)^2 (0.012)}{(0.005)^2} \left. \vphantom{\frac{(0.034)^2 (0.012)}{(0.005)^2}} \right\} 0.555 = Q$$

$$E = 0.437V$$

13. Calculate E and K for the cell if $[Fe^{2+}] = 0.012 M$, $[Fe^{3+}] = 0.024 M$, $[Zn^{2+}] = 0.037 M$



$$E^{\circ} = 1.53V$$

$$E = 1.53 - \frac{0.05916V}{2} \log \frac{[Fe^{2+}]^2 [Zn^{2+}]}{[Fe^{3+}]^2}$$

$$= 1.53 - \frac{0.05916V}{2} \log \frac{(0.012)^2 (0.037)}{(0.024)^2} \left. \vphantom{\frac{(0.012)^2 (0.037)}{(0.024)^2}} \right\} 9.25 \times 10^{-3} = Q$$

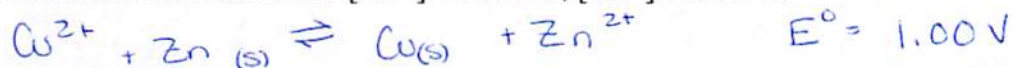
$$= 1.53 - (-0.06)$$

$$E = 1.59$$

$$K = 10^{\frac{E^{\circ} n}{0.05916}} = 5.3 \times 10^{51}$$

$K > Q$ \therefore rxn proceeds to ~~left~~ right
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14. Calculate E for the cell if $[Cu^{2+}] = 0.056 M$, $[Zn^{2+}] = 0.017 M$



$$E = E^{\circ} - \frac{0.05916 V}{n} \log Q = 1.00 - \frac{0.05916}{2} \cdot \log \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

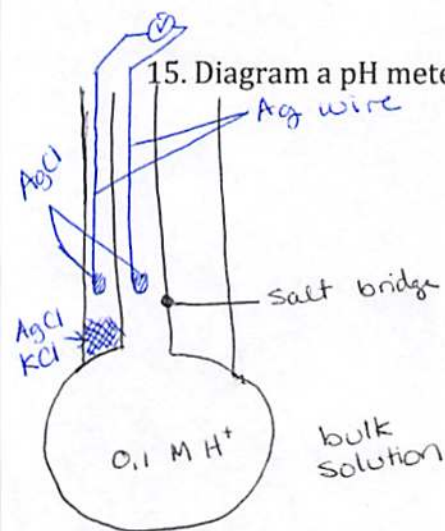
$$E = 1.00 - 0.015 = 0.985 V$$

$$Q = \frac{0.017}{0.056} = 0.303$$

$$K = 10^{\frac{E^{\circ} n}{0.05916}} = 6.4 \times 10^{33}$$

$Q < K$ rxn proceeds to right

15. Diagram a pH meter and explain how it measures proton concentration in solution.



~~Corrected~~ A pH meter is made from an indicator and reference electrode that are electrically connected by an external circuit, but physically isolated by a salt bridge.

The indicator electrode contains an Ag wire w/ AgCl paste. These are in a $0.1 M H^+$ solution that is separated by a pH sensitive glass from bulk solution.

The outer surface of the glass has a ~~fixed~~ protonation state dependent on bulk solution proton concentration. The differences between protonation of inner & outer surface of the glass creates a potential difference we can measure.

The indicator electrode is connected to a reference electrode of Ag wire in a saturated solution of AgCl & KCl.