CH302 Unit8 Day3 Activity
Name:__________________KEY________________

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In a virtual world, even though you are an engineer or biologist, the only job available to you is as a BS chemist. Your boss has asked you to work on creating a high voltage battery. You scan the chemicals on the shelf. You find that you have the following chemicals available, Cu, $CuNO_3$, Sc, $ScNO_3$, Zn, $ZnNO_3$, Pb, $PbNO_3$.

You Google a reduction table and find the following data:

$Pb^{2+} + 2e^- \rightarrow Pb$ E= -.13 V
$Cr^{3+} + 3e^- \rightarrow Cr$ E= -.73 V
$Cu^{2+} + 2e^- \rightarrow Cu$ E= +.34 V
$Sc^{3+} + 3e^- \rightarrow Sc$ E= -2.1 V

1 From the list of chemicals and the stated potentials is it possible to construct a voltaic cell at standard conditions?

Yes. A voltaic cell must have a difference in standard reduction potentials that is positive. With the numbers above, we could select several pairs of values that would have a positive difference.

2 To maximize the potential of the cell (and impress your boss), which two half reactions should you select?

We need the most positive value and the most negative value to maximize the potential (the biggest positive and biggest negative are the numbers farthest from one another on a number line, if that helps you visualize!). So let's select Copper and Scandium (the last two reactions).

3 In this cell, what will serve as the anode, and what will serve as the cathode?

At the cathode, REDUCTION is occurring. At the anode, OXIDATION is occurring. The equation for finding cell potential is Ecell = Ecat - Ean or Ecell = Ered - Eox. In a voltaic cell, we would like a positive overall Ecell. Therefore, we need the substance with a positive reduction potential to be at the cathode and the substance with a negative reduction potential to be at the anode. Cathode = Copper and Anode = Scandium.

4 What will be the standard potential of the electrochemical cell?

Ecell = Ecat - Ean or Ecell = Ered - Eox.
Ecell = 0.34V - (-2.1V) = 2.44V

5 In preparation for writing up your findings for your boss, write the short hand notation for the cell you will construct.

<Sc | Sc^{3+} || Cu^{2+} | Cu>

6 Write the overall balanced redox reaction describing the chemistry of this cell.

Use the method of half-reactions:

Oxidation 1/2 Reaction: Sc --> Sc^{3+}
Reduction 1/2 Reaction: Cu^{2+} --> Cu

Balance charge with electrons:
Oxidation 1/2 Reaction: Sc --> Sc^{3+} + 3e-
Reduction 1/2 Reaction: Cu^{2+} + 2e- --> Cu

Use coefficients to balance the number of electrons used in both half-reactions:
Oxidation 1/2 Reaction: 2x(Sc --> Sc^{3+} + 3e-)
NEW Oxidation 1/2 Reaction: 2Sc --> $2Sc^{3+}$ + 6e-
Reduction 1/2 Reaction: 3x(Cu^{2+} + 2e- --> Cu)
NEW Reduction 1/2 Reaction: $3Cu^{2+}$ + 6e- --> 3Cu

Combine:
NEW Oxidation 1/2 Reaction: 2Sc --> $2Sc^{3+}$ + 6e-
NEW Reduction 1/2 Reaction: $3Cu^{2+}$ + 6e- --> 3Cu

Balanced Overall: 2Sc + $3Cu^{2+}$--> 3Cu + $2Sc^{3+}$

Assume you put the cell together, it works, and you show it to your boss. Unfortunately, there is a bit of an issue. While, copper is currently selling for $3.50 a pound, scandium is selling for $125,000 per pound. The scandium that you helped yourself to was actually your boss's personal savings account. As he was watching the demonstration, his eyes began to tear up. Your sad, sad mistake used up the precious metal he had planned to sell to finance his summer home at the coast. The boss demands that you recover all the scandium that you have lost while running your voltaic cell. Fortunately, you know that you can run a voltaic cell in the opposite direction by applying a potential across the cell reversing the redox reaction. Even more fortunately for you, a gentleman named Faraday determined that one mole of electrons provides 96,485 coulomb of charge.

7 What is the minimum potential you must apply to the cell to ***reverse*** the reaction? Write the balanced redox reaction associated with this cell.

Ecell = Ecat - Ean or Ecell = Ered - Eox.
Ecell = -2.1V - 0.34V = -2.44V (we swtiched the metals at the anode and the cathode, so the values of the voltages at the cathode and anode are now switched in this equation).

3Cu + $2Sc^{3+}$--> 2Sc + $3Cu^{2+}$

8 Write the half reaction that will occur at the anode and the ½ reaction that will occur at the cathode in this cell.

Anode: Cu --> Cu^{2+} + $2e^-$ (still oxidation)

Cathode: Sc^{3+} + $3e^-$ --> Sc (still reduction)

9 How many moles of electrons will be need to reduce each mole of scandium ion.

To reduce one atom of Sc^{3+} we will need 3 electrons

So for 1 mole of Sc^{3+}, we will need 3 moles of electrons

10 Assuming in the process of practicing and demonstrating your voltaic cell you used up 100 grams of the Sc, how much charge will you need to add to the cell to produce 100 g of Sc?

Sc - 44.96 g/mol

$$100gSc \times \frac{1moleSc}{44.96g} = 2.22moles$$

$$2.22moles \times \frac{3electrons}{1Sc} = 6.67moles$$

$$6.67moles \times \frac{96{,}485Coulombs}{1moleElectrons} = 643{,}805.6Coulombs$$

11 Your power source can deliver charge at a rate of 100 mAmps. How long will it take you to regenerate the 100 g of Sc? (1 Amp = 1 Coulomb/s)

$$643{,}805.6Coulombs \times \frac{1\sec ond}{0.1Amp} = 6{,}438{,}056\sec onds$$

107,301 minutes

1788.3 hours

74.5 days