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Chemistry Lab

Experiment

Booklet

April 23rd, 2022

State Tournament

PART – 1 of 2

Instructions: This exam consists of a set of experiments based on oxidation-reduction reactions and aqueous solutions worth 100 points and a multiple choice exam worth 100 points (**200 points total**).

Students may NOT write on the Experiment or Exam Booklet. Students may **only mark on their answer sheets.**

Be strategic, figure out the way that you and your team can bank as many points as possible in the time given. Place the answers to the lab experiments and multiple-choice exam on the provided answer sheets. Answers not placed on the answer sheet will not be scored.

Ties will be broken by first the quality, accuracy, and completeness of the **experimental data and results**, followed by (if necessary) **selected multiple choice problems**.

You will need to perform the experiment and have your station completely cleaned up **<u>and reset to their original positions</u>** or a penalty of up to 10 % will be assessed against your score.

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Potentially Useful Information

1 mL = 1 cm^3

The density of water at room temperature, ρ_{H2O} = 1.00 g/mL

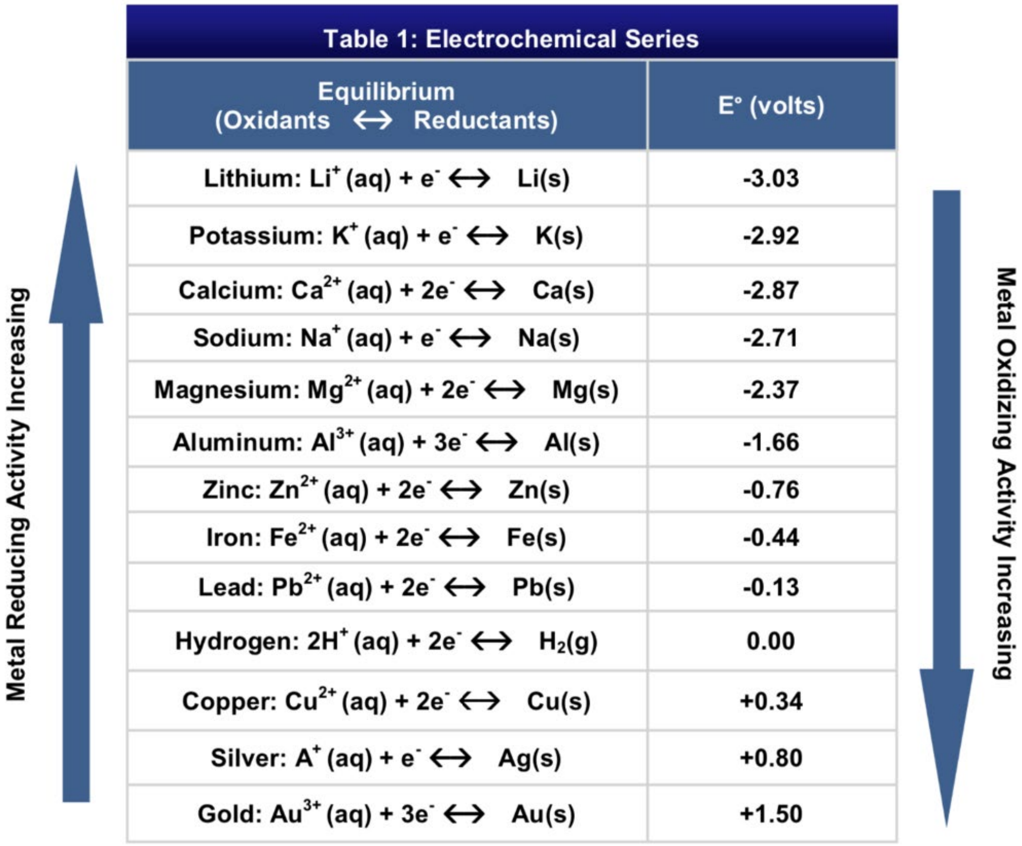
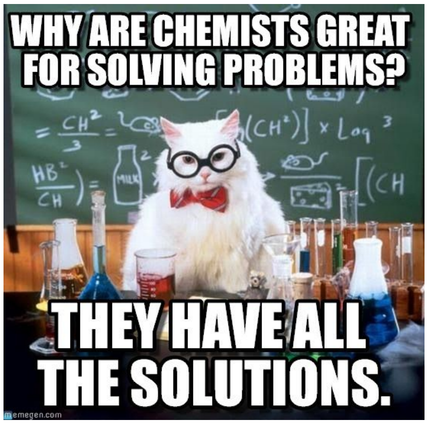


Table 1: Electrochemical Series

Equilibrium (Oxidants ↔ Reductants)	E° (volts)
Lithium: Li^+ (aq) + e^- ↔ Li(s)	-3.03
Potassium: K^+ (aq) + e^- ↔ K(s)	-2.92
Calcium: Ca^{2+} (aq) + $2e^-$ ↔ Ca(s)	-2.87
Sodium: Na^+ (aq) + e^- ↔ Na(s)	-2.71
Magnesium: Mg^{2+} (aq) + $2e^-$ ↔ Mg(s)	-2.37
Aluminum: Al^{3+} (aq) + $3e^-$ ↔ Al(s)	-1.66
Zinc: Zn^{2+} (aq) + $2e^-$ ↔ Zn(s)	-0.76
Iron: Fe^{2+} (aq) + $2e^-$ ↔ Fe(s)	-0.44
Lead: Pb^{2+} (aq) + $2e^-$ ↔ Pb(s)	-0.13
Hydrogen: $2H^+$ (aq) + $2e^-$ ↔ H_2(g)	0.00
Copper: Cu^{2+} (aq) + $2e^-$ ↔ Cu(s)	+0.34
Silver: A^+ (aq) + e^- ↔ Ag(s)	+0.80
Gold: Au^{3+} (aq) + $3e^-$ ↔ Au(s)	+1.50



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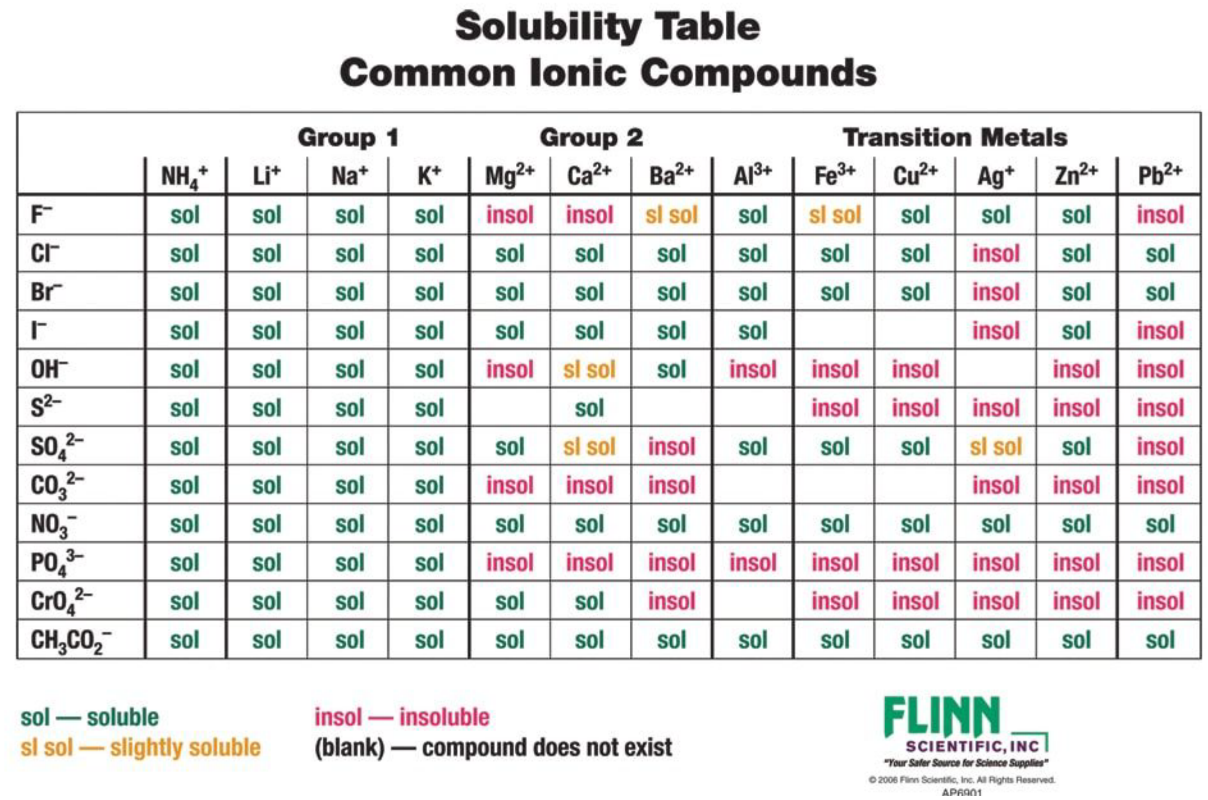

Solubility Table
Common Ionic Compounds

		Group 1			Group 2				Transition Metals				
	NH_4^+	Li^+	Na^+	K^+	Mg^{2+}	Ca^{2+}	Ba^{2+}	Al^{3+}	Fe^{3+}	Cu^{2+}	Ag^+	Zn^{2+}	Pb^{2+}
F^-	sol	sol	sol	sol	insol	insol	sl sol	sol	sl sol	sol	sol	sol	insol
Cl^-	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	insol	sol	sol
Br^-	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	insol	sol	sol
I^-	sol	sol	sol	sol	sol	sol	sol	sol			insol	sol	insol
OH^-	sol	sol	sol	sol	insol	sl sol	sol	insol	insol	insol		insol	insol
S^{2-}	sol	sol	sol	sol		sol			insol	insol	insol	insol	insol
SO_4^{2-}	sol	sol	sol	sol	sol	sl sol	insol	sol	sol	sol	sl sol	sol	insol
CO_3^{2-}	sol	sol	sol	sol	insol	insol	insol				insol	insol	insol
NO_3^-	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol
PO_4^{3-}	sol	sol	sol	sol	insol	insol	insol	insol	insol	insol	insol	insol	insol
CrO_4^{2-}	sol	sol	sol	sol	sol	sol	insol		insol	insol	insol	insol	insol
$CH_3CO_2^-$	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol

sol — soluble
sl sol — slightly soluble

insol — insoluble
(blank) — compound does not exist

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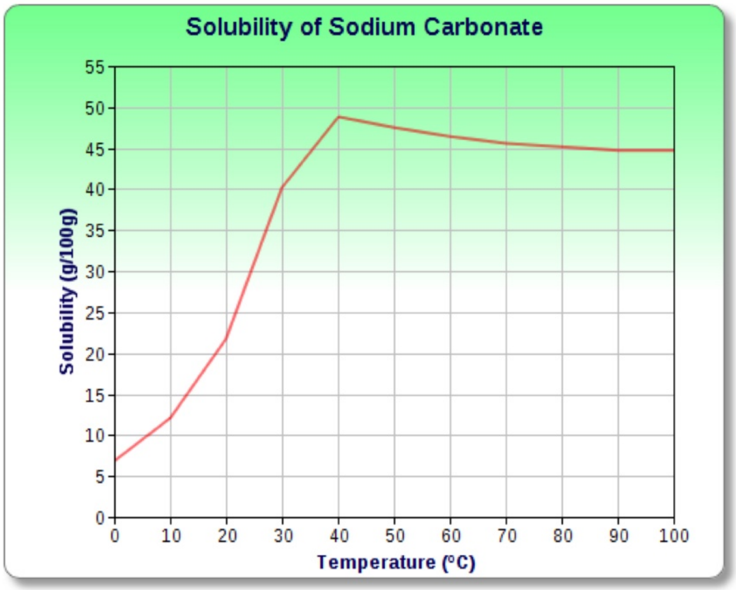

$$T(°C) = [T(°F) - 32°F] \times \frac{5(°C)}{9(°F)}$$

$$T(°F) = \left[T(°C) \times \frac{9(°F)}{5(°C)}\right] + 32°F$$

$$T(K) = [T(°C) + 273.15(°C)] \times \frac{1(K)}{1(°C)}$$

$$T(°C) = [T(K) - 273.15(K)] \times \frac{1(°C)}{1(K)}$$

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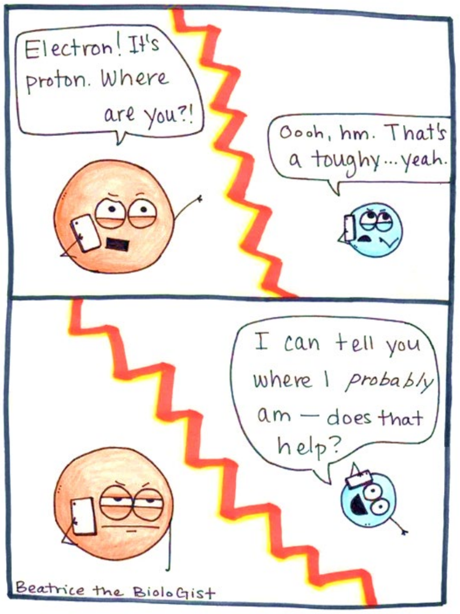
Key:
Element Name
Atomic number
Symbol
Atomic weight (mean relative mass)

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hydrogen 1 H 1.008																		Helium 2 He 4.0026
Lithium 3 Li 6.94	Beryllium 4 Be 9.0122												Boron 5 B 10.81	Carbon 6 C 12.011	Nitrogen 7 N 14.007	Oxygen 8 O 15.999	Fluorine 9 F 18.998	Neon 10 Ne 20.180
Sodium 11 Na 22.990	Magnesium 12 Mg 24.305												Aluminium 13 Al 26.982	Silicon 14 Si 28.085	Phosphorus 15 P 30.974	Sulfur 16 S 32.06	Chlorine 17 Cl 35.45	Argon 18 Ar 39.948
Potassium 19 K 39.098	Calcium 20 Ca 40.078(4)		Scandium 21 Sc 44.956	Titanium 22 Ti 47.867	Vanadium 23 V 50.942	Chromium 24 Cr 51.996	Manganese 25 Mn 54.938	Iron 26 Fe 55.845(2)	Cobalt 27 Co 58.933	Nickel 28 Ni 58.693	Copper 29 Cu 63.546(3)	Zinc 30 Zn 65.38(2)	Gallium 31 Ga 69.723	Germanium 32 Ge 72.63	Arsenic 33 As 74.922	Selenium 34 Se 78.96(3)	Bromine 35 Br 79.904	Krypton 36 Kr 83.798(2)
Rubidium 37 Rb 85.468	Strontium 38 Sr 87.62		Yttrium 39 Y 88.906	Zirconium 40 Zr 91.224(2)	Niobium 41 Nb 92.906(2)	Molybdenum 42 Mo 95.96(2)	Technetium 43 Tc [97.91]	Ruthenium 44 Ru 101.07(2)	Rhodium 45 Rh 102.91	Palladium 46 Pd 106.42	Silver 47 Ag 107.87	Cadmium 48 Cd 112.41	Indium 49 In 114.82	Tin 50 Sn 118.71	Antimony 51 Sb 121.76	Tellurium 52 Te 127.60(3)	Iodine 53 I 126.90	Xenon 54 Xe 131.29
Caesium 55 Cs 132.91	Barium 56 Ba 137.33	57-70 *	Lutetium 71 Lu 174.97	Hafnium 72 Hf 178.49(2)	Tantalum 73 Ta 180.95	Tungsten 74 W 183.84	Rhenium 75 Re 186.21	Osmium 76 Os 190.23(2)	Iridium 77 Ir 192.22	Platinum 78 Pt 195.08	Gold 79 Au 196.97	Mercury 80 Hg 200.59	Thallium 81 Tl 204.38	Lead 82 Pb 207.2	Bismuth 83 Bi 208.98	Polonium 84 Po [208.98]	Astatine 85 At [209.99]	Radon 86 Rn [222.02]
Francium 87 Fr [223.02]	Radium 88 Ra [226.03]	89-102 **	Lawrencium 103 Lr [262.11]	Rutherfordium 104 Rf [265.12]	Dubnium 105 Db [268.13]	Seaborgium 106 Sg [271.13]	Bohrium 107 Bh [270]	Hassium 108 Hs [277.15]	Meitnerium 109 Mt [276.15]	Darmstadtium 110 Ds [281.16]	Roentgenium 111 Rg [280.16]	Copernicium 112 Cn [285.17]	Ununtrium 113 Uut [284.18]	Flerovium 114 Fl [289.19]	Ununpentium 115 Uup [288.19]	Livermorium 116 Lv [293]	Ununseptium 117 Uus [294]	Ununoctium 118 Uuo [294]

*lanthanoids	Lanthanum 57 La 138.91	Cerium 58 Ce 140.12	Praseodymium 59 Pr 140.91	Neodymium 60 Nd 144.24	Promethium 61 Pm [144.91]	Samarium 62 Sm 150.36(2)	Europium 63 Eu 151.96	Gadolinium 64 Gd 157.25(3)	Terbium 65 Tb 158.93	Dysprosium 66 Dy 162.50	Holmium 67 Ho 164.93	Erbium 68 Er 167.26	Thulium 69 Tm 168.93	Ytterbium 70 Yb 173.05
**actinoids	Actinium 89 Ac [227.03]	Thorium 90 Th 232.04	Protactinium 91 Pa 231.04	Uranium 92 U 238.03	Neptunium 93 Np [237.05]	Plutonium 94 Pu [244.06]	Americium 95 Am [243.06]	Curium 96 Cm [247.07]	Berkelium 97 Bk [247.07]	Californium 98 Cf [251.08]	Einsteinium 99 Es [252.08]	Fermium 100 Fm [257.10]	Mendelevium 101 Md [258.10]	Nobelium 102 No [259.10]

Formula	Name
CATION: Positive Ion	
NH_4^+	ammonium ion
ANIONS: Negative Ions	
Based on a Group 4A element	
CN^-	cyanide ion
$CH_3CO_2^-$	acetate ion
CO_3^{2-}	carbonate ion
HCO_3^-	hydrogen carbonate ion (or bicarbonate ion)
Based on a Group 5A element	
NO_2^-	nitrite ion
NO_3^-	nitrate ion
PO_4^{3-}	phosphate ion
HPO_4^{2-}	hydrogen phosphate ion
$H_2PO_4^-$	dihydrogen phosphate ion
Based on a Group 6A element	
OH^-	hydroxide ion
SO_3^{2-}	sulfite ion
SO_4^{2-}	sulfate ion
HSO_4^-	hydrogen sulfate ion (or bisulfate ion)
Based on a Group 7A element	
ClO^-	hypochlorite ion
ClO_2^-	chlorite ion
ClO_3^-	chlorate ion
ClO_4^-	perchlorate ion
Based on a transition metal	
CrO_4^{2-}	chromate ion
$Cr_2O_7^{2-}$	dichromate ion
MnO_4^-	permanganate ion



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TO REDOX OR NOT TO REDOX, THAT IS THE QUESTION

Introduction

The purpose of this experiment is to determine the identity of an electrode paired with copper in an electrochemical cell and to determine if four additoinal reactions are RedOx reactions. All RedOx reactions will require full analysis. Several questions about the solution chemistry involved follow each experiment.

Materials:

12-well plate
Voltmeter
Squares of sandpaper
Copper electrode
1.0 M Copper (II) sulfate electrolyte (shared)
Unknown metal electrode
1.0 M Unknown metal sulfate electrolyte (shared)
Saturated potassium chloride (shared)
Tissue paper (for salt bridge)
Aluminum foil
Saturated sodium carbonate solution (shared)
1.0 M Hydrochloric acid (shared)
Magnesium filings
Plastic pipettes
Wood splint
Plastic tweezers
Deionized water (at sink)
Analytical balance
Pyrex beakers

Take careful notice of the layout of your station.

Points will be deducted (up to 10%) from your score if you do not clean and replace all of the items back to their original positions!

Safety Precautions:

1.0 M hydrochloric acid is a strong acid and very damaging to the eyes and skin! Wear chemical splash goggles to perform this experiment. Immediately rinse off any acid that gets on your skin with runnung water.

OPTIONAL: Gloves and a chemical-resistant apron or lab coat may be worn for this experient as well if desired.

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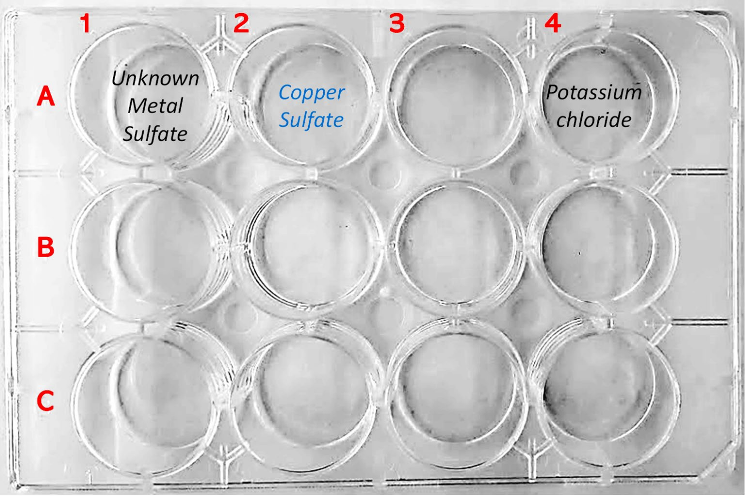
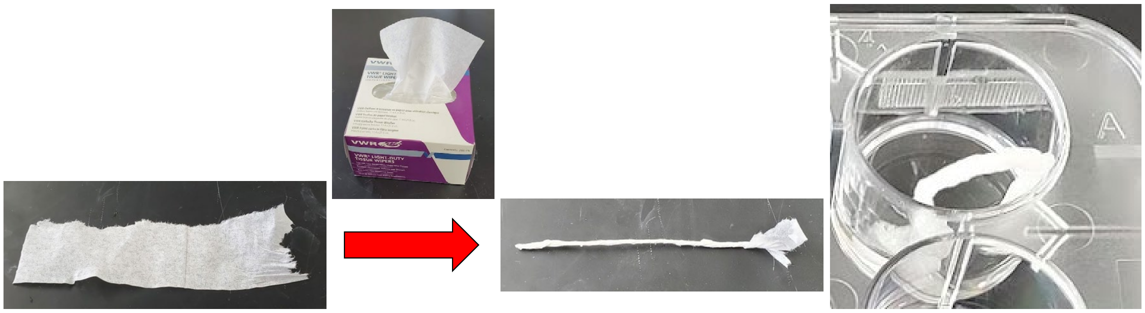


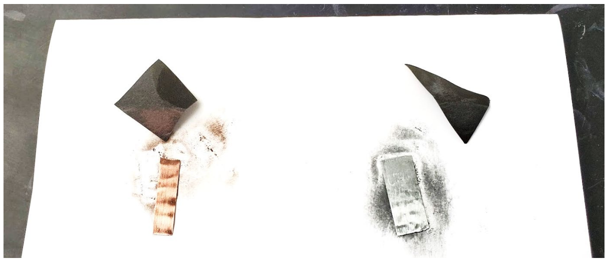
Procedure 1

ELECTROCHEMICAL DETERMININATION OF ELECTRODE IDENTITY

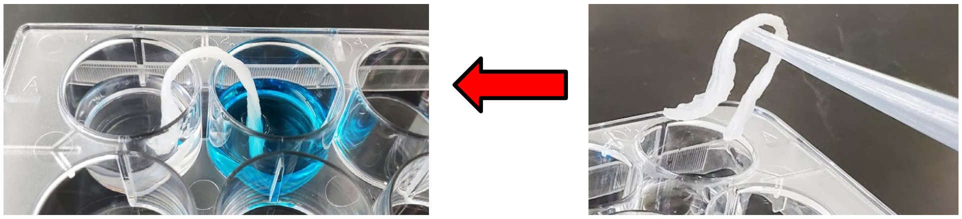
1. Locate your 12-well plate
2. Place 40 drops of 1.0 M **unknown metal sulfate** solution in the top left well (**A1**)
3. Place 40 drops of 1.0 M **copper (II) sulfate** solution to the left in well **A2**
4. Place 20 drops of **saturated potassium chloride** solution into the top right well (**A4**)
5. Prepare a twisted tissue paper salt bridge by cutting a 1 to 2 cm wide strip of tissue paper strip from a paper towel or kimwipe, twisting into a filament



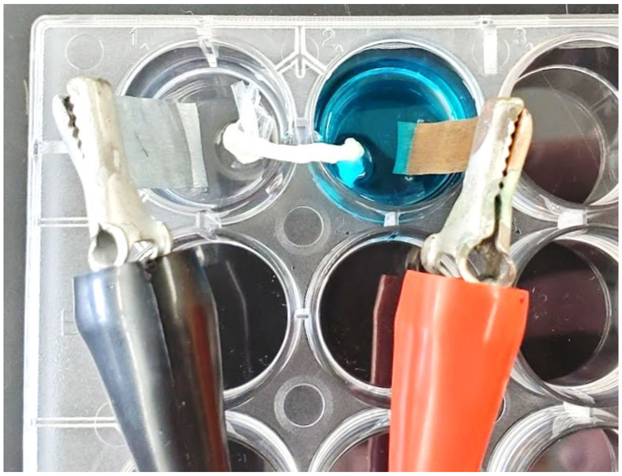
6. Soak the paper filament in satrated potassium chloride solution, in well A4.
7. Obtain a copper and an UNKNOWN metal electrode. Sand your electrodes using the provided squares of sandpaper. Work over a sheet of paper to prevent scaring the benchtop. ALSO, be sure use the labeled “copper” and “unknown” sanding paper to avoid cross contamination of the electrodes with metal particles.



8. Remove the tissue paper salt bridge from the potassium chloride solution, and drape between the left hand and right hand resivoirs of your electrochemical cell. Be sure the paper contacts the solution on both sides.



9. Place a copper strip in the RED alligator clip of the voltmeter
10. Place the unknown metal strip in the BLACK alligator clip of the voltmeter.
11. Use your voltmeter (set to **DC** volts, ⎓V) to measure the voltage across the two electrodes, (notice: when the electrodes are attached properly, the voltage will be POSITIVE. If your voltage is negative, reverse the locations of the voltmeter leads. BE CAREFUL NOT TO SPILL SOLUTIONS ONTO THE VOLTMETER!
12. Lower the copper into the copper electrolyte and the Unknown into the unknown metal sulfate electrolyte.



13. After the voltage stabilizes (may take several seconds, but usually less than a minute), record the ***Cell Voltage*** on your ***Experimental Data Sheet***
14. The data at the very beginning of the experiment is more accurate than after letting the electrochemical cell run for awhile. Over time, the salt bridge causes the solutions to mix and can decrease the voltage.
15. Use the electrochemical series reference table at the beginning of this booklet to determine the identity of the UNKNOWN metal paired with copper in your electrochemical cell.
16. Your experimental voltage may be a bit different than the calculated theoretical voltage, but should be close enough to determine the likely identity of the UNKNOWN metal electrode.
17. Write the ***Identity of the UNKNOWN Metal*** electrode on your ***Experimental Data Sheet***

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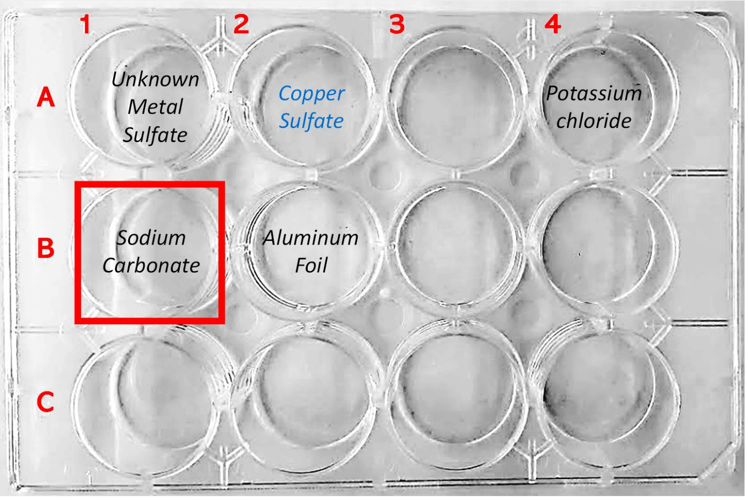
ANSWER THE FOLLOWING QUESTIONS ON YOUR Experimental Data Sheet

18. Write the ***half-reaction*** in the direction that it is occuring at the **COPPER** electrode:
19. Write the ***half-reaction*** in the direction that it is occuring at the now determined **UNKNOWN** electrode:
20. Write the ***BALANCED NET Chemical Equation*** representing the reaction occuring the electrochemical cell:
21. Which metal electrode is the **ANODE**?
22. Which metal electrode is the **CATHODE**?
23. Which metal **ATOM** (or ion) is bring **OXIDIZED**?
24. Which metal **ATOM** (or ion) is being **REDUCED**?
25. Which metal **ATOM** (or ion) is the **OXIDIZING AGENT**?
26. Which metal **ATOM** (or ion) is the **REDUCING AGENT**?
27. **CONCEPT QUESTION:** How many **grams** of **copper (II) sulfate pentahydrate** would be required to prepare 100.0 mL of a 1.00 M solution of copper sulfate electrolyte?
28. **CONCEPT QUESTION:** What is the **PERCENT BY MASS** of **Cu^{2+} ion** in the resulting 1.00 M copper (II) sulfate solution? (The density of 1.00 M copper sulfate solution is 1.19 g/mL at 20°C)



Procedure 2

29. Procedure 2 will use the UNKNOWN electrolyte solution from your electrochemical cell solution from Procedure 1, the unknown electrolyte is the **sulfate salt** matching the electrode identity.
30. Disassemble your electrochemical cell (but do not dump your electrolyte solutions)
31. Remove the paper salt bridge and discard
32. Remove the electrodes and wipe them clean with a paper towel
33. Fill your 250 mL glass beaker about ¾ full with deionized water

34. Using your plastic pipette, add **20 drops** of **deionized water** to well **B1**, directly below the (previously) UNKNOWN metal sulfate solution.
35. Place **5 drops** of **saturated sodium carbonate solution** into well **B1** and stir with your pipette
36. Rinse your pipette by repeatedly aspirating in your beaker of deionized water
37. Place several drops of the UNKNOWN metal sulfate electrolyte solution into well **B1** and stir with your pipette. You can mix by slowly aspirating the mixture several times with your plastic pipette.
38. Rinse your pipette by repeatedly aspirating in your beaker of deionized water
39. Make a note of your observations on your ***Experimental Data Sheet***

ANSWER THE FOLLOWING QUESTIONS ON YOUR Experimental Data Sheet

40. Based on the identity of the UNKNOWN you determined in Procedure 1, propose and write a ***BALANCED NET Chemical Equation*** representing the overall reaction occuring in **Procedure 2**:
41. Is this reaction a **REDOX** reaction?
42. **If so**, write the **OXIDATION** and **REDUCTION** ***half-reactions***. (**If not**, write the **TYPE** of reaction that **IS** occuring in both blanks of your answer sheet, and write "**NA**" for the answer to the followng 4 questions.)
43. Which **ATOM** (or ion) is being **OXIDIZED**?
44. Which **ATOM** (or ion) is being **REDUCED**?
45. Which **ATOM** (or ion) is the **OXIDIZING AGENT**?
46. Which **ATOM** (or ion) is the **REDUCING AGENT**?
47. **CONCEPT QUESTION:** How many grams of the *now determined* **UNKNOWN sulfate monohydrate** would be required to prepare 100.0 mL of a 1.00 M solution of UNKNOWN sulfate electrolyte?

Procedure 3 – *CAUTION: This procedure may create some fumes, avoid breathing with your face too close to the well plate . . .*

48. Obtain a strip of aluminum foil and cut/tear off an approximately 1 cm x 1 cm square of foil
49. Place the foil into well **B2**, directly below the copper sulfate solution.

50. Using your plastic pipette, add **10 drops** of copper sulfate solution from well A2 to the aluminum foil in well **B2**

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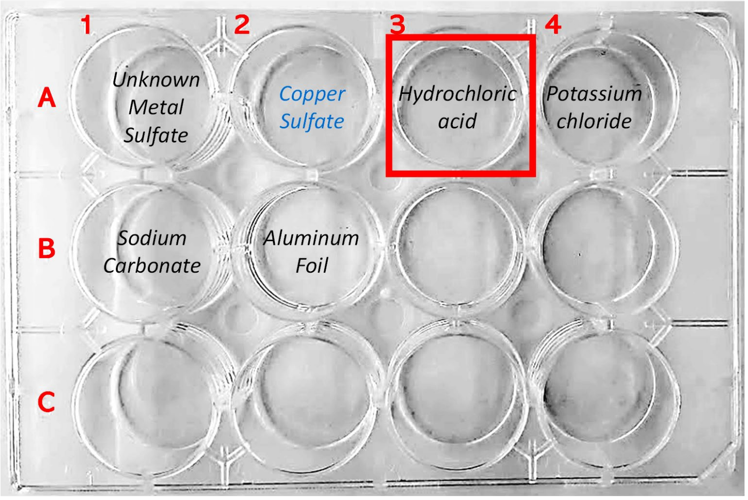
51. Rinse your pipette by repeatedly aspirating in your beaker of deionized water
52. This reaction may take some time to complete.
53. Make a note of your observations on your ***Experimental Data Sheet***

ANSWER THE FOLLOWING QUESTIONS ON YOUR Experimental Data Sheet

54. Look carefully at the contents of well B2, propose and write a ***BALANCED NET Chemical Equation*** representing the overall reaction occuring in **Procedure 3**:
55. Is this reaction a **REDOX** reaction?
56. **If so**, write the **OXIDATION** and **REDUCTION** ***half-reactions***. (**If not**, write the **TYPE** of reaction that **IS** occuring in both blanks of your answer sheet, and write "**NA**" for the answer to the followng 4 questions.)
57. Which **ATOM** (or ion) is being **OXIDIZED**?
58. Which **ATOM** (or ion) is being **REDUCED**?
59. Which **ATOM** (or ion) is the **OXIDIZING AGENT**?
60. Which **ATOM** (or ion) is the **REDUCING AGENT**?



Procedure 4 – ***CAUTION: This procedure may create some fumes, avoid breathing with your face too close to the well plate . . .***

61. Using your plastic pipette, add **10 drops** of **deionized water** to well **A3**
62. Place **10 drops** of **1.0 M hydrochloric acid** into well **A3**.
63. Add **1 magnesium shaving** to well **A3**
64. Make a note of your observations on your ***Experimental Data Sheet***
65. This reaction can take some time to complete.

ANSWER THE FOLLOWING QUESTIONS ON YOUR Experimental Data Sheet

66. Look carefully at the surface of the magnesium shavings, propose and write a ***BALANCED NET Chemical Equation*** representing the overall reaction occuring in **Procedure 4**:

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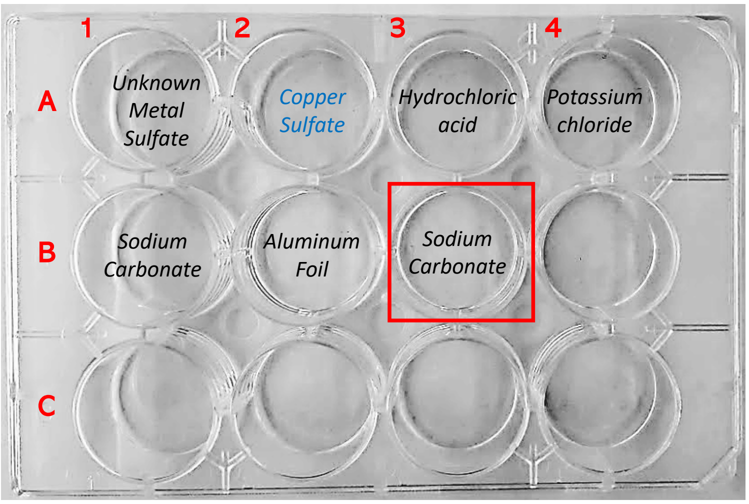
67. Is this reaction a **REDOX** reaction?
68. **If so**, write the **OXIDATION** and **REDUCTION** ***half-reactions***. (**If not**, write the **TYPE** of reaction that **IS** occuring in both blanks of your answer sheet, and write "**NA**" for the answer to the followng 4 questions.)
69. Which **ATOM** (or ion) is being **OXIDIZED**?
70. Which **ATOM** (or ion) is being **REDUCED**?
71. Which **ATOM** (or ion) is the **OXIDIZING AGENT**?
72. Which **ATOM** (or ion) is the **REDUCING AGENT**?
73. **CONCEPT QUESTION:** How many **mL** of 12.0 M concentrated hydrochloric acid would required to prepare 100.0 mL of 1.0 M hydrochloric acid in a 100 mL volumetric flask?



Procedure 5

74. Add **40 drops** of saturated sodium carbonate solution to well **B3**.
75. Watch carefully while adding **several drops** of **1.0 M hydrochloric acid** to the sodium carbonate solution.
76. Make a note of your observations on your ***Experimental Data Sheet***

ANSWER THE FOLLOWING QUESTIONS ON YOUR ***Experimental Data Sheet***

77. Propose and write a ***BALANCED NET Chemical Equation*** representing the overall reaction occuring in **Procedure 5**:
78. Is this reaction a **REDOX** reaction?
79. **If so**, write the **OXIDATION** and **REDUCTION** ***half-reactions***. (**If not**, write the **TYPE** of reaction that **IS** occuring in both blanks of your answer sheet, and write "**NA**" for the answer to the followng 4 questions.)
80. Which **ATOM** (or ion) is being **OXIDIZED**?
81. Which **ATOM** (or ion) is being **REDUCED**?
82. Which **ATOM** (or ion) is the **OXIDIZING AGENT**?
83. Which **ATOM** (or ion) is the **REDUCING AGENT**?

84. **CONCEPT QUESTIONS:** Assuming the temperature in the lab is 70 °F, what is the approximate concentration of the saturated sodium carbonate in g/100g water? (see plot in "reference data" section at the beginning of the lab booklet)
85. What is the ***molality*** of the saturated sodium carbonate at this temperature?

Disposal:

- *Use a pair of tweezers to remove any remaining aluminum foil and dispose of in trash can*
- *Place the copper and unknown metal electrodes in the Mixed Metal Waste beaker*
- *Use a pair of tweezers to put any remaining magnesium shaving in the Mixed Metal Waste Beaker.*
- *Carefully empty your well plate into the sink. All electrolytes can be disposed of down the drain.*
- *Rinse the well plate, be carefull not to splash water back up at you. This can happen if the water stream directly hits a well. Angle the well plate away from you down in the sink while rinsing*
- *Tap the rinsed well plate up side down onto several paper towels to remove any clinging droplets.*
- ***Thoroughly rinse all remaining beakers and pipettes, shake dry, and return ALL ITEMS to their ORIGINAL PLACES at your station.***