

Colligative Logic Puzzle

Five grams of sucrose, ethanol, methanol, calcium chloride, and aluminum chloride have been dissolved separately, each in 200 mL of water. These solutions were then placed randomly in the following containers: 250-mL beaker, 250-mL Erlenmeyer flask, 600-mL beaker, 500-mL round bottom flask and a 1-L Florence flask. The containers were then randomly labeled A-E.

It your task to determine each solution's label and container based upon the following data.

- The solution in the largest container has the highest boiling point.
- The sugar solution is in the largest beaker.
- Flasks hold volatile solutes.
- Solution A is made with an ionic solid.
- Solutions labeled with vowels are in beakers.
- The compound with the lowest molar mass is in the smallest flask.
- The solution with the lowest freezing point is C.
- Solute B is a common gasoline additive.

ANSWER

	A	B	C	D	E
	Calcium Chloride	Ethanol	Methanol	Aluminum Chloride	Sucrose
250-mL beaker	X				
250-mL Erlenmeyer flask			X		
600-mL beaker					X
500-mL rd. bottom flask		X			
1-L Florence flask				X	

WORK

	Molar Mass	Mass	Moles	Volume	Molality	Particles	Total Molality	FP	BP
Sucrose	342.3	5	0.015	0.2	0.073	1	0.073	-0.136	100.037
Ethanol	46.069	5	0.109	0.2	0.543	1	0.543	-1.009	~80.000
Calcium Chloride	101.986	5	0.049	0.2	0.245	3	0.735	-1.368	100.377
Aluminum Chloride	133.359	5	0.037	0.2	0.187	4	0.750	-1.395	100.384
Methanol	32.04	5	0.156	0.2	0.780	1	0.780	-1.451	~80.000

Electrochemical Logic Puzzle I

Following a lecture on electrochemical cells, a young chemistry student searches his/her home for metal samples for a class project. The student finds five odd shaped pieces of metal in various locations about the house.

The metal objects are pure elements, non-uniform in shape, and obviously not identical in composition. The objects were found in the following locations: the backyard, the master bedroom, the basement, the garage, and near the computer in the den. The student correctly assumes that the samples include the following metals: zinc, aluminum, magnesium, silver and tin. The student randomly labels the metal objects A-E and performs some experiments. The experimental results are summarized below.

- The metal found in the garage forms a +3 ion.
- The metal found in the backyard has the third most positive reduction potential of the five chosen.
- Metals A, B, C, and E, all react with dilute hydrochloric acid, metal D does not.
- The metal by the computer is the least dense of all these metals.

The metal pieces are inserted into a lemon and voltages between the pieces are measured with a digital voltmeter.

- When the black lead is attached to metal C, and the red lead is connected to each of the other metals, the corresponding voltages are always negative.
- When the black lead is attached to metal E, and the red lead is connected to each of the other metals individually, A and D are reduced while B and C are oxidized.
- When the black lead is attached to the metal from the master bedroom and the red lead is attached to the metal from the basement the voltmeter reads +0.9 V.

Determine the correct metal for each label and its original location about the house.

REDUCTION POTENTIALS

Reaction				Potential (V) relative to SHE	
Mg^{2+}	+	2e^-	\rightarrow	Mg	-2.37
Al^{3+}	+	3e^-	\rightarrow	Al	-1.66
Zn^{2+}	+	2e^-	\rightarrow	Zn	-0.76
Sn^{2+}	+	2e^-	\rightarrow	Sn	-0.14
Ag^+	+	e^-	\rightarrow	Ag	+0.80

ANSWER

	A	B	C	D	E
Backyard					Zn
Basement	Sn				
Garage		Al			
Master bedroom				Ag	
Computer in the den			Mg		

Electrochemical Logic Puzzle II

A student performs a series of electrochemical experiments. Electrochemical cells are constructed with five different metal strips labeled A-E. In each experiment, two of the metal strips are inserted into a banana and a voltage is measured across the strips with a multimeter. The following results were obtained:

- When the black lead was attached to metal A, all the other metals were positive.
 - When the black lead was attached to metal B, C was positive and D and E were negative.
 - When the black lead was attached to metal E, D was positive.
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- Rank the metals A through E in an electrochemical series from the element most likely to be reduced (most positive reduction potential) to the element most likely to be oxidized (most negative reduction potential).
 - A new element (element X) is introduced into the banana experiment. When the black lead is placed on D, X is negative. Where does element X fit into the electrochemical series you developed for question one?
 - Describe another experiment to confirm element X's position in the electrochemical series.

Assume that the standard hydrogen electrode (SHE) is introduced into this experiment as the anode relative to each metal strip A through E. Two of the metals give positive voltages relative to the SHE. The voltage between metal E and the SHE has an E^0 of +0.25 V.

- Which of the other elements are positive relative to the SHE?
- Suppose that the SHE relative to C has an E^0 of -1.25 V. What is the E_{cell} in an electrochemical reaction involving electrode C and electrode E if electrode C is acting as an anode?

ANSWER

- A-E-D-B-C
- X-D-B-C
- The given information indicates X's position to elements D, B, and C. Element X's position relative to elements A and E is not known. Attach the black lead on the unknown metal X. Independently attach the red lead to metals A and E. The resulting voltages give X's position relative to all five of the metal elements A-E.
- A and E are positive.
- 1.50V

EXAMPLE EXPERIMENTAL DATA

		Black (-)						
		Ag	Cu	Pb	Fe	Zn	Mg	
	-----		-0.5	-0.6	-1.1	-1.3	-2.0	Ag
		-----		-0.6	-0.8	-1.0	-1.4	Cu
			-----		-0.2	-0.5	-0.5	Pb
				-----		-0.3	-1.1	Fe
					-----		-0.5	Zn
						-----		Mg
								Red (+)

	Ag	-----						
	Cu	0.4	-----					
	Pb	0.9	0.6	-----				
	Fe	1.1	0.8	0.3	-----			
	Zn	1.3	0.9	0.5	0.2	-----		
	Mg	1.6	1.3	1.0	0.8	0.2	-----	
		Ag	Cu	Pb	Fe	Zn	Mg	
Red (+)								Black (-)

REFERENCE INFORMATION

This puzzle was originally designed as a follow up to the 'Voltaic Cells' microscale lab activity developed in Nebraska in the summer of 1988 by Robert Curtright (Lincoln Northeast HS, Lincoln, Nebraska) and Edward Kinzer (Lakeview HS, Columbus, Nebraska).

Use the link below for an electronic copy of the 'Voltaic Cells' lab activity.
<http://dwb.unl.edu/Chemistry/MicroScale/MScale30.html>

Original Activity Reference

Russo T., 1986, Redox Introduction, Microchemistry for High School, pp. 60-61