

Taking the Color out of Blood

(What determines a compound's solubility properties?)

Terms to understand: solvent, solute, phase, phase diagram, equilibrium, partition coefficient, liquid-liquid extraction, solubility, hydrophobic, hydrophilic.

Learning Objectives

Content

- To understand the solubility properties of solvents and solutes in terms of their chemical structures and relate it to Stokes' extraction of hematin from hemoglobin.

Process

- To be able to interpret phase diagrams.
- To be able to apply concepts to new situations

Prior Knowledge

- General Chemistry Course
- Organic Chemistry Course

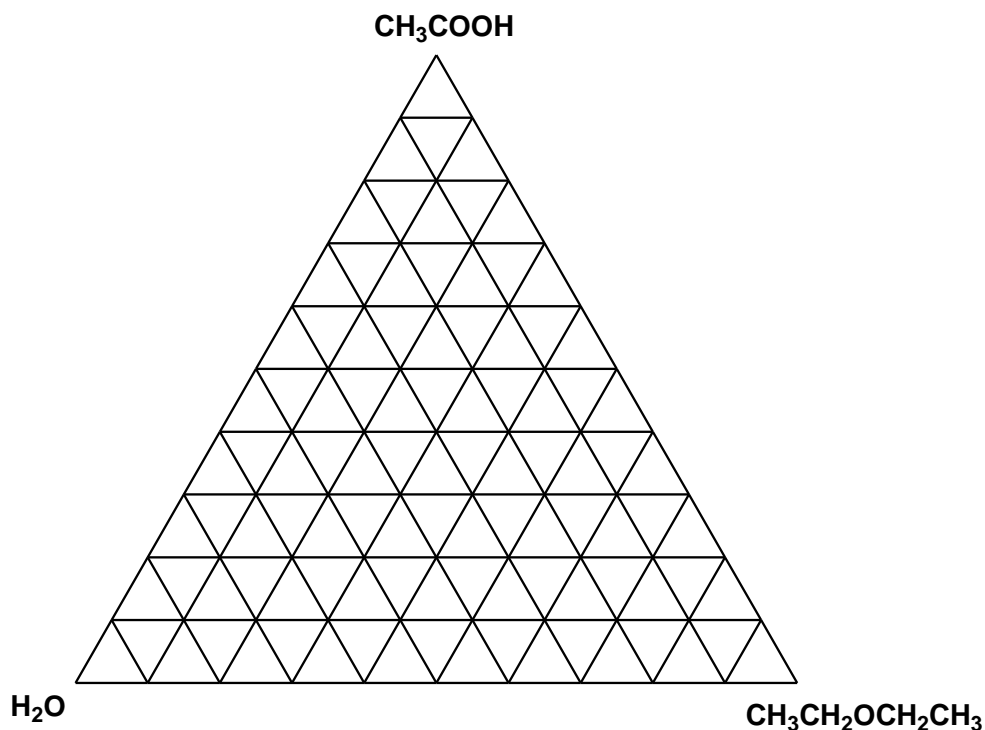
Two pure liquids are miscible if they form a single liquid phase regardless of the mixing proportions. Miscible liquids have similar properties as in “like dissolves like.” An example of two miscible liquids is water and ethanol. Some liquids are immiscible in that they do not mix at any proportion as with oil and water. Then there are liquids that are partially miscible. They will mix to form a single phase at certain proportions and not at others. Water and diethyl ether are such a pair. At room temperature, water will dissolve in diethyl ether to 1% by weight and diethyl ether will mix with water to the extent of 13% by weight. Mixtures between 1% and 87% water in diethyl ether will separate into two phases--water saturated with diethyl ether and diethyl ether saturated with water.

1. On the line below representing **weight** percent mixtures of water and diethyl ether, indicate the regions where one and two phases exist.

100% H₂O. ____ . ____ . ____ . ____ . ____ . ____ . ____ . ____ . ____ . ____ . 100% diethyl ether

2. If 50 g of water were mixed with 50 g of diethyl ether,
 - a. What would be the weight percent composition of water and diethyl ether in the two resulting phases?
 - b. Which of the two phases would be on top? Which would be on the bottom? What determines this?
 - c. How would the polarities of the two phases compare to the two pure liquids from which they are derived?
3. Stokes added an equal **volume** of diethyl ether to a dilute aqueous solution of hemoglobin and generated a two-phase system.
 - a. What would be the weight percentages of water and ether in the two phases?
 - b. Which phase contained the hemoglobin?
 - c. Knowing the structures of water and diethyl ether, what does this imply about the chemical properties of hemoglobin?
4. If 50g of water were added to the original 50:50 mixture in Question 2,
 - a. Would there still be two phases? How do you know?
 - b. What would be the composition of the phase(s)?

5. Acetic acid is completely miscible with diethyl ether and with water. We can represent this with an equilateral triangle in which the line at the base corresponds to the line in question 1. The proportions are measured in *weight* percent, not in volume or mole fraction. The corners of the diagram represent pure liquids.



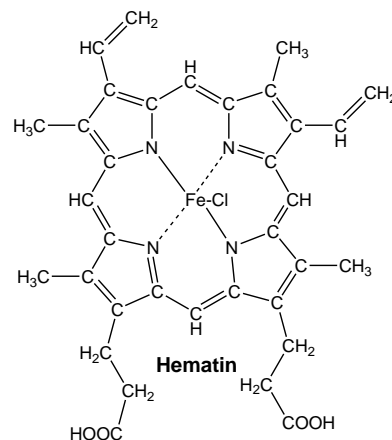
On the above figure, darken the line that corresponds to the line in Question 1.

6. On the above figure, identify the line that represents all combinations of water and diethyl ether that contain 30% by weight of acetic acid.
7. On the above figure, draw a line that represents all mixtures with acetic acid that contain equal weights of water and diethyl ether.

8. Based on the following information, map out the regions on the above figure where all three liquids are miscible and where two phases would co exist at room temperature. Each person should plot and check several points. Shade the region where two phases exist.

Water Wt%	Acetic Acid Wt%	Diethyl ether Wt%	Number of phases
10	0	90	2
90	0	10	2
10	10	80	2
80	10	10	2
10	30	60	1
20	30	50	1
30	30	40	2
40	30	30	2
50	30	20	1
30	40	30	1
35	35	30	1
40	20	40	2

9. It is known that in organic solvents, acetic acid forms hydrogen-bonded dimers. What would be a reasonable structure for the dimer?
10. What would be expected to happen to acetic acid in aqueous solutions?
11. At equilibrium, do you think acetic acid would partition equally between the aqueous and organic phases? What is the basis for your answer?
12. When Stokes added acetic acid to the two-phase water:ether mixture, the acid denatured hemoglobin and its bound heme group was released. The heme was oxidized immediately to hematin by molecular oxygen turning the solution brown. The structure of protonated hematin is shown at the right. Based on its structure, explain why it was extracted from the “aqueous” phase into the “organic” phase when Stokes gently mixed the solutions.



13. Describe in full sentences

- a. What is happening to the composition of the “organic” phase when Stokes “washes” it successively with water?
- b. Explain the behavior of the hematin during the final wash.

14. The addition of a small amount of base to the washed organic phase causes hematin to extract into the aqueous phase. Explain.

15. In basic solution hematin is slightly soluble in water. In acid solution it is insoluble in water and diethyl ether. However, hematin is soluble in the organic phase of water, acetic acid, diethyl ether mixtures. Based on the structure of hematin, explain its solubility properties described above.