

EXPERIMENT 8: SOLUBILITY CURVE FOR A TERNARY SYSTEM OF LIQUIDS

Before the experiment: *Read the booklet carefully. Be aware of the safety issues. Make sure you understand the Gibbs Triangle.*

Object

To determine the solubility curve for a ternary system of two immiscible liquids and a third liquid which is miscible with each of them

Theory

Equilibrium data of ternary systems are usually graphically shown using either right triangular or equilateral triangular diagrams. These diagrams are also called as the Gibbs Triangle.

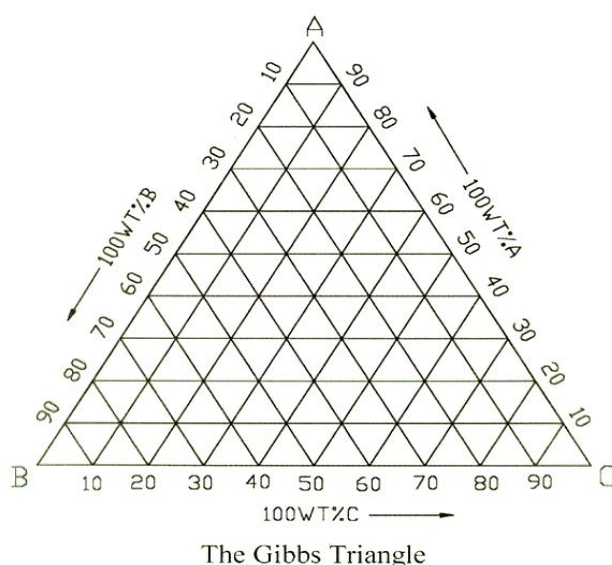


Figure 1. Solubility curve for a ternary diagram. [1]

The pure components on an equilateral triangle are represented by each corner. The mole fractions of the three components are represented by the distances (parallel to the edges), connecting a given point to sides of the triangle. The straight-line joining an apex to a point on the opposite edge is of special interest [1]. There are several ways of determining the overall composition and two of them are explained below.

Method I.

Draw lines through X, parallel to the sides of the Gibbs Triangle A'C' intersects AB at A', B'C'' intersects AB at B'.

Concentration of B = AA'

Concentration of C = A'B'

Concentration of A = B'B

This method is well explained in Figure 2.

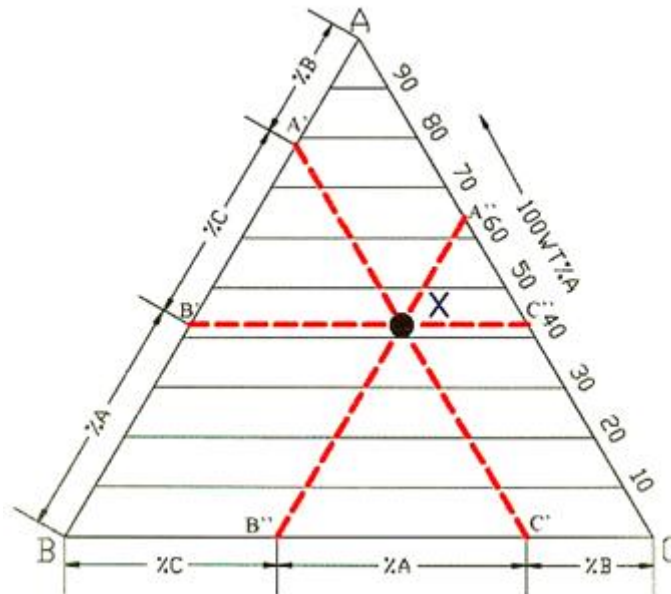


Figure 2. Explanation of Method I. [1]

Method II.

This method is an application of the Inverse Lever Rule. Draw straight lines from each corner, through X. Then the following ratios give the concentration values of A, B, and C. In Figure 3. The method is explained visually.

$$\%A = \frac{AX}{AM} \quad \%B = \frac{BX}{BN} \quad \%C = \frac{CX}{CL}$$

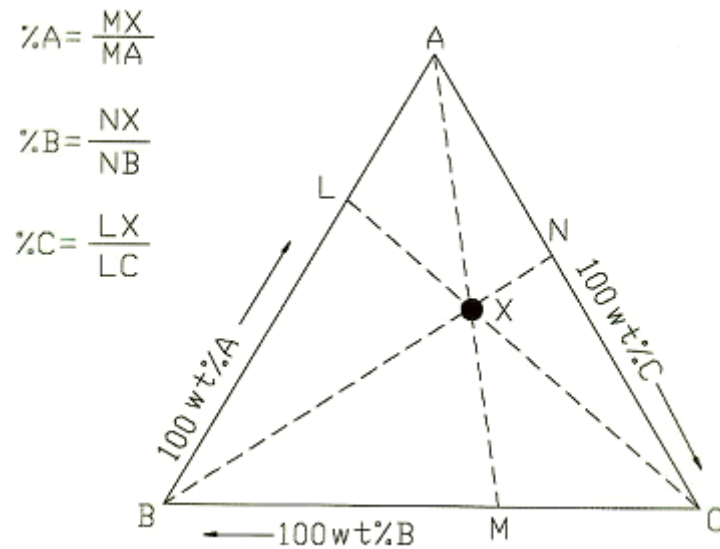


Figure 3. Explanation of Method II [1]

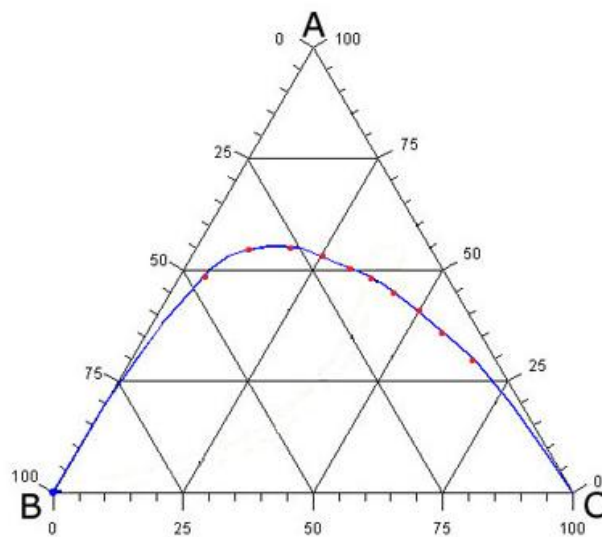


Figure 4. Binodal curve on ternary phase diagram [2]

After the experiment, when the results of runs are all plotted, the phase diagram can be completed by drawing the binodal curve through the points. The curve indicates the boundaries of the homogeneous (1-phase) (on or upper the curve) and heterogeneous (2-phase) (below the curve) domains. That a passage to a miscible mixture is ensured by gradual addition of component A is clearly seen from the phase diagram. The amount of A needed to make B and C completely miscible is known from the intersection of the biphasic curve with the broken line [3].

Experimental Work

Apparatus and Chemicals: 250 ml and 500 ml Erlenmeyer flasks, 2 ml and 5 ml pipettes, 2 burettes and holders. Distilled water, benzene and glacial acetic acid.

Procedure

1. Using the 5 ml pipette, introduce 5 ml of benzene into the 250 ml Erlenmeyer flask, then add 1 ml of water from one burette and from another burette add glacial acetic acid slowly, until, after vigorous shaking, a clear (non-cloudy) solution is obtained which is saturated with respect to the three components. Record the volumes added.
2. Add 2 ml of water to the liquid, shake vigorously, and repeat the addition of acetic acid until the mixture again becomes homogeneous.
3. Add successively 3, then 4, 5, and finally 6 ml of water, and in each case add enough acetic acid to produce a clear liquid. Record and tabulate all the results.

Safety Issues: Acetic acid and benzene are hazardous in case of skin contact, eye contact, ingestion, and inhalation. In case of skin contact, flush skin with plenty of water. Remove contaminated clothing. Check for and remove any contact lenses. Especially in the case of eye contact of these chemicals, immediately flush eyes with running water. In case of ingestion do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as collar, tie or waistband. If inhalation occurs, immediately get a breath of fresh air.

Calculations

1. Assuming that there is no volume changes upon mixing, compute the volumes of the three components in equilibrium using basis of 100 ml total volume in each case.
2. Plot the volume fractions of each component on a triangular diagram. Connect the six points by a smooth curve which is prolonged by a dotted line ending at the vertices of the triangle on the assumption that water and benzene are completely immiscible at room temperature.
3. Obtain the critical volumes for the two immiscible components B and C of the mixture. For this purpose, take a basis of 100 ml of acetic acid, and for each given volume of B (V_B), determine the corresponding critical volume of C (V_C). Plot V_B vs. V_C .

References

- [1] Selvaduray, Guna, "Ternary Phase Diagrams, An Introduction", San Jose State University, 2004.
- [2] Mazzotti, Marco, "Fundamentals of Thermodynamics, Institute of Process Engineering ETH Zurich, 2013. (Online: <http://www.hyper-tvt.ethz.ch/fundamentals-thermo-ternary.php>)
- [3] Vernon, A. A., and B. Brown, "The combination water-nitrobenzene-acetic acid has certain advantages over the system water-benzene-acetic acid", *Journal of Chemical Education*, Volume 14 (3), pp. 143-144, 1937.
- [4] Material Safety Data Sheet, Acetic Acid MSDS.
<http://www.sciencelab.com/msds.php?msdsId=9922769>.
- [5] Material Safety Data Sheet, Benzene MSDS.
<http://www.sciencelab.com/msds.php?msdsId=9927339>.