Determination of Liquid Phase Range of Matters by Graphic-Analytical Method

Beycan İbrahimoğlu#1, Beycan İbrahimoğlu#1
[1]Anadolu Plasma Tecnology Centre, Ankara, Turkey

Abstract

Phase diagrams demonstrate the number and type of the phases, the composition of each phase and the current microstructure, pressure and temperature interval on diagram. At the same time, in a technology process, the phase diagram of material is determined by the P-T phase diagram as a function of temperature and pressure. The main point of this work is to determine the thermodynamic parameters and the temperature-pressure intervals that make up the boundaries of the liquid phase, which serve as a gap between the solid and gas phases, as the application of the graphic-analytical system and the basic points of the matter.

Keywords — *Phase Diagram, Liquid Phase, Graphic-Analytical Method, Critical Pressure*

I. INTRODUCTION

Phase diagrams illustrate physical and chemical conditions of homogeneous matters in given pressure and temperature with graphics. Phase diagrams and phase transitions are essential for understanding microstructure of the matter [1]. All matters have unique phase diagrams. Every phase diagram has boundary lines, which separate phases, critical point and triple point of a pure matter. In Figure 1, a phase diagram is displayed as an example.

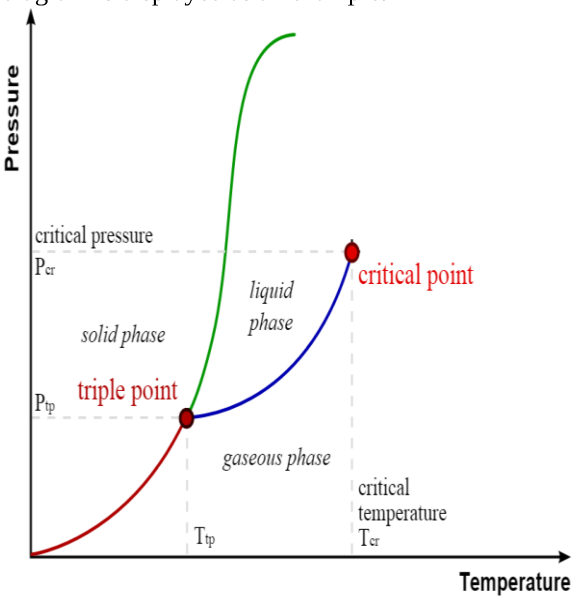

Fig 1: Phase diagram

In this study, the only liquid phase of matter is stated. The liquid phase of matter is a transitional phase between solid and gas phases. In low temperature and high pressure, it transforms to a solid state, in high temperature and low pressure it transforms to a gas state. Thus, the liquid phase of matter is not just a phase but is also a thermodynamical phase. A liquid has a definite volume because an intermolecular force of attraction is just strong enough to confine the molecules in a definite space. As a result, a liquid drop tends to form a sphere, as it offers the smallest area for a definite volume. Since the intermolecular force of attraction is weaker in a liquid than in a solid, molecular separation of a liquid is higher, which causes liquid to acquire the shape of the container. Also, the limited amount of space between particles means that liquids have only limited compressibility. Determination of the liquid phase boundary that depends on the temperature and pressure is crucial in industrial and scientific research.

II. FUNDAMENTAL POINTS

In phase diagrams, the liquid phase of matter exists between triple point (T_{tr}) and critical temperature (T_{cr}). The specifications of these points are given for all matters [4], [5], [9], [10], [13], [17]. The triple point is the specific point where liquid transforms into solid state at the minimum pressure. The critical point is the specific point of the pressure-temperature curve at the maximum pressure that indicates conditions under which a liquid and vapor can coexist. The density of liquid phase is maximum in T_{tr} and minimum in T_{cr}. The point of transition between liquid and gas state is the critical point [19]. Also, it is possible to say that there is a dynamical balance between vapor and liquid phase at the critical point [1], [15], [18], [18]. The pressure that corresponds to the critical point is named critical pressure (P_{cr}). In liquid – gas transitions, effects of pressure and density are not noticeable. On the contrary, it is mainly the effect of the temperature. In Figure 2, temperature and pressure intervals of the liquid phase can be seen. In this figure, point A represents the triple point (T_{tr}) and point B represents the critical point (T_{cr}). Also, these points create interval of liquid phase in both pressure and temperature axis.

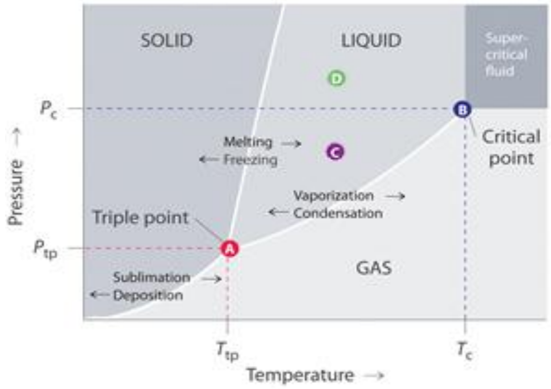

Fig 2: Fundamental points in phase diagram

One of the parameters that form liquid phase of a matter is pressure, therefore the pressure values should be examined. Studies show liquid phase can exist even in infinite pressure, which is impossible in practice. To clarify this condition liquid phase of a pure matter is investigated with different methods. As can be seen in Figure 2, triple point is the initial point of the liquid phase and the value of the pressure at this point is the minimum for the liquid phase [4].

Critical pressure value that is given in gas-liquid boundary curve is the pressure value which coincides with critical temperature. It is not applicable to label the pressure value coinciding with the T_{cr} point as critical pressure. However, there aren't any other fundamental points that can define critical pressure. Only pressure value at the triple point (P_{tr}) is used to determine the pressure interval of the liquid phase. It is not possible to determine pressure interval of the liquid phase in a phase diagram because there are no two points. To solve this problem, Point C and point D are demonstrated as an example in Figure 2. The pressure value of point C is less than critical pressure. On the contrary, the pressure value of point D is higher than critical pressure. Although critical pressure should represent the boundary point to a phase transition, as well as critical temperature, both points take part in the liquid state.

III.GRAPHIC-ANALYTICAL METHOD

Through the graphic-analytical method, the physical processes become more understandable and better solutions are found to problems. This method is widely used in various scientific. By implementing a graphic-analytical method to the thermodynamical parameters of a single phase, obtaining information about other thermodynamical phases and fundamental points are possible. This implementation provides great advantages and some studies were done with various gases [2], [4]-[9], [11], [15], [16]. Broad explanation of implementation of graphic-analytic method is given in “Reference [8]”.

To give a significant example, this case of a graphic-analytical method was used by William Kelvin and new temperature scale and significant physical parameter were found. The physical parameter is named “Absolute Zero” and equals to -273,15 ^oC, which is 0 K [4]-[6], [9], [10], [14]. This term defines minimum temperature for matters. Kelvin scale, which is found by graphic-analytical method, is the most appropriate scale for physical equations and as an example, the volume-temperature relation of Helium and Neon at various pressure values is displayed in Figure 3.

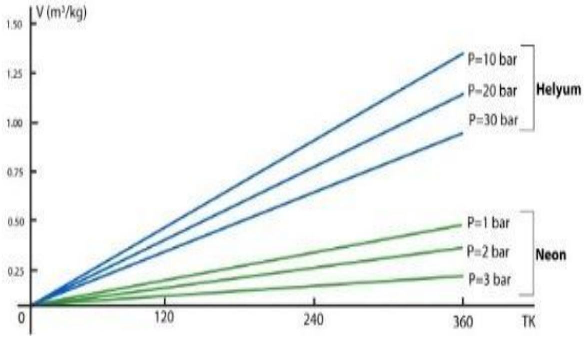

Fig 3: Volume – Temperature graph of Helium and Neon

The graphic-analytical method can be used for other matters, and the desired parameters can be obtained. The application of the graphic-analytical method to the viscosity, density and other physical parameters of the matter in solid and liquid phases has determined the triple, critical, boiling and freezing temperature [3]-[5], [7]-[8], [9], [12]. In this article, application of specific graphic-analytic method is explained, and some experimental results are displayed [4], [5], [8], [9].

IV. EXPERIMENTAL STUDIES

When the Density – Temperature diagram of any matter is observed, it is possible to see all isobars intersect at a specific point on the temperature axis (at zero density). This intersection proofs that there is another fundamental point. This point can be named as thermal dıssocıatıon point. Studies show that this value is different in every matter and corresponds to matter’s dissociation temperature. Thermal dıssocıatıon point of Xenon is displayed in Figure 4.

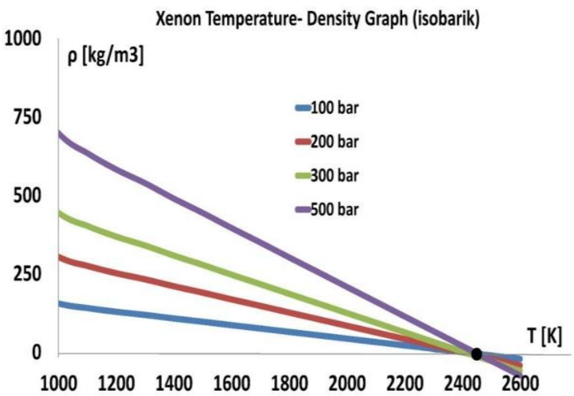

Fig 4: Density-Temperature diagram of Xenon

By implementing graphic-analytical method in density temperature diagram, the specific point on the Temperature axis can be found with little error. Results of various studies are given in Table 1 [2]-[4], [7]-[9], [11]-[13], [15].

TABLE I
Thermal Dissociation Values

	Thermal dissociation temperature [K]	
	Graphical-Analytical Method	Experimental Results
Oxygen	2550	2405 [20]
Argon	2920	
Nitrogen	3700	7100 [20]
Florine	3000	11500 [20]
Carbon Dioxide	2223	600 [20]

Additionally, besides absolute zero or thermal dissociation points, other physical parameters of matters can be found by using graphical-analytical method. By implementing graphical-analytical method freezing temperature, boiling temperature, triple point and critical point can be found.

In this article, some experimental results and the ways of finding the important parameters through graphical-analytical method is demonstrated. The method of finding critical temperature from pressure density diagram of some matters is shown below. In Figure 5, experimental results of benzonitrile are displayed on density-temperature diagram.

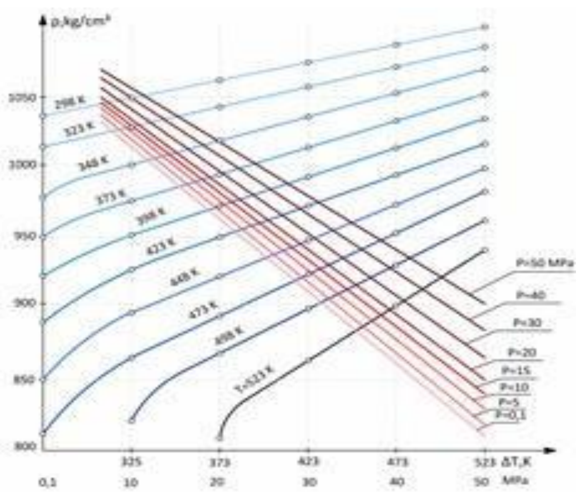

Fig 5: Viscosity-Temperature diagram of Benzonitrile

Figure 5 shows us all isobars intersects in single point. Also, in pressure-density graph of benzonitrile, all isotherms intersect in a specific point which corresponds to 1850 MPa pressure. Above all, this point is identified as the critical point of benzonitrile. Pressure – density graph of benzonitrile is shown in Figure 9.

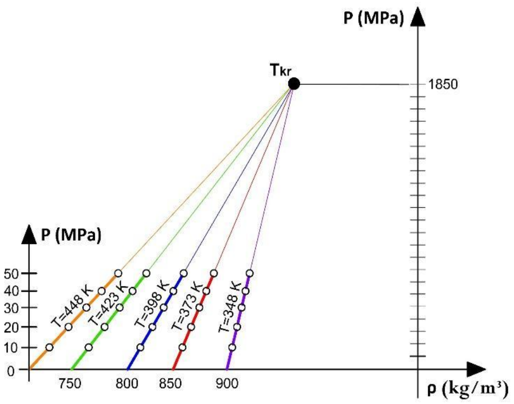

Fig 6: Finding T_{cr} from pressure-density diagram of benzonitrile

The same method can be implemented to the o-toluidine and m-toluidine graphs. Pressure-density diagram and intersecting isotherms at critical point are displayed for o-toluidine in Figure 6.

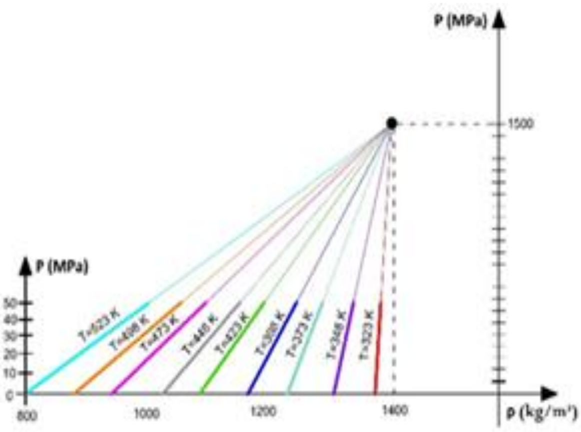

Fig 6: Finding T_{cr} from pressure-density diagram of o-toluidine

Also, Pressure-density diagram and intersecting isotherms at critical point are displayed for o-toluidine in Figure 7.

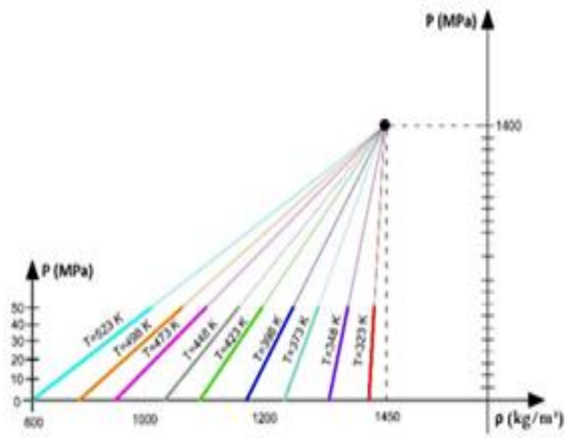

Fig 7: Finding T_{cr} from pressure-density diagram of p-toluidine

V. CONCLUSION

The definition of critical pressure is initially questioned in this writing. In all sources, critical pressure is defined as the pressure value which corresponds to critical temperature. Critical temperature is the boundary value for liquid phase of a matter. Also, triple point is the minimum pressure and temperature value for liquids. Both points are important, because they represent limit values. However, critical pressure doesn't represent any limit value. Thus, the term of critical pressure should be determined. Lots of scientists made experiments and studies about liquid-solid phase transition at a high pressure. As a result of these studies, probability of critical pressure was mentioned, however none of them are confirmed as critical pressure [19]. In this study, new specific point is revealed in liquid-solid phase transition at a high pressure. This point is determined by graphic-analytical method. This writing aims to explain graphic-analytical method, which is alternative solution for certain problems. It can be used in various scientific subjects. This method is also applied on thermodynamic diagrams of matters. Information about physical parameters and fundamental points of liquids and gases are obtained by the graphic-analytical method. Also, it is possible to obtain information about a phase by applying the graphic-analytical method to another phase of the matter. It is difficult to carry out experiments at a high temperature and pressure. Thus, the graphic-analytical method makes it possible to obtain adequately error free data and this is shown by comparing experimental data and graphic-analytical method [2]-[4], [7]-[9], [11], [12], [15]. In more detail, physical parameters like Absolute Zero and dissociation temperature of a liquid and gaseous matters can be obtained by graphic-analytical method. Moreover, triple and critical points, and dissociation value of matters can be determined by this method. As the pressure curves in volume-temperature diagram intersects at zero volume (absolute zero), they also intersect in density-temperature diagram at zero density. This point can be determined as a fundamental point, because intersection on a specific point can be seen in all matters. Figure 12 shows the intersections at specific points in both volume temperature and density temperature diagrams of Argon.

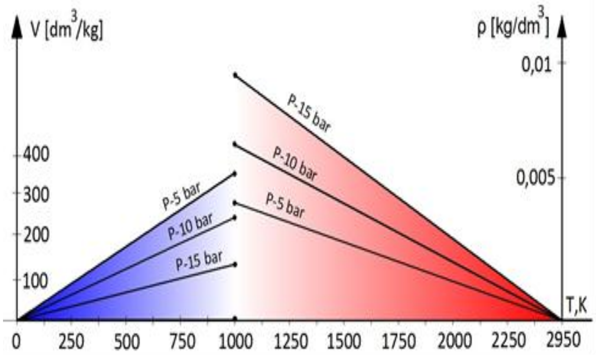

Fig 6: Finding specific points in argon's diagrams

The point which is determined by this method, can be perceived as the boundary value for liquid form in the phase diagrams, and can be called the Critical Pressure.

REFERENCES

[1] M.F. Ashby, Materials: Engineering, Science, Processing and Design, 3rd ed., Elsevier Butterworth-Heinemann, 2014.

[2] B.I. Farzaliev and A.M. Ragimov, "Investigation of phase changes in masses" Proceedings of the Academy of Sciences of Azerbaijan, 1984.

[3] B. Ibrahimoğlu and A. Rehimov, "Determination of Experimental Pressure and Temperature Dates of Liquids by Mathematical Methods", Journal of Engineering Physics, vol. 19, pp. 498-498, 1985.

[4] B.I. Farzaliev, A.M. Ragimov and A.T. Gadzhiv, "Graphic Definition of The Parameters of The Triple Point of The Equilibrium", Neft ve Gaz, pp. 57-60, 1985.

[5] B.I. Farzaliev, N.F. Aliev, "Determination of melting line of gases by graphical analytic method", in Proc. Scientific Conference AzTU, 1985, paper 21. (in Russian).

[6] B.I. Farzaliev and Y. Naziyev, Y and N.F. Aliev, "Equation of the Melting Curve of Some Aramatics and Nitriles", in Proc. Conference on Scientific Technologies, 1992, paper 10, p.2-5.

[7] B. Ibrahimoğlu, "Gazlarda Kritik Basıncın Grafo-Analitik Yöntemle Bulunması", Türk İşi Bilimi ve Tekniği Dergisi. Vol. 45, pp. 43-46, 2017

[8] B. Ibrahimoğlu and O.E. Ataer, "Erime Eğrisi Üzerinde Bir Uç Noktanın Belirlenmesi", in Proc. Ulusal Isı Bilimi ve Tekniği Kongresi, 1997, paper 33.11.

[9] B. Ibrahimoğlu, N. Veziroğlu and A. Hüseynov. "Study of Thermodynamic Parameters of Hydrogen Gas by Grapho-Analytic Method", International Journal of Hydrogen Energy, vol. 30, pp. 515-519, 2005.

[10] S.O. Hüseynov, M. Naziyev, B.I Farzaliyev, and T.G. Movsumov, "Experimental Study of the Density and Dynamic Viscosity of Benzonitrile", Neft ve Gaz, pp. 46-52, 1978.

[11] B. Ibrahimoğlu, N. Veziroğlu, A. Hüseynov and D. Schur, "Study of Thermodynamic Parameters of Hydrogen Gas by Graph-Analytic-Method", Hydrogen Materials Science and Chemistry of Carbon Nanomaterials, pp. 225-232, 2004.

[12] B. Ibrahimoğlu, "Determination of 1/V-T (P, Constant) Diagrams of Hydrogen Gases by Graph-Analytical Methods", Journal of Thermal Engineering, vol.3, pp. 1071-1071, Jan. 2017

[13] N.B. Vargaftik, Spravočnik po teplofizičeskim svojstvam gazov i židkostej. Moscow, Nauka, 1972.

[14] H.E. Sostmann and J.P. Tavener, "Fundamentals of Thermometry (Part I)", Isotech Journal of Thermometry 1, pp. 1-18, 1990

[15] B.I. Farzaliev and N.F. Aliev, "Determination of Melting Line of Gases by Graphical Analytic Method" in Proc. Scientific Conference AzTU, 1992, paper 21.

[16] A.V. Molozevskiy, A Geometrical Thermodynamics, Moscow, Trudi MGU, 1969. (in Russian)

[17] Critical Pressure. (1984). In Great Soviet encyclopedia. Soviet State.

[18] F.P. Hall, H. Insley, E.M. Levin, H.F. McMurdie, and C.R. Robbins, "General discussion of phase diagrams", Phase Diagrams for Ceramists, vol. 1, pp. 5-36.

[19] P. W. Bridgman, "Collected experimental papers", American Journal of Physics, vol. 33, pp.516-517, 1964

[20] T.L Cottrell, The Strenghts of Chemical Bonds, 2d ed., Butterworth, London, 1958