ON THE TEMPERATURE-PRESSURE-CONCENTRATION DIAGRAM FOR BINARY SYSTEMS IN WHICH THE ONLY CRYSTALLINE PHASES ARE THE PURE COMPONENTS

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Abstract

An isometric drawing of the three dimensional temperature-pressure-concentration diagram for a hypothetical binary system in which there are critical end points and in which the only crystalline phases are the pure components is given and the significance of the fields is stated. This diagram is analogous to the three dimensional temperature-pressure-concentration diagram for a hypothetical binary system in which there is a continuous critical curve from the critical point of one component to the critical point of the other component, the only crystalline phases in the system being the pure components, that was published by H. W. Bakhuis Roozeboom in his treatise, *Die heterogenen Gleichgewichte.*

The relations of the fluid and crystalline phases during the formation of pegmatite dikes and hypogene ore deposits have been the subject of much discussion by geologists and geochemists in recent years. In these discussions two types of binary system have often served as starting points, namely, binary systems in which there is a continuous critical curve from the critical point of the first component to the critical point of the second component, and binary systems in which this critical curve has critical end points, both types of binary system having no intermediate crystalline compound and no solid solution.

A drawing and a photograph of a model of the three dimensional temperature-pressure-concentration diagram for binary systems in which there is a continuous critical curve from the critical point of the first component to the critical point of the second component and in which the only crystalline phases are the pure components were published by H. W. Bakhuis Roozeboom as Plates I and II of Teil 1 of Heft 2 of his treatise, Die heterogenen Gleichgewichte,[1] and the significance of the fields in the three dimensional diagram was explained by him on pages 125–129.

An analogous isometric drawing[2,3] of the three dimensional tempera-

[1] Friedrich Vieweg und Sohn, Braunschweig (1904).

[2] A perspective drawing of the three dimensional temperature-pressure-concentration diagram for a binary system with critical end points appeared in Boeke-Eitel's *Grundlagen der physikalisch-chemischen Petrographie,* 2[te] Aufl., Gebrüder Borntraeger, Berlin (1923), on page 346. In this drawing, however, the saturation surface of the fluid phase between the critical end points is not shown. The intersection of the surfaces representing the saturated fluids (liquids) with the upper plane of the parallelepiped is also not drawn.

[3] Niggli has given twc series of sections of the temperature-pressure-concentration diagram for a binary system with critical end points, one series perpendicular to the pressure axis and the other perpendicular to the temperature axis (Das Magma und seine Produkte. I. Teil: *Physikalisch-chemische Grundlagen, Akademische Verlagsgesellschaft,* Leipzig (1937), pages 238–239). He also gave a perspective drawing of the three-phase surfaces, gas-liquid-solid, in the three dimensional diagram (*ibid.* p. 236), and an excellent discussion of equilibrium relations in systems of this type (as well as many other types).

ture-pressure-concentration diagram for binary systems in which there are critical end points and in which the only crystalline phases are the pure components is given here as Fig. 1. The significance of the various fields in this figure is as follows:

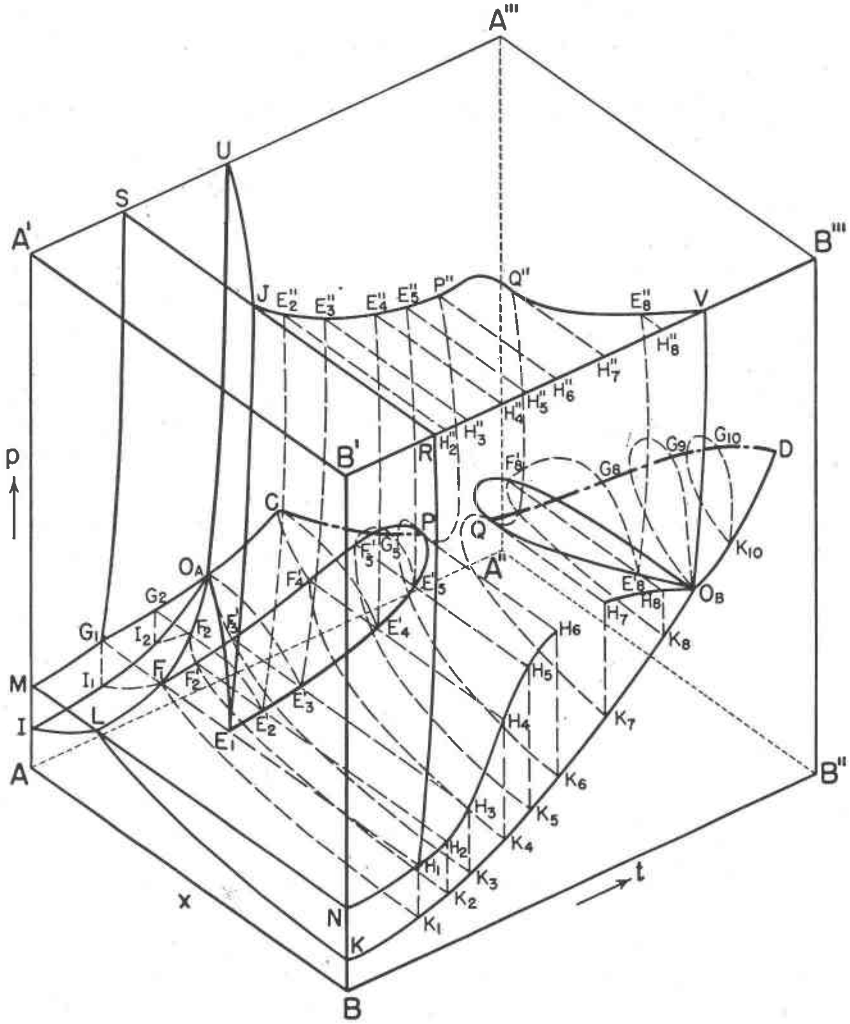

FIG. 1. Isometric drawing of the three dimensional temperature-pressure-concentration diagram of a hypothetical binary system in which there are critical end points and in which the only crystalline phases are the pure components.

Full lines are intersections of the bounding surfaces of fields.

The dash-dot-dash lines are the two segments of the critical curve.

Dashed lines are sections at constant temperature.

In the field $A'B'RSG_1MNH_1$ a random point represents a two phase mixture—crystalline component A and crystalline component B. The proportions of the two phases are given by the relative lengths of the two segments into which a horizontal line parallel to the concentration axis through the random point from the plane $AA'A'''A''$ to the plane $BB'B'''B''$ is divided by the random point. The segment from the random point to the plane $BB'B'''B''$ represents the mass of crystaline A and the segment from the random point to the plane $AA'A'''A''$ represents the mass of crystalline B.

In the field $LIMG_1F_1I_1I_2G_2F_2O_A$ a random point represents a two phase mixture—crystalline component A and fluid. The composition of the fluid is given by the point in which a horizontal line parallel to the concentration axis through the random point intersects the surface $\cancel{LIMG_1F_1I_1I_2G_2F_2O_A}$. The proportions of the two phases are given by the relative lengths of the two segments into which the horizontal line parallel to the concentration axis through the random point is divided by the random point. The segment from the random point to the plane $AA'A'''A''$ represents the mass of the fluid and the segment from the random point to the surface $LII_1F_1F_2I_2O_A$ represents the mass of crystalline component A.

In the field $SJUO_AE_1G_1G_2$ a random point represents a two-phase mixture—crystalline component A and fluid. The composition of the fluid is given by the point in which a horizontal line parallel to the concentration axis through the random point intersects the surface JUO_AE_1. The proportions of the two phases are given by the relative lengths of the two segments into which the horizontal line parallel to the concentration axis through the random point is divided by the random point. The segment from the random point to the plane $AA'A'''A''$ represents the mass of the fluid and the segment from the random point to the surface JUO_AE_1 represents the mass of the crystalline component A.

In the field $LKNH_1F_1K_1K_2H_2F_2'F_3'K_3H_3H_4F_4'K_4K_5H_5F_5'PK_6H_6$ a random point represents a two phase mixture—crystalline component B and fluid. The composition of the fluid is given by the point in which a horizontal line parallel to the concentration axis through the random point intersects the surface $KK_1K_2K_3K_4K_5K_6PF_5'F_4'F_3'F_2'F_1$ L. The proportions the two phases are given by the relative lengths of the two segments into which the horizontal line parallel to the concentration axis through the random point is divided by the random point. The segment from the random point to the plane $BB'B'''B''$ represents the mass of the fluid and the segment from the random point to the surface

$$KK_1K_2K_3K_4K_5K_6PF_5'F_4'F_3'F_2'F_1 \ L$$

represents the mass of crystalline component B.

In the field

$$H_1E_1JRH_2''H_2E_2'E_2''E_3''H_3''H_3E_3'E_4'E_4''H_4''H_4H_5E_5'E_5''H_5''H_6''H_6PP''$$

a random point represents a two phase mixture—crystalline component B and fluid. The composition of the fluid is given by the point in which a horizontal line parallel to the concentration axis through the random point intersects the surface $E_1E_2'E_3'E_4'E_5'PP''E_5''E_4''E_3''E_2''J$. The proportions of the two phases are given by the relative lengths of the two segments into which the horizontal line parallel to the concentration axis through the random point is divided by the random point. The segment from the random point to the plane $BB'B'''B''$ represents the mass of the fluid and the segment from the random point to the surface $E_1E_2'E_3'E_4'E_5'PP''E_5''E_4''E_3''E_2''J$ represents the mass of crystalline component B.

In the field $K_6H_6''P''PK_7H_7''Q''Q$ a random point represents a two phase mixture—crystalline component B and fluid. The composition of the fluid is given by the point in which a horizontal line parallel to the concentration axis through the random point intersects the surface $K_6PP''Q''QK_7$. The proportions of the two phases are given by the relative lengths of the two segments into which the horizontal line parallel to the concentration axis through the random point is divided by the random point. The segment from the random point to the plane $BB'B'''B''$ represents the mass of the fluid and the segment from the random point to the surface $K_6PP''Q''QK_7$ represents the mass of crystalline component B.

In the field $K_7QH_7H_8K_8F_8'O_B$ a random point represents a two phase mixture—crystalline component B and fluid. The composition of the fluid is given by the point in which a horizontal line parallel to the concentration axis through the random point intersects the surface $K_7QF_8'K_8O_B$. The proportions of the two phases are given by the relative lengths of the two segments into which the horizontal line parallel to the concentration axis through the random point is divided by the random point. The segment from the random point to the plane $BB'B'''B''$ represents the mass of the fluid and the segment from the random point to the surface $K_7QF_8'K_8O_B$ represents the mass of crystalline component B.

In the field $H_7QQ''H_7''H_8''H_8E_8'E_8''VO_B$ a random point represents a two phase mixture—crystalline component B and fluid. The composition of the fluid is given by the point in which a horizontal line parallel to the concentration axis through the random point intersects the surface $QQ'E_8''E_8'O_BV$. The proportions of the two phases are given by the relative lengths of the two segments into which the horizontal line parallel to the concentration axis through the random point is divided by the random point. The segment from the random point to the plane $BB'B'''B''$ represents the mass of the fluid and the segment from the random point to the surface $QQ''E_8''E_8'O_BV$ represents the mass of crystalline component B.

In the field $E_1F_1F_2'F_2E_2'E_3'F_3'O_ACE_4'F_4'F_5'G_5E_5'P$ a random point represents a two phase mixture—fluid I (gas) and fluid II (liquid). The compositions of the two fluids are given by the two points in which a horizontal line parallel to the concentration axis through the random point intersects the bounding surface of the field, the composition of fluid I (gas) being represented by the intersection point nearer the plane $AA'A'''A''$ and the composition of fluid II (liquid) being represented by the intersection point nearer the plane $BB'B'''B''$. The proportions of the two phases are given by the relative lengths of the two segments into which the horizontal line across the field parallel to the concentration axis through the random point is divided by the random point. The segment from the random point to the boundary of the field nearer the plane $AA'A'''A''$ represents the mass of fluid II (liquid) and the segment from the random point to the boundary of the field nearer the plane $BB'B'''B''$ represents the mass of fluid I (gas).

In the field $QE_8'F_8'G_8G_9O_BK_{10}G_{10}D$ a random point represents a two phase mixture—fluid I (gas) and fluid II (liquid). The compositions of the two fluids are given by the two points in which a horizontal line parallel to the concentration axis through the random point intersects the bounding surface of the field, the composition of fluid I (gas) being represented by the intersection point nearer the plane $AA'A'''A''$ and the composition of fluid II (liquid) being represented by the intersection point nearer the plane $BB'B'''B''$. The proportions of the two phases are given by the relative lengths of the two segments into which the horizontal line across the field parallel to the concentration axis through the random point is divided by the random point. The segment from the random point to the boundary of the field nearer the plane $AA'A'''A''$ represents the mass of fluid I (gas) and the segment from the random point to the boundary of the field nearer the plane $BB'B'''B''$ represents the mass of fluid II (liquid).

In the remaining field occupying the remainder of the parallelepiped (extending downward from the area $VQ''P''JUA'''B'''$ in the top plane of the parallelepiped and upward from the entire base of the parallelepiped) a random point represents a homogeneous fluid.

In the surface G_1SRH_1 a random point represents a three phase mixture—crystalline component A, crystalline component B and fluid. The composition of the fluid is represented by the point in which a horizontal line parallel to the concentration axis through the random point intersects the curve E_1J. The relative masses of the three phases are not determined by the position of the random point (since a particular total composition can be obtained with an infinite number of different mixtures of the three phases).

In the surface MG_1H_1N a random point represents a three phase mixture—crystal line component A, crystalline component B and fluid. The composition of the fluid is represented by the point in which a horizontal line parallel to the concentration axis through the random point intersects the curve LF_1. The relative masses of the three phases are not determined by the position of the random point.

In the surface $G_1G_2O_AE_1$ a random point represents a three phase mixture—crystalline component A, fluid I (gas) and fluid II (liquid). The composition of fluid I (gas) is represented by the point in which a horizontal line parallel to the concentration axis through the random point intersects the curve $F_1F_2O_A$. The composition of fluid II (liquid) is represented by the point in which a horizontal line parallel to the concentration axis through the random point intersects the curve E_1O_A. The relative masses of the three phases are not determined by the position of the random point.

In the surface $F_1F_2'F_3'F_4'F_5'PH_6H_5H_4H_3H_2H_1$ a random point represents a three phase mixture—crystalline component B, fluid I (gas) and fluid II (liquid). The composition of fluid I (gas) is represented by the point in which a horizontal line parallel to the concentration axis through the random point intersects the curve $F_1F_2'F_3'F_4'F_5'P$. The composition of fluid II (liquid) is represented by the point in which a horizontal line parallel to the concentration axis through the random point intersects the curve $E_1E_2'E_3'E_4'E_5'P$. The relative masses of the three phases are not determined by the position of the random point.

In the surface $QF_8'O_BH_8H_7$ a random point represents a three phase mixture—crystalline component B, fluid I (gas) and fluid II (liquid). The composition of fluid I (gas) is represented by the point in which a horizontal line parallel to the concentration axis through the random point intersects the curve $QF_8'O_B$. The composition of fluid II (liquid) is represented by the point in which a horizontal line parallel to the concentration axis through the random point intersects the curve $QE_8'O_B$. The relative masses of the three phases are not determined by the position of the random point.

A random point on the straight line G_1H_1 represents a four phase mixture—crystalline component A, crystalline component B, fluid I (gas) and fluid II (liquid). The composition of fluid I (gas) is represented by the point F_1. The composition of fluid II (liquid) is represented by the point E_1. The relative masses of the four phases are not determined by the position of the random point on the line G_1H_1.

Diagrams for more complicated types of systems will undoubtedly be needed in the experimental study of systems related to those in which pegmatite dikes and hypogene ore deposits are formed and in the geological application of the experimental results. The two types of binary system in which the only crystalline phases are the pure components serve as stepping stones to the more complicated types.

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