

Application of phase diagram of two components biology essay



**ASSIGN
BUSTER**

A phase diagram is a graphical representation of chemical equilibrium. Since chemical equilibrium is dependent on the composition of the system, the pressure, and the temperature, a phase diagram should be able to tell us what phases are in equilibrium for any composition at any temperature and pressure of the system. First, a few terms will be defined, then we will discuss two component phase diagrams starting with simple systems and progressing to more complex systems.

System- A system is that part of the universe which is under consideration. Thus, it may or may not have fixed boundaries, depending on the system. For example, if we are experimenting with a beaker containing salt and water, and all we are interested in is the salt and water contained in that beaker, then our system consists only of salt and water contained in the beaker.

If the system cannot exchange mass or energy with its surroundings, then it is termed an isolated system. (Our salt and water system, if we put a lid on it to prevent evaporation, and enclosed it in a perfect thermal insulator to prevent it from heating or cooling, would be an isolated system.)

If the system can exchange energy, but not mass with its surroundings, we call it a closed system. (Our beaker, still sealed, but without the thermal insulator is a closed system).

If the system can exchange both mass and energy with its surroundings, we call it an open system. (Our beaker - salt - water system open to the air and not insulated is thus an open system).

Phase- A phase is a physically separable part of the system with distinct physical and chemical properties. A system must consist of one or more phases. For example, in our salt-water system, if all of the salt is dissolved in the water, consists of only one phase (a sodium chloride - water solution). If we have too much salt, so that it cannot all dissolve in the water, we have 2 phases, the sodium chloride - water solution and the salt crystals. If we heat our system under sealed conditions, we might have 3 phases, a gas phase consisting mostly of water vapor, the salt crystals, and the sodium chloride - water solution.

In a magma a few kilometers deep in the earth we might expect one or more phases. For example if it is very hot so that no crystals are present, and there is no free vapor phase, the magma consists of one phase, the liquid. At lower temperature it might contain a vapor phase, a liquid phase, and one or more solid phases. For example, if it contains crystals of plagioclase and olivine, these two minerals would be considered as two separate solid phases because olivine is physically and chemically distinct from plagioclase.

Component- Each phase in the system may be considered to be composed of one or more components. The number of components in the system must be the minimum required to define all of the phases. For example, in our system salt and water, we might have the components Na, Cl, H, and O (four components), NaCl, H, and O (three components), NaCl and HO (two components), or NaCl-H₂O (one component). However, the possible phases in the system can only consist of crystals of halite (NaCl), H₂O either liquid or vapor, and NaCl-H₂O solution. Thus only two components (NaCl and H₂O)

are required to define the system, because the third phase (NaCl - H₂O solution) can be obtained by mixing the other two components.

The Phase Rule

The phase rule is an expression of the number of variables and equations that can be used to describe a system in equilibrium. In simple terms, the number of variables are the number of chemical components in the system plus the extensive variables, temperature and pressure. The number of phases present will depend on the variance or degrees of freedom of the system. The general form of the phase rule is stated as follows:

$$F = C + 2 - P$$

where F is the number of degrees of freedom or variance of the system.

C is the number of components, as defined above, in the system.

P is the number of phases in equilibrium,

and the 2 comes from the two extensive variables, Pressure and Temperature.

But for the sake of convenience, all two components system in equilibrium are described by 'reduced phase rule'. Since the effect of pressure on such solids and liquids is negligible. The value of F is reduced by 1. In such case phase rule reduced to

$$P + F = C + 1$$

This is known as 'condensed' or 'reduced phase rule'

TWO COMPONENT EUTECTIC SYSTEMS

Figure 1 shows the simplest of two component phase diagrams. The components are A and B, and the possible phases are pure crystals of A, pure crystals of B, and liquid with compositions ranging between pure A and pure B. Compositions are plotted across the bottom of the diagram. Note that composition can be expressed as either a percentage of A or a percentage of B, since the total percentage must add up to 100.

(Compositions might also be expressed as mole fraction of A or B, in which case the total must add up to 1). Temperature or pressure is plotted on the vertical axis. For the case shown, we consider pressure to be constant, and therefore have plotted temperature on the vertical axis.

The curves separating the fields of A + Liquid from Liquid and B + Liquid from Liquid are termed liquidus curves. The horizontal line separating the fields of A + Liquid and B + Liquid from A + B all solid, is termed the solidus. The point, E, where the liquidus curves and solidus intersect, is termed the eutectic point. At the eutectic point in this two component system, all three phases, that is Liquid, crystals of A and crystals of B, all exist in equilibrium. Note that the eutectic is the only point on the diagram where this is true.

Since we looking at a system at constant pressure, the phase rule in this case is $F = C + 1 - P$. The eutectic point is therefore an invariant point. If we change the composition of the liquid or the temperature, the number of phases will be reduced to 2.

If the system contains only pure A, then the system is a one component system and phase A melts at only one temperature, the melting temperature

of pure A, T_{mA} . If the system contains only pure B, then it is a one component system and B melts only at the melting temperature of pure B, T_{mB} .

For all compositions between pure A and pure B, the melting temperature is drastically reduced, and melting begins at the eutectic temperature T_E . Note that for all compositions between A and B the melting also occurs over a range of temperatures between the solidus and the liquidus. This is true for all compositions except one, that of the eutectic. The eutectic composition melts at only one temperature, T_E .

We will now consider the crystallization of a liquid with composition X in Figure 1. First, however, we must state the following rule, which must always be obeyed:

Rule 1- In equilibrium crystallization or melting in a closed system, the final composition of the system will be identical to the initial composition of the system.

Therefore, according to rule 1, composition X, which is made up of a mixture of 80% A and 20% B, will have, as its final crystalline product a mixture of 80% crystals of A and 20% crystals of B.

Composition X will be all liquid above the temperature T_1 , because it will lie in the field of all Liquid. If the temperature is lowered to T_1 , at T_1 crystals of A begin to form.

Further lowering of the temperature causes more crystals of A to form. As a result, the liquid composition must become more enriched in B as more

crystals of A form out of the liquid. Thus, with lowering of temperature, the liquid composition will change from point 1 to point 2 to point 3 to point E as the temperature is lowered from T_1 to T_2 to T_3 to T_E respectively. At all temperatures between T_1 and T_E , two phases will be present in the system; liquid and crystals of A. At the eutectic temperature, T_E , crystals of B will begin to form, and three phases will coexist; crystals of A, crystals of B, and liquid. The temperature must remain at T_E until one of the phases disappears. Thus when the liquid crystallizes completely, only pure solid A and pure solid B will remain and mixture of these two solid phases will be in the proportions of the original mixture, that is 80% A and 20% B.

The crystallization history of composition X can be written in abbreviated form as follows:

$T > T_1$ - all liquid

T_1 - T_E - liquid + A

at T_E - liquid + A + B

T If we were to stop the crystallization process at any point during crystallization and observe how much of each phase is present we can use the following example to determine what we would see.

For example, at a temperature T_2 the amount of crystals of A and liquid (the only two phases present at this temperature) could be determined by measuring the distances a and b on figure 1. The percentages would then be given by the lever rule:

$$\% \text{ crystals of A} = b/(a + b) \times 100$$

$$\% \text{ liquid} = a/(a + b) \times 100$$

Note that since the amount of crystals must increase with falling temperature the proportional distance between the vertical line which marks the initial composition and the liquidus increases as temperature falls. Thus the distance used to calculate the amount of solid is always measured toward the liquid side of the initial composition.

At the temperature T₃, note that more crystals must have formed since the proportional distance $d/(c+d)$ is greater than the proportional distance $b/(a+b)$. Thus at T₃ the lever rule gives:

$$\% \text{ crystals of A} = d/(d + c) \times 100$$

$$\% \text{ liquid} = c/(c + d) \times 100$$

At T₃, note that the composition of the liquid is given at point 3, i. e. 53% A, the composition of the solid is pure A, and the composition of the system is still 80% A and 20% B. Make sure you understand the difference between composition of the phases and the amount or percentages of the phases.

The melting process is exactly the reverse of the crystallization process. That is if we started with composition X at some temperature below T_E the first liquid would form at T_E. The temperature would remain constant at T_E until all of the crystals of B were melted. The liquid composition would then change along the liquidus curve from E to point 1 as temperature increased until the temperature T₁ was reached. Above T₁ the system would contain

only liquid with a composition of 80% A and 20% B. The melting process in abbreviated form is listed below:

T at T_E — Liquid + A + B

$T_E - T_1$ — Liquid + A

$T > T_1$ — all Liquid

Lead -Silver System:-

The temperature composition phase diagram of Pb-Ag system shown is the graphical representation of phases of this system existing under different conditions of temperature & composition.

A indicates the melting pt.(961oC) of silver. B

indicates the melting pt.(327oC) of lead.

Only one phase, liquid phase above ACB.

Two solid phases exist below DCE. Melt

and a solid phase exist between ACB and

DCE. Melt and solid Ag exist within the

area ACD. Melt and solid Pb exist within

the area BCE.

Ag and Pb mixture of composition x is a melt

at F corresponding to t_1 °C. When this melt

is cooled, solidification starts at the pt. G corresponding to t_2 °C. Solid phase

separating out is pure Ag. More Ag

separates out as the system is cooled and

as a result, composition of the melt

existing at equilibrium with the solid

changes along GC. Thus at t_3 °C solid Ag is at equilibrium with a melt of composition L.

At 303 °C, corresponding to the pt H, complete solidification occurs. Two separate solid phases are present at this pt. They are solid Ag and another solid containing 97.4% Pb and 2.6% Ag called “eutectic solid”. Mixtures of any composition from D to C behave exactly like this. But initial solidification temperature decreases

along AC, as the composition of the mixture changes

along DC. However, the final solidification temperature remains constant at 303 °C along DC for all these mixtures. Mixture of composition, y is a melt at

M. Solidification commences at N. Pure solid Pb separates and composition of the melt existing at equilibrium changes along NC, when the system is cooled. Solidification is complete at Q, corresponding to 303°C. Two, such as solid Pb and eutectic solid exist at Q.

Mixture of any composition from C to E behave exactly like this. Initial solidification temperature rises along CB and final solidification temperature remains constant at 303°C along CE for these mixtures of composition from C to E.

Behaviour of mixtures on either side of C on cooling their melt can be summarized as follows. (i) Their solidification starts at definite higher temperatures, given by the points on ACB, depending upon their composition. Their solidification completes at 303°C, irrespective of their composition.

In other words, when these solids are heated, they start melting at 303°C. They melt completely at definite higher temperatures given by the line ACB. Thus, they solidify over a temperature range on

cooling their melt or they melt over a temperature range when the solids are heated. Composition of the mixture determines the temperature range. It becomes narrower, as the

composition approaches C from either side

of this point. Solidification starts at this temperature.

Temperature does not change, until solidification is complete. This mixture

behaves like pure Ag or pure Pb in this

respect. That is, it shows definite

solidification temperature or melting

temperature. It melts completely at 303°C.

Complete melting of other mixtures occurs

at higher temperatures than 303°C,

depending upon their composition, even

though melting commences at 303°C.

Thus mixture C has the lowest melting pt. or it is the easily melting mixture.

Therefore it is called eutectic mixture.

The composition: 97.4 % Pb & 2.6% Ag is

eutectic composition. Either pure Pb or

pure Ag does not solidify from a melt of eutectic composition. The mixture solidifies completely as eutectic solid. Separation of Ag or Pb is not possible by cooling a melt of eutectic composition.

Desilverization Of Lead:

-Pattinson's Process: This process of desilverization of lead is based upon the Pb - Ag phase diagram.

-Pb extracted from its ores always contains small amounts of Ag and it is known as “ argentiferous lead”.

The argentiferous lead is allowed to cool from molten state. Pure Pb solidifies.

The melt gets enriched with silver.

Solidification of pure Pb continues, until the melt is cooled to 303oC. Solid Pb formed at every stage is removed. At 303oC, the

melt is an eutectic mixture of 97.4% Pb

and 2.6% Ag. Pure lead does not solidify

from it. The eutectic mixture itself

solidifies, when cooled. The solid contains

2.6% Ag. This is Pattinson's process.

The eutectic solid is melted and heated

in air, when lead is oxidized to PbO. PbO

floats over the melt as a solid scum.

-It is skimmed off. When Pb is removed like this completely, the melt left behind is Ag. It is cast into bars.