Phase transformations in metals

It follows that some of the parent phase volume disappears. * Transformation reaches completion If growth Is allowed to proceed until the equilibrium fraction Is attained. Two types of Nucleation 1 . Homogeneous: nuclei of the new phase form uniformly throughout the parent phase. 2. Heterogeneous: nuclei form preferentially at structural inhomogeneous, such as container surfaces, grain boundaries, insolvable impurities, dislocations, etc. Homogeneous nucleation: solidification of a pure material, assume nuclei of solid phase form In the interior of the liquid phase.

There are two contributions to the total free energy change AC that accompany a solidification transformation 1 . The volume free energy Agave - which is the difference in free energy between the solid and liquid phases. Agave will be negative if the temperature is below the equilibrium solidification temperature. The magnitude of its contribution is the product of Agave and the volume of the spherical nucleolus (4/3 aorta) 2. Surface free energy y: energy comes from the formation of the solid-liquid phase boundary during the solidification transformation. Is postlude; the magnitude of this contribution Is the product of y ND the surface area of the nucleus (nor) * the total free energy change GAG Is equal to the sum of these two contributions: GAG= 4/3 aorta GAG_v+rattrap y * In a physical sense, this means that as a solid particle begins to form as atoms in the liquid cluster together, its G first increases. If this cluster (embryo) reaches a size equal to the critical radius, r*, then growth will continue with the accompaniment of a decrease In LEG. An embryo with a radius greater than Is called a nucleus.

A critical free energy occurs at the maximum of the curve, which corresponds to the activation energy needed for the formation of a stable

nucleus. Critical radius of a stable solid particle nucleus:) Activation free energy required for the formation of a stable nucleus:) This volume free energy change is the driving force for the solidification transformation, its magnitude is a function of temperature. At the equilibrium solidification temperature (or melting temperature) Tm, Agave Is O, and with decreasing temp It becomes Increasingly more negative.

Agave temperature decreases meaning, nucleation occurs more readily at temperature below Tm The number of stable nuclei n*(having r> r*) is a function of temperature as well: 1) changes in T have a greater effect on than on he denominator. As T is lowered below Tm the exponential term decreases such that the magnitude of n* increases *another important temperature dependent step in nucleation: the clustering of atoms during short range diffusion during the formation of nuclei. The influence of temp on the rate of diffusion: high temp increases diffusion.

Diffusion is related to the frequency at which atoms from the liquid attach themselves to the solid nucleolus, VT. Thus, low temp results in a reduction in VT. The nucleation rate N is the product of n* and VT Heterogeneous nucleation has a lower activation energy than homogeneous because he surface free energy is reduced when nuclei form on the surface of preexisting surfaces. Growth occurs by long range diffusion consequently, the growth rate G is determined by the rate of diffusion, and its temperature dependence is the same as the diffusion coefficient (recall chapter that diffusion increases as temperature increases).

Most phase transformations require some finite time to go to completion, and the rate is important in the relationship between heat treatment and the development of macrostructure * for solid systems the rate is so slow that true equilibrium structures are rarely achieved, equilibrium is maintained only if heating and cooling are carried out at SLOW unpractical rates. *for other than equilibrium cooling Superimposing: cooling to below a phase transition temperature without the occurrence of the transformation Superannuating: heating to above a phase transition temperature without the occurrence of the transformation