

# [Nucleation and growth in solid-state reactions](https://assignbuster.com/nucleation-and-growth-in-solid-state-reactions/)

Nucleation As in solidification, nucleation occurs most easily on surfaces already present in the structure, thereby minimizing the surface energy term. Thus, the precipitates heterogeneously nucleate most easily at grain boundaries and other defects. Growth of the precipitates normally occurs by long-range diffusion and redistribution of atoms. Diffusing atoms must be detached from their original locations (perhaps at lattice points in a solid solution), move through the surrounding material to the nucleus, and be incorporated into the crystal structure of the precipitate.

In some cases, the diffusing atoms might be so tightly bonded within an existing phase that the detachment process limits the rate of growth. In other cases, attaching the diffusing atoms to the precipitate—perhaps because of the lattice strain—limits growth. This result sometimes leads to the formation of precipitates that have a special relationship to the matrix structure that minimizes the strain at the interface between the parent phase and the precipitate particles. In most cases, however, the controlling factor is the diffusion step.

Kinetics The overall rate, or kinetics, of a transformation depends on both nucleation and growth. If more nuclei are present at a particular temperature, growth occurs from a larger number of sites and the phase transformation is completed in a shorter period of time. At higher temperatures, the diffusion coefficient is higher, growth rates are higher, and again we expect the transformation to be completed in a shorter time, assuming an equal number of nuclei. Effect of Temperature In many phase transformations, the material undercools below the temperature at which the phase transformation occurs under equilibrium conditions.

Under equilibrium conditions the undercooling of water and other liquids and other super saturation phenomena. Because both nucleation and growth are temperature dependent, the rate of phase transformation depends on the undercooling. The rate of nucleation is low for small undercooling's (since the thermodynamic driving force is low) and increases for larger undercooling's as the thermodynamic driving force increases at least up to a certain point (since diffusion becomes slower as temperature decreases). At the same time, the growth rate of the new phase decreases continuously, because of slower diffusion, as the undercooling increases.

At any particular temperature, the overall rate of transformation is the product of the nucleation and growth rates. In the combined effect of the nucleation and growth rates is shown. A highest transformation rate may be observed at a critical undercooling. In some processes, such as the recrystallization of a cold-worked metal, we find that the transformation rate continually decreases with decreasing temperature. In this case, nucleation occurs easily, and diffusion—or growth—predominates (i. e. , the growth is the rate limiting step for the transformation).