

Ginstling-Brounshtein Equation

The **Ginstling-Brounshtein (G-B) equation** is a diffusion-controlled kinetic model developed by **A. M. Ginstling** and **B. I. Brounshtein** in 1950. It is an improvement over the Jander equation because it provides a more accurate mathematical description of diffusion through the product layer surrounding spherical particles.

The model assumes that the reaction occurs on the surface of spherical particles and that the rate-controlling step is the diffusion of atoms or ions through the product layer formed during the reaction.

Definition

The Ginstling-Brounshtein equation is a kinetic equation used to describe diffusion-controlled solid-state reactions in spherical particles, where the reaction rate is controlled by diffusion through the growing product layer.

Need for the Ginstling-Brounshtein Equation

Although the Jander equation successfully explains many diffusion-controlled reactions, it makes certain simplifying assumptions that are not always valid. The Ginstling-Brounshtein equation provides a more rigorous mathematical treatment of diffusion in spherical particles and is therefore considered more accurate for many solid-state reactions.

Assumptions

- The reactant particles are perfectly spherical.
- All particles have nearly the same size.
- The reaction begins uniformly over the particle surface.
- A continuous product layer surrounds the unreacted core.
- Diffusion through the product layer is the rate-controlling step.
- The diffusion coefficient remains constant during the reaction.
- The temperature remains constant.

Concept of the Model

Consider a spherical particle of initial radius R . As the reaction proceeds, an unreacted core of radius r remains inside the particle while the product layer grows around it. Reactant ions must diffuse through this product layer before reaching the reaction interface.

Initially

- The particle consists entirely of reactant.
- The unreacted core radius is equal to the original particle radius.
- No product layer is present.

During the Reaction

- The product layer becomes progressively thicker.
- The unreacted core gradually shrinks.
- The diffusion path continuously increases.
- The reaction rate decreases with time.

Derivation

Notation

- α = Fraction of reaction completed
- t = Reaction time
- R = Initial particle radius
- r = Radius of the unreacted core
- k = Diffusion-controlled rate constant

For a spherical particle, the fraction of unreacted material is

$$1 - \alpha = \frac{r^3}{R^3}$$

Therefore,

$$\frac{r}{R} = (1 - \alpha)^{1/3}$$

Using Fick's law of diffusion and integrating the diffusion equation for spherical geometry, Ginstling and Brounshtein obtained the following integrated rate equation:

$$1 - \frac{2}{3}\alpha - (1 - \alpha)^{2/3} = kt$$

This equation is known as the **Ginstling-Brounshtein equation**.

Meaning of the Equation

The equation is expressed as

$$1 - \frac{2}{3}\alpha - (1 - \alpha)^{2/3} = kt$$

where:

- α = Fraction of reaction completed
- k = Diffusion-controlled rate constant
- t = Reaction time

The equation indicates that the extent of reaction depends on the diffusion of reactant species through the growing product layer. As the product layer thickens, diffusion becomes slower and the overall reaction rate decreases.

Physical Significance

The Ginstling-Brounshtein equation explains the behaviour of diffusion-controlled solid-state reactions more accurately than the Jander equation. As the reaction proceeds, the thickness of the product layer surrounding the unreacted core continuously increases. This increasing thickness makes diffusion of atoms or ions more difficult, causing the reaction rate to decrease gradually.

- The reaction is initially fast because the diffusion path is short.
- The product layer becomes thicker with time.
- The diffusion distance continuously increases.
- The movement of atoms or ions becomes slower.
- The overall reaction rate decreases as the reaction progresses.

Graphical Representation

If a reaction follows the Ginstling-Brounshtein model, a graph of

$$1 - \frac{2}{3}\alpha - (1 - \alpha)^{2/3}$$

against reaction time t gives a straight line passing through the origin.

The slope of the straight line is equal to the diffusion-controlled rate constant k .

Applications

- Study of diffusion-controlled solid-state reactions.
- Preparation of advanced ceramic materials.
- Synthesis of ferrites and spinel compounds.
- Oxidation of metals at high temperatures.
- Powder metallurgy.
- Sintering of ceramic materials.
- Preparation of semiconductor materials.
- Study of diffusion in crystalline solids.

Advantages

- Provides a more accurate description of diffusion than the Jander equation.
- Based on rigorous mathematical treatment of spherical diffusion.
- Applicable to many ceramic and metallurgical reactions.
- Useful for determining diffusion-controlled rate constants.
- Widely accepted in materials science and solid-state chemistry.

Limitations

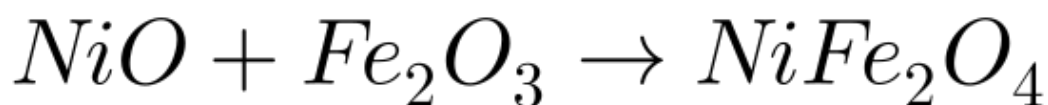
- Applicable only when diffusion is the rate-controlling step.
- Assumes spherical particles of uniform size.
- Assumes a constant diffusion coefficient throughout the reaction.
- Not applicable to nucleation-controlled reactions.
- Cannot accurately describe reactions involving particle fracture or significant porosity.

Comparison Between Jander and Ginstling-Brounshtein Equations

Feature	Jander Equation	Ginstling-Brounshtein Equation
Year	1927	1950
Developed by	Wilhelm Jander	Ginstling and Brounshtein
Main assumption	Diffusion through product layer	Diffusion through product layer
Accuracy	Moderate	Higher
Particle shape	Spherical	Spherical
Industrial use	Common	More widely preferred

Example

During the high-temperature preparation of nickel ferrite, the reaction



produces a layer of nickel ferrite around the unreacted particles. Nickel and iron ions must diffuse through this product layer before the reaction can continue. Since diffusion controls the reaction rate, the kinetics can often be described using the Ginstling-Brounshtein equation.

Summary

The Ginstling-Brounshtein equation is one of the most important diffusion-controlled kinetic models in solid-state chemistry. It is derived from Fick's law for spherical particles and provides a more accurate description of diffusion than the Jander equation. The model is widely used in the study of ceramics, metallurgy, ferrites, semiconductors and other advanced materials.

Important Points for Examination

- Proposed by Ginstling and Brounshtein in 1950.
- Applicable to diffusion-controlled solid-state reactions.
- Based on diffusion through a growing product layer.
- More accurate than the Jander equation.
- Assumes spherical particles and a constant diffusion coefficient.
- The integrated equation is:

$$1 - \frac{2}{3}\alpha - (1 - \alpha)^{2/3} = kt$$

- A linear plot of $1 - \frac{2}{3}\alpha - (1 - \alpha)^{2/3}$ versus t

confirms the applicability of the model.

- The slope of the graph gives the diffusion-controlled rate constant.
- The equation is widely used in ceramic chemistry, powder metallurgy and materials science.