Catalyst Effectiveness Factor from the Thiele Modulus

Thiele modulus and internal effectiveness factor of a porous catalyst pellet (sphere, cylinder-approx. or slab) for a first-order reaction, and the observed rate.

Method: Levenspiel; Chemical Reaction Engineering; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Pellet shape	Sphere	
Sphere diameter or slab thickness	4.0000	mm
First-order rate constant per pellet volume	5.0000	Hz
Effective diffusivity in the pellet	1.0000e-07	m²/s

Calculated results

Parameter	Value	Unit
Characteristic length V/S	0.66667	mm
Generalised Thiele modulus	4.7140	
Effectiveness factor	19.713	%
Observed rate constant	0.98566	Hz

Notes for this case

• Isothermal pellet and first-order kinetics; a slab reacting from both faces has L_c equal to half its thickness, a sphere d/6. For φ above about 3, η ≈ 1/φ: strong pore-diffusion limitation.

Formula and method

$$\phi = L_c\sqrt{\frac{k_v}{D_e}},\ L_c = \frac{V_p}{S_p}\ (\text{sphere } d_p/6,\ \text{slab},\ \text{both faces } d_p/2),\quad \eta_{sphere} = \frac{1}{3\phi^2}\left(\frac{3\phi}{\tanh 3\phi} - 1\right),\quad \eta_{slab} = \frac{\tanh\phi}{\phi}$$

Variables

shape	Pellet shape	-
d_p	Sphere diameter or slab thickness	m
k_v	First-order rate constant per pellet volume	1/s
D_e	Effective diffusivity in the pellet	m²/s
L_c	Characteristic length V/S	m
ϕ	Generalised Thiele modulus	-
η	Effectiveness factor	-
ηk_v	Observed rate constant	1/s

Method and standards

Generalised Thiele modulus.

Assumptions and limits

- Isothermal; first order.

References

• Levenspiel
• Chemical Reaction Engineering
• 3rd ed. (Wiley, 1999)
• ch. 18 (effectiveness factor and generalised Thiele modulus)
• Fogler
• Elements of Chemical Reaction Engineering

- 5th ed.
- ch. 15

Report details

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Release checks	2 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/chemical/reactors/thiele-effectiveness-factor

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.