# Plug-Flow and Batch Reactor Conversion (1st and 2nd Order)

Conversion in a plug-flow or batch reactor for first- and second-order kinetics from rate constant and time, with the CSTR time for the same conversion.

**Method:** Perry's Chemical Engineers' Handbook; 9th ed. (McGraw-Hill, 2019); ...

## Input parameters

Unit system: SI

| Parameter | Value | Unit |
|---|---|---|
| Reaction order | First order | |
| Rate constant, in the units chosen below<br>A plain number in the units chosen in 'Units of k'. First order: per s, min or h; second order: m³ or L per mol per s, min or h. | 0.002000 | |
| Units of k | 1/s or m³/(mol·s) | |
| Residence (or batch) time | 20.000 | min |
| Initial concentration (2nd order) | 1.0000 | mol/L |

## Calculated results

| Parameter | Value | Unit |
|---|---|---|
| Conversion | 90.928 | % |
| CSTR residence time for the same conversion | 83.526 | min |
| CSTR / PFR volume ratio | 4.1763 | |

## Formula and method

$$X_1 = 1 - e^{-k\tau}, \quad X_2 = \frac{k\tau C_0}{1 + k\tau C_0}, \quad \tau_{CSTR,1} = \frac{X}{k(1-X)}, \quad \tau_{CSTR,2} = \frac{X}{kC_0(1-X)^2}$$

### Variables

| | | |
|---|---|---|
| $\mathrm{order}$ | Reaction order | - |
| $k$ | Rate constant, in the units chosen below | - |
| $\mathrm{units\ of}\ k$ | Units of k (per s, min or h; m³ or L per mol) | - |
| $\tau$ | Residence (or batch) time | s |
| $C_0$ | Initial concentration (2nd order) | mol/m³ |
| $X$ | Conversion | - |
| $\tau_{CSTR}$ | CSTR residence time for the same conversion | s |
| $\tau_{CSTR}/\tau$ | CSTR / PFR volume ratio | - |

### Method and standards

Ideal reactor design equations (isothermal, constant density).

### Assumptions and limits

- Isothermal; constant density; irreversible.
- k is converted to SI from the units chosen (1/s or m³/(mol·s)); a textbook value of 0.12 1/min must be entered with the per-minute units, not as 0.12 1/s.
- At complete conversion the CSTR time is infinite and is not shown; with no residence time the volume ratio is not shown.

### References

• Perry's Chemical Engineers' Handbook
• 9th ed. (McGraw-Hill, 2019)
• sec. 7 and 19 (reaction kinetics and reactor design): ideal plug-flow and stirred-tank reactors

## Report details

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|---|---|
| Report reference | FCC-1DDB-N7YP (the same inputs always give the same reference) |
| Generated | 17 November 2026, 19:44 UTC |
| Calculator | Plug-Flow and Batch Reactor Conversion (1st and 2nd Order) |
| Method last reviewed | 13 November 2026 |
| Software release | FireCAD Calc, release of 17 November 2026 |
| Release checks | 4 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/unit-operations/plug-flow-reactor-conversion

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.