Batch Reactor: Peak Heat Release and Cooling Area

Peak heat release of a first-order exothermic batch reaction at the start of the batch, the cooling area needed to hold temperature, and the heat released by a time.

Method: Batch reactor energy balance for first-order kinetics (Levenspiel, Chemical Reaction Engineering, 3rd ed. (Wiley, 1999), ch. 9; Fogler, ch. 13)

Input parameters

Unit system: SI

Parameter	Value	Unit
Reacting volume	10.000	m³
Initial concentration, in kmol/m³ (= mol/L; not mol/m³)	2.0000	
First-order rate constant at the operating temperature	1.0000	1/h
Heat of reaction (released)	100.00	kJ/mol
Overall coefficient	400.00	W/(m²·K)
Reaction temperature	80.000	°C
Mean coolant temperature	30.000	°C
Time into the batch	1.0000	h

Calculated results

Parameter	Value	Unit
Peak heat release (at t = 0)	555.56	kW
Cooling area needed	27.778	m²
Heat release at time t	204.38	kW
Heat released up to t	351.18	kWh
Conversion at t	63.212	%

Notes for this case

- Isothermal operation with all reactant charged at the start: the cooling must match the initial peak. Semi-batch feeding spreads the load. Check the adiabatic temperature rise for runaway risk.

Formula and method

$$Q_0 = (-\Delta H_r) k C_{A0} V, \quad A = \frac{Q_0}{U(T_r - T_c)}, \quad Q(t) = Q_0 e^{-kt}, \quad X = 1 - e^{-kt}$$

Variables

V	Reacting volume	m³
C_{A0}	Initial concentration, in kmol/m³ (= mol/L; not mol/m³)	kmol/m³
k	First-order rate constant at the operating temperature	1/s
$-\Delta H_r$	Heat of reaction (released)	J/mol
U	Overall coefficient	W/(m²·K)
T_r	Reaction temperature	K
T_c	Mean coolant temperature	K
t	Time into the batch	s
Q_0	Peak heat release (at t = 0)	W
A	Cooling area needed	m²
$Q(t)$	Heat release at time t	W

$E(t)$	Heat released up to t	J
$X(t)$	Conversion at t	-

Method and standards

First-order heat release.

Assumptions and limits

- Isothermal; first order; all charged at start; the reactor is held at T_r (no heat accumulation).
- The concentration is entered as a number in kmol/m³ (the same number as mol/L); a value in mol/m³ would be 1000 times too large.

References

• Batch reactor energy balance for first-order kinetics (Levenspiel, Chemical Reaction Engineering, 3rd ed. (Wiley, 1999), ch. 9; Fogler, ch. 13)

Report details

Report reference	FCC-XRK5-60EB (the same inputs always give the same reference)
Generated	17 November 2026, 19:45 UTC
Calculator	Batch Reactor: Peak Heat Release and Cooling Area
Method last reviewed	13 November 2026
Software release	FireCAD Calc, release of 17 November 2026
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/batch-reactor-heat-removal

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.