Important Formulas in Design of Reactors & Recycle Reactors for Single Reactions

List of 27 Important Formulas in Design of Reactors & Recycle Reactors for Single Reactions

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1) Final Reactant Conversion

Open Calculator

fx $$X_f = \left(\frac{R+1}{R}\right) \cdot X_1$$

ex $$0.600167 = \left(\frac{0.3+1}{0.3}\right) \cdot 0.1385$$

2) Initial Reactant Concentration for First Order Reaction in Vessel i

Open Calculator

fx $$C_{\ i\text{-}1} = C_i \cdot \left(1 + \left(k' \cdot trC2'\right)\right)$$

ex $$3415.8\text{mol/m}^3 = 30\text{mol/m}^3 \cdot \left(1 + \left(2.508\text{s}^{-1} \cdot 45\text{s}\right)\right)$$

3) Initial Reactant Concentration for First Order Reaction using Reaction Rate

Open Calculator

fx $$C_o = \frac{trC2' \cdot r_i}{X_{i\text{-}1} - X_i}$$

ex $$76.5\text{mol/m}^3 = \frac{45\text{s} \cdot 0.17\text{mol/m}^3\text{*s}}{0.8 - 0.7}$$

4) Initial Reactant Concentration for Second Order Reaction for Plug Flow or Infinite Reactors

Open Calculator

fx $$C_o = \frac{1}{\left(\frac{1}{C}\right) - \left(k'' \cdot \tau_p\right)}$$

ex $$83.98656\text{mol/m}^3 = \frac{1}{\left(\frac{1}{24\text{mol/m}^3}\right) - \left(0.062\text{m}^3/(\text{mol*s}) \cdot 0.48\text{s}\right)}$$

5) Rate Constant for First Order Reaction using Recycle Ratio

Open Calculator

fx $$k' = \left(\frac{R+1}{\tau}\right) \cdot \ln\left(\frac{C_o + (R \cdot C_f)}{(R+1) \cdot C_f}\right)$$

ex $$31.10252\text{s}^{-1} = \left(\frac{0.3+1}{0.05\text{s}}\right) \cdot \ln\left(\frac{80\text{mol/m}^3 + (0.3 \cdot 20\text{mol/m}^3)}{(0.3+1) \cdot 20\text{mol/m}^3}\right)$$

6) Rate Constant for Second Order Reaction using Recycle Ratio

Open Calculator

fx $$k'' = \frac{(R+1) \cdot C_o \cdot (C_o - C_f)}{C_o \cdot \tau \cdot C_f \cdot (C_o + (R \cdot C_f))}$$

ex $$0.906977\text{m}^3/(\text{mol*s}) = \frac{(0.3+1) \cdot 80\text{mol/m}^3 \cdot (80\text{mol/m}^3 - 20\text{mol/m}^3)}{80\text{mol/m}^3 \cdot 0.05\text{s} \cdot 20\text{mol/m}^3 \cdot (80\text{mol/m}^3 + (0.3 \cdot 20\text{mol/m}^3))}$$

7) Reactant Concentration for First Order Reaction in Vessel i

Open Calculator

fx $$C_i = \frac{C_{i\text{-}1}}{1 + \left(k' \cdot trC2'\right)}$$

ex $$0.439136\text{mol/m}^3 = \frac{50\text{mol/m}^3}{1 + (2.508\text{s}^{-1} \cdot 45\text{s})}$$

8) Reactant Concentration for Second Order Reaction for Plug Flow or Infinite Reactors

Open Calculator

fx $$C = \frac{C_o}{1 + \left(C_o \cdot k'' \cdot \tau_p\right)}$$

ex $$23.66304\text{mol/m}^3 = \frac{80\text{mol/m}^3}{1 + (80\text{mol/m}^3 \cdot 0.062\text{m}^3/(\text{mol*s}) \cdot 0.48\text{s})}$$

9) Reaction Rate for Vessel i for Mixed Flow Reactors of Different Sizes in Series

Open Calculator

fx $$r_i = \frac{C_{\ i\text{-}1} - C_i}{trC2'}$$

ex $$0.444444\text{mol/m}^3\text{*s} = \frac{50\text{mol/m}^3 - 30\text{mol/m}^3}{45\text{s}}$$

10) Recycle Ratio

Open Calculator

fx $$R = \frac{V_R}{V_D}$$

ex $$0.300008 = \frac{40\text{m}^3}{133.33\text{m}^3}$$

11) Recycle Ratio using Reactant Conversion

Open Calculator

fx $$R = \frac{1}{\left(\frac{X_f}{X_1}\right) - 1}$$

ex $$0.300108 = \frac{1}{\left(\frac{0.6}{0.1385}\right) - 1}$$

12) Recycle Ratio using Total Feed Rate

Open Calculator

$$R = \left(\frac{F0'}{F}\right) - 1$$

$$0.25 = \left(\frac{15\text{mol/s}}{12\text{mol/s}}\right) - 1$$

13) Space Time for First Order Reaction for Plug Flow or for Infinite Reactors

Open Calculator

$$\tau_p = \left(\frac{1}{k'}\right) \cdot \ln\left(\frac{C_o}{C}\right)$$

$$0.480053\text{s} = \left(\frac{1}{2.508\text{s}^{-1}}\right) \cdot \ln\left(\frac{80\text{mol/m}^3}{24\text{mol/m}^3}\right)$$

14) Space Time for First Order Reaction for Vessel i using Molar Flow Rate

Open Calculator

$$trC2' = \frac{V_i \cdot C_o}{F_0}$$

$$48\text{s} = \frac{3\text{m}^3 \cdot 80\text{mol/m}^3}{5\text{mol/s}}$$

15) Space Time for First Order Reaction for Vessel i using Reaction Rate

Open Calculator

$$trC2' = \frac{C_o \cdot (X_{i\text{-}1} - X_i)}{r_i}$$

$$47.05882\text{s} = \frac{80\text{mol/m}^3 \cdot (0.8 - 0.7)}{0.17\text{mol/m}^3\text{*s}}$$

16) Space Time for First Order Reaction for Vessel i using Volumetric Flow Rate

Open Calculator

fx $$trC2' = \frac{V_i}{\upsilon}$$

ex $$49.18033\text{s} = \frac{3\text{m}^3}{0.061\text{m}^3/\text{s}}$$

17) Space Time for First Order Reaction in Vessel i

Open Calculator

fx $$trC2' = \frac{C_{\ i\text{-}1} - C_i}{C_i \cdot k'}$$

ex $$0.265816\text{s} = \frac{50\text{mol/m}^3 - 30\text{mol/m}^3}{30\text{mol/m}^3 \cdot 2.508\text{s}^{-1}}$$

18) Space Time for First Order Reaction using Recycle Ratio

Open Calculator

fx $$\tau = \left(\frac{R+1}{k'}\right) \cdot \ln\left(\frac{C_o + (R \cdot C_f)}{(R+1) \cdot C_f}\right)$$

ex $$0.620066\text{s} = \left(\frac{0.3+1}{2.508\text{s}^{-1}}\right) \cdot \ln\left(\frac{80\text{mol/m}^3 + (0.3 \cdot 20\text{mol/m}^3)}{(0.3+1) \cdot 20\text{mol/m}^3}\right)$$

19) Space Time for Second Order Reaction for Plug Flow or Infinite Reactors

Open Calculator

fx $$\tau_p = \left(\frac{1}{C_o \cdot k''}\right) \cdot \left(\left(\frac{C_o}{C}\right) - 1\right)$$

ex $$0.47043\text{s} = \left(\frac{1}{80\text{mol/m}^3 \cdot 0.062\text{m}^3/(\text{mol*s})}\right) \cdot \left(\left(\frac{80\text{mol/m}^3}{24\text{mol/m}^3}\right) - 1\right)$$

20) Space Time for Second Order Reaction using Recycle Ratio

Open Calculator

fx $$\tau = \frac{(R+1) \cdot C_o \cdot (C_o - C_f)}{C_o \cdot k'' \cdot C_f \cdot (C_o + (R \cdot C_f))}$$

ex $$0.731433s = \frac{(0.3+1) \cdot 80mol/m^3 \cdot (80mol/m^3 - 20mol/m^3)}{80mol/m^3 \cdot 0.062m^3/(mol^*s) \cdot 20mol/m^3 \cdot (80mol/m^3 + (0.3 \cdot 20mol/m^3))}$$

21) Space Time for Vessel i for Mixed Flow Reactors of Different Sizes in Series

Open Calculator

fx $$trC2' = \frac{C_{i-1} - C_i}{r_i}$$

ex $$117.6471s = \frac{50mol/m^3 - 30mol/m^3}{0.17mol/m^3{}^*s}$$

22) Total Feed Reactant Conversion

Open Calculator

fx $$X_1 = \left(\frac{R}{R+1}\right) \cdot X_f$$

ex $$0.138462 = \left(\frac{0.3}{0.3+1}\right) \cdot 0.6$$

23) Volume leaving System

Open Calculator

fx $$V_D = \frac{V_R}{R}$$

ex $$133.3333m^3 = \frac{40m^3}{0.3}$$

24) Volume of Fluid returned to Reactor Entrance

Open Calculator

fx $$V_R = V_D \cdot R$$

ex $$39.999m^3 = 133.33m^3 \cdot 0.3$$

25) Volume of Vessel i for First Order Reaction using Molar Feed Rate

Open Calculator

fx $$V_i = \frac{trC2' \cdot F_0}{C_o}$$

ex $$2.8125m^3 = \frac{45s \cdot 5mol/s}{80mol/m^3}$$

26) Volume of Vessel i for First Order Reaction using Volumetric Flow Rate

Open Calculator

fx $$V_i = \upsilon \cdot trC2'$$

ex $$2.745m^3 = 0.061m^3/s \cdot 45s$$

27) Volumetric Flow Rate for First Order Reaction for Vessel i

Open Calculator

fx $$\upsilon = \frac{V_i}{trC2'}$$

ex $$0.066667m^3/s = \frac{3m^3}{45s}$$

Variables Used

- **C** Reactant Concentration *(Mole per Cubic Meter)*
- **C_{i-1}** Reactant Concentration in Vessel i-1 *(Mole per Cubic Meter)*
- **C_f** Final Reactant Concentration *(Mole per Cubic Meter)*
- **C_i** Reactant Concentration in Vessel i *(Mole per Cubic Meter)*
- **C_o** Initial Reactant Concentration *(Mole per Cubic Meter)*
- **F** Fresh Molar Feed Rate *(Mole per Second)*
- **F_0** Molar Feed Rate *(Mole per Second)*
- **$F0'$** Total Molar Feed Rate *(Mole per Second)*
- **k'** Rate Constant for First Order Reaction *(1 Per Second)*
- **k''** Rate Constant for Second Order Reaction *(Cubic Meter per Mole Second)*
- **R** Recycle Ratio
- **r_i** Reaction Rate for Vessel i *(Mole per Cubic Meter Second)*
- **$trC2'$** Adjusted Retention Time of Comp 2 *(Second)*
- **V_D** Volume Discharged *(Cubic Meter)*
- **V_i** Volume of Vessel i *(Cubic Meter)*
- **V_R** Volume Returned *(Cubic Meter)*
- **X_1** Total Feed Reactant Conversion
- **X_f** Final Reactant Conversion
- **X_i** Reactant Conversion of Vessel i
- **X_{i-1}** Reactant Conversion of Vessel i-1
- **υ** Volumetric Flow Rate *(Cubic Meter per Second)*
- **τ** Space Time *(Second)*
- **τ_p** Space Time for Plug Flow Reactor *(Second)*

Constants, Functions, Measurements used

- Function: **ln**, ln(Number)
  Natural logarithm function (base e)
- Measurement: **Time** in Second (s)
  Time Unit Conversion
- Measurement: **Volume** in Cubic Meter (m^3)
  Volume Unit Conversion
- Measurement: **Volumetric Flow Rate** in Cubic Meter per Second (m^3/s)
  Volumetric Flow Rate Unit Conversion
- Measurement: **Molar Flow Rate** in Mole per Second (mol/s)
  Molar Flow Rate Unit Conversion
- Measurement: **Molar Concentration** in Mole per Cubic Meter (mol/m^3)
  Molar Concentration Unit Conversion
- Measurement: **Reaction Rate** in Mole per Cubic Meter Second (mol/m^3*s)
  Reaction Rate Unit Conversion
- Measurement: **First Order Reaction Rate Constant** in 1 Per Second (s^{-1})
  First Order Reaction Rate Constant Unit Conversion
- Measurement: **Second Order Reaction Rate Constant** in Cubic Meter per Mole Second ($m^3/(mol*s)$)
  Second Order Reaction Rate Constant Unit Conversion

Check other formula lists

- Basics of Chemical Reaction Engineering Formulas
- Basics of Parallel & Single Reactions Formulas
- Basics of Reactor Design and Temperature Dependency from Arrhenius Law Formulas
- Forms of Reaction Rate Formulas
- Important Formulas in Basics of Chemical Reaction Engineering & Forms of Reaction Rate
- Important Formulas in Constant and Variable Volume Batch Reactor
- Important Formulas in Constant Volume Batch Reactor for First, Second & Third Order Reaction
- Important Formulas in Design of Reactors & Recycle Reactors for Single Reactions
- Important Formulas in Potpourri of Multiple Reactions
- Reactor Performance Equations for Constant Volume Reactions Formulas
- Reactor Performance Equations for Variable Volume Reactions Formulas

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