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

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

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

#### 1) Final Reactant Conversion

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

Open Calculator 

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

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

$$fx \quad C_{i-1} = C_i \cdot \left( 1 + (k' \cdot \text{tr}C2') \right)$$

Open Calculator 

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

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

$$fx \quad C_o = \frac{\text{tr}C2' \cdot r_i}{X_{i-1} - X_i}$$

Open Calculator 

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



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

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

[Open Calculator !\[\]\(4729e517bc6a7cd81c8025b9646574fb\_img.jpg\)](#)

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

#### 5) Rate Constant for First Order Reaction using Recycle Ratio

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

[Open Calculator !\[\]\(e474458956c9a37fbf9586ddb60a7fa1\_img.jpg\)](#)

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

#### 6) Rate Constant for Second Order Reaction using Recycle Ratio

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

[Open Calculator !\[\]\(4fe57c3593bf1b21d272ae7ac8dfaf77\_img.jpg\)](#)

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

#### 7) Reactant Concentration for First Order Reaction in Vessel i

$$fx \quad C_i = \frac{C_{i-1}}{1 + (k' \cdot \tau C_i')}$$

[Open Calculator !\[\]\(2bae76de5ebbd5c4d7d47162f1673734\_img.jpg\)](#)

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



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

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

Open Calculator 

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

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

$$fx \quad r_i = \frac{C_{i-1} - C_i}{\tau C^2}$$

Open Calculator 

$$ex \quad 0.4444444 \text{ mol/m}^3 \cdot \text{s} = \frac{50 \text{ mol/m}^3 - 30 \text{ mol/m}^3}{45 \text{ s}}$$

### 10) Recycle Ratio

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

Open Calculator 

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

### 11) Recycle Ratio using Reactant Conversion

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

Open Calculator 

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



### 12) Recycle Ratio using Total Feed Rate

[Open Calculator !\[\]\(2e897e890e69d81eae4503a8342c36b0\_img.jpg\)](#)

$$fx \quad R = \left( \frac{F_0'}{F} \right) - 1$$

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

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

[Open Calculator !\[\]\(0aff635c4179ba9e710b00f4b01d3b20\_img.jpg\)](#)

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

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

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

[Open Calculator !\[\]\(6bb0e4f14c4133b37d2887cb37e67ddd\_img.jpg\)](#)

$$fx \quad \tau_{rC2'} = \frac{V_i \cdot C_o}{F_0}$$

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

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

[Open Calculator !\[\]\(799877f5c2f906134441300079881630\_img.jpg\)](#)

$$fx \quad \tau_{rC2'} = \frac{C_o \cdot (X_{i-1} - X_i)}{r_i}$$

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



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

[Open Calculator !\[\]\(5eb1325dfdc3f1cad8426726c0db51cd\_img.jpg\)](#)

$$fx \quad \tau_{rC2'} = \frac{V_i}{v}$$

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

### 17) Space Time for First Order Reaction in Vessel i

[Open Calculator !\[\]\(5a132f13505a6571904d622757b7a8f0\_img.jpg\)](#)

$$fx \quad \tau_{rC2'} = \frac{C_{i-1} - C_i}{C_i \cdot k'}$$

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

### 18) Space Time for First Order Reaction using Recycle Ratio

[Open Calculator !\[\]\(d5d7044e5caf6907399af2dced8d6ff8\_img.jpg\)](#)

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

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

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

[Open Calculator !\[\]\(aab88c0d099e5d18d6533a97b13ec28d\_img.jpg\)](#)

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

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



## 20) Space Time for Second Order Reaction using Recycle Ratio

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

[Open Calculator !\[\]\(feabb98897b440bc8695a03336a6e2df\_img.jpg\)](#)

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

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

$$\text{fx } \text{tr}C2' = \frac{C_{i-1} - C_i}{r_i}$$

[Open Calculator !\[\]\(642aa997563f9a325b310230bb5078b7\_img.jpg\)](#)

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

## 22) Total Feed Reactant Conversion

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

[Open Calculator !\[\]\(51514032c8ca341817228f39f1307b05\_img.jpg\)](#)

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

## 23) Volume leaving System

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

[Open Calculator !\[\]\(f219cfc00b8db0cd1a81ae1fc9afaf28\_img.jpg\)](#)

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

## 24) Volume of Fluid returned to Reactor Entrance

$$\text{fx } V_R = V_D \cdot R$$

[Open Calculator !\[\]\(8aa05b4b06c05d58ddd90cdbf335b307\_img.jpg\)](#)

$$\text{ex } 39.999\text{m}^3 = 133.33\text{m}^3 \cdot 0.3$$



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

$$\text{fx } V_i = \frac{\text{tr}C_2' \cdot F_0}{C_o}$$

[Open Calculator !\[\]\(3d8c13c92b853674f749aac6fa869926\_img.jpg\)](#)

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

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

$$\text{fx } V_i = v \cdot \text{tr}C_2'$$

[Open Calculator !\[\]\(17acf1afa8cdf0b67c53d4865a5ed469\_img.jpg\)](#)

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

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

$$\text{fx } v = \frac{V_i}{\text{tr}C_2'}$$

[Open Calculator !\[\]\(d8ab143e904bfa3467271eec5af75a9b\_img.jpg\)](#)

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













## 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)
- $C_0$  Initial Reactant Concentration (Mole per Cubic Meter)
- $F$  Fresh Molar Feed Rate (Mole per Second)
- $F_0$  Molar Feed Rate (Mole per Second)
- $F_0'$  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)
- $trC_2'$  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
- $u$  Volumetric Flow Rate (Cubic Meter per Second)
- $\tau$  Space Time (Second)
- $\tau_p$  Space Time for Plug Flow Reactor (Second)



## Constants, Functions, Measurements used

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



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- [Basics of Parallel & Single Reactions Formulas](#) 
- [Basics of Reactor Design and Temperature Dependency from Arrhenius Law Formulas](#) 
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