Important Formulas on Reversible Reaction PDF

Formulas
Examples
with Units

List of 23
Important Formulas on Reversible Reaction

1) Backward Reaction Rate Constant for 2nd Order Opposed by 1st Order Reaction Formula

Evaluate Formula

Formula

$$k2_b' = k_f' \cdot \frac{\left(A_0 - x_{eq}\right) \cdot \left(B_0 - x_{eq}\right)}{x_{eq}}$$

Example with Units

$$0.0265\,\text{m}^3/(\text{mol}*\text{s}) = 0.00618\,\text{L}/(\text{mol}*\text{s}) \cdot \frac{\left(100\,\text{mol/L} - 70\,\text{mol/L}\right) \cdot \left(80\,\text{mol/L} - 70\,\text{mol/L}\right)}{70\,\text{mol/L}}$$

2) Backward Reaction Rate Constant for 2nd Order Opposed by 2nd Order Reaction Formula

Evaluate Formula

Formula

$$k_b' = k_f' \cdot \frac{\left(A_0 - x_{eq}\right) \cdot \left(B_0 - x_{eq}\right)}{x_{eq}^2}$$

Example with Units

$$0.0004\,\text{L}/(\text{mol}*\text{s}) = 0.00618\,\text{L}/(\text{mol}*\text{s}) \cdot \frac{\left(100\,\text{mol/L} - 70\,\text{mol/L}\right) \cdot \left(80\,\text{mol/L} - 70\,\text{mol/L}\right)}{70\,\text{mol/L}^2}$$

3) Backward Reaction Rate Constant given Keq and kf Formula

Evaluate Formula

Formula

$$k_{bbr}' = K_{eqm} \cdot k_f'$$

Example with Units

$$0.1007\,\text{L}/(\text{mol}*\text{s}) = 16.3 \cdot 0.00618\,\text{L}/(\text{mol}*\text{s})$$

4) Concentration of Product C given kf and kb Formula

Evaluate Formula

Formula

$$[C]_{eq} = \frac{k_f'}{k_b'} \cdot \left(\frac{[A]_{eq} \cdot [B]_{eq}}{[D]_{eq}}\right)$$

Example with Units

$$19.5076\,\text{mol/L} = \frac{0.00618\,\text{L}/(\text{mol}*\text{s})}{0.000378\,\text{L}/(\text{mol}*\text{s})} \cdot \left(\frac{0.600\,\text{mol/L} \cdot 0.700\,\text{mol/L}}{0.352\,\text{mol/L}}\right)$$

5) Concentration of Product D given kf and kb Formula

Evaluate Formula

Formula

$$[D]_{eq} = \frac{k_f'}{k_b'} \cdot \left(\frac{[A]_{eq} \cdot [B]_{eq}}{[C]_{eq}}\right)$$

Example with Units

$$0.354\,\text{mol/L} = \frac{0.00618\,\text{L}/(\text{mol}*\text{s})}{0.000378\,\text{L}/(\text{mol}*\text{s})} \cdot \left(\frac{0.600\,\text{mol/L} \cdot 0.700\,\text{mol/L}}{19.4\,\text{mol/L}}\right)$$

6) Concentration of Reactant A given kf and kb Formula

Evaluate Formula

Formula

$$[A]_{eq} = \frac{k_b'}{k_f'} \cdot \left(\frac{[C]_{eq} \cdot [D]_{eq}}{[B]_{eq}}\right)$$

Example with Units

$$0.5967\,\text{mol/L} = \frac{0.000378\,\text{L}/(\text{mol}*\text{s})}{0.00618\,\text{L}/(\text{mol}*\text{s})} \cdot \left(\frac{19.4\,\text{mol/L} \cdot 0.352\,\text{mol/L}}{0.700\,\text{mol/L}}\right)$$

7) Concentration of Reactant B given kf and kb Formula

Evaluate Formula

Formula

$$[B]_{eq} = \frac{k_b'}{k_f'} \cdot \left(\frac{[C]_{eq} \cdot [D]_{eq}}{[A]_{eq}} \right)$$

Example with Units

$$0.6961\,\text{mol/L} = \frac{0.000378\,\text{L/(mol*s)}}{0.00618\,\text{L/(mol*s)}} \cdot \left(\frac{19.4\,\text{mol/L} \cdot 0.352\,\text{mol/L}}{0.600\,\text{mol/L}} \right)$$

8) Equilibrium Rate Constant given kf and kb Formula

Evaluate Formula

Formula

$$K_{eqm} = \frac{k_f'}{k_b'}$$

Example with Units

$$16.3492 = \frac{0.00618\,\text{L/(mol*s)}}{0.000378\,\text{L/(mol*s)}}$$

9) Forward Rate Constant given Keq and kb Formula

Evaluate Formula

Formula

$$k_{fr}' = K_{eq} \cdot k_b'$$

Example with Units

$$0.0227\,\text{L/(mol*s)} = 60 \cdot 0.000378\,\text{L/(mol*s)}$$

10) Forward Rxn Rate Const for 2nd Order Opposed by 1st Order Rxn given Ini Conc of Reactant B Formula

Evaluate Formula

Formula

$$k_{fB}' = \left(\frac{1}{t} \right) \cdot \left(\frac{x_{eq}}{B_0^2 - x_{eq}^2} \right) \cdot \ln \left(\frac{x_{eq} \cdot \left(B_0^2 - x \cdot x_{eq} \right)}{B_0^2 \cdot \left(x_{eq} - x \right)} \right)$$

Example with Units

$$1.8E\text{-}6\,\text{L/(mol*s)} = \left(\frac{1}{3600\,\text{s}} \right) \cdot \left(\frac{70\,\text{mol/L}}{80\,\text{mol/L}^2 - 70\,\text{mol/L}^2} \right) \cdot \ln \left(\frac{70\,\text{mol/L} \cdot \left(80\,\text{mol/L}^2 - 27.5\,\text{mol/L} \cdot 70\,\text{mol/L} \right)}{80\,\text{mol/L}^2 \cdot \left(70\,\text{mol/L} - 27.5\,\text{mol/L} \right)} \right)$$

11) Forward Rxn Rate Const for 2nd Order Opposed by 2nd Order Rxn given Ini Conc of Reactant A Formula

Evaluate Formula

Formula

$$k_{fA}' = \left(\frac{1}{t} \right) \cdot \left(\frac{x_{eq}^2}{2 \cdot A_0 \cdot \left(A_0 - x_{eq} \right)} \right) \cdot \ln \left(\frac{x \cdot \left(A_0 - 2 \cdot x_{eq} \right) + A_0 \cdot x_{eq}}{A_0 \cdot \left(x_{eq} - x \right)} \right)$$

Example with Units

$$0.0744\,\text{L/(mol*s)} = \left(\frac{1}{3600\,\text{s}} \right) \cdot \left(\frac{70\,\text{mol/L}^2}{2 \cdot 100\,\text{mol/L} \cdot \left(100\,\text{mol/L} - 70\,\text{mol/L} \right)} \right) \cdot \ln \left(\frac{27.5\,\text{mol/L} \cdot \left(100\,\text{mol/L} - 2 \cdot 70\,\text{mol/L} \right) + 100\,\text{mol/L} \cdot 70\,\text{mol/L}}{100\,\text{mol/L} \cdot \left(70\,\text{mol/L} - 27.5\,\text{mol/L} \right)} \right)$$

12) Product Conc for 1st Order Opposed by 1st Order Rxn given Initial Conc of B greater than 0 Formula

Evaluate Formula

Formula

$$x = x_{eq} \cdot \left(1 - \exp \left(- k_f \cdot \left(\frac{A_0 + B_0}{B_0 + x_{eq}} \right) \cdot t \right) \right)$$

Example with Units

$$24.042\,\text{mol/L} = 70\,\text{mol/L} \cdot \left(1 - \exp \left(- 0.0000974\,\text{s}^{-1} \cdot \left(\frac{100\,\text{mol/L} + 80\,\text{mol/L}}{80\,\text{mol/L} + 70\,\text{mol/L}} \right) \cdot 3600\,\text{s} \right) \right)$$

13) Product Conc of First Order Opposed by First Order Reaction given Initial Conc of Reactant Formula

Evaluate Formula

Formula

$$x = x_{eq} \cdot \left(1 - \exp\left(-k_f \cdot t \cdot \left(\frac{A_0}{x_{eq}}\right)\right)\right)$$

Example with Units

$$27.5817\,\text{mol/L} = 70\,\text{mol/L} \cdot \left(1 - \exp\left(-0.0000974\,\text{s}^{-1} \cdot 3600\,\text{s} \cdot \left(\frac{100\,\text{mol/L}}{70\,\text{mol/L}}\right)\right)\right)$$

14) Product Concentration of 1st Order Opposed by 1st Order Reaction at given Time t Formula

Evaluate Formula

Formula

$$x = x_{eq} \cdot \left(1 - \exp\left(-\left(k_f + k_b\right) \cdot t\right)\right)$$

Example with Units

$$27.5904\,\text{mol/L} = 70\,\text{mol/L} \cdot \left(1 - \exp\left(-\left(0.0000974\,\text{s}^{-1} + 0.0000418\,\text{s}^{-1}\right) \cdot 3600\,\text{s}\right)\right)$$

15) Rate Constant for Backward Reaction Formula

Evaluate Formula

Formula

$$k_{brc}' = k_f \cdot \frac{A_0 - x_{eq}}{x_{eq}^2}$$

Example with Units

$$6E\text{-}7\,\text{L/(mol*s)} = 0.0000974\,\text{s}^{-1} \cdot \frac{100\,\text{mol/L} - 70\,\text{mol/L}}{70\,\text{mol/L}^2}$$

16) Rate Constant for Forward Reaction Formula

Evaluate Formula

Formula

$$k_f = \left(\frac{1}{t}\right) \cdot \left(\frac{x_{eq}}{2 \cdot A_0 - x_{eq}}\right) \cdot \ln\left(\frac{A_0 \cdot x_{eq} + x \cdot \left(A_0 - x_{eq}\right)}{A_0 \cdot \left(x_{eq} - x\right)}\right)$$

Example with Units

$$9.1E\text{-}5\,\text{s}^{-1} = \left(\frac{1}{3600\,\text{s}}\right) \cdot \left(\frac{70\,\text{mol/L}}{2 \cdot 100\,\text{mol/L} - 70\,\text{mol/L}}\right) \cdot \ln\left(\frac{100\,\text{mol/L} \cdot 70\,\text{mol/L} + 27.5\,\text{mol/L} \cdot \left(100\,\text{mol/L} - 70\,\text{mol/L}\right)}{100\,\text{mol/L} \cdot \left(70\,\text{mol/L} - 27.5\,\text{mol/L}\right)}\right)$$

17) Reactant Concentration at given Time t Formula

Evaluate Formula

Formula

$$A = A_0 \cdot \left(\frac{k_f}{k_f + k_b}\right) \cdot \left(\left(\frac{k_b}{k_f}\right) + \exp\left(-\left(k_f + k_b\right) \cdot t\right)\right)$$

Example with Units

$$72.4209\,\text{mol/L} = 100\,\text{mol/L} \cdot \left(\frac{0.0000974\,\text{s}^{-1}}{0.0000974\,\text{s}^{-1} + 0.0000418\,\text{s}^{-1}}\right) \cdot \left(\left(\frac{0.0000418\,\text{s}^{-1}}{0.0000974\,\text{s}^{-1}}\right) + \exp\left(-\left(0.0000974\,\text{s}^{-1} + 0.0000418\,\text{s}^{-1}\right) \cdot 3600\,\text{s}\right)\right)$$

18) Time taken for 1st Order Opposed by 1st Order Reaction Formula

Evaluate Formula

Formula

$$t = \frac{\ln\left(\frac{x_{eq}}{x_{eq} - x}\right)}{k_f + k_b}$$

Example with Units

$$3584.7067\,\text{s} = \frac{\ln\left(\frac{70\,\text{mol/L}}{70\,\text{mol/L} - 27.5\,\text{mol/L}}\right)}{0.0000974\,\text{s}^{-1} + 0.0000418\,\text{s}^{-1}}$$

19) Time taken for 1st Order Opposed by 1st Order Reaction given Initial Concentration of Reactant Formula

Evaluate Formula

Formula

$$t = \left(\frac{1}{k_f}\right) \cdot \left(\frac{x_{eq}}{A_0}\right) \cdot \ln\left(\frac{x_{eq}}{x_{eq} - x}\right)$$

Example with Units

$$3586.1788\,s = \left(\frac{1}{0.0000974\,s^{-1}}\right) \cdot \left(\frac{70\,mol/L}{100\,mol/L}\right) \cdot \ln\left(\frac{70\,mol/L}{70\,mol/L - 27.5\,mol/L}\right)$$

20) Time taken for 2nd Order Opposed by 1st Order Reaction given Initial Conc of Reactant A Formula

Evaluate Formula

Formula

$$t = \left(\frac{1}{k_f'}\right) \cdot \left(\frac{x_{eq}}{\left(A_0^2\right) - \left(x_{eq}^2\right)}\right) \cdot \ln\left(\frac{x_{eq} \cdot \left(A_0^2 - x \cdot x_{eq}\right)}{A_0^2 \cdot \left(x_{eq} - x\right)}\right)$$

Example with Units

$$0.6334\,s = \left(\frac{1}{0.00618\,L/(mol*s)}\right) \cdot \left(\frac{70\,mol/L}{\left(100\,mol/L^2\right) - \left(70\,mol/L^2\right)}\right) \cdot \ln\left(\frac{70\,mol/L \cdot \left(100\,mol/L^2 - 27.5\,mol/L \cdot 70\,mol/L\right)}{100\,mol/L^2 \cdot \left(70\,mol/L - 27.5\,mol/L\right)}\right)$$

21) Time taken for 2nd Order Opposed by 2nd Order Reaction given Initial Conc of Reactant B Formula

Evaluate Formula

Formula

$$t_{2nd} = \left(\frac{1}{k_f'}\right) \cdot \left(\frac{x_{eq}^2}{2 \cdot B_0 \cdot \left(B_0 - x_{eq}\right)}\right) \cdot \ln\left(\frac{x \cdot \left(B_0 - 2 \cdot x_{eq}\right) + B_0 \cdot x_{eq}}{B_0 \cdot \left(x_{eq} - x\right)}\right)$$

Example with Units

$$74302.8643\,s = \left(\frac{1}{0.00618\,L/(mol*s)}\right) \cdot \left(\frac{70\,mol/L^2}{2 \cdot 80\,mol/L \cdot \left(80\,mol/L - 70\,mol/L\right)}\right) \cdot \ln\left(\frac{27.5\,mol/L \cdot \left(80\,mol/L - 2 \cdot 70\,mol/L\right) + 80\,mol/L \cdot 70\,mol/L}{80\,mol/L \cdot \left(70\,mol/L - 27.5\,mol/L\right)}\right)$$

22) Time Taken for Completion of Reaction Formula

Evaluate Formula

Formula

$$t = \left(\frac{1}{k_f}\right) \cdot \left(\frac{x_{eq}}{2 \cdot A_0 - x_{eq}}\right) \cdot \ln\left(\frac{A_0 \cdot x_{eq} + x \cdot \left(A_0 - x_{eq}\right)}{A_0 \cdot \left(x_{eq} - x\right)}\right)$$

Example with Units

$$3374.5327\,s = \left(\frac{1}{0.0000974\,s^{-1}}\right) \cdot \left(\frac{70\,mol/L}{2 \cdot 100\,mol/L - 70\,mol/L}\right) \cdot \ln\left(\frac{100\,mol/L \cdot 70\,mol/L + 27.5\,mol/L \cdot \left(100\,mol/L - 70\,mol/L\right)}{100\,mol/L \cdot \left(70\,mol/L - 27.5\,mol/L\right)}\right)$$

23) Time taken when Initial Concentration of Reactant B greater than 0 Formula

Evaluate Formula

Formula

$$t = \frac{1}{k_f} \cdot \ln\left(\frac{x_{eq}}{x_{eq} - x}\right) \cdot \left(\frac{B_0 + x_{eq}}{A_0 + B_0}\right)$$

Example with Units

$$4269.2605\,s = \frac{1}{0.0000974\,s^{-1}} \cdot \ln\left(\frac{70\,mol/L}{70\,mol/L - 27.5\,mol/L}\right) \cdot \left(\frac{80\,mol/L + 70\,mol/L}{100\,mol/L + 80\,mol/L}\right)$$

Variables used in list of Important Formulas on Reversible Reaction above

- $[A]_{eq}$ Concentration of Reactant A at Equilibrium *(Mole per Liter)*
- $[B]_{eq}$ Concentration of Reactant B at Equilibrium *(Mole per Liter)*
- $[C]_{eq}$ Concentration of Product C at Equilibrium *(Mole per Liter)*
- $[D]_{eq}$ Concentration of Product D at Equilibrium *(Mole per Liter)*
- **A** Concentration of A at Time t *(Mole per Liter)*
- A_0 Initial Concentration of Reactant A *(Mole per Liter)*
- B_0 Initial Concentration of Reactant B *(Mole per Liter)*
- k_b Backward Reaction Rate Constant *(1 Per Second)*
- k_b' Backward Reaction Rate Constant for 2nd Order *(Liter per Mole Second)*
- k_{bbr}' Backward Reaction Rate Constant given kf and Keq *(Liter per Mole Second)*
- k_{brc}' Rate Constant of Backward Reaction *(Liter per Mole Second)*
- K_{eq} Equilibrium Constant for Second Order Reaction
- K_{eqm} Equilibrium Constant
- k_f Forward Reaction Rate Constant *(1 Per Second)*
- k_f' Forward Reaction Rate Constant for 2nd Order *(Liter per Mole Second)*
- k_{fA}' Forward Reaction Rate Constant given A *(Liter per Mole Second)*
- k_{fB}' Forward Reaction Rate Constant given B *(Liter per Mole Second)*
- k_{fr}' Forward Reaction Rate Constant given kf and Keq *(Liter per Mole Second)*
- $k2_b'$ Rate Constant for Backward Reaction *(Cubic Meter per Mole Second)*
- **t** Time *(Second)*
- t_{2nd} Time for 2nd Order *(Second)*
- **x** Concentration of Product at Time t *(Mole per Liter)*
- x_{eq} Concentration of Reactant at Equilibrium *(Mole per Liter)*

Constants, Functions, Measurements used in list of Important Formulas on Reversible Reaction above

- Functions: **exp**, exp(Number)
  n an exponential function, the value of the function changes by a constant factor for every unit change in the independent variable.
- Functions: **ln**, ln(Number)
  The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.
- Measurement: **Time** in Second (s)
  Time Unit Conversion
- Measurement: **Molar Concentration** in Mole per Liter (mol/L)
  Molar Concentration 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 ($m^3/(mol*s)$), Liter per Mole Second (L/(mol*s))
  Second Order Reaction Rate Constant Unit Conversion

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