Practice Rate Law Problems - Chapter 17 Name ___________________________________

Per ___________

1. For the reaction 3 ClO^- (aq) $\rightarrow$ ClO_3^- (aq) + 2 Cl^- (aq) doubling the concentration of ClO^- quadruples the initial rate of formation of ClO_3^-. What is the rate expression for the reaction?

2. The reaction $C_6H_5N_2Cl$ (aq) + H_2O (l) $\rightarrow$ C_6H_5OH (aq) + N_2 (g) + HCl (aq) is first order in $C_6H_5N_2Cl$ and zero order in H_2O. What is the rate expression?

3. For the reaction H_3PO_4 (aq) + 3 I^- (aq) + 2 H^+ (aq) $\rightarrow$ H_3PO_3 (aq) + I_3^- (aq) + H_2O (l) the rate expression under certain conditions is given by Rate = $k[H_3PO_4][I^-][H^+]^2$. What method(s) could be used if you want to double the reaction rate?

4. What is the overall order of reaction for each of the following?
   a) Rate = $k[NO_2]^2$ b) Rate = k c) Rate = $k[H_2][Br_2]^{1/2}$ d) Rate = $k[NO]^2[O_2]$

5. For the reaction 2 NO (g) + Cl_2 (g) $\rightarrow$ 2 NOCl (g) If the concentration of NO is tripled, the rate of the reaction increases by a factor of nine. If the concentration of Cl_2 is cut in half, the rate of the reaction is decreased to half the original rate. Find the order of reaction for each reactant and write the rate expression for the reaction.

6. In the decomposition of ammonia on a platinum surface at 856°C , 2 NH_3 (g) $\rightarrow$ N_2 (g) + 3 H_2 (g) , changing the concentration of NH_3 has no effect on the rate. Write the rate law for the reaction.

7. A reaction has the experimental rate law of Rate = $k[A]^2$.
   a) What happens to the rate if the concentration of A is tripled?
   b) What happens to the rate if the concentration if A is reduced to one third the initial concentration?

8. The reaction 2 NO_2 (g) + O_3 (g) $\rightarrow$ N_2O_5 (s) + O_2 (g) is first order with respect to each reactant.
   a) Write the rate expression for the reaction
   b) How does doubling the concentration of NO_2 affect the reaction rate?
   c) How does tripling the concentration of O_3 affect the reaction rate?

9. For the reaction 2 A + B $\rightarrow$ C + D, if the concentration of A is doubled, the reaction rate doubles. If the concentration of B is halved, there is no change in the reaction rate. Determine the order of reaction with respect to each reactant and the overall order of reaction. Write the rate law for the reaction.

10. Describe four conditions that affect the rate of a reaction and use the principles of the collision theory to explain why each factor affects the rate as it does.

11-16: For each of the following sets of data, support your reasoning mathematically.

11. For the reaction A + B $\rightarrow$ AB , the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (mol/L•s)
1	0.720 M	0.180 M	0.470
2	0.720 M	0.720 M	1.880
3	0.360 M	0.180 M	0.117

   a) Determine the order with respect to each reactant
   b) Determine the overall order of reaction
   c) Write the rate expression for the reaction.
   d) Find the value of the rate constant, k.

12. For the reaction $2A + B \rightarrow A_2B$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (mol/L•s)
1	0.420 M	0.530 M	0.420
2	0.420 M	1.590 M	3.780
3	0.140 M	0.530 M	0.140

a) Determine the order with respect to each reactant
b) Determine the overall order of reaction
c) Write the rate expression for the reaction.
d) Find the value of the rate constant, k.

13. For the reaction $A + B \rightarrow AB$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (mol/L•min)
1	0.480 M	0.190 M	0.350
2	0.480 M	0.380 M	0.350
3	0.240 M	0.190 M	0.087

a) Determine the order with respect to each reactant
b) Determine the overall order of reaction
c) Write the rate expression for the reaction.
d) Find the value of the rate constant, k.

14. For the reaction $A + 2B \rightarrow AB_2$, the following data were obtained.

Trial	Initial [A]	Initial[B]	Initial Rate (M/hr)
1	0.660 M	0.470 M	0.370
2	0.660 M	0.940 M	1.480
3	0.220 M	0.470 M	0.123

a) Determine the order with respect to each reactant
b) Determine the overall order of reaction
c) Write the rate expression for the reaction.
d) Find the value of the rate constant, k.

15. For the reaction $2A + B_2 \rightarrow 2AB$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (M/s)
1	0.300 M	0.430 M	0.340
2	0.300 M	1.720 M	1.360
3	0.150 M	0.430 M	0.340

a) Determine the order with respect to each reactant
b) Determine the overall order of reaction
c) Write the rate expression for the reaction.
d) Find the value of the rate constant, k.

16. For the reaction $A + B \rightarrow AB$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (mol/L•hr)
1	0.600 M	0.360 M	0.460
2	0.600 M	1.080 M	1.380
3	0.200 M	0.360 M	0.051

a) Determine the order with respect to each reactant
b) Determine the overall order of reaction
c) Write the rate expression for the reaction.
d) Find the value of the rate constant, k.

17. The rate expression for a particular reaction is Rate = $[A][B]^2$. If the initial concentration of B is increased from 0.1 M to 0.3 M, the initial rate will increase by what factor?

18 . Consider the reaction A + 2B $\rightarrow$ C. The rate law for this reaction is second order in A and second order in B. If the rate constant at 25 °C is 1.25×10^{-2} s^{-1} , find the rate of reaction when the concentration of A is 0.27M and the concentration of B is 0.32 M.

19. Consider the reaction A + 2B $\rightarrow$ C + D. The rate law for this reaction is first order in A and first order in B. If the rate constant at 25 °C is 1.94×10^{2} s^{-1} , find the rate of reaction when the concentration of A is 0.68 M and the concentration of B is 0.14M.

20. Consider the reaction 2A + B $\rightarrow$ C + 2 D. The rate law for this reaction is first order in A and first order in B. If the rate constant at 25 °C is 3.01×10^{2} s^{-1} , find the rate of reaction when the concentration of A is 0.47 M and the concentration of B is 0.79 M

Practice Rate Law Problems - Chapter 17 Name ____________**KEY**________________

Per ___________

1. For the reaction 3 ClO^- (aq) $\rightarrow$ ClO_3^- (aq) + 2 Cl^- (aq) doubling the concentration of ClO^- quadruples the initial rate of formation of ClO_3^-. What is the rate expression for the reaction?

   Rate = k[ClO^-]^2

2. The reaction $C_6H_5N_2Cl$ (aq) + H_2O (l) $\rightarrow$ C_6H_5OH (aq) + N_2 (g) + HCl (aq) is first order in $C_6H_5N_2Cl$ and zero order in H_2O. What is the rate expression?

   Rate = k[$C_6H_5N_2Cl$]

3. For the reaction H_3PO_4 (aq) + 3 I^- (aq) + 2 H^+ (aq) $\rightarrow$ H_3PO_3 (aq) + I_3^- (aq) + H_2O (l) the rate expression under certain conditions is given by Rate = k[H_3PO_4][I^-][H^+]^2. What method(s) could be used if you want to double the reaction rate?

   Double the concentration of H_3PO_4 or double the concentration of I^-.

4. What is the overall order of reaction for each of the following?

   a) Rate = k[NO_2]^2 b) Rate = k c) Rate = k[H_2][Br_2]$^{1/2}$ d) Rate = k[NO]^2[O_2]

   a) second order **b) zero order** **c) 3/2 order** **d) third order**

5. For the reaction 2 NO (g) + Cl_2 (g) $\rightarrow$ 2 NOCl (g) If the concentration of NO is tripled, the rate of the reaction increases by a factor of nine. If the concentration of Cl_2 is cut in half, the rate of the reaction is decreased to half the original rate. Find the order of reaction for each reactant and write the rate expression for the reaction. **Second order with respect to NO and first order with respect to Cl_2.**

   Rate = k[NO]^2[Cl_2]

6. In the decomposition of ammonia on a platinum surface at 856°C , 2 NH_3 (g) $\rightarrow$ N_2 (g) + 3 H_2 (g) , changing the concentration of NH_3 has no effect on the rate. Write the rate law for the reaction.

   Rate = k

7. A reaction has the experimental rate law of Rate = k[A]^2.

   a) What happens to the rate if the concentration of A is tripled?

   b) What happens to the rate if the concentration if A is reduced to one third the initial concentration?

   a) Rate is increased by a factor of 9 (nine times as fast as the original rate)

   b) Rate is decreased to 1/9 the original rate

8. The reaction 2 NO_2 (g) + O_3 (g) $\rightarrow$ N_2O_5 (s) + O_2 (g) is first order with respect to each reactant.

   a) Write the rate expression for the reaction **Rate = k[NO_2][O_3]**

   b) How does doubling the concentration of NO_2 affect the reaction rate? **Doubles the rate**

   c) How does tripling the concentration of O_3 affect the reaction rate? **Triples the rate**

9. For the reaction 2 A + B $\rightarrow$ C + D, if the concentration of A is doubled, the reaction rate doubles. If the concentration of B is halved, there is no change in the reaction rate. Determine the order of reaction with respect to each reactant and the overall order of reaction. Write the rate law for the reaction.

   First order with respect to A, zero order with respect to B. First order overall.

   Rate = k[A]

10. Describe four conditions that affect the rate of a reaction and use the principles of the collision theory to explain why each factor affects the rate as it does.

    (1) Concentration of reactants. (or pressure if referring to gases)

A reaction only occurs if the reactant particles collide. If there are very few particles present, the chances of collision are very slight, so few reactions will take place per unit time. If the concentration is high, the chance of a collision is much greater, and more collisions will take place per unit time, resulting in a faster reaction rate.

(2) Temperature.

Temperature affects reaction rate two ways: Changing the temperature will change the number of effective collisions per unit time (this is by far the dominating factor) and it changes the number of collisions overall per unit time. An increase in temperature will result in more particles having enough energy to overcome the activation energy barrier. Without this energy, the collisions that occur will not result in a reaction. If more of the collisions per unit time can result in a reaction, the rate of reaction will increase.

(3) Nature of the reactants

For example, the size and shape of a reactant will affect the number of effective collisions possible. Since a reaction will only occur if particles collide in the correct orientation, a large, complex molecule will result in a slower reaction rate. The collisions would occur, but there would be less likelihood of the particles colliding in the correct orientation, so fewer reactions would take place per unit time. The strength of the bonds within the reactants will also have an effect. If it takes a lot of energy to break a bond in order for a reaction to occur, fewer particles will have enough energy when they collide to overcome the activation energy barrier, so there will be fewer effective collisions per unit time.

(4) Presence or absence of a catalyst

A catalyst changes the mechanism of the reaction to a pathway with a lower activation energy. Since less energy is needed to overcome the activation energy barrier, more of the particles will have the required amount of energy, so more of the collisions will be effective. (Reminder: The presence of a catalyst does NOT change the amount of energy the particles have, it only changes the amount of energy needed for the reaction to occur)

(5) Surface area of a solid reactant (this factor pertains to heterogeneous reactions only)

The more contact that can occur between reactants, the faster the reaction will be. With a solid, large pieces expose only a small number of the reactant particles to another reactant, so collisions cannot occur. If collisions do not occur, no reaction will take place.

11-16: For each of the following sets of data, support your reasoning mathematically.

11. For the reaction $A + B \rightarrow AB$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (mol/L•s)
1	0.720 M	0.180 M	0.470
2	0.720 M	0.720 M	1.880
3	0.360 M	0.180 M	0.117

a) Determine the order with respect to each reactant **Second order in A, first order in B**

b) Determine the overall order of reaction **Third order overall**

c) Write the rate expression for the reaction. **Rate = $k[A]^2[B]$**

d) Find the value of the rate constant, k. **k = 5.04**

12. For the reaction $2A + B \rightarrow A_2B$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (mol/L•s)
1	0.420 M	0.530 M	0.420
2	0.420 M	1.590 M	3.780
3	0.140 M	0.530 M	0.140

a) Determine the order with respect to each reactant **First order in A, second order in B**

b) Determine the overall order of reaction **Third order overall**

c) Write the rate expression for the reaction. **Rate = $k[A][B]^2$**

d) Find the value of the rate constant, k. **k = 3.56**

13. For the reaction $A + B \rightarrow AB$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (mol/L•min)
1	0.480 M	0.190 M	0.350
2	0.480 M	0.380 M	0.350
3	0.240 M	0.190 M	0.087

a) Determine the order with respect to each reactant **Second order in A, zero order in B**
b) Determine the overall order of reaction **Second order overall**
c) Write the rate expression for the reaction. **Rate = k$[A]^2$**
d) Find the value of the rate constant, k. **k = 1.52**

14. For the reaction $A + 2B \rightarrow AB_2$, the following data were obtained.

Trial	Initial [A]	Initial[B]	Initial Rate (M/hr)
1	0.660 M	0.470 M	0.370
2	0.660 M	0.940 M	1.480
3	0.220 M	0.470 M	0.123

a) Determine the order with respect to each reactant **First order in A, second order in B**
b) Determine the overall order of reaction **Third order overall**
c) Write the rate expression for the reaction. **Rate = k$[A][B]^2$**
d) Find the value of the rate constant, k. **k = 2.54**

15. For the reaction $2A + B_2 \rightarrow 2AB$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (M/s)
1	0.300 M	0.430 M	0.340
2	0.300 M	1.720 M	1.360
3	0.150 M	0.430 M	0.340

a) Determine the order with respect to each reactant **Zero order in A, first order in B**
b) Determine the overall order of reaction **First order overall**
c) Write the rate expression for the reaction. **Rate = k[B]**
d) Find the value of the rate constant, k. **k = 0.791**

16. For the reaction $A + B \rightarrow AB$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (mol/L•hr)
1	0.600 M	0.360 M	0.460
2	0.600 M	1.080 M	1.380
3	0.200 M	0.360 M	0.051

a) Determine the order with respect to each reactant **Second order in A, first order in B**
b) Determine the overall order of reaction **Third order overall**
c) Write the rate expression for the reaction. **Rate = $[A]^2[B]$**
d) Find the value of the rate constant, k. **k = 3.55**

17. The rate expression for a particular reaction is Rate = $[A][B]^2$. If the initial concentration of B is increased from 0.1 M to 0.3 M, the initial rate will increase by what factor?
Rate is increased by a factor of nine (nine times faster than the original rate)

18 . Consider the reaction $A + 2B \rightarrow C$. The rate law for this reaction is second order in A and second order in B. If the rate constant at 25 °C is 1.25×10^{-2} s^{-1} , find the rate of reaction when the concentration of A is 0.27M and the concentration of B is 0.32 M. **Rate = 9.3 x 10^{-5} M/s**

19. Consider the reaction $A + 2B \rightarrow C + D$. The rate law for this reaction is first order in A and first order in B. If the rate constant at 25 °C is 1.94×10^2 s^{-1} , find the rate of reaction when the concentration of A is 0.68 M and the concentration of B is 0.14M. **Rate = 18 M/s**

20. Consider the reaction $2A + B \rightarrow C + 2D$. The rate law for this reaction is first order in A and first order in B. If the rate constant at 25 °C is 3.01×10^2 s^{-1} , find the rate of reaction when the concentration of A is 0.47 M and the concentration of B is 0.79 M. **Rate = 110 M/s**