ChemQuest 43

Rate and Concentration

Name: _____

Date: _____

Hour: _____

Information: Reaction Order

Below is a table of data corresponding to the following balanced equation:

$$2\ ClO_2\ (aq) + 2\ OH^-\ (aq) \rightarrow ClO_3^-\ (aq) + ClO_2^-\ (aq) + H_2O\ (l)\ .$$

Six experiments were carried out with differing concentrations of ClO_2 and OH^- in each experiment. The measurement of how quickly ClO_2 disappears is given in the table for each of the six experiments. How quickly a reactant disappears (or how quickly a product forms) is a good measurement of how fast a reaction takes place.

Table 1: Experimental data for the reaction of ClO_2

Experiment	**Initial [ClO_2]**	**Initial [OH^-]**	**Initial Rate of disappearance of ClO_2 (M/s)**
1	0.020	0.030	0.00276
2	0.040	0.030	0.01104
3	0.020	0.060	0.00552
4	0.040	0.060	0.02208
5	0.040	0.090	0.03312
6	0.120	0.030	0.09936

Critical Thinking Questions

1. What happens to the rate of a reaction as the concentrations of the reactants increases? Justify your answer with data from the table above.

2. Consider the molecular level of what is happening when ClO_2 reacts with OH^- to form products. Offer an explanation for why changing the concentration of reactants changes the rate of a reaction.

3. Does the reaction depend on the concentration of ClO_2 and the concentration of OH^- equally? In other words, is the rate more dependent on ClO_2, on OH^-, or is it equally dependent on the concentration of both. Justify your answer.

4. If you wanted to know how the rate of reaction depends on the concentration of ClO_2 you could compare experiments 1 and 2. But if you compared experiments 1 and 4, you would not be able to accurately see how the reaction depends on the concentration of ClO_2. Why?

5. Which two experiments would you want to compare to determine how much the rate of reaction depends upon the concentration of OH^-?

   A) 1 and 4 B) 5 and 6 C) 1 and 6 D) 1 and 3

6. Considering $[ClO_2]$ in experiments 1 and 2, complete the following sentence.

   When $[ClO_2]$ increases by a factor of 2, the rate of reaction increases by a factor of 2 to the ____ power.

7. Considering $[OH^-]$ in the two experiments you identified in question 5, complete the following sentence.

   When $[OH^-]$ increases by a factor of 2, the rate of reaction increases by a factor of 2 to the ____ power.

8. Considering $[ClO_2]$ in experiments 2 and 6, complete the following sentence.

   When $[ClO_2]$ increases by a factor of 3, the rate of reaction increases by a factor of 3 to the ____ power.

9. Considering $[OH^-]$ in experiments 2 and 5, complete the following sentence.

   When $[OH^-]$ increases by a factor of 3, the rate of reaction increases by a factor of 3 to the ____ power.

10. The rate dependence with respect to $[ClO_2]$ is said to be <u>second order</u>. Given your answers to questions 6 and 8, explain what "second order" means.

11. The rate dependence with respect to $[OH^-]$ is said to be <u>first order</u>. Given your answers to questions 7 and 9, explain what "first order" means.

12. Can you find the order for a reactant just by looking at the balanced equation?

13. The overall "order" of the reaction for this reaction is <u>third order</u>. Explain how the overall order of a reaction is found.

Information: Rate Law

Once you know the order with respect to each reactant, you can determine the "rate law" for the reaction. Each reaction has a different rate law. The rate law is a convenient way of expressing how the rate of a reaction depends upon concentration. The rate law for the reaction we have been considering so far is

$$\text{Rate} = k[ClO_2]^2[OH^-]^1$$

Each reaction has a rate constant, given the symbol k. As you will soon see, the rate constant can be determined from experiments in a similar fashion to how you determined the orders for reactants.

Critical Thinking Questions

14. What is the relationship between the order of the reactant and the exponent for the reactant in the rate law?

15. Using the data from any of the six experiments in Table 1, verify that the rate constant is 230 $1/(M^2s)$. For example, let's pick experiment 3 to use. The rate is given and so are the concentrations of ClO_2 and OH^-. Plug these given data into the rate law and solve for k. Use units in your calculation to verify that the units for k are $1/(M^2s)$.

16. Now that you know the rate constant, you can calculate the rate for any concentration of reactants. For example, calculate the rate of reaction when the concentration of ClO_2 is 0.32 and the concentration of OH^- is 0.42.

Skill Practice

17. In a certain reaction, it is discovered that if the concentration of a reactant is tripled, then the rate of the reaction increases from 0.0670 M/s to 1.809 M/s. What is the order with respect to this reactant?

18. Given the following data, write the rate law for the reaction. Then find the rate constant (include units).

$$H_2O_2 + 2\,HI \rightarrow 2\,H_2O_2 + I_2$$

Experiment	$[H_2O_2]$	[HI]	Rate (M/s)
1	0.1	0.1	0.0076
2	0.1	0.2	0.0608
3	0.2	0.2	0.2432