ChemQuest 42

Rates of Reactions Introduction

Name: ____________________
Date: ____________
Hour: _____

Information: Average Rate of Reaction

Recall that during a chemical reaction reactants are transformed into products: A + B → C + D. A very important question is: how fast do such processes happen? For example, we need to know how long it will take for a medicine to work in our bodies and how long will it take to produce chemicals in industry.

How fast do reactants A and B disappear? How fast do products C and D form? We can express such questions in the form of an equation as shown below.

$$\text{rate of disappearance of reactant A} = -\frac{\text{change in molarity of reactant A}}{\text{change in time}} = -\frac{\Delta[\text{reactant A}]}{\Delta\text{time}}$$

Keep in mind that all rates are written as positive numbers; thus, the function for the negative sign in the above equation is to yield a positive result for the rate.

Critical Thinking Questions

1. What is molarity?
   Molarity is a measure of the moles of solute per liter of solution.

2. What do the symbols Δ and [ ] mean in the above equation?
   Δ means "change" and [ ] means concentration in molarity.

3. What units would you expect for the rate of disappearance of a reactant? (Assume time is measured in seconds.)
   Molarity per second

4. How is the change in molarity of a reactant calculated? Would this be a positive or a negative number?
   Final molarity minus initial molarity. It would be a negative number because the molarity of a reactant decreases as the reaction proceeds.

5. How is the change in molarity of a product calculated? Would this be a positive or a negative number?
   Final molarity minus initial molarity. It would be a positive number because the molarity of a product increases as the reaction proceeds.

6. When writing the equation for the rate of formation of a product, the negative sign in the above equation is not needed. Explain why.
   The only purpose of the negative sign is to give a positive number and the negative sign is only needed for calculating the change in concentration for a reactant because the change will be a negative number, as mentioned in our answer to question 4.

Information: Stoichiometry and Average Rate

Consider the decomposition of N_2O_5 and the experimental data for the reaction taking place inside a container that has a volume of 3.0 L.

$$2\,N_2O_5\,(g) \rightarrow 4\,NO_2\,(g) + O_2\,(g)$$

Time (s)	Moles N_2O_5	Moles NO_2	Moles O_2
0	0.4320	0	0
600	0.4194	0.0252	0.0063
1200	0.4104	0.0432	0.0108
1800	0.4032	0.0576	0.0144

Critical Thinking Questions

7. Calculate the change in moles of each reactant and product between 600 and 1200 seconds.

change in moles of N_2O_5: 0.4194 – 0.4104 = 0.0090

change in moles of NO_2: 0.0432 – 0.0252 = 0.0180

change in moles of O_2: 0.0108 – 0.0063 = 0.0045

8. Compare your answers in question 7. What is the relationship between the coefficients in the balanced chemical equation and the number of moles used up or produced in a reaction?
   The change in N_2O_5 is twice the change in O_2 which corresponds to the 2:1 ratio of the balanced equation. Also, the change in NO_2 is twice the change of N_2O_5, which also corresponds to the 4:2 ratio of the balanced equation.

9. Fill in the missing blanks in the table above.
   $\Delta[O_2]$ = 0.0144-0.0108 = 0.0036; $\Delta[NO_2]$ = 4(0.0036) = 0.0144; $\Delta[N_2O_5]$=2(0.0036) = 0.0072

10. Calculate the following values. Be sure to use molarity in your calculations.
    a) Rate of disappearance of N_2O_5 between time 0 and 600 s.

$$\frac{\frac{0.4194\text{ mol}}{3.0\text{ L}} - \frac{0.4320\text{ mol}}{3.0\text{ L}}}{600\text{ s} - 0\text{ s}} = \frac{0.1398 - 0.144}{600} = -7.0\text{x}10^{-6}\text{ M/s}$$

    b) Rate of appearance of NO_2 between time 0 and 600 s.

$$\frac{\frac{0.0252\text{ mol}}{3.0\text{ L}} - \frac{0\text{ mol}}{3.0\text{ L}}}{600\text{ s} - 0\text{ s}} = \frac{0.0084}{600} = 1.4\text{x}10^{-5}\text{ M/s}$$

    c) Rate of appearance of O_2 between time 0 and 600 s.

$$\frac{\frac{0.0063\text{ mol}}{3.0\text{ L}} - \frac{0\text{ mol}}{3.0\text{ L}}}{600\text{ s} - 0\text{ s}} = \frac{0.0021}{600} = 3.5\text{x}10^{-6}\text{ M/s}$$

11. Compare each of the rates. What relationship exists between the rates and the coefficients in the balanced chemical equation?

They are related by the coefficients in the balanced equation so that

Rate O_2 = 2(Rate N_2O_5) = 4(Rate NO_2)

12. Calculate the following values. Be sure to use molarity in your calculations.

a) Rate of disappearance of N_2O_5 between time 600 and 1200 s.

$$\frac{\frac{0.4104\text{ mol}}{3.0\text{ L}} - \frac{0.4194\text{ mol}}{3.0\text{ L}}}{600\text{ s} - 0\text{ s}} = \frac{0.1368 - 0.1398}{600} = -5.0x10^{-6}\text{ M/s}$$

b) Rate of appearance of NO_2 between time 600 and 1200 s.

Rate NO_2 = 2(RateN_2O_5) = 2(5.0x10^{-6}) = 1.0x10^{-5} M/s

c) Rate of appearance of O_2 between time 600 and 1200 s.

Rate O_2 = 1/2(Rate N_2O_5) = 2.5x10^{-6} M/s

13. As the reaction proceeds are the rates constant? What affects the rate?

No, they are not constant. The rates are gradually slowing. For example, between 0 and 600 seconds N_2O_5 was disappearing at a rate of 7.0x10^{-6} M/s, but between 600 and 1200 seconds N_2O_5 was disappearing at a rate of 5.0x10^{-6} M/s. The other reactants also slowed. It seems that rate is dependent on concentration.