



## Rates of Reaction

Consider the decomposition of dinitrogen pentoxide:



Suppose the average rate of change in  $\text{N}_2\text{O}_5$  concentration per second was determined to be  $-1.36 \times 10^{-3} \text{ M/s}$  at a particular moment:

$$\frac{\Delta[\text{N}_2\text{O}_5]}{\Delta t} = -1.36 \times 10^{-3} \text{ M/s}$$

Since 4 mol  $\text{NO}_2$  are produced for every 2 mol of  $\text{N}_2\text{O}_5$  used, the average rate of formation of  $\text{NO}_2$  would be:

$$\frac{\Delta[\text{NO}_2]}{\Delta t} = \left(\frac{4}{2}\right)(1.36 \times 10^{-3} \text{ M/s}) = 2.72 \times 10^{-3} \text{ M/s}$$

Since 1 mol  $\text{O}_2$  is produced for every 2 mol  $\text{N}_2\text{O}_5$  that react, the average rate of formation of  $\text{O}_2$  would be:

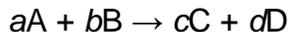
$$\frac{\Delta[\text{O}_2]}{\Delta t} = \left(\frac{1}{2}\right)(1.36 \times 10^{-3} \text{ M/s}) = 6.80 \times 10^{-4} \text{ M/s}$$

The average rate of reaction could also be written:

$$-\frac{1}{2} \frac{\Delta[\text{N}_2\text{O}_5]}{\Delta t} = \frac{1}{4} \frac{\Delta[\text{NO}_2]}{\Delta t} = \frac{\Delta[\text{O}_2]}{\Delta t} = 6.80 \times 10^{-4} \text{ M/s}$$

Note: The units  $\text{M/s}$  could also be written as  $\text{mol/L}\cdot\text{s}$ ,  $\text{mol L}^{-1}\text{s}^{-1}$  or  $\text{M s}^{-1}$ .

In general, for the reaction:



the rate of reaction is defined by:

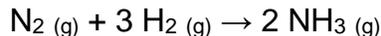
$$\text{rate} = -\frac{1}{a} \frac{\Delta\text{A}}{\Delta t} = -\frac{1}{b} \frac{\Delta\text{B}}{\Delta t} = \frac{1}{c} \frac{\Delta\text{C}}{\Delta t} = \frac{1}{d} \frac{\Delta\text{D}}{\Delta t}$$

Note the use of a negative sign denotes a decrease in the concentration of a reactant with time, and a positive sign denotes the increase in the concentration of a product with time.



## EXERCISES

A. Consider the reaction:



Fill in the blanks:

- 1) For every molecule of  $\text{N}_2$  that reacts, \_\_\_\_\_ molecules of  $\text{H}_2$  react.  
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- 2) Hydrogen is disappearing \_\_\_\_\_ as fast as the nitrogen.  
how many times ?
- 3) For every molecule of  $\text{N}_2$  that reacts, \_\_\_\_\_ molecules of  $\text{NH}_3$  are formed.  
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- 4) The rate at which  $\text{NH}_3$  is formed is \_\_\_\_\_ as fast as the rate at which the  $\text{N}_2$  disappears.  
how many times ?

B. Consider the following equation:



Suppose that at a particular moment, the ammonia is reacting at a rate of  $0.24 \text{ mol L}^{-1}\text{s}^{-1}$ .

- 1) Write the rate expression for this reaction.
- 2) What is the rate at which oxygen is reacting?
- 3) What is the rate at which NO is being formed?
- 4) What is the rate at which  $\text{H}_2\text{O}$  is being formed?

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## SOLUTIONS

A. (1) three (2) three times (3) two (4) twice

B. (1)  $-\frac{1}{4} \frac{\Delta[\text{NH}_3]}{\Delta t} = -\frac{1}{5} \frac{\Delta[\text{O}_2]}{\Delta t} = \frac{1}{4} \frac{\Delta[\text{NO}]}{\Delta t} = \frac{1}{6} \frac{\Delta[\text{H}_2\text{O}]}{\Delta t}$  (2)  $0.30 \text{ M/s}$  (3)  $0.24 \text{ M/s}$  (4)  $0.36 \text{ M/s}$

