

# AP Chemistry Unit 5.1: Measuring Reaction Rates

Static Study Guide • Unit 5 • Topic 1

# 1 What is Reaction Rate?

## Defining Reaction Rate

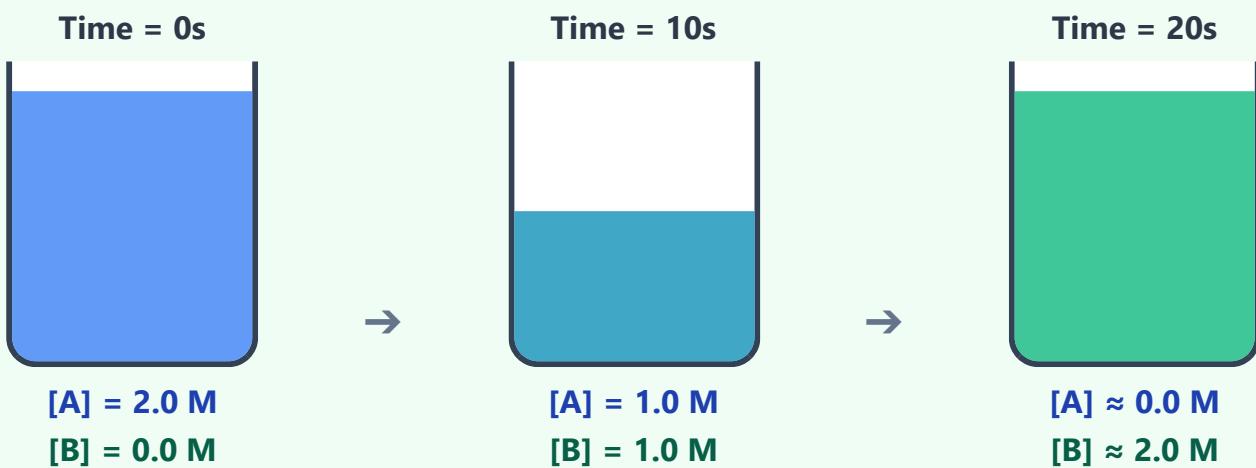
Reaction rate is the measure of how quickly reactants turn into products. Just as speed is distance per time (miles/hour), reaction rate is concentration per time.

### Core Definition

Reaction rate is the change in concentration of a reactant or product per unit time.

$$\text{Rate} = \frac{\text{Change in Concentration}}{\text{Change in Time}} = \frac{\Delta[\text{Concentration}]}{\Delta t}$$

## Visualizing Reaction Progress



### Key Observation:

**Rate decreases over time.** Notice how the reaction is fastest at the start (steepest change) when reactant concentration is highest. As reactants are used up (like fuel in a fire), the reaction slows down.



## Bathtub Analogy

### Bathtub Draining

- **Measure:** Water level (gallons)
- **Change:** Decreases over time
- **Formula:**  $\Delta\text{Volume} / \Delta\text{Time}$
- **Result:** -2 gal/min

### Chemical Reaction

- **Measure:** Concentration (Molarity)
- **Change:** Reactants decrease
- **Formula:**  $\Delta[\text{Concentration}] / \Delta\text{Time}$
- **Result:** -0.1 M/s

**Key Insight:** Both measure "how fast something changes" - water level vs. concentration!

### Units of Reaction Rate

Since Rate = Concentration / Time:

- **Concentration:** Molarity (M) = mol/L
- **Time:** Seconds (s), minutes (min), etc.
- **Standard Rate Unit: M/s** (Molarity per second)

**Note:** Reactant rates are negative (disappearing), Product rates are positive (appearing). We often express rate as a positive value by taking the absolute value or adding a negative sign to the reactant side formula.



## Section 1 Review Questions

### Question 1 (MCQ)

What does reaction rate measure?

**Answer:** The change in concentration per unit time

*Explanation: Rate is defined as  $\Delta[\text{concentration}]/\Delta t$ . It quantifies the speed of chemical change.*

## Question 2 (MCQ)

What are the standard units for reaction rate in AP Chemistry?

**Answer:** molarity per second (M/s)

*Explanation: Since concentration is Molarity (M) and standard time is seconds (s), the unit is M/s.*

## Question 3 (MCQ)

As a reaction proceeds, what happens to the concentration of reactants?

**Answer:** It decreases over time

*Explanation: Reactants are consumed to form products, so their concentration drops.*

## Question 4 (MCQ)

On a concentration vs. time graph, what does the slope of the curve represent?

**Answer:** The reaction rate at that moment

*Explanation: Slope = rise/run =  $\Delta$ Concentration/ $\Delta$ Time, which is the definition of rate.*

## Question 5 (MCQ)

Why does reaction rate typically decrease as the reaction proceeds?

**Answer:** There are fewer reactant molecules available

*Explanation: Fewer reactant molecules mean fewer collisions, resulting in a slower reaction.*

## Question 6 (Fill in Blank)

The formula for reaction rate is: Rate =  $\Delta$ [Concentration] /  $\Delta$ \_\_\_\_\_

**Answer:** time (or t)

### Question 7 (Fill in Blank)

As reactants are consumed, their concentration \_\_\_\_\_ over time.

**Answer:** decreases

### Question 8 (Fill in Blank)

The steeper the slope on a concentration vs. time graph, the \_\_\_\_\_ the reaction rate.

**Answer:** faster

### Question 9 (Problem)

For the reaction  $A \rightarrow B$ , the concentration of A decreases from 1.50 M to 0.90 M over 30 seconds. Calculate the average rate of the reaction in M/s.

**Answer:** 0.02 M/s

*Explanation: Rate =  $-\Delta[A]/\Delta t = -(0.90 - 1.50) / 30 = -(-0.60)/30 = 0.02 \text{ M/s.}$*

### Question 10 (Problem)

A reaction has an instantaneous rate of 0.15 M/s at  $t = 5$  seconds. If the concentration of reactant at this time is 2.0 M, approximately how much will the concentration decrease in the next 2 seconds if the rate remains constant?

**Answer:** 0.30 M

*Explanation:  $\Delta[\text{Concentration}] = \text{Rate} \times \text{Time} = 0.15 \text{ M/s} \times 2 \text{ s} = 0.30 \text{ M.}$*



Not all species in a reaction change at the same rate. The coefficients in the balanced equation dictate the relative rates. To find the "overall" reaction rate, we divide the rate of any species by its stoichiometric coefficient.

### The Pizza Party Analogy

Recipe:  $2 \text{ Dough} + 3 \text{ Cheese} \rightarrow 1 \text{ Pizza}$

#### The Logic:

If you make **5 Pizzas** in 1 minute:

- You used **10 Dough** ( $5 \times 2$ )
- You used **15 Cheese** ( $5 \times 3$ )

#### The Math (Normalization):

- Pizza Rate:  $5 \div 1 = 5$
- Dough Rate:  $10 \div 2 = 5$
- Cheese Rate:  $15 \div 3 = 5$

Dividing by the "recipe number" (coefficient) gives you the same rate for everything!

### General Formula for Rate Relationships

For reaction:  $aA + bB \rightarrow cC + dD$

$$\text{Rate} = -\frac{1}{a} \frac{\Delta[A]}{\Delta t} = -\frac{1}{b} \frac{\Delta[B]}{\Delta t} = +\frac{1}{c} \frac{\Delta[C]}{\Delta t} = +\frac{1}{d} \frac{\Delta[D]}{\Delta t}$$

## Visual Example: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

If  $\text{H}_2\text{O}$  forms at **0.40 M/s**:

**$\text{H}_2$**

**Coefficient: 2**

Rate = 0.40 M/s

Normalized:  $0.40/2 =$   
**0.20**

**$\text{O}_2$**

**Coefficient: 1**

Rate = 0.20 M/s

Normalized:  $0.20/1 =$   
**0.20**

**$\text{H}_2\text{O}$**

**Coefficient: 2**

Rate = 0.40 M/s

Normalized:  $0.40/2 =$   
**0.20**

**The Overall Reaction Rate is 0.20 M/s**



### Section 2 Review Questions

#### Question 1 (MCQ)

For the reaction  $2\text{A} \rightarrow \text{B}$ , if A is disappearing at 0.60 M/s, at what rate is B forming?

**Answer:** 0.30 M/s

*Explanation: 2 moles of A make 1 mole of B. So B forms at half the rate A disappears.  $0.60 / 2 = 0.30$ .*

#### Question 2 (MCQ)

Why do we divide each species' rate by its coefficient?

**Answer:** To normalize rates and get the overall reaction rate

*Explanation: It provides a standard value for the reaction speed independent of which chemical you measure.*

### Question 3 (MCQ)

For the reaction  $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ , if  $\text{H}_2$  disappears at 0.40 M/s, what is the overall reaction rate?

**Answer:** 0.20 M/s

*Explanation: Overall Rate = Rate of Species / Coefficient =  $0.40 / 2 = 0.20 \text{ M/s.}$*

### Question 4 (MCQ)

In the pizza analogy ( $2 \text{ Dough} + 3 \text{ Cheese} \rightarrow 1 \text{ Pizza}$ ), if you use 10 dough per minute, how many cheese do you use per minute?

**Answer:** 15 cheese/min

*Explanation: Ratio is 2:3.  $(10 \text{ dough} / 2) = 5 \text{ batches. } 5 \text{ batches} \times 3 \text{ cheese} = 15.$*

### Question 5 (Fill in Blank)

For the reaction  $3\text{A} \rightarrow 2\text{B}$ , if A disappears at 0.90 M/s, then B forms at \_\_\_\_\_ M/s.

**Answer:** 0.60

*Explanation: Rate B =  $(2/3) \times \text{Rate A} = (2/3) \times 0.90 = 0.60.$*

### Question 6 (Fill in Blank)

When you divide each species' rate by its coefficient, you get the \_\_\_\_\_ reaction rate.

**Answer:** overall

### Question 7 (Problem)

For the reaction  $2\text{NO}_2 \rightarrow 2\text{NO} + \text{O}_2$ , if  $\text{NO}_2$  is disappearing at 0.50 M/s, at what rate is  $\text{O}_2$  forming?

**Answer:** 0.25 M/s

*Explanation: 2 moles  $\text{NO}_2$  produce 1 mole  $\text{O}_2$ . Rate  $\text{O}_2$  = Rate  $\text{NO}_2$  / 2 =  $0.50 / 2 = 0.25.$*

### Question 8 (Problem)

For the reaction  $4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O}$ , if the overall reaction rate is 0.10 M/s, at what rate is  $\text{H}_2\text{O}$  forming?

**Answer:** 0.60 M/s

*Explanation: Rate  $\text{H}_2\text{O} = \text{Overall Rate} \times \text{Coefficient} = 0.10 \times 6 = 0.60 \text{ M/s.}$*