



The Mathematics of Every Breath

Reading Worksheet — Level F | tahricteaches.com

Take a deep breath. The air filling your lungs right now contains roughly 2.2×10^{22} molecules of oxygen and nitrogen. That number — 22 sextillion — is derived from **Avogadro's number** (6.022×10^{23} per mole) and the approximate volume of a typical breath. It is a number so large it defies easy intuition. But it has a remarkable consequence: statistically, at least one molecule in every breath you take was once exhaled by Julius Caesar.

The reasoning is straightforward. Caesar lived approximately 2,000 years ago. In that time, his exhaled molecules have been thoroughly mixed into Earth's atmosphere by wind, weather, and oceanic evaporation. The atmosphere contains roughly 1.04×10^{44} molecules in total. A single breath exhales about 2.2×10^{22} molecules. After 2,000 years of **atmospheric diffusion**, those molecules are essentially evenly distributed across the entire globe. The math confirms that your current breath almost certainly contains at least one atom Caesar exhaled.

The same calculation applies to every person who ever lived — Cleopatra, Shakespeare, countless unnamed ancestors. We share air with all of history. The atmosphere is a kind of molecular commons, a shared physical inheritance stretching back billions of years. The molecules themselves carry no memory of their histories, but **statistical probability** forces us to acknowledge a physical truth: we are in molecular contact with the past.

This is the kind of fact Neil deGrasse Tyson deploys strategically. On its surface, it sounds like a party trick. But it carries genuine scientific content — a demonstration of Avogadro's number, of **atmospheric mixing** timescales, and of the law of large numbers applied to everyday experience. It makes abstract chemistry tangible in a way that no equation alone can achieve.

The deeper implication is philosophical. If the boundaries between "my air" and "Caesar's air" are meaningless at the molecular level, then the boundaries between self and world are more porous than we typically imagine. Atoms cycle through soil, ocean, atmosphere, and lung without regard for ownership or species. We inhale history. We exhale it back. Every breath is, in this sense, a small act of cosmic participation.



A. Vocabulary Matching

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|----------------------|--|
| 1. Avogadro's number | a. the number of particles in one mole of any substance (6.022×10^{23}) |
| 2. diffusion | b. the layer of gases surrounding Earth, held in place by gravity |
| 3. mole | c. a chemistry unit representing exactly 6.022×10^{23} particles |
| 4. probability | d. the movement of molecules from an area of high concentration to low concentration |
| 5. atmosphere | e. the mathematical likelihood that a particular event will occur |



B. True or False

- | | |
|---|---|
| 1. <input type="checkbox"/> T <input type="checkbox"/> F Avogadro's number is approximately 6.022×10^{23} . | 2. <input type="checkbox"/> T <input type="checkbox"/> F A typical breath contains about 2.2×10^{22} molecules. |
| 3. <input type="checkbox"/> T <input type="checkbox"/> F Caesar's exhaled molecules remain concentrated near Rome. | 4. <input type="checkbox"/> T <input type="checkbox"/> F Atmospheric diffusion distributes molecules evenly across the globe over time. |
| 5. <input type="checkbox"/> T <input type="checkbox"/> F The "Caesar breath" calculation applies only to Julius Caesar, not other historical figures. | 6. <input type="checkbox"/> T <input type="checkbox"/> F The atmosphere contains roughly 1.04×10^{44} total molecules. |
| 7. <input type="checkbox"/> T <input type="checkbox"/> F The "Caesar breath" idea demonstrates Avogadro's number in a real-world context. | 8. <input type="checkbox"/> T <input type="checkbox"/> F Tyson uses this fact only for entertainment, not for scientific education. |
| 9. <input type="checkbox"/> T <input type="checkbox"/> F At the molecular level, personal ownership of air molecules is meaningless. | |



C. Fill in the Blanks

Word Bank: diffusion mole atmosphere probability Avogadro

1. _____ number is the count of particles in one mole of any substance.

2. The movement of molecules from high concentration to low is called _____.

3. A _____ is a chemistry unit representing 6.022×10^{23} particles.

4. The _____ surrounding Earth holds all the air we breathe.

5. Statistical _____ tells us we almost certainly breathe molecules Caesar once exhaled.

D. Comprehension Questions

1. Explain the mathematical reasoning behind the "Caesar breath" claim.

2. How does atmospheric diffusion make the Caesar breath calculation possible?

3. What does Tyson mean when he says this fact makes "abstract chemistry tangible"?

E. Discussion Questions

1. The article calls the atmosphere "a shared physical inheritance." What does this mean, and what might it imply for how we think about the air we share?

2. "We inhale history. We exhale it back." Is this a scientific statement, a philosophical one, or both? Defend your answer with specific examples from the article.



Answer Key

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A. Vocabulary

1-a, 2-d, 3-c, 4-e, 5-b

B. True or False

1-T, 2-T, 3-F, 4-T, 5-F, 6-T, 7-T, 8-F, 9-T

C. Fill in the Blanks

1-Avogadro's, 2-diffusion, 3-mole, 4-atmosphere, 5-probability

D. Comprehension Questions

1. Caesar exhaled roughly 2.2×10^{22} molecules per breath; after 2,000 years of diffusion, those molecules are evenly spread across 10^{44} atmospheric molecules. The ratio shows at least one of Caesar's molecules is statistically present in every breath we take today.
2. Diffusion causes molecules to move from areas of high concentration to low concentration. Over 2,000 years, Caesar's exhaled molecules have been mixed by wind, weather, and evaporation across the entire global atmosphere, making them effectively uniformly distributed.
3. Avogadro's number is an abstract, enormous figure (6.022×10^{23}) that is hard to feel as real. The Caesar breath example connects it to a lived experience — a breath you can take right now — making the scale of that number feel concrete and imaginable.