

**Teacher’s Guide**

**Gas Laws and Scuba Diving**

***October 2023***

**Table of Contents**

[***Anticipation Guide***](#_1fob9te)***2***

Activate students’ prior knowledge and engage them before they read the article.

[***Reading Comprehension Questions***](#_3znysh7) ***3***

These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[***Graphic Organizer***](#_9f8azrtnp6p5) ***5***

Thishelps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.

[***Answers***](#_djipzn7z1r1b) ***6***

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

[***Additional Resources***](#_8qbtv1wio6jt) ***9***

Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.

***[Chemistry Concepts and Standards](#_gy1yjx1c39og) 10***

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Anticipation Guide

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. The air pressure at the top of a tall building is higher than at the bottom of the building. |
|  |  | 2. Diving 10 meters deep in water doubles the pressure exerted on your body. |
|  |  | 3. Pressure changes in your body when diving are most noticeable in body cavities containing air, such as the lungs, ears, and sinuses. |
|  |  | 4. The regulator of a scuba tank keeps the pressure in a diver’s lungs the same as surface air pressure. |
|  |  | 5. Scuba divers must ascend slowly and breathe regularly when ascending from a deep dive. |
|  |  | 6. Gases are more soluble in liquids at lower pressures. |
|  |  | 7. Formation of nitrogen gas bubbles in the blood can cause many physical problems for divers. |
|  |  | 8. Contamination of the air in scuba tanks is rare if a certified dive shop is used. |
|  |  | 9. Taking a hot shower right after a deep dive is recommended for scuba divers. |
|  |  | 10. Since 1983, for scuba divers use scuba computers to track depth of dives and calculate nitrogen absorption. |

# Student Reading Comprehension Questions

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: Use the article to answer the questions below.

1. List three relationships among gas properties that impact scuba diving.
2. Compare the air pressure at sea level and at the top of a tall mountain.
3. Why might your ears hurt during plane descent?
4. Are pressure changes greater in water or air? Explain.
5. What does it mean to say that two variables are related directly? What does it mean to say that two variables are related inversely? Give an example of each from the article.
6. If the pressure of a gas is doubled, what happens to the volume? Which law applies here?
7. A diver is at a depth of 20 m. How deep would a diver need to dive to double the pressure at 20 m?
8. Explain why vacationing scuba divers should not dive in the morning and then fly home in the afternoon.
9. Explain one way that technology has improved diving safety.

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. Research decompression sickness (the “bends”). What are the symptoms, causes, and treatment?
2. Research and explain the relationships between oxygen, carbon monoxide, and your blood.

# Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: As you read, complete the graphic organizer below to describe how an understanding of gas behavior and gas laws can help make scuba diving safer.

|  |  |  |
| --- | --- | --- |
| **Concept** | **Explanation** | **Effects on scuba diving** |
| **Boyle’s Law** |  |  |
| **Henry’s Law** |  |  |
| **Gas solubility and temperature** |  |  |
| **Important changes to scuba diving in past 40 years** (since publication of the original article) |  |  |

**Summary:** On the back of this sheet, write a short email (3-4 sentences) to a friend about the importance of understanding gas laws when scuba diving.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. List three relationships among gas properties that impact scuba diving.   
   Three relationships that impact scuba diving include pressure-volume effects, pressure-solubility, and temperature-solubility effects.
2. Compare the air pressure at sea level and at the top of a tall mountain.  
   Air pressure at sea level is greater than the air pressure at the top of a mountain.
3. Why might your ears hurt during plane descent?  
   Since the air pressure is lower at higher altitude, the pressure inside your ear is lower than the air pressure outside your ear as you begin to descend in a plane. You may feel pain as the inside and outside pressure equalize.
4. Are pressure changes greater in water or air? Explain.  
   For a specific depth change, pressure changes are greater in water than air because water (liquid) has a higher density than air (gas).
5. What does it mean to say that two variables are related directly? What does it mean to say that two variables are related inversely? Give an example of each from the article.  
   When two variables are related directly, they change in the same direction. For example, according to Henry’s Law, as the pressure above a liquid increases, the amount of gas that can dissolve increases. When two variables are inversely related, they change in opposite directions. For example, according to Boyle’s Law, as pressure increases, volume decreases. This relationship is also shown with temperature and gas solubility; at higher temperatures gases are less soluble.
6. If the pressure of a gas is doubled, what happens to the volume? Which law applies here?  
   If the pressure of a gas is doubled, the volume is cut in half. This is an example of Boyle’s Law.
7. A diver is at a depth of 20 m. How deep would a diver need to dive to double the pressure at 20 m?  
   According to the graphic, at 20 m, a diver feels 3 atm pressure. To experience a pressure of 6 atm, the diver would be at a depth of 50 m.
8. Explain why vacationing scuba divers should not dive in the morning and then fly home in the afternoon.  
   As a diver comes to the surface, water pressure decreases causing the solubility of dissolved air to decrease. The gas “comes out of solution” similar to seeing gas bubbles in an open soda bottle. At higher altitudes, the solubility of gas will further decrease, and gas bubbles can form in the blood. This can lead to health issues, some of which can be serious.
9. Explain one way that technology has improved diving safety.  
   One way that technology has improved diving safety is that diving tables published by the US Navy have been replaced by computers that divers wear. These computers monitor time and depth of a dive. They also provide guidelines for coming to the surface safely.
10. Research decompression sickness (the “bends”). What are the symptoms, causes, and treatment?  
    Decompression sickness occurs when dissolved gas comes out of solution and forms bubbles in the blood and body tissue. This can occur when divers rise rapidly to the surface of the water. Nitrogen is not used by the body the way oxygen is, so it is often the gas that causes the problem. The quantity of nitrogen gas that comes out of solution is a result of the length of time and depth of the dive. It can be prevented if divers come to the surface slowly, which allows some of the nitrogen gas to escape. Symptoms include joint pain, itchy skin, dizziness, and fatigue. Doctors treat decompression sickness by putting the diver in a hyperbaric recompression chamber. This process simulates a dive in that gas bubbles can be reabsorbed and oxygen can be given to help injured tissues.
11. Research and explain the relationships between oxygen, carbon monoxide, and your blood.   
    Oxygen gas is transported throughout the body by binding to a protein known as hemoglobin in the bloodstream. If a person inhales carbon monoxide gas in a contaminated scuba tank, this gas binds to the hemoglobin molecule instead of oxygen. In fact, carbon monoxide binds 200-300 times more than oxygen gas. This is how tissues and cells are deprived of oxygen during carbon monoxide poisoning.

**Graphic Organizer Rubric**

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

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# Additional Resources and Teaching Strategies

**Additional Resources**

* **Labs and demos**

* <https://teachchemistry.org/classroom-resources/crush-the-can>
* <https://teachchemistry.org/classroom-resources/exploring-gas-solubility>
* <https://teachchemistry.org/classroom-resources/density-of-gases-and-particle-diagrams>
* <https://teachchemistry.org/classroom-resources/three-station-gas-lab>
* **Simulations**

* <https://phet.colorado.edu/sims/html/gases-intro/latest/gases-intro_en.html>
* <https://www.learner.org/series/chemistry-challenges-and-solutions/when-chemicals-meet-water-the-properties-of-solutions/decompression-sickness-and-henrys-law-animation/>
* <https://teachchemistry.org/classroom-resources/gases-animation>
* **Lessons and lesson plans**

* <https://teachchemistry.org/classroom-resources/robert-boyle-video-questions>
* **Projects and extension activities**

* + <https://cen.acs.org/physical-chemistry/chemical-bonding/Periodic-Graphics-Gases-scuba-diving/96/i34>

**Teaching Strategies**

Consider the following tips and strategies for incorporating this article into your classroom:

* **Composition of Air:** Review the composition of air (approximately 78% N2, 21% O2, 1% other gases) before reading the article. Some students may not realize that air is almost 80% nitrogen gas (N2). See <https://www.noaa.gov/jetstream/atmosphere> for more detailed information.
* **Alternative to Anticipation Guide:** Before reading, ask students if they have snorkeled or been scuba diving. Ask them to describe the differences in the two activities. Ask how an understanding of chemistry might help them be safer scuba divers. Their initial ideas can be collected electronically via Jamboard, Padlet, or similar technology.
  + As they read, students can find information to confirm or refute their original ideas.
* After they read, ask students what they learned about gases and scuba diving. Ask students how the information will be helpful if they want to become certified scuba divers.
  + As an interesting side note, I once had a student who shared that he wanted to snorkel at a greater depth without diving, so he tried making a snorkel that was a meter long. It didn’t work, and this article helped him understand why! ~ *Susan Cooper*

# Chemistry Concepts and Standards

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Gases
* Gas laws
* Pressure
* Temperature
* Volume
* Solubility

**Correlations to Next Generation Science Standards**

This article relates to the following performance expectations and dimensions of the NGSS:

**HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**Disciplinary Core Ideas:**

* PS.1.A: Structure and Properties of Matter
* ETS.1.C: Optimizing the Design Solution

**Crosscutting Concepts:**

* Patterns
* Scale, proportion, and quantity
* Systems and system models

**Science and Engineering Practices:**

* Constructing explanations (for science) and designing solutions (for engineering)

**Nature of Science:**

* Scientific knowledge assumes an order and consistency in natural systems.

See how *ChemMatters* correlates to the[**Common Core State Standards** online](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html).