

NOT EVERY PATIENT NEEDS OXYGEN. EVERY PATIENT DESERVES THE RIGHT AMOUNT.

OXYGEN REVEALED

UNDERSTANDING OXYGEN AND
PRESCRIBING OXYGEN FOR PATIENTS



UNDERSTAND

The science of oxygen and how it works.



ASSESS

Evaluate oxygenation accurately and confidently.



PRESCRIBE

Choose the right flow, device, and target for each patient.



MONITOR

Track response, avoid harm, and adjust appropriately.



PROTECT

Avoid the risks of over-oxygenation and under-treatment.



THE RIGHT OXYGEN. THE RIGHT PATIENT. THE RIGHT OUTCOME.



NASAL CANNULA



SIMPLE MASK



VENTURI MASK



NON-REBREATHER



ALFRED RICKS JR., MD

THE INCREDIBLE MEDICAL SCHOOL

INCREDIBLE OXYGEN

Alfred Ricks Jr., M.D.



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Oxygen is the most abundant chemical element by mass in our biosphere, air, sea, and land. It is the third most abundant chemical element in the universe. It is about 90% of water and 66% of the human body.

Joseph Priestley, an Englishman, clergyman, and self taught chemist has been credited as discovering oxygen with his publication in 1775. He noticed that if mercuric oxide was heated, it produced a gas that made a candle burn faster. However, Carl Wilhelm Scheele, from Sweden, discovered oxygen in 1772. It was named by Antoine Laurent Lavoisier in 1774. Priestley was the first to isolate carbon monoxide.

The name is derived from the Greek “oxygenes” which means acid forming. It was believed that all acids contained oxygen.

The 10 Most Abundant Elements in the Universe (relative to silicon)

1. Hydrogen	40,000
2. Helium	3,100
3. Oxygen	22
4. Neon	8.6
5. Nitrogen	6.6
6. Carbon	3.5
7. Silicon	1.00
8. Magnesium	0.91
9. Iron	0.60
10. Sulfur	0.38

AIR COMPOSITION

<u>Compound</u>	<u>Percentage</u>
Nitrogen (N ₂)	78.084
Oxygen (O ₂)	20.947
Water vapor*	01.00 - 05.00
Argon (Ar)	0.934
Carbon dioxide (CO ₂)	0.031
	Total of Above = 99.996% total
Neon (Ne)	0.001818
Methane (CH ₄)	0.0002
Helium (He)	0.000524
Krypton (Kr)	0.000114
Hydrogen (H ₂)	0.00005
Xenon (Xe)	0.0000087
Ozone (O ₃)	0.000007
Nitrogen dioxide (NO ₂)	0.000002
Iodine (I ₂)	0.000001
Carbon monoxide (CO)	trace
Ammonia (NH ₃)	trace

Noble gases are any of the elements in Group 18 (Group O) of the periodic table, including helium, neon, argon, krypton, xenon, and radon, which are monatomic and with limited exceptions chemically inert. They are also called inert gases. A noble gas is an element with its outer electron shell completely filled, thus making them either totally or very unreactive. Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe), and Radon (Rn).

Water vapor* (When included in this list it is 1-5% of air.) The water vapor pressure depends only on the temperature in any gas saturated with water vapor. In the body (alveoli), the temperature is usually constant and the water vapor pressure remains at 47 mmHg.

THE ATOM

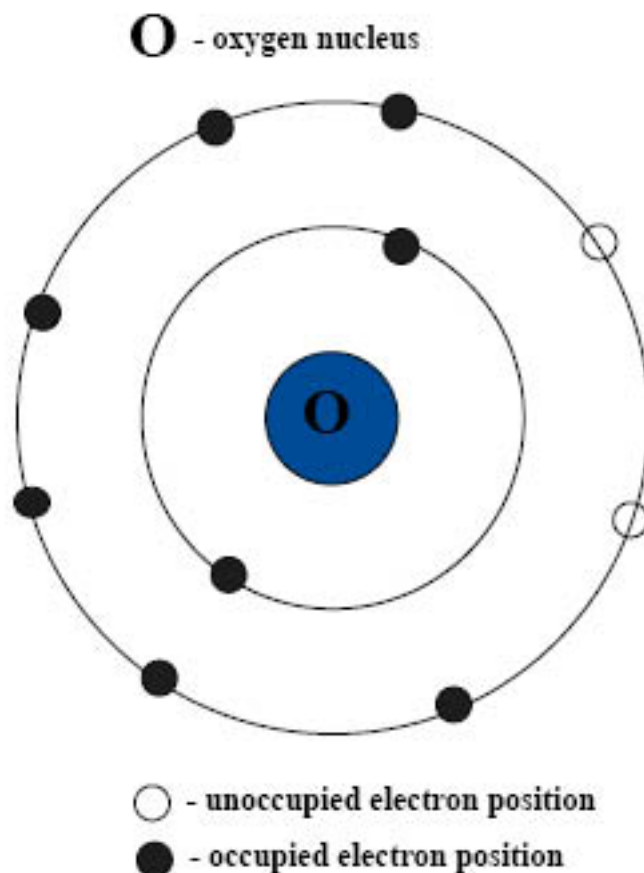
The **Atom** is the basic particle of matter. The center of the atom is the **nucleus**. The nucleus contains **protons** which are particles with a positive charge. The number of protons determines the type of atom. The nucleus also contains **neutrons** which are particles with no charge. In the space around the nucleus, there are negative charged particles called **electrons**. The size of the space determines the atom's size. The number and arrangement of the electrons in the 'electron cloud' around the nucleus determines properties of the atom such as bonds formed with adjacent atoms. **Ions** are atoms that have more or fewer electrons than protons. Atoms that have more electrons than protons are called **anions**. Atoms that have fewer electrons than protons are called **cations**.

Each element is composed of only one type of atom. The atom's type is determined by the number of protons in the nucleus. This number of protons is called the **atomic number**. You can find the atomic number for all elements in the periodic table of the elements.

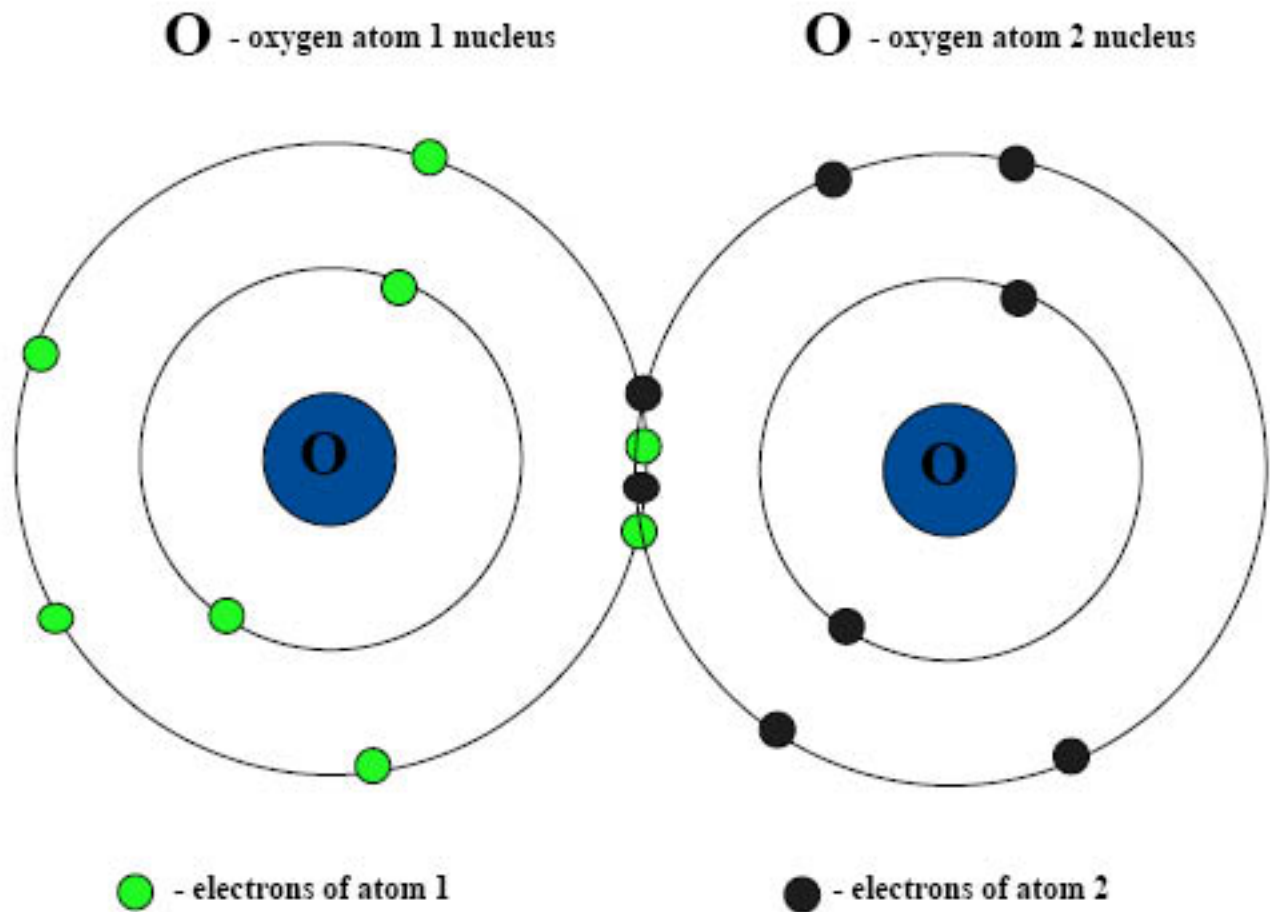
Almost all the **mass of an atom** is the protons and neutrons in the nucleus. **Isotopes** are atoms of an element with a different number of neutrons. The sum of the protons and neutrons in the nucleus is the **mass number**. The mass number is not the same as the **atomic mass** which is the actual mass (how much matter an atom contains) of an atom. The atomic mass is not simply adding up the masses of the protons, neutrons, and electrons. This atomic mass can be determined by experiments. To simplify the atomic mass for use in experiments, the atomic mass unit was developed. The **atomic mass unit** is the unit equal to one-twelfth the mass of carbon-12 (carbon atom with 6 protons and 6 neutrons). The atomic mass unit is the mass relative to the mass of carbon-12. It is approximately 1.660×10^{-27} kg. Oxygen was the atomic weight standard of comparison for the other elements until 1961 when carbon 12 was adopted as the new standard of comparison. The periodic table of the elements contains the atomic mass unit for each element. The number may be slightly different on various tables due to isotopes differences.

Two or more atoms bond to form **molecules**. Air contains oxygen as two atoms of oxygen (O_2) which have combined.

Although it is not possible to simply illustrate the actual electrons movement pattern in the electron cloud around the nucleus, we use a simple model to discuss the electrons.



The electrons in the outer layer are called the **valence** electrons. Oxygen has six valence electrons. Bonding of the atoms to form molecules and compounds is associated with the valence electrons in the outer layer. There are exceptions, but atoms tend to favor having eight electrons in the outer valence layer, so oxygen is usually listed as having a valence of -2 (the outer layer has 2 less than the eight electrons needed to complete the outer valence layer).



Oxygen (O₂)

Oxygen is a diatomic molecule which is a molecule containing two of the same atoms. The two atoms bond by sharing their two electrons with the other atom. This bonding, called a **covalent bond**, completes the eight electrons needed in each oxygen atom's outer layer.

Oxygen

A colorless, odorless, and tasteless gas. As a liquid or solid it is a pale blue color and strongly paramagnetic.

Atomic Number: 8

Symbol: O (monatomic oxygen gas)

Atomic Weight: 15.9994

Electron Configuration: [He]2s²2p⁴

Number of Protons/Electrons: 8

Number of Neutrons: 8

Isotopes: eight isotopes of oxygen are known. Natural oxygen is a mixture of three stable isotopes. Isotopes are the same element with the same number of protons in the nucleus (same atomic number) but with different numbers of neutrons.

Radioactive Isotopes: 14

Stable Isotopes: 3 (¹⁶O, ¹⁷O, ¹⁸O)

Element Classification: Non-Metal

Melting / Freezing Point (solid/liquid point): 54.36K, -218.79°C, -361.82°F

Boiling Point (liquid/gas point): 90.18K, -183.96°C, -297.31°F

Density: 1.149 g/cc (at -183°C)

Critical Temperature: -181.8°F (-118.4°C)

Critical Pressure: 729.1 psia (49.6 atm)

Covalent Radius: 73 pm

Ionic Radius: 132 (-2e)

Crystal Structure: Cubic

Specific Heat: 0.916 (O-O) (at 20°C J/g mol)

Pauling Negativity Number: 3.44

Oxidation States: -2, -1

Ozone, O₃ triatomic gas, is formed by the action of electrical discharge or by the action of ultraviolet light on oxygen.

When cooled to very low temperatures, oxygen changes from a gas to a liquid. Oxygen in liquid form occupies a much smaller volume than its gas form. A small volume of liquid oxygen which produces a large volume of oxygen gas can be transported and stored, such as at hospitals, in a small storage container. Liquid oxygen has an expansion ratio of 861:1.

Important information is found in **The Periodic Table of the Elements**. Below is a sample of some of the elements in the periodic table. You can find complete tables on the internet.

1	+1
H	
Hydrogen	
1.00794	

6	-4
C	
Carbon	
12.01	

8	-2
O	
Oxygen	
16	

19	+1
K	
Potassium	
39.1	

Atomic Number	Valence
Element Symbol	
Element Name	
Atomic Mass	
<i>KEY</i>	

12	+2
Mg	
Magnesium	
24.31	

11	+1
Na	
Sodium	
22.99	

17	-1
Cl	
Chlorine	
35.45	

20	+2
Ca	
Calcium	
40.08	

PARTIAL PRESSURE OF GASES IN AIR

Compound	Partial Pressure	
Nitrogen (N ₂)	593.4 mmHg	(760 mmHg X 78.084% = 593.4)
Oxygen (O ₂)	159.2 mmHg	
Argon (Ar)	7.09 mmHg	
Carbon dioxide (CO ₂)	0.235 mmHg	
Total of Above = 759.925 mmHg of Total of 760 mmHg		

UNDERSTANDING PRESSURE AS A MEASUREMENT OF AMOUNT

If a person weighs 200 pounds, they can stand on one leg and increase the pressure on that one leg. They could also change position to sitting on their buttocks, increasing the pressure on their buttocks and decreasing the pressure on the leg. Their weight remains the same, but the pressure at various points can change. Understanding that pressure is a measurement of force per unit area, and that weight is a measurement of the heaviness of an object, we will use them as the same for this discussion.

I have two containers. One has apples in it and the other has oranges in it. If I place one container on each of your shoulders you will feel the pressure (weight) of the containers pressing down on you. There are several ways that I can tell you how much pressure (weight) there is on you.

1- The apples weigh 156 pounds and the oranges weigh 42 pounds (other fruit weigh 2 pounds). The total weight is 200 pounds.

2- There are 780 apples and 210 oranges (10 of other fruit). The total is 1,000 fruits.

3- Apples are 78% of the total weight and oranges are 21% of the total weight (other fruit is 1% of the total weight).

4- Apples are 78% of the total number of fruits and oranges are 21% of the total number of fruits (other fruit are 1% of the total number of fruits).

Each of the amounts above provides information in a different way and can be used differently in measurements and calculations.

Just as the fruit (apples and oranges) can be measured differently, gases (air) can be measured differently.

weight (pounds, kilograms)

gas amount (cubic feet, cubic meters)

liquid amount (gallons, liters)

pressure (inHg, mmHg, psi, kPa)

Thinking of the fruit as apples and oranges, we can change it to air as nitrogen and oxygen:

Fruit: apples oranges other fruit

Air: nitrogen oxygen other gases

The measurement can now be applied to nitrogen and oxygen which make up our air (although the values are fictional).

1- The nitrogen weighs 156 pounds and the oxygen 42 pounds (other gases weigh 2 pounds). The total is 200 pounds.

2- There are 780 molecules of nitrogen and 210 molecules of oxygen (10 molecules of other gases). The total is 1,000 molecules.

3- nitrogen is 78% of the total weight and oxygen is 21% of the total weight (other gases are 1% of the total weight).

4- nitrogen is 78% of the total molecules and oxygen are 21% of the total molecules (other gases are 1% of the total molecules).

Now, let's look at the pressure (amount; weight) of nitrogen and oxygen (gases in air), and how they are measured.

PROPERTIES AND PRESSURES OF GASES

The molecules of various gases in a container (closed flask, tank, respiratory passages, atmosphere), constantly move against a surface. This causes a pressure. The pressures of each of the various gases in the container add up to a **total pressure**. Each of the gases pressure if acting alone is the **partial pressure** of the gas. The **Partial Pressure** is the pressure which a gas exerts. It depends on the number of moles of the gas in a given volume at a given temperature. The amount of gas in a solution depends on its partial pressure AND its solubility in the solution (solubility coefficient).

As we've seen air is made up of various gases primarily nitrogen, oxygen and carbon dioxide. If I blow this air into a balloon, the balloon expands as the amount of gas increases in the balloon. The amount of gases in the balloon is the pressure of the gases in the balloon. The molecules of nitrogen, oxygen, and carbon dioxide are moving and striking the wall of the balloon and producing the pressure. Each gas has a pressure. The gases together produce a total pressure and each gas alone produces a pressure which is the partial pressure of that gas. The pressure inside the balloon is higher than the surrounding pressure outside the balloon which is why the balloon is expanded. If we decrease the volume the pressure in the balloon must increase unless we release some of the gas inside the balloon. If we take the balloon to a higher altitude where the pressure outside the balloon will be less, the balloon will expand. If we take the balloon to a lower altitude where the pressure outside the balloon is higher, the balloon will shrink in size. Just as the gases inside the balloon produce a pressure, the gases in the atmosphere (air) also produce a pressure. This pressure of air at sea level is 760 mmHg. We know that the percentage of oxygen in the air is 21% and that the partial pressure of oxygen at sea level is 21% times 760 mmHg which is 159 mmHg. The partial pressure is the quantity of a gas.

When you blow up a balloon, you exert pressure on the inside walls of the balloon. When that pressure exceeds the outside air pressure plus the pressure exerted by the latex itself, the balloon begins to expand. The pressure inside a balloon is always a little higher than the surrounding air pressure, because the latex is pushing back as the air inside pushes out. When a balloon rises in the atmosphere, for example, the outside pressure decreases and the balloon expands. Eventually, the inside pressure causes the balloon to burst.

The atmospheric pressure is the pressure or weight of the overlying air. At sea level, this pressure is equal to the pressure needed to make a column of mercury 760 mm high. So the pressure is written as 760 mmHg. This is also referred to as 1 atmosphere.

1 atm = 760 mmHg = 760 torr. The atmospheric pressure is also measured in psi – pounds per square inch. If you take a 1 square inch column of air and extend it several miles up to the top of the atmosphere, it would have a pressure of 14.7 psi which is also a weight of 14.7 pounds. On the other hand, water is much heavier than air. A 1 square inch column of water only 33 feet high has the same pressure of 14.7 psi and would weigh 14.7 pounds.

The percentage of oxygen in the air at sea level is 21%. As you travel up in the atmosphere, the pressure decreases but the percentage of oxygen remains the same at 21%. It is the number of oxygen molecules that are less. An example:

(A) 42 oxygen molecules and 158 nitrogen molecules = 200 molecules. (42 is 21% of 200).

(B) 21 oxygen molecules and 79 nitrogen molecules = 100 molecules (21 is 21% of 100)

Think of “A” as at sea level and “B” as at 3,000 ft above sea level. As you can see, the percentage of oxygen is the same, but there are fewer molecules of oxygen (less oxygen).

We also use partial pressure when referring to gases dissolved in solutions such as blood. The partial pressure of a gas dissolved in blood is the partial pressure that the gas WOULD have if the gas were allowed to equilibrate with a volume of gas.

One classification of altitude uses the following:

High: 8,000 to 12,000 feet

Very High: 12,000 to 18,000 feet

Extremely High: Over 18,000 feet

The percentage of oxygen in the air is approximately the same up to over 50,000 feet. The molecules of oxygen in a volume (such as in a breath) is decreased but the percentage of oxygen (21%) is the same.

Charles' Law (or Gay-Lussac's Law)

The volume of gas varies directly with the temperature. Increasing temperature increase the volume of the gas, and decreasing temperature decreases the volume of the gas. The pressure must be held constant and the temperature must be in the absolute temperature scale (Kelvin).

Kelvin (K) is the temperature scale defined as a hypothetical temperature of absolute zero. Absolute zero is temperature where all molecular movement stops.

$$K = ^\circ\text{C} + 273.15$$

$$^\circ\text{C} = K - 273.15$$

$$K = (^\circ\text{F} + 459.67) \times 5/9$$

$$^\circ\text{F} = (K \times 9/5) - 459.67$$

$$^\circ\text{F} = (^\circ\text{C} \times 9/5) + 32$$

$$^\circ\text{C} = (^\circ\text{F} - 32) \times 5/9$$

	Kelvin	Celsius	Fahrenheit
Water boils	373.15K	100 ⁰ C	212 ⁰ F
Water Freezes	273.15K	0 ⁰ C	32 ⁰ F
Absolute zero	0.00K	-273.15 ⁰ C	-459.67 ⁰ F

Boyle's Law

The volume of a gas varies inversely with pressure. **PV = constant.**

If the pressure (P) decreases, the volume (V) increases. If the pressure increases, the volume decreases. The temperature must remain constant.

Avogadro's Law

At the same temperature and pressure, one gram-molecule of any gas occupies the same volume. One mole of any gas contains the same number of molecules. This number is called Avogadro's Number (N_A) and is 6.02×10^{23} .

Atomic mass of oxygen is 16 grams (look at periodic table)

1 mole of $\text{O}_2 = 2 \times 16 = 32$ grams

$$1 \text{ molecule of } \text{O}_2 = \frac{32 \text{ grams}}{6.02 \times 10^{23}} = 5.32 \times 10^{-23} \text{ gram}$$

$$1 \text{ atom of } \text{O}_2 = \frac{5.32 \times 10^{23} \text{ grams}}{2} = 2.66 \times 10^{-23} \text{ grams}$$

Ideal Gas Equation

Charles' law, Boyle's law, and Avogadro's law can be used to produce the Ideal Gas Equation. It is useful for most gases at pressures less than 100 atmospheres.

PV = nRT

P = Pressure in atmospheres (atm),

V = Volume in liters (L)

n = Gas quantity (moles),

T = Temperature (Kelvin).

R = gas constant = $0.082 \frac{\text{liter} \cdot \text{atm}}{\text{deg} \cdot \text{mole}}$

At **standard temperature and pressure (STP)** the temperature is 0°C and pressure is 1 atm.

At STP, 1 mole of any gas occupies 22.40 liters.

PV = nRT can be converted to $V = \frac{nRT}{P}$

$$V = \frac{(1 \text{ mole}) \left(\frac{0.082 \text{ L} \cdot \text{atm}}{\text{K} \cdot \text{mole}} \right) (273.15\text{K})}{(1 \text{ atm})}$$

V = 22.40 liters

Dalton's Law

The total pressure of mixed gases is equal to the total sum of each of the mixed gases partial pressure

Henry's Law

The amount of gas dissolved in physical solution in a liquid at a given temperature is directly proportional to the partial pressure of the gas. The constant of proportionality is the solubility coefficient of the gas.

Solubility Coefficients At Body Temperature (higher solubility to lower solubility)

Carbon dioxide 0.57

Oxygen 0.024

Carbon monoxide 0.018

Nitrogen 0.012

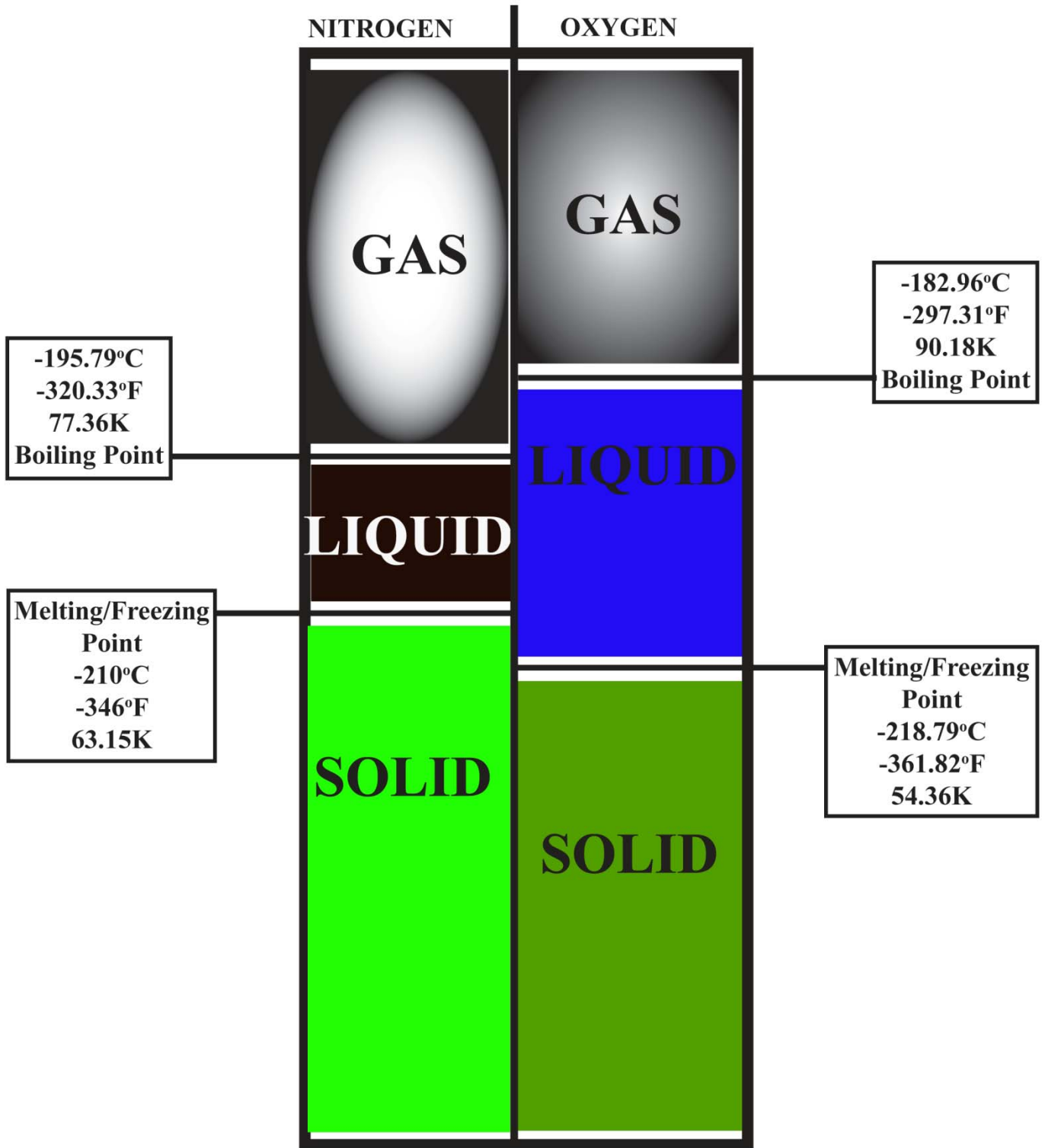
helium 0.008

OXYGEN IN WATER

Just as oxygen is dissolve in blood, oxygen is also dissolved in water. The solubility of oxygen is greater in colder water than warmer water. Oxygen (gases) is much less soluble in warmer water. The solubility is also proportional to the partial pressure of oxygen in air. Fish gills extract this oxygen out of the water and returns carbon dioxide to the water much like humans. The water itself (H₂O) is not broken into hydrogen and oxygen. Fish use the oxygen that is dissolve in the water. Just as a carbonated beverage has carbon dioxide dissolved in it, water has oxygen dissolved in it. Aquariums use a bubbler system to put air (oxygen) back into the water. Oxygen is water soluble. The oxygen dissolves in water by diffusion from the surrounding air, aeration of water tumbling over falls and rapids, and from photosynthesis.

Just about all the oxygen we breathe is made by green plants. Half of the earth's oxygen supply is produced by phytoplankton in the oceans. By photosynthesis, these one-celled plants use energy from the sun, carbon dioxide, and other nutrients to release oxygen into the water. Half of the world's oxygen is produced by phytoplankton photosynthesis. The other half is produced by photosynthesis on land by plants such as trees, shrubs, and grasses.

AIR (gas)





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