ALTITUDE SAI

OXYGEN LEVELS AT ALTITUDE

Although the percentage of oxygen in inspired air is constant at different altitudes, the fall in atmospheric pressure at higher altitude decreases the partial pressure of inspired oxygen and hence the driving pressure for gas exchange in the lungs. An ocean of air is present up to 9-10 000 m, where the troposphere ends and the stratosphere begins. The weight of air above us is responsible for the atmospheric pressure, which is normally about 100 kPa at sea level. This atmospheric pressure is the sum of the partial pressures of the constituent gases, oxygen and nitrogen, and also the partial pressure of water vapor (6.3 kPa at 37°C). As oxygen is 21% of dry air, the inspired oxygen pressure is $0.21 \times (100 - 6.3) = 19.6$ kPa at sea level.

Atmospheric pressure and inspired oxygen pressure fall roughly linearly with altitude to be 50% of the sea level value at 5500 m and only 30% of the sea level value at 8900 m (the height of the summit of Everest). A fall in inspired oxygen pressure reduces the driving pressure for gas exchange in the lungs and in turn produces a cascade of effects right down to the level of the mitochondria, the final destination of the oxygen.

RESOURCE: *Altitude / Air Pressure Calculator (http://www.altitude.org/air_pressure.php)*

WHY IS THERE LESS OXYGEN AT HIGH ALTITUDE?

We all live underneath a huge ocean of air that is several miles deep: the atmosphere. The pressure on our bodies is about the same as ten metres of sea water pressing down on us all the time. At sea level, because air is compressible, the weight of all that air above us compresses the air around us, making it denser. As you go up in elevation (while mountaineering, for example), the air becomes less compressed and is therefore thinner.

The important effect of this decrease in pressure is this: in a given volume of air, there are fewer molecules present. This is really just another way of saying that the pressure is lower (this is called ***Boyle's law***). The percentage of those molecules that are oxygen is exactly the same: 21% (20.9% actually). The problem is that there are fewer molecules of everything present, including oxygen.

Although the percentage of oxygen in the atmosphere is the same, the "*thinner air*" means there is less oxygen to breathe. Try using the *Barometric Pressure Calculator* (https://baillielab.net/critical_care/air_pressure/) to see how air pressure changes at high altitudes. Or use the altitude oxygen graph (*below*) to see how much less oxygen is available at any altitude.

The body makes a wide range of physiological changes in order to cope better with the lack of oxygen at high altitude. This process is called *acclimatization* (https://www.wildsafe.org/resources/outdoor-safety-101/altitude-safety-101/). If you don't acclimatize properly, you greatly increase your chance of developing AMS (*Acute Mountain Sickness*) (https://www.wildsafe.org/resources/outdoor-safety-101/altitude-safety-101/altitude-illnesses/), or even worse, HAPE (*High Altitude Pulmonary Edema*) (https://www.wildsafe.org/resources/outdoor-safety-101/altitude-safety-101/altitude-illnesses/) or HACE (*High Altitude Cerebral Edema*) (https://www.wildsafe.org/resources/outdoor-safety-101/altitude-safety-101/altitude-illnesses/).

RESOURCE: *Barometric Pressure Calculator (https://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/barfor.html)*

Use the table below to see how the effective amount of oxygen in the air varies at different altitudes. Although air contains 20.9% oxygen at all altitudes, lower air pressure at high altitude makes it feel like there is a lower percentage of oxygen. The chart is based on the ideal gas law equation for pressure versus altitude

(*Barometric Formula* (http://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/barfor.html)), assuming a constant atmospheric temperature of 32 degrees Fahrenheit (0 Celsius), and 1 atmosphere pressure at sea level.

Altitude (feet)	Altitude (meters)	Effective Oxygen %	Altitude Category	Example
0 ft	0 m	20.9 %	Low	Sea Level
1,000 ft	305 m	20.1 %	Low	
2,000 ft	610 m	19.4 %	Low	
3,000 ft	914 m	18.6 %	Medium	
4,000 ft	1,219 m	17.9 %	Medium	
5,000 ft	1,524 m	17.3 %	Medium	Boulder, CO (5328')
6,000 ft	1,829 m	16.6 %	Medium	Mt. Washington (6288')
7,000 ft	2,134 m	16.0 %	Medium	
8,000 ft	2,438 m	15.4 %	High	Aspen, CO (8,000')
9,000 ft	2,743 m	14.8 %	High	
10,000 ft	3,048 m	14.3 %	High	
11,000 ft	3,353 m	13.7 %	High	Mt. Phillips (11,711')
12,000 ft	3,658 m	13.2 %	High	Mt. Baldy (12,441')
13,000 ft	3,962 m	12.7 %	Very High	
14,000 ft	4,267 m	12.3 %	Very High	Pikes Peak (14,115')
15,000 ft	4,572 m	11.8 %	Very High	
16,000 ft	4,877 m	11.4 %	Very High	Mont Blanc (15,781')

17,000 ft	5,182 m	11.0 %	Very High	
18,000 ft	5,486 m	10.5 %	Extreme	
19,000 ft	5,791 m	10.1 %	Extreme	Kilimanjaro (19,341')
20,000 ft	6,096 m	9.7 %	Extreme	Denali (20,308')
21,000 ft	6,401 m	9.4 %	Extreme	
22,000 ft	6,706 m	9.0 %	Extreme	
23,000 ft	7,010 m	8.7 %	Extreme	Aconcagua (22,841')
24,000 ft	7,315 m	8.4 %	Extreme	
25,000 ft	7,620 m	8.1 %	Extreme	
26,000 ft	7,925 m	7.8 %	Ultra	
27,000 ft	8,230 m	7.5 %	Ultra	
28,000 ft	8,534 m	7.2 %	Ultra	K2 (28, 251')
29,000 ft	8,839 m	6.9 %	Ultra	Mt. Everest (29,029')

Sources:

BMJ. 1998 Oct 17; 317(7165): 1063–1066.
doi: 10.1136/bmj.317.7165.1063
PMCID: PMC1114067
PMID: 9774298
ABC of oxygen

USGS Map Point Elevation Query Service
https://nationalmap.gov/epqs/

Source of Effective Oxygen %:
The answers given by the Barometric Formula equation.

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