# THE COMPOSITION OF THE ATMOSPHERE

**Matter and Energy in the Atmosphere**. The atmosphere at any given instant is a complex mechanical mixture of matter and energy. There are four phases of matter: plasmas, gases, liquids, and solids. There are many kinds of energy, depending upon which physical system you happen to be using. In these papers, we will be dealing mostly with electromagnetic energy, electrostatic energy, gravitational energy, kinetic energies (including sound energies), wind energy, and others as the occasion arises.

The material portion of the atmosphere is composed primarily of gases—more than 99.9% of it is gases—with liquids and solids held in suspension for varying periods of time and plasmas notable only in the rarefied upper reaches.

Energy is present in the atmosphere in several forms, but we will concern ourselves only with two kinds at this time: the energies of molecular motion (enthalpy), and electromagnetic energies (photons). Enthalpy is inseparable from the matter that possesses it, being a measure of the motions of matter's constituent atoms and molecules. Photons are emitted by matter and are absorbed by matter, but are separate from it. They have no mass, move at the speed of light, and are pure energy.

**Atmospheric Gases**. Most of the atmosphere (99.9%) is composed of gases. The gaseous composition of tropospheric air is estimated in Table CTA01. Values for the relative abundance of the atmospheric gases were obtained from Wikipedia's "Atmosphere of the Earth" and were retrieved on 28 February 2011.

The original values for nitrogen and oxygen were 0.78084 and 0.20946. Together with the increase in carbon dioxide to the current level of 0.00039 and the addition of the other minor gases, this brought the total abundance to some 0.00055 above unity. Consequently, the values for nitrogen and oxygen were reduced proportionately to the values shown in the table.

The table values are averages based on samplings. Consequently, they cannot be expected to correspond to the real concentrations at any time and place in the free atmosphere.

In addition, all samples of real atmospheric air from the free atmosphere will contain water vapor in varying amounts. The average abundance of water vapor in the atmosphere is somewhere around 0.0040. This parameter is extremely variable, and will range from practically nil in the high atmosphere over the polar deserts to as much as 0.060 in the rainy tropics during a rainstorm.

I cannot stress too strongly that the atmosphere is composed of humid air and only of humid air. Dry air does not exist in the free atmosphere. Consequently, equations and tables that specify parameters for dry air are valid only in the laboratory—and are suspect (in my mind) even there.

 

**TABLE CTA01**

**GASEOUS COMPOSITION OF THE DRY ATMOSPHERE**

| GAS | SYMBOL | ABUNDANCE |
|---|---|---|
| | | |
| Nitrogen | $N_2$ | 0.780795000000 |
| Oxygen | $O_2$ | 0.209447777200 |
| Argon | Ar | 0.009340000000 |
| Carbon Dioxide | $CO_2$ | 0.000390000000 |
| Neon | Ne | 0.000018180000 |
| Helium | He | 0.000005240000 |
| Methane | $CH_4$ | 0.000001790000 |
| Krypton | Kr | 0.000001140000 |
| Hydrogen | $H_2$ | 0.000000550000 |
| Nitrous Oxide | $N_2O$ | 0.000000300000 |
| Carbon Monoxide | CO | 0.000000010000 |
| Xenon | Xe | 0.000000009000 |
| Ozone | $O_3$ | 0.000000003500 |
| Nitrogen Dioxide | $NO_2$ | 0.000000000200 |
| Iodine | $I_2$ | 0.000000000100 |
| | | |
| Dry Air | - | 1.000000000000 |
| | | |

Of the gases shown in the table, only nitrogen and argon remain in relatively fixed proportions. The relative proportions of oxygen, water vapor, carbon dioxide, and ozone vary significantly by means of both natural and anthropogenic processes. The other gases vary in their relative proportions as well, but less significantly. It should be noted that varying the relative proportion of any one component (such as adding water vapor) automatically changes the proportions of all of the other components.

These variable gases listed above are added to and subtracted from the atmosphere by a variety of processes. Processes that add gases to the atmosphere are referred to as ***sources***. Processes that remove gases from the atmosphere are referred to as ***sinks***.

Human beings inhale oxygen and exhale carbon dioxide and water vapor. Green plants absorb carbon dioxide and emit oxygen and water vapor. Both oxygen and carbon dioxide readily dissolve in the waters that cover three-fourths of the earth’s surface—and are just as readily released back into the atmosphere. Those same waters are continually evaporating water vapor into the atmosphere.

Ozone is continuously created in the upper reaches of the earth’s atmosphere from oxygen under bombardment by hard radiation; and is created in the troposphere by lightning and other electrostatic discharges (It's what produces that "electrical" smell during thunderstorms). It is naturally unstable, however, and breaks down into oxygen over time.

Obviously, a change in the abundance of any one of the table components will change the abundance of all of the others, as well.

**Atmospheric Liquids**. Water is the only significant atmospheric liquid. Most clouds are composed of droplets of liquid water, so are fogs, mist, rain and sea spray. As we shall see later, water persists in liquid form in clouds well below the presumed "freezing point" of 0°C. Liquid cloud droplets can be found at temperatures approaching -40°C/F.

**Atmospheric Solids**. The most important solids in the atmosphere are ice crystals (most cirrus clouds are composed of ice crystals), snow, hail, pellet snow, dust, sand, salt, pollen, and the like.

**Kinetic Energy**. The molecules of the atmosphere are very small, very numerous, and move in a variety of ways. Gas molecules move from place to place—colliding, tumbling, rebounding, and moving in all possible directions and with a wide range of speeds. This type of movement is considered external kinetic energy. Molecules also have internal kinetic energy: they rotate, spin, vibrate, and librate (flex their axes). All of these energies go to make up the kinetic energy content of the atmosphere.

As we shall see later, we cannot precisely measure the total kinetic energy content of the atmosphere or any parcel of it because we cannot precisely measure the internal energies of the molecules of the atmosphere's gases. We can measure the average external energies, however, and the atmospheric temperatures are those measures.

**Electromagnetic Energy**. Photons are massless packets of energy found throughout the known universe. All electromagnetic energy is composed of photons. Light and radiant heat are both composed of photons, as are magnetic fields, radio waves, and all other forms of electromagnetic radiation. Almost all matter radiates photons more or less continually (albeit at discrete intervals), and almost all matter absorbs at least some photons.

The atmosphere is heated primarily by its absorption of photons emitted by the earth's surface and by the sun. This absorption is accomplished primarily by water vapor, by clouds and particulates, and by carbon dioxide and certain other minor gases. The atmosphere is cooled primarily by the emission of photons by these same gases and clouds.

**Summary.** This completes our overview of the composition of the atmosphere. We have seen that it is not a uniform continuous fluid, but a collection of discrete particles. These particles include photons, molecules, droplets of liquids, and fragments of solids. All of these particles are in continuous motion.

All matter in the atmosphere is almost always either being warmed or being cooled. Ice crystals are sublimating and melting, water droplets and other water surfaces are evaporating and freezing, and water vapor is condensing into liquid water and ice crystals. Winds are blowing and currents are swirling; lightning flashes and thunder rumbles. Clouds, fog, and mist form and dissipate. Rain, snow, hail and sleet fall to the ground—only to start evaporating as soon as they start to fall.

It is a complex picture; but not so complex that it can't be understood.

 