THE COMPOSITION OF THE ATMOSPHERE

A. Matter and Energy in the Atmosphere. The atmosphere at any given instant is a complex mechanical mixture of matter and energy: three phases of matter and several kinds of energy.

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.

Energy is present in the atmosphere in several forms, but we will concern ourselves only with two: the energies of molecular motion (sensible heat or enthalpy), and electromagnetic energies (photons). Heat energy 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.

B. **Atmospheric Gases**. Most of the atmosphere (99.9%) is composed of gases. The gaseous composition of tropospheric air is roughly as follows:

GAS	**PERCENTAGE**
Nitrogen	77.31%
Oxygen	20.74%
Water Vapor	1.00%*
Argon	0.91%
Carbon dioxide	0.04%*
Ozone	0.0000044%*

*highly variable

Numbers in the above table do not total 100% exactly, due to rounding. Other gases in the atmosphere include neon, helium, krypton, xenon, hydrogen, methane, nitrous oxide, sulfur dioxide, nitrogen dioxide, ammonia, carbon monoxide, iodine and thousands of industrial gases. For the atmosphere as a whole, these are present in very small amounts. Locally, however, they might be very significant.

The proportions shown above vary widely from place to place in the atmosphere, and from time to time. The numbers above are averages only, and are far from being fixed. Almost any parcel of real air will have different proportions than these. Of the gases shown in the table, only nitrogen and argon remain in relatively fixed proportions. The other four gases (oxygen, water vapor, carbon dioxide, and ozone) are added to and subtracted from the atmosphere by a variety of natural processes. Processes that add gases to the atmosphere are referred to as ***sources***. Processes that remove gases 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.

Water vapor is particularly variable throughout the atmosphere. Natural water vapor percentages may drop to almost zero in the polar deserts and rise to as much as 9% during downpours in the humid tropics. Obviously, a change in the percentage of any one of the table components will change the percentage of all of the others, as well.

C. 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.

D. 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.

E. Heat 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 energy. Molecules also have internal energy: they rotate, spin, and vibrate. All of these energies go to make up the heat energy content of the atmosphere (enthalpy).

As we shall see later, we cannot precisely measure the total heat content of the atmosphere or any portion 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.

F. 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. All matter radiates photons more or less continually (albeit at discrete intervals), and all matter absorbs at least some photons.

The atmosphere is heated primarily by the minor gases (water vapor, oxygen, carbon dioxide, and ozone) and clouds absorbing photons emitted by the earth and sun, and the atmosphere is cooled by the emission of photons by these same minor gases and clouds.

G. 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 bits are in continuous motion.

All matter in the atmosphere absorbs photons and is warmed thereby. At the same time all matter emits photons and is cooled thereby. Ice crystals are sublimating and melting, water droplets and other water surfaces are evaporating, 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.

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