About Air Ions

Dr. William Lee

Almost all positive ("+") natural ions during fair weather come from radioactivity. About 40% of these natural air ions come from radioactive minerals in the ground. Each time a radioactive atom decays near the air, it typically ejects an energetic alpha particle, produces 50,000 – 500,000 air ion pairs as it travels a few cm through the air. Another 40% comes from radon in the air (which produces about 250,000 ion pairs for each radon atom), and 20% comes from cosmic rays (high-energy protons from distant supernovas). Indoors, ions "live" typically 30 seconds before touching a surface and shorting to ground. Outdoor ions usually "live" several minutes more. **Natural negative ions usually come from radioactivity and evaporating water**. Lightning, thunderstorms, and forest fires can contribute "+" and "-" ions, but these ions are not produced under everyday conditions.

Ions cannot be produced without an energy source. An "energy source" means, heat or flame, radioactivity, frictional rubbing, electricity, evaporation (which is a heat process), etc. Minerals that are not radioactive do not spontaneously emit ions. Normal fair-weather ion concentrations are 200 to 800 negative and 250 to 1500 positive ions per cubic centimeter. Indoor levels are usually lower. Several hours before a storm, + ion concentration will increase dramatically, sometimes exceeding 5000 ions per cubic centimeter (cm^3). During a storm, – ions increase to several thousand while + ions decrease, often to below 500.

Ions can also be produced by high-energy events, such as an open flame or a glowing hot object. Hot objects usually emit equal numbers of + and – ions. High DC voltage (over 1000 Volts), especially when connected to pointed metal edges or needles, will produce ions of the same polarity as the voltage source. This is the basis of electric ionizers. Evaporating water will produce – ions in the air and as a consequence leave + charges behind in the water that hasn't yet evaporated. If the excess + charges left behind are not conducted back to ground, the water will become + enough that – ion production will cease. For example, a fountain that has a motor that plugs into the wall will continuously produce – ions (until the water runs out) but a battery operated fountain will stop producing – ions after a few minutes if the fountain is well insulated from ground. The same is true of a battery-powered air ionizer. In general, for about every 3×10^{14} water molecules that evaporate, one water molecule carries an excess – charge.

Because a large concentration of + ions can attract – ions, high concentrations of + and – ions are often found together. Typically, a high concentration (1000 or more) of both may be found in one area outdoors while low concentration (300 or less) is found typically one city block away. A cloud of pure + ions

(no -) with a concentration of 1000 ions/cm^3 would be very unstable and would fall apart if its diameter were more than about 30m (100'). For this reason, high concentrations of exclusively + (or exclusively –) ions tend to be compact, and don't extend more than about 30m. The only exception is during storms, when strong atmospheric electric fields can maintain a high concentration of exclusively one ion polarity. Indoors, the concentration of ions can vary radically from place to place (even over a distance of less than a meter). This strong variation occurs because air mixing (circulation) is often poor or nonexistent indoors. For this reason, if for example a negative ionizer is used indoors, a fan is usually needed; otherwise, the ions may just stay within an invisible "cloud" that extends no more than 2 m in front of the ionizer. **The resistivity of air (in ohm cm) is 6×10^{18} /N, where N is the number of ions/cc (whichever is lower of + or -). The "half-life" (in seconds) of charges on a charged object is approximately T1/2 = 1.2×10^{5}/N.**

The lifetime of "fast" ions (these are the most common type) is determined by how long they last before they collide with a solid (or dust) which usually neutralizes their charge. Indoors, electric fields are stronger than outdoors. Plastic surfaces charge to a typical potential of -1000 volts. This produces electric fields of 500-5000 volts per meter (V/m) near the plastic surface. The electric field repels negative ions (air molecules with an extra O- or OH-.) The mobility of "fast" ions is about 1.2×10^{-4} m/s per V/m (meters/second per volt/meter of electric field). Therefore, in a typical electric field near charged plastic of 2000 V/m, fast – ions are repelled at a speed of 2000 x 1.2×10^{-4} = 0.24 m/s. Positive ions (air molecules with an extra H+ or positive ammonia molecule) are attracted to the plastic by the same field. Mobility of fast + ions is slightly lower (about 1×10^{-4} m/s per V/m) so they have a slightly slower speed. (**There are also "slow" ions, which literally travel slower** in a given electric field because they have a bigger volume [per amount of electric charge]. Typically these slow ions are much less common than fast ones. The Air Ion Counter Model AIC2 detects both, and displays the total number of charges per cc in the air. However, the sensitivity to slow ions is about 50% low.) If + ions in the air touch negatively-charged plastic, the ions give up their + charge. This partially neutralizes the – charge on the plastic. Under typical conditions, 99% neutralization of the – charge on the plastic would occur in a few hours. However, dust blowing by will rub against the plastic and acquire a + charge. This dust carries the + charge away (ultimately to Earth ground). As a result, the plastic usually retains some negative charge. A good way to standardize (and lengthen) the lifetime of indoor ions is to put them in a large cardboard box. (Cardboard is actually somewhat conductive, so there is little electric field inside a box.) Average ion lifetime in a one cubic foot cardboard box is around 50 seconds, regardless of humidity, so if, for example, 4 pCi/L of radon is in the box, it will produce a continuous 1600 + ions/cm3 in the box.

You can produce negative ions directly by rubbing cotton fabric (or your hair) against a plastic object, which will then briefly emit negative ions. You can use a plastic comb on your hair. If you then blow air past the comb, the air will have between 1000 and 10,000 -ions/cm^3 immediately next to the comb. The number is lower in high humidity. Also, your breath contains about 20,000 to 50,000 – ions/cm^3 from the evaporating water, but you must be grounded to exhale a concentration this high. If you are insulated from ground, you will become more positively charged with each exhalation (by about five volts) because your breath is removing negative charge. Eventually, you will become sufficiently positive (after exhaling about 20 times), that the negative ions will immediately return to you. This is the same effect that occurs in building cooling systems that use an evaporating water tower. If not properly grounded, the water pump and vents will become very positive. (If the inside vents are isolated from the evaporating water via a heat exchanger, the vents may become very positive and produce a large number of + ions. This can be corrected simply by grounding the vent).

Indoors, near ground level or in the basement, most + ions come from radon gas, although solid elements such as thorium and uranium can also contribute if they are on the surface of the concrete or rock. The number of ions is directly proportional to radon concentration multiplied by average ion lifetime. (Strong electric fields indoors will reduce the ion lifetime.) Because it is unlikely that a high level of 1000 + ions/cm^3, (or 1.00 on the Air Ion Counter Model AIC2) can come from anything else other than radioactive decay, flame, smoke, or a hot electric heating element, it is probable that 1000 + ions/cm^3 in a basement signifies the presence of at least 4 pCi/L (picocuries per liter) of radon (2000 ions/cm^3 = 8 pCi/L, etc.) Four pCi/L is the maximum allowable amount in the U.S. If radon is the source of the ions, then the concentration of ions will be approximately equal throughout the basement. If, instead, it is +1000 near a water heater but only 100 + ions/cm^3 elsewhere, it is not radon, but instead it from a little exhaust from the water heater. A slightly higher concentration of + ions near cracks in the concrete foundation or near corners indicate the radon is coming in there. If the average + ion count is low (for example, less than 100), then there is essentially no radon present. It is not possible to "hide" the ions that radon produces. "No + ions" means "no radon".