FORMS OF CONDENSATION OF WATER VAPOR.[1]

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Water, chemical H_2O, exists in the three ordinary states of matter at the usual earth temperatures. Under normal air pressure at sea level the solid state can only exist below the temperature of 32° F. and the liquid state between the temperature of 32° F. and 212° F. The gaseous state, water vapor, may exist at any earth temperature. It is transparent, odorless and tasteless. It is about five-eighths as heavy as dry air under the same conditions of temperature and pressure. Each of these states can be transformed into each of the others. The change from liquid to solid is called freezing, from solid to liquid melting, from liquid or solid to gas evaporation and from gas to solid liquid condensation.

The amount of water vapor which will saturate a given space varies directly with the temperature. A cubic foot of saturated space or air at 32° F. contains 2.113 grains and at 100° F. 19.766 grains. In general the capacity of space or air for water vapor doubles with each 20° F. increase in temperature. The following table shows the capacity for water vapor of space or air in grains per cubic foot from 10° to 104° F.

GRAINS OF WATER VAPOR IN A CUBIC FOOT OF SATURATED AIR OR SPACE AT VARIOUS TEMPERATURES

Fahr.	Fahr.	Fahr.	Fahr.
10°..... .776	34°.....2.279	58°.....5.370	82°.....11.626
12°..... .856	36°.....2.456	60°.....5.745	84°.....12.356
14°..... .941	38°.....2.646	62°.....6.142	86°.....13.127
16°.....1.032	40°.....2.849	64°.....6.563	88°.....13.937
18°.....1.128	42°.....3.064	66°.....7.009	90°.....14.790
20°.....1.235	44°.....3.294	68°.....7.480	92°.....15.689
22°.....1.355	46°.....3.539	70°.....7.980	94°.....16.634
24°.....1.483	48°.....3.800	72°.....8.508	96°.....17.626
26°.....1.623	50°.....4.076	74°.....9.066	98°.....18.671
28°.....1.773	52°.....4.372	76°.....9.655	100°.....19.766
30°.....1.935	54°.....4.685	78°.....10.277	102°.....20.917
32°.....2.113	56°.....5.016	80°.....10.934	104°.....22.125

The absolute humidity of air is the amount of water vapor which the air contains and is measured in units of weight per unit volume, usually in grains per cubic foot or in grams per cubic meter. Thus, air at 60° F. may contain 5.745 grains, which is its capacity at that temperature, or any amount less than that. Usually air does not

[1] The object of this paper is not to present new facts concerning the topics under discussion but rather to bring out interrelations and organization among a group of topics which are usually treated as more or less unrelated.

contain as much water vapor as its capacity permits. Relative humidity is the ratio between the amount of water vapor which the air holds and its capacity at the existing temperature, and is expressed in per cent. Thus, air at 60° can hold 5.745 grains of water vapor but may be holding only 3.8 grains, in which case the relative humidity is 3.8/5.745 equals .66 or 66 per cent. Thus, the formula for finding relative humidity when the absolute humidity and capacity are known is:

$$\frac{\text{Absolute humidity}}{\text{Capacity}}$$ equals relative humidity if expressed in hundredths or per cent. A/C=R.

Air is said to be saturated when it contains all the water vapor which it can hold. From the foregoing discussion and table it appears that air at 60° containing 3.8 grains, if cooled, will be saturated when the temperature reaches 48°. This temperature is called the dew point. The dew point of air is the temperature at which saturation occurs and depends upon the absolute humidity. If air is cooled below the dew point some of the water vapor is forced out as liquid or solid particles. This process is known as condensation. Condensation is the process by which water vapor is changed to liquid or solid form.

As condensation occurs from air it may occur on solid surfaces with which the air is in contact or it may occur in the open air. Some authorities state that condensation can only occur in open air in which foreign particles are floating and that these foreign particles act as nuclei for the condensation. Whether this be entirely true or not it is well known that many fog droplets and rain drops do contain particles of foreign matter. To an observer of condensation the position at which it occurs has led him to apply different names to exactly the same form. Thus very small particles of liquid condensation is called dew if it occurs on solid surfaces, fog if at low altitudes about him and cloud if at higher altitudes. Other forms are likewise distinguished and will be noted later.

As condensation occurs in air whose dew point is above 32° it results in liquid particles and when below 32° it results in ice crystals. These ice crystals are always in feathery form well known in snow flakes and frost particles. In contrast, ice formed from freezing liquid water is glassy although it also has crystalline structure. Thus it is easy to determine whether any ice observed is formed from condensation of water vapor or from freezing liquid water. The marked contrast between particles which condense above and below 32° has given rise to a variation in name of otherwise similar forms. For example, a snow flake and rain drop differ only in this particular.

The amount of condensation which takes place at a given time in a given amount of air determines the size of the condensed particles for the particles grow in size as the condensation continues. Since the specific gravity of water or ice is many times that of air it is imposible for still air to sustain either indefinitely. However, when the particles first begin to form, their mass is so small compared to the surface exposed that they apparently float although there must be a gradual settling of the particles. As the particles continue to grow larger the mass increases more rapidly than the exposed surface and the tendency to settle becomes more

pronounced. As the particles grow still larger the downward motion becomes distinctly apparent and they are considered as falling. Thus condensed particles appear to either float or fall and this distinction has given rise to a variation of names for otherwise similar forms. For example, a rain drop differs from a liquid cloud particle in this particular only. When condensed particles fall the process is called precipitation and the resultant deposit upon the earth is also called precipitation or a precipitated form. Thus rain is precipitation or a precipitated form.

From the foregoing discussion it appears that there are three primary conditions which have led to the variation in names of condensed forms. They are, first, the position at which the condensation takes place, whether it be on solid surface, at low altitudes about the observer, or at higher altitudes; second, the temperature of condensation, whether it be above 32°; and third, the size of the particles whether they are small enough to float or large enough to fall. In view of these considerations, the water forms which appear from the air in the succession of weather conditions should be divided into a primary group and a secondary or derived group. The forms in the primary group are those which result directly from condensation and the forms in the secondary group are those which are derived from the primary forms by change of state or other modification. The primary forms are cloud, rain, snow, fog, flying frost, mist, dew and frost. The secondary forms are haze, hail, sleet, glaze, pellet snow, frozen dew and columnar frost.

Thus the definition of primary forms becomes very simple for it is only necessary to state the conditions under which the condensation takes place. Cloud is condensed at higher altitudes, either above or below 32°, in particles small enough to float. Rain is condensed at higher altitudes, above 32°, in particles large enough to fall. Snow is condensed at higher altitudes, below 32° in particles large enough to fall. Fog is condensed at low altitudes, above 32°, in particles small enough to float. Flying frost is condensed at low altitudes, below 32°, in particles small enough to float. Mist is condensed at low altitudes, above 32°, in particles large enough to fall. Dew is condensed on solid surfaces, above 32°. Frost is condensed upon solid surfaces, below 32°. No name has been applied to the form which is condensed at low altitudes, below 32°, in particles large enough to fall although on very cold mornings the form called flying frost often has a distinctly downward drift and accumulates on the earth surface.

The secondary forms can be defined by reference to the primary form from which they are derived or by description. Sleet is rain which freezes as it falls. Glaze is rain which freezes as it strikes solid surfaces. Since these two forms usually occur together they are popularly called sleet. The storm from which these two forms, or the latter only, are precipitated is called ice storm by the U. S. Weather Bureau. Pellet snow is snow which has partially melted and refrozen as it falls. Frozen dew is dew which has frozen. Columnar frost is partially primary frost and partially ice formed by the freezing of capillary water as it emerges from the earth pores. The feathery ice is primary frost and the glassy ice is frozen water. Haze, in so far as it is condensed water vapor is a primary form of very thin cloud or fog

but is very commonly only dust or smoke in the air. Hail stones are composed of alternate concentric layers of glassy and feathery ice. The feathery layers are of primary form but the glassy layers are partially condensed above freezing and partially melted from the underlying feathery layer and this combination afterward frozen. This peculiar form is developed at high altitudes where strong convection currents of air alternately carry the growing stone above and below the freezing line in a region where condensation is going on. When it is in a region below freezing a layer of frost forms on its surface and when it passes into the region above freezing part of this frost melts and some dew accumulates with it. This is frozen when the stone passes again into the lower temperature. The number of times which the stone is carried above and below the freezing line determines the number of layers which compose the stone.