

# Science and National Progress

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## FOG AND SMOKE.

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**A** FOG consists of drops of liquid suspended in a gas, usually air, while a smoke is composed of solid particles. Fogs are formed outdoors when moist air is cooled beyond the saturation or dew-point, but not enough to precipitate in large drops as rain. Fogs are more frequent at the sea-shore than inland because the air above the ocean is more nearly saturated as a rule than on the land and consequently fog forms readily when the temperature drops. A striking case of this is the fog which comes rolling in from the sea at San Francisco on summer afternoons. We speak of the sun burning off the fog; but that is purely figurative. What happens is that the drops of water evaporate. They will start to do this normally as soon as the temperature rises above the dew-point. Under special conditions we may get what are known as dry fogs, for dense fogs have been noticed around London when the air was only about half-saturated. This is probably due to films of oil from coal smoke which coat the drops of water and retard the evaporation.

Everybody is familiar with the fact that the steam issuing from the spout of a tea-kettle condenses at least temporarily to fog and one of the laboratory methods of producing fog is to let a jet of steam emerge into a cooler atmosphere. The condensation of water vapor from the breath on cold days is another case of the same sort and shows that the important thing is not the initial temperature of the steam jet. Many people think that the water in a kettle is boiling when they see the steam from the nozzle condensing to fog; but this is not always the case. It is not necessary, however, to lift the lid in order to tell whether the water is boiling. If the fog rises vertically, the water is simmering. When the water boils, there is more pressure and the fog forms a curved line.

By taking special precautions it is possible in the laboratory to cool water somewhat below the freezing-point without any ice being formed. This is more difficult the larger the scale, but it occurs on Mt. Washington at times when a southerly wind brings up a drifting fog. When the temperature of the air and of the ground is below freezing, this fog deposits feathery crystals of ice on every surface that obstructs its passage, forming what are known as frost feathers. A round post will have an almost uniform crop of crystals on its windward half, pointing so accurately to windward that it is possible to trace changes in the direction of the wind from the successive layers of crystals lying at different angles. The rate of growth varies with the density of fog and the speed of the wind. A rough average is half an inch per hour and two inches per hour seems to be a maximum value. The phenomenon is what one would expect from liquid particles cooled below the freezing-point.

These supercooled fogs are quite different from the so-called ice storms which occur once or more every winter and which sometimes do so much damage to trees. In the ice storms the moisture deposits as liquid water on the branches and twigs, freezing there to solid ice. These storms occur

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when the temperature is below freezing and a warm rain or mist comes down from above without getting chilled to the freezing-point before it strikes the trees.

While fog is due to the production of very small drops, rain is due to the formation of larger drops which fall with perceptible speed. There is no absolute dividing line between the two because most people would classify as rain what a Scotchman might call a mist. According to the Weather Bureau, rain appears to begin when the drops reach a diameter of 0.04 millimeter. The maximum rate of fall of these drops is very small. Larger drops fall faster. According to Lenard, drops of about 1.3 millimeter have a final velocity of 4.8 meters per second, those with a diameter of about 3.5 millimeters reach a velocity of 7.4 meters per second, while drops from 4.5 to 6.5 millimeters show a practically constant rate of about 8 meters per second. This limiting

value is due to the drops becoming deformed, so that they become flattened out, instead of retaining the shape of spheres. They, therefore, offer an increased resistance to the air through which they fall. In consequence of this deformation large drops break up rapidly in the air into smaller drops. Lenard found that drops of 4 millimeters diameter were stable under all conditions, but that drops of 5.5 millimeters diameter and over could not exist for more than a few seconds after attaining their final velocity relatively to the air. This is in harmony with the results of other observers. Wiesner concluded that natural rain drops cannot have a diameter larger than 7.2 millimeters, while Ritter found that the largest drops of natural rain did not exceed 6.6 millimeters diameter. An independent confirmation is found in Bentley's experiments on the size and frequency of drops during rains in northern Vermont. He found that over 60 per cent of the rain drops were between 0.8 and 3.5 millimeters in diameter and he observed none larger than five millimeters or about two-tenths of an inch.

The fact that large drops break up into smaller ones after they reach a certain speed has been used by an Englishman in India named Simpson as the basis for what is at present the most generally accepted theory of thunderstorms. Simpson assumes that in thunderstorms we have a rapidly ascending current of air which spreads out above a certain height and consequently slows up. Large rain drops will fall through this air current until they reach a point where they are broken into smaller drops and are then carried to the upper and colder levels where they grow again and repeat the cycle. When the drops break up they become charged positively while the negative ions are carried up more rapidly by the air and are finally caught by cloud particles at some higher level. On this hypothesis positively charged rain should fall in bursts in the center of the thunderstorm while negatively charged rain should fall in the lulls and on the outskirts of the thunderstorm. This actually happens. Simpson satisfied himself that the electricity generated by the breaking up of the falling drops might easily account for the gradient of 30,000 volts/cm necessary for lightning. Unfortunately Simpson does not discuss the question as to the minimum size of thunderstorms. It would be of great assistance to the study of meteorology if we could have a synthetic and dwarfed thunder-

storm in the laboratory by starting with a vertical blower and a watering-pot.

The optical properties of suspended drops of water are very interesting, the best known case of this being the rainbow. When direct sunlight falls upon a transparent sphere, such as a rain drop, some of the light is reflected from the surface and some of it passes into the drops where it is split into its constituent colors by refraction. After one or more reflections at the internal surface of the drop, the colored light passes out again. Under most conditions this light is divergent sooner or later and consequently is soon spread over such an area as to be practically imperceptible. At certain angles the light leaves the drop as a practically parallel beam, and it is these nearly parallel rays which give rise to the single and double rainbow. Since the rainbow appears along the circumference of a circle whose center is on the straight line connecting the sun with the eye of the observer, no two persons really see the same rainbow. One man sees the light from one set of drops and another sees that from a different set. For a similar reason the rainbow that one sees reflected in the water is not, strictly speaking, the same rainbow that one sees by looking at the sky, though in these cases the substitute is exactly as good as the original. When the rainbow is double, the inner and brighter one is due to light that enters the upper half of the drops and comes out from the lower after one internal reflection, while the outer and fainter rainbow is due to light which enters the lower portions of the drops and comes out from the upper portions after two internal reflections. The double reflection reverses the colors so that the red is on the inside and the violet on the outside, instead of the other way round as in the primary rainbow.

When the sun shines on fog or mist, a fog-bow is often seen which may be four times as broad as the ordinary rainbow, but which is not so bright in color. The size of the bow depends on the size of the drops, the diameter of the bow being less with very small drops than with large ones. The cloud effect known as the Specter of the Brocken is so-called because it is often observed on the mountain of that name in Germany. It is seen when the sun casts a giant shadow of the observer on a fog bank across the valley, the fog-bow forming a circle of glory round the specter's head. Similar but more brilliant glories are observed when an aeronaut in a balloon sees his shadow projected upon the top of a cloud, these glories being more perfect than those seen on the mountains because the drops in the upper portions of the clouds are apt to be more uniform in size.

Most people are familiar with the colored corona surrounding a bright object when seen through spectacles covered with fine drops of moisture. The colors are due to diffraction by the spherules of water. Under suitable circumstances we may see coronas surrounding the sun and such circles may be seen around the sun on almost any day of the year if we view the sun from some poorly-reflecting surface like water in order to eliminate the blinding glare of the sunlight. In order to have the formation of a well-defined corona, it is necessary that the drops should be exclusively or chiefly of one size. By measurement of coronas it is possible to infer the size of the drops which give rise to them because the corona is larger the smaller the drops. This method has been used to determine the diameters of the drops of water forming clouds.

A cloud is a mass of dense fog. Since the sunlight is scattered from the surface, the cloud normally appears white. If, however, the clouds are illuminated chiefly by the red and yellow rays from the setting sun, all sorts of colors may be observed. The upper part of a tall cumulus is often a delicate pink, while the lower portion is ashy gray; and below that the blue and green sky tints may be visible. A decided pink or straw-colored yellow is often seen when looking at the dazzling white on the sunny side of a cumulus cloud. Apparently the surface particles of the cloud are being evaporated in the sunshine, and the adjacent layer of air is supersaturated with moisture at a relatively high temperature;

possibly minute particles of water are present and modify the orange and pink tints that are spread in spots over the cloud. The tints are seen only when cumuli are sending up great thunderheads like explosions of steam boilers.

Still another color phenomenon is associated with the under sides of cumulus clouds, as in approaching thunderstorms, when the landscape beyond the cloud is brilliantly lighted by the sunshine; in such cases the observer may see patches of yellow or green on the lower side of the cloud, being light from the bright landscape beyond, reflected by the big drops.

As an intermediate stop between fog and smoke we have the precipitation of water vapor in solid form as snow, sleet or hail. When the dew point is decidedly below freezing, water vapor condenses directly to crystals of ice, ice needles, or snow flakes. When supercooled rain drops strike solid substances they cover these with a coating of transparent ice. When snow crystals and supercooled rain drops come in contact we get sleet and sleet changes to hail when the supercooled drops precipitate in the form of sheaths of ice. In order that hail stones should grow to any appreciable size, they must be carried up and down a number of times. Even in midsummer the temperature six kilometers above the earth's surface will be at least  $-26^{\circ}\text{C}$ . and may easily be  $-40^{\circ}\text{C}$ . The reason that we get hail chiefly in summer is because then we have the hot air at the earth's surface giving a sharp temperature gradient and therefore a rapid upward sweep. The warm air may contain a great deal of water vapor which permits the formation of a large formation of ice. In winter the vertical temperature gradient is less and also the amount of water vapor in the air. Consequently, we get no real hail, especially far from the sea.

There is no especial difficulty in forming a fairly good picture of the way a hailstone is formed. The structure of the hailstone gives us some clues. Round a cloudy opaque center, something like sleet, there are transparent shells of ice arranged more or less like the coating of an onion. These are often full of air bubbles and appear partly white. Trabert has pointed out that a hailstone seems to contain three kinds of ice; the center of frozen snow; the concentric sheaths of ice; and occasionally clear, even crystalline, ice on the outside, though in very many cases this last form cannot be detected.

What takes place in the hailstone from the inside to the outside takes place also in the clouds from above to below. In the uppermost portions of the clouds we have snow crystals and supercooled drops; in the lowest portions only the ordinary mist at a temperature not much above the freezing-point. The upper region furnishes the center of the hailstone; the middle one the concentric sheaths of ice; and the third the material of the more or less crystalline deposits gradually formed on the hailstone. In fact, the hailstones often reach the earth while their temperature is far below the freezing-point.

Hailstones can only form if they are supported during formation by strong ascending currents. Further, the structure of a hailstone indicates that it is often carried up and down past the zero isothermal. Now, a current of air sufficiently strong just to support a hailstone as big as a pea would be more than sufficient to carry up the water it condenses within itself; hence, hailstones would always have a greater downward velocity relative to the ascending current than the water in the current and there would be a large amount of splashing between the two. There would be, consequently, a much greater amount of separation of electricity than would have taken place without the hailstones, and this might very well account for the great violence of the electrical discharges in hail storms.

Unless subjected to special treatment, the air always contains dust. The air of large cities invariably shows hundreds of thousands of dust-motes per cubic centimeter, that of the village or town thousands, and that of the open country at least hundreds. The dust may be soil from the fields and roads, particles of animal or plant origin, including pollen,

products of combustion, salt from the spray of the ocean, volcanic dust, or cosmic dust. The dust from the eruption of Krakatoa was shot high into the air and was carried entirely round the world, falling on the decks of ships and on various parts of the earth. Owing to the enormous distances to which volcanic dust may be carried, it is necessary to have some definite test before we can say that a given sample of dust is really cosmic dust coming from meteors which have burned up in passing through the earth's atmosphere. This matter has been studied by Hartley and Ramage, who collected numerous samples of dust in the neighborhood of Dublin and examined them spectroscopically as well as other samples furnished by friends.

The astonishing thing about the results was the number of different elements found in the dusts from different sources. In flue dusts from chemical plants, copper smelters and iron furnaces, it was not surprising that lead, silver, copper, nickel and manganese should be present in relatively large proportions; but nobody was prepared to find rubidium, gallium, indium and thallium in all samples. The nature of soot from different sources is characterized by the small proportion in most specimens of iron and of metals precipitated from hydroxides; its large proportion of lime and the greater variability in the proportions of its different constituents distinguishes it from other kinds of dust collected from the clouds or in the open air. It was unexpected when nickel, calcium, manganese, copper, and silver were found to be constant constituents of soot from different chimneys. It is interesting to note that in Dublin there is more lead, copper and silver in the soot from a laundry chimney than from a bedroom chimney.

The principal characteristics of dust which has fallen directly from the clouds or has been collected by hail, snow, sleet, or rain is its regularity in composition—each specimen appears to contain the same proportion of iron, nickel, calcium, copper, potassium, and sodium. There is a very considerable difference between the dust from sleet, snow, and hail suddenly precipitated, the difference being in the proportion of lead, which, in the dust from sleet, is much larger than in the other specimens, though dust from hail and one quantity collected from rain contains more than is found in any other specimen with such an origin.

Hartley and Ramage believed that dust which fell on the night of November 16, 1897, might have been of cosmic origin but the evidence is not very convincing. This dust fell for the most part on a perfectly calm, fine night and there was no rain for twenty-four hours or more afterward. Since then no one has apparently been interested in detecting the fall of cosmic dust in his own back-yard.

In 1884 the problem of precipitating smoke electrically was studied by Sir Oliver Lodge, who has recently been lecturing in this country on psychic research. Lodge found that with a potential difference of several thousand volts, alternating current, and a brush discharge, the smoke agglomerated and settled rapidly, but neither he nor anybody else has really worked out the theory of the action. The process is too slow to be useful with the large masses of rapidly moving smoke as it comes from a stack and it was only through the much later work of Cottrell, now Director of the Bureau of Mines, that the electrical precipitation of suspended particles has been put on a commercial basis. Cottrell made use of a high tension direct current.

If a needle point is connected to one side of a high-potential direct-current line opposite to a flat plate connected to the other side of the line, the air space between becomes highly charged with electricity of the same sign as the needle point irrespective of whether this is positive or negative, and any insulated body brought into this space instantly receives a charge of the same sign. If this body is free to move, as in the case of a floating particle, it will be attracted to the plate or opposite charge and will move at a rate proportional to its charge and the potential between the point and the plate. Even if there are no suspended particles the gas molecules

themselves undergo this same process, as is evidenced by a strong wind from the point to the plate even in perfectly transparent gases. The old familiar experiment of blowing out a candle flame by presenting it to such a charge point is simply another illustration of the same phenomena.

The procedure used to get direct current consisted in transforming the alternating current from an ordinary lighting or power circuit up to some 20,000 or 30,000 volts and then commutating this high potential current into an intermittent direct current by means of a special rotary contact maker by a synchronous motor. This direct current is applied to a system of electrodes in the flue carrying the gases to be treated. While any smooth conducting surface worked well for the plate electrodes, it was difficult to find anything suitable for the point electrodes when working on a commercial scale.

The clue to the solution of this difficulty came from an almost accidental observation. Working one evening in the twilight when the efficiency of the different points could be judged roughly by the pale luminous discharge from them, it was noticed that under the particular conditions employed at the time, this glow only became appreciable when the points had approached the plates almost to within the distance for disruptive discharge, while at the same time a piece of cotton-covered magnet wire which carried the current from the transformer and commutator to the discharge electrodes, although widely separated from any conductor of opposite polarity, showed a beautiful uniform purple glow along its whole length. The explanation lay in the fact that every loose fiber of the cotton insulation, although a relatively poor conductor compared to a metallic point, was still sufficiently conductive from its natural hygroscopic moisture to act as a discharge point for this high potential current and its fineness and sharpness, of course, far exceeded that of the sharpest needle of thinnest metallic wire. Acting on this suggestion it was found that a piece of this cotton-covered wire, when used as a discharge electrode, at ordinary temperatures, proved far more effective in precipitating the sulphuric acid mists, which were then the object of study, than any system of metallic points which it had been possible to construe. Perhaps the greatest advantage thus gained lay in the less accurate spacing demanded between the electrodes of opposite polarity in order to secure a reasonably uniform discharge.

In practice of course a more durable material than cotton was demanded for the hot acid gases to be treated, and this has been found in asbestos or mica, the fine filaments of the one and the scales of the other supplying the discharge points of edges of the excessive fineness required. These materials are twisted up with wires or otherwise fastened to suitable metallic supports to form the discharge electrodes in such wise that the current has to pass only a short distance by surface leakage over them, the slight deposit of moisture or acid fume, naturally settling on them, serving to effect the conduction. If the condition of the gases does not supply such coating sufficiently, a special treatment of the material before being placed in the flue is resorted to.

The Cottrell process has proved a great success commercially and new applications are continually being developed. It has been used to remove sulphuric acid, arsenic, cement dust, zinc oxide, etc. It has not, however, solved the problem of the smelters so far as the farmer is concerned, because it removes liquids and solids only and does not take out the gaseous sulphur dioxide to which the farmer also objects.

The removal of dust from the air is an important matter in some industries. In photographic work, dust particles in the film mean clear spots on the negative and black ones on the positive. In the manufacture of gas mantles, contamination by dust may cause pinholes in the product. Dust and soot in the air may be a very serious matter in the ventilating of electrical generators because 65,000 cubic feet of air may pass through a moderately large generator per minute or about 94,000,000 cubic feet per day. There are a number of

firms which make apparatus for washing and cooling air. All of them remove the dust by spraying drops of water through the air instead of bubbling air through the water, this latter method not being effective. Everybody knows how effectively a rain clears the air and it is this principle which is employed commercially.

When dust is blown about by the wind, it becomes electrified. In South Africa at Bloemfontein at an elevation of 4,500 feet, the normal fine weather charge of the air is positive and seldom exceeds a maximum value of 200 volts per meter. During a dust storm the sign of the charge changes and the value may exceed 500 volts per meter. A so-called dust devil or whirlwind which carries a column of fine sand up two or three hundred feet in the air will affect an instrument two miles away, reversing the charge. This is because the sand particles are charged positively. In England a cloud of dust increases the positive charge in the air instead of decreasing it. This is because the dust in England is usually calcareous and acquires a negative charge. It is also known that red lead acquires a positive charge when blown into the air and sulphur a negative one.

I am indebted to Dr. Reid Hunt for information in regard to another difference between siliceous and calcareous dusts. The flint particles in South Africa are not rounded and the sharp edges of the dust wound the lungs and permit the tuberculosis bacteria to enter, whereas there is not the same danger in the case of calcareous dusts. If dried rhubarb is ground up, the calcium oxalate forms a dust composed of needles and is exceedingly irritating to the lungs.

The blue of the sky is due chiefly, if not entirely, to the blue light scattered by fine drops or fine particles suspended in the air. Tobacco smoke is reddish by transmitted light and bluish by scattered light when the particles are fine enough. If it were not for dust-motes there would be a different and less brilliant twilight. The bending or refraction of light, as the sun's rays pass obliquely from the ether, at sunrise, or at sunset, into the optically denser medium of the air, displaces the apparent position of the sun, elevating it by an amount about equal to its apparent diameter, so that one may still see it and receive its light directly when geometrically it is entirely below the horizon. A little later in the evening and its rays fall upon the upper air too obliquely to be bent down to the earth by refraction, but darkness does not yet ensue, for the rays are scattered by the dust-motes and sent downward from particle to particle, resulting in a soft, shimmering light that almost imperceptibly fades away, and which in higher latitudes, because of the obliqueness there of the sun's path to the horizon, may last for hours.

An observer inside of a bank of fog usually reports that the sky is cloudy and of a gray tint, since this is about the character of the light that penetrates the bank of fog, unless it be a very light fog or haze, or he be near the surface. There is quite a distinction between the tints seen inside a wet fog or cloud and those seen inside a dry fog or haze, such as is always associated with the harmattan on the west coast of Africa. In the latter case the sky has a chalky-white tint and the air is very dry. We attribute the whitish tint not to any moisture, but to the presence of innumerable fragments of microscopic diatoms or siliceous shells. The whitish color of the haze must be attributed to the reflection of light from their surfaces. A similar white haze occurs in air that is full of grains of pollen, or fine crystals of snow, or almost any other kind of small particles.

At the Krakatoa eruption on August 27, 1883, an immense volume of dust and aqueous vapor was thrown to a great height in the atmosphere above the Straits of Sunda. The antitrades spread this over the Northern Hemisphere, and winds higher up in the tropics carried it westward round the world, forming a layer of minute particles miles above the earth's surface. After sunset, and by virtue of the diffusion of red light by this layer of particles, the whole western sky, even to near the zenith, glared with a lurid red as

though lighted up from some great and distant fire. These remarkable sunsets continued, slowly diminishing in brilliance, through the years 1884 and 1885 in temperate latitudes, while their northern limit advanced slowly toward the pole, showing that minute particles of solid matter may float for years in the high upper atmosphere, so long as slowly rising currents buoy them up.

The tails of comets seem to consist almost entirely of colloidal particles. The great comet of 1882 was invisible against the solar disk, a position which corresponds to attempted observation of colloidal particles in the ordinary microscope against a luminous background. It became visible again after passing beyond the sun's disk, a position corresponding to successful observation of the same colloidal particles in the ultramicroscope against a dark background, the eye of the observer being protected from the source of illumination. The streaming of the tail of a comet away from the sun may be due to the ionization of the colloidal particles, and their consequent electrical repulsion, it may be a thermal effect, or it may be due to the pressure of light as was pointed out by Maxwell.

In the very clear air of Egypt the contrast between lights and shadows is very marked because the shadows are illuminated but slightly by diffracted light and are therefore darker than in countries where there is more dust or moisture. If the photographer is to get any detail in the shadows, he must expose a negative about twice as long as one would in northern latitudes under equally favorable conditions. A slight haze increases the brightness of the sky very much.

What we call haze is due entirely to dust, for water vapor does not give rise to haze, though the effect of dust is more marked the greater the amount of water vapor in the air. Aitken has estimated that 12 to 22 billion particles of atmospheric dust in a column of air having a cross-section of one square centimeter are required to produce a complete haze, that is, to make a distant object invisible. This does not mean that we cannot see the distant object, the mountain for instance; it means that we don't see it, which may be a very different thing. When in a trolley car at night in a dimly lighted city, one sees almost nothing outside, because the light coming through the window is masked practically completely by the light reflected from the glass which therefore acts chiefly as a mirror. If the power goes off, as happens occasionally in many places, no light is reflected from the glass, which ceases to be a mirror and becomes a window again. It is then possible to see objects outside quite distinctly. Up to a certain amount of haze our view of the distant object is interfered with chiefly by the light scattered by the haze. If we could eliminate that, we ought to see the mountain distinctly. Most of the light scattered by the haze is polarized and we can therefore eliminate it by the proper use of a Nicol prism.

Many years ago it was shown by Tyndall that the whole effect of light on fog and haze may change in a remarkable way if one varies the ratio between polarized and unpolarized light. When using a Nicol prism a mountain may be seen clearly even though it is almost invisible to the naked eye. The light of the sky is polarized and may be quenched in great part by a Nicol prism while the light from a cloud is not polarized and therefore cannot be extinguished. A cloud may therefore appear to the naked eye dark against a bright sky and may yet appear as a white cloud on a dark ground if the light from the sky is quenched by means of a Nicol prism.

Although this work was done by a distinguished Englishman whose name is known to all scientific men, I have been told that neither the British navy officials nor our own had made any study before the war of these methods of overcoming certain cases of low visibility. The light reflected from the surface of the sea at a slight angle is polarized pretty completely, whereas the light reflected from a vessel is not. During the war people therefore learned to use a Nicol prism or a

form of interferometer to enable them to detect periscopes and camouflaged ships. The aviators were much bothered by haze in taking photographs, but they got round the difficulty in another way. Since most of the light scattered by the haze is of relatively short wave-length, they used a color screen which cut out this light and were enabled to take much better photographs.

If smoke particles are concentrated enough to form a cloud which moves along, they will tend to carry with them the gases inside the cloud because the mingling with the air takes place relatively slowly by diffusion. At the eruption of Mont Pelée when St. Pierre was destroyed, the descending cloud carried down with it large amounts of heated steam. The mean density of the water vapor and the solid particles was greater than that of air and the cloud sank as a whole. In the war the French always mixed some form of smoke with their gas clouds. That had several advantages. It enabled the observers to see what the gunners were doing, it increased the apparent density of the cloud, and it caused the cloud to hold together better than it would have otherwise. It is only fair to say, however, that there are no satisfactory data to show how real these last two advantages are; but one would expect them to be of less importance in gas warfare where the amount of smoke is small than in the case of a volcanic eruption where the total amount of solid matter in the cloud is relatively high. On the other hand a smoke cloud may hold together pretty well for a mile or two, which it could hardly do if the air in the cloud did not move with it to a great extent.

It has been shown that it is possible to adjust a toy balloon so that it will sink in pure air and will rise in air to which smoke has been added. This is another form of the same problem whether a beaker weighs more in case a fly, which is heavier than air, hovers in the beaker without touching it. So long as the fly is there, the fly and the air constitute a medium which is denser than air and consequently the downward thrust is greater when the fly is there than when it is not. If anybody doubts this, let him consider the case where a glass plate is laid over the mouth of the beaker imprisoning the hovering fly. Disturbing factors, such as change of temperature due to the fly, are supposed to be eliminated.

#### THE USE AND VALUE OF PHYSICAL AND CHEMICAL CONSTANTS.

BY HUGH K. MOORE.

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[At a meeting of the Interallied Chemical Conference held in London, July 14-17, 1919, there was formed an International Union of Pure and Applied Chemistry which recommended that in the United States an American Publication Committee should be created charged with the general organization and prosecution of the printing in the United States of critical tables of physical and chemical constants.

At the meeting of the International Research Council held in Brussels July 22, 1919, the International Union of Pure and Applied Chemistry became the Chemical Section of the International Research Council. The original recommendation in regard to the publication of the tables of physical and chemical constants was confirmed both by the Chemical Section and the Physical Section of the International Research Council. The work of arranging for this publication has been undertaken by the National Research Council in coöperation with the American Chemical Society and the American Physical Society. The present arrangements for this publication have been put into the hands of three trustees, namely, Mr. Hugh K. Moore, Chairman, appointed by the National Research Council; Dr. Edward P. Hyde, appointed by the American Physical Society; and Dr. Julius Stieglitz, appointed by the American Chemical Society. At the request of the Editorial

Committee of this Department, Dr. Moore has written the following brief paper on the use and value of chemical and physical constants and the desirability of the American publication of critical tables of them.—EDITORS.]

The value to industry of physical and chemical constants and their accessibility in an American publication cannot be overemphasized. They make available in the most compact form and with the least expenditure of time a survey of the present scientific and technical knowledge in any given field in so far as this knowledge can be expressed in figures. Their importance and the importance of their ready accessibility was most conspicuously revealed during the war. Practically the only tables of physical and chemical constants available during the war were in German publications. So insistent was the need in the work of the various scientific bureaus of the Army and Navy and of the Council of National Defense and the National Research Council for these tables that the colleges and universities and industrial laboratories of the country were combed for copies of Landolt and Börnstein's Tabellen (which is the principal German publication). Their use, however, was limited to men who could read German, and in many instances these tables were found to be seriously inaccurate. In addition, not one-third of the constants now called for by the industries are to be found in these Tabellen and not even one-half of the constants asked for by industrial concerns are to be found published anywhere. It is an extraordinary thing that a country, so advanced in science as America fondly believes itself to be, should have been dependent, as far as certain important scientific information goes, on the publications of an enemy country in its own language.

Now that the military struggle between America and Germany has ended, the great industrial war after the war is in full swing, and the accurate determination and accessibility of physical and chemical constants is no less important to American industry on a peace-time basis than it was on the war-time basis. Unless we have scientific literature in the English language so that the information contained therein may be accessible to the great number of Americans who do not understand German, the United States will fall way behind in the industrial competition which is now under way. The early publication, therefore, in America of accurately worked out critical tables of physical and chemical constants is a crying need.

The use of physical and chemical constants enters into the every-day life of the whole nation. For example, the constants of milk vary within certain limits and by means of the variations in these constants it can be readily determined whether the farmer's greatest producer is the cow or the pump. The determination of the value of sugar is made by an instrument known as the polariscope; the change in a beam of light passed through a sugar solution as determined by the polariscope bears a direct relation to the sugar contents of the solution. When we consider the immense quantities of sugar used in the United States it becomes evident that a slight error in the constants of the polariscope may cost the sugar refiners millions of dollars annually. This expense is, of course, finally borne by the consumer of sugar. As far back as the time of Grant's administration the German banks set up laboratories to determine some of the constants of the effect of sugar on polarized light and loaned money for the purchasing of sugar on the basis of these determinations.

It is not generally known that copper forms with carbon monoxide a volatile liquid similar in character to nickel carbonyl. No tables of constants which I know mention this fact, let alone giving the properties of such a compound. Lack of data on this subject has caused the loss of millions of dollars to the copper smelters through flue gases, which loss is passed on to the public.

The lack of figures on the cubical expansion of liquids may cause great expense in addition to being the direct cause of many serious accidents. I give one example. One of the large industrial concerns of the country received orders for