Growth of the resistant strain, on the other hand, may take place either in the presence or absence of streptomycin. The latter property appears to be a relatively permanent alteration, while in the case of the dependent strain the relationship between streptomycin and the essential metabolite may be a reversible one.

Details of these and related studies will be presented at a later date.

References

1. Alexander, H. E., and Leidy, G. J. *J. exp. Med.*, 1947, **85**, 607.
2. Chandler, C. A., and Schoenbach, E. B. *Proc. Soc. exp. Biol. Med.*, 1947, **64**, 208.
3. Klein, M., and Kimmelman, L. J. *J. Bact.*, 1946, **52**, 471.
4. Miller, C. P., and Bohnhoff, M. *J.A.M.A.*, 1946, **130**, 485.
5. Miller, C. P., and Bohnhoff, M. *Science*, 1947, **105**, 620.
6. Murray, R., Kilham, L., Wilcox, C., and Finland, M. *Proc. Soc. exp. Biol. Med.*, 1946, **63**, 470.
7. Price, C. W., Randall, W. A., Chandler, V. L., and Reedy, R. J. *J. Bact.*, 1947, **53**, 481.

The Static Electrification of Dust Clouds

John G. Miller,[1] Heinz Heinemann,
and W. S. W. McCarter

Attapulgus Clay Company,
Philadelphia, Pennsylvania

In studying the passage of finely powdered minerals through a metal tube, we have discovered that the dust coating acquired by the inside of the tube has an important role in the electrostatic charging of the dust clouds formed in that process.

The observations leading to this discovery were made using an apparatus and method similar to that of Wilson, Janes, and Campau (*10*). Attaclay, pyrophyllite, bauxite, and mixtures of these were studied.

Charging tests. The tube was made of brass tubing of $\frac{5}{8}''$ internal diameter, 20″ long, fitted with a jet and venturi orifice at the hopper inlet to increase the suction on the hopper. The tube was insulated by Lucite at its supports and connected to the gas line by a polystyrene adaptor. The blowing gas was dry nitrogen, passed into the tube through a rotameter. The exit end of the tube extended 3″ into a large box used to collect the dust clouds and was paraffined on the outside to prevent discharging of the tube by attraction of the dust clouds onto the metal. A Kelvin voltmeter was used to determine the sign and magnitude of the charge placed on the tube.

A small copper cone was set in the top opening of the hopper. Its bottom opening was easily constricted or widened to regulate the passage of the powder into the tube. Because of the differences in flowability of the powders studied, it was found advantageous to fill the cone rather than the hopper. Furthermore, by separate passage of small units of powder a more detailed picture of the coating and charging was obtained.

The materials used in this study were characterized by the following properties:

	Attaclay	*Pyrophyllite*	*Activated bauxite*
Mineralogical content	Attapulgite: magnesium aluminum silicate	Pyrophyllite: aluminum silicate	γ-Alumina containing kaolinite and anatase
Volatile matter (%)	7.9	3.7	7.5
Packed bulk density, lbs/cu ft	29.7	52.4	60.6
Specific gravity	2.35	2.80	3.19
Screen analysis:			
on 200 mesh	3	0	4
200–325 mesh	11	5	12
through 325 mesh	86	95	84

Before each powder or powder mixture was studied, the tube was cleaned thoroughly. The cone opening was adjusted to suit the powder studied; the cone was filled and put in place in the hopper; and the tube was grounded to remove any precharging, especially that due to contact of the powder with its glass container (*4*, *9*). The cone opening adjustment varied considerably with the powders, since Attaclay flows more readily than pyrophyllite or bauxite. A gas flow of between 1.4 and 1.7 cu ft/min was used throughout. Each coneful was passed through the blower in approximately the same time, 4.5–6 min, and each powder met about the same frictional force in its passage. The tube was discharged after each passage to permit filling the cone with the next sample.

Adhesion tests. These were made with the aid of the blowing system just described. A 3″ square of clean, 0.008″ electrolytic sheet copper was hung vertically by a wire attached to a grounded metal support. It was backed by a piece of cardboard, which prevented motion of the plate and protected its back from deposition of dust. The blower tube was pointed at the center of this plate, the end of the tube being held at a distance of 3 or 6″ from the plate. The dust was blown at the same rate as in the charging experiments and, following the passage of a coneful, the plate was removed, tapped to shake off the looser material, and weighed to determine that which adhered firmly. The tapping procedure was easily made sufficiently uniform because of the sharp demarcation between the adhesion of the loose and the firmly-held material, as attested by the reproducibility of the results. The plate was cleaned carefully between determinations.

Early in the studies, the importance of the coating inside the tube was noticed. Until this had formed, the charge placed on the tube was low and not reproducible, but when the lining had formed, a higher, more constant value was shown. The ease of formation of the lining varied noticeably with the nature of the powder. With Attaclay, this coating was apparently fully formed before the second coneful had passed. With pyrophyllite, 3 conefuls sufficed in general, and with bauxite as many as

---

[1] Address: Harrison Laboratory, University of Pennsylvania, Philadelphia.

6 were required to complete the lining. In the passage of the pyrophyllite, and more often in that of the bauxite, occasional momentary decays of the voltage gave indication of temporary loss of a portion of the coating.

The linings of Attaclay and of pyrophyllite were uniform, compact, and smooth in appearance, while those of bauxite were striated and rough as a rule. The Attaclay and pyrophyllite clouds were always negatively charged; the bauxite, positive in sign.

The ease of formation of the coating follows the same order as the ease of flow of the powders, as judged roughly by the size of the cone opening required for equal rate of flow, and certainly follows the order of adhesivity of the powders for a metal surface (Table 1).

TABLE 1

THE ADHESION OF THE DUSTS TO COPPER

Powder	Distance (″)	Weight adherent (mg)
Attaclay	6	31.9 ± 2.9
	3	44.1 ± 2.5
Pyrophyllite	6	23.1 ± 0.8
	3	24.8 ± 1.0
Bauxite	6	1.3 ± 0.1
	3	1.3 ± 0.2

Similar but less complete results were obtained with a plate of aluminum foil. Only the Attaclay is appreciably sensitive to the force with which the dust hits the plate, the amount adhering for the 3″ distance being 38% greater than that with the blower 6″ from the plate.

Most striking were the studies of mixed powders. It has long been known that the charging of mixtures behaves in an apparently unpredictable manner, and careful work has shown that small amounts of a foreign substance have a profound effect on the charging of many dusts (*6*, *10*). Here, mixtures of Attaclay with bauxite and of pyrophyllite with bauxite were studied.

On mixing equal volumes of Attaclay and bauxite, the Attaclay alone coated the tube on the passage of the first coneful, and the tube showed a positive charge, indicating that the dust clouds bore the negative charge typifying clay clouds. On passage of the second coneful, the voltage rose from zero, fell back to zero, and finally rose again, the tube showing a negative charge at the end of the passage. On examining the lining of the tube, it was seen that the original white lining of Attaclay had been coated over by the yellowish bauxite during this passage. Following this, further samples of the mixture produced only a negative charge on the tube, the bauxite covering being maintained. At the end of these experiments, one coneful of pure Attaclay was blown through the tube with the result that the clay coated the bauxite and the dust was negatively charged.

When 5 volumes of Attaclay were mixed with one of bauxite, the lining of the tube was always composed of Attaclay, and the tube was always positively charged.

The effect of mixing bauxite with pyrophyllite was more pronounced than that with Attaclay. With 5 volumes of pyrophyllite to one of bauxite, passage of the first sample showed a rise, total decline, and final steady rise of the voltage of the tube, apparently accompanying an initial coating by pyrophyllite followed by adhesion of the bauxite to this foundation. The tube was negatively charged, and the visible part of the coating was bauxite at the end. In a volume ratio of one part of bauxite to 10 of pyrophyllite, only the pyrophyllite coated the tube, and the dust clouds were negative in charge.

The charging of the dust clouds could also be followed roughly by the fact that the positively charged clouds, whether of bauxite alone or of bauxite mixtures, were more dense and much more permanent than the negatively charged ones of Attaclay or pyrophyllite and their mixtures with bauxite.

When the blowing gas was admitted to the tube at higher space velocities of the order of 3 cu ft/min, the charging was low and erratic. This may have been due to difficulty in formation of the coating and disruption of the coating caused by the high velocity of the dust particles.

That bauxite adheres to surfaces composed of bauxite or other powders more readily than to metal was indicated by the adhesion tests. When the bauxite was blown onto the copper plate, heavy deposits would form, only to slide off on the slightest tapping. Furthermore, the tendency of the bauxite to cake and its resistance to flow reveal the strong adhesion of the bauxite particles to each other.

Frictional electrification processes such as described here are important because they are in widespread commercial use for the dispersion of dusts. Our observations add to the evidence that in these processes the charge separation is principally due to contact between the dielectric particles rather than to that between dielectric and metal (*2*, *5*, *7*).

The studies of the coating formed in the tube account especially for the fact observed by Rudge (*8*) and Wilson, Janes, and Campau (*10*) that the nature of the metal surface of the tube has no important effect in such frictional charging.

Böning (*1*) and Israel (*3*) observed that when a dielectric dust was blown against a rough surface of the same or other dielectrics, the dispersed particles became positively charged. A smooth dielectric surface caused negative charge. Our experiments are in accord with these, in that the bauxite coatings appeared rough, the clay and pyrophyllite linings smooth.

MacLeod and Smith (*6*), in work with separate powders, noticed that if the dust lining formed in the tube is allowed to accumulate to a considerable thickness, it reduces the difference in the total weights of the positively and negatively charged particles in the dust clouds formed.

Wilson, Janes, and Campau (*10*) report findings which, by their similarity to the effects we have found due to the coating process, can be ascribed to that phenomenon. They found that consistent results were obtained if the metal tube was cleaned only between changes in the materials studied, and that their slower-flowing materials required passage of a large number of samples for satisfactory charging records.

In conclusion, we note the possibility that the bauxite in the mixtures with Attaclay and pyrophyllite exerts at least part of its effect by coating over the individual particles of clay or pyrophyllite in the mixture so that the outer surface of a large fraction of the particles in the mixture would be composed of bauxite.

References

1. Böning, P. *Z. tech. Physik,* 1927, **8,** 385.
2. Frenkel, J. *J. Phys.* (USSR), 1941, **5,** 25.
3. Israel, H. *Z. tech. Physik,* 1928, **9,** 289.
4. Knoblauch, O. *Z. phys. Chem.,* 1901, **39,** 225.
5. Loeb, L. B. *Science,* 1945, **102,** 573.
6. MacLeod, G. F., and Smith, L. M. *J. agric. Res.,* 1943, **66,** 87.
7. Richards, H. F. *Phys. Rev.,* 1923, **22,** 122.
8. Rudge, W. A. D. *Proc. roy. Soc. Lond.,* 1914, **A90,** 256,
9. Schnurmann, R. *Proc. phys. Soc. Lond.,* 1941, **53,** 547.
10. Wilson, H. F., Janes, R. J., and Campau, E. J. *J. econ. Entomol.,* 1944, **37,** 651.

The Effect of α-Tocopheryl Phosphate on Diphosphopyridine Nucleotidase

Wm. M. Govier[1] and Naomi S. Jetter

Department of Pharmacology, Medical Research Division, Sharp & Dohme, Inc., Glenolden, Pennsylvania

We have previously reported (*2*) that the inhibition of E-deficient heart-muscle succinoxidase and the stimulation of lactic dehydrogenase from the same source by α-tocopheryl phosphate probably are best explained by the assumption that the compound (α-TPh) inhibits the enzyme diphosphopyridine nucleotidase (DPNase). The preservation of DPN thereby would produce inhibition of succinoxidase by the promotion of oxalacetate formation by the DPN-requiring malic dehydrogenase and would produce stimulation of lactic dehydrogenase, since this enzyme requires DPN.

Ames (*1*) recently has concurred that inhibition of succinoxidase by α-TPh is due to DPNase inhibition and has amplified this concept to show that α-TPh can form an insoluble salt with calcium, thus removing the latter ion so that it does not activate DPNase.

Neither our previous investigation nor that of Ames was based on direct measurements of DPNase activity in the presence of tocopherol. The present paper presents such data, which confirm the hypothesis.

Normal guinea pig hearts were homogenized in distilled water, a 10% suspension being used as a source of DPNase. Sodium-*dl*-α-tocopheryl phosphate was prepared by E. M. Schultz, of the Department of Organic Chemistry of this Division. DPN was prepared by the method of Williamson and Green (*5*) and was estimated in the reaction mixtures by the fluorometric method of Levitas, *et al.* (*3*).

The experiments were set up in 15-ml graduated centrifuge tubes, each of which contained 1 ml of M/5 phosphate buffer, pH 7.2, 0.5 ml of homogenate, and 0.5 ml of buffer containing 500γ of DPN. $CaCl_2$ and α-TPh were dissolved in water and added in the order described below. The volumes were made to 3.0 ml with distilled water. After completion of additions, the contents of the tubes were mixed, and the tubes were incubated at 37° for 0 time, 15, 30, and 45 min, and 1 hr, after which times the enzymes were inactivated by the addition of 0.2 ml of 20% trichloracetic acid. The incubation was carried out without stirring, in order to minimize solubility product effects. After filtration, the filtrates were analyzed for DPN, and the results were plotted against time.

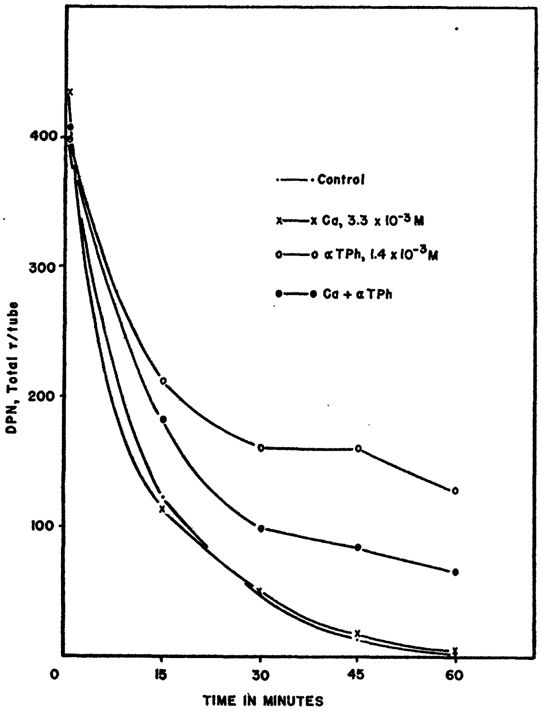

Fig. 1

Fig. 1 demonstrates that the rate of breakdown of DPN is inhibited markedly by α-TPh. In this experiment α-TPh was present in the concentration of 1.4×10^{-3} M and $CaCl_2$, 3.3×10^{-3} M. The calcium relieved the α-TPh inhibition but did not increase the rate of DPNase activity when α-TPh was not added. In view of the data of Ames (*1*), showing the effect of varying concentrations of α-TPh and of calcium on DPN breakdown, it was thought desirable to carry out experiments similar to his by the above techniques. Table 1 shows the results of such experiments. The data agree very well with those of Ames, as to the effect not only of varying concentrations but also of the order of addition of α-TPh and calcium. Percentage inhibition has been calculated on the basis of the 1-hr values.

The fact that calcium has less effect in relieving the tocopherol inhibition when added before the α-TPh is explained by Ames as being due to the removal of some of the calcium as calcium phosphate, thus allowing the α-TPh to remove the residual calcium more efficiently.

It would seem that another interpretation of these

---

[1] Present address: Department of Pharmacology and Endocrinology, Research Division, The Upjohn Company, Kalamazoo, Michigan.