paraffin oil is by contrast yellowish red. This finding, of a less alkaline state in the tissues than in the blood, is confirmed with phenol red (yellow at pH 6.6; red at pH 7.8). The circulating fluids of mice injected with this substance are damson colored, whereas an intense yellow suffuses the tissues. With both indicators a significant phenomenon is to be witnessed during the dissection. Almost immediately on exposure to air the connective tissue stained with cresol red becomes more alkaline as shown by a change from yellow through red to rose-purple, while with phenol red not only this tissue but the cartilage, tendons and bony surfaces undergo alterations in hue that are similar in significance. Krogh[2] has shown the ease with which carbon dioxide passes through animal membranes.

Brom thymol blue, the next indicator of the series (yellow at pH 6.0; blue at pH 7.6), stains but poorly and produces an acid intoxication in mice, as is clearly attested by the yellow hue of both blood and tissues in the prostrated animals.

Brom cresol purple, which is yellow at pH 5.2, and purple at pH 6.6, stains the tissues intensely, but the dose necessary for the purpose comes close to that which is lethal. Through its use differences in the reaction of individual organs can be made out such as were foreshadowed by the work with litmus. In animals receiving it, the circulating fluids, the skin epithelium, connective tissue, bone, cartilage, tendons, aorta and heart valves are all rendered intensely purple, whereas the fatty tissue, striped muscle, liver, kidneys, lymphnodes, pancreas and certain other viscera exhibit various shades of greenish-yellow, changing to purple when alkali is applied. There can be no doubt that under the circumstances of the work a considerable acidity prevails in the last-mentioned group of organs. The color nuances to be observed in many regions of the body constitute a clear-cut tissue differentiation on the basis of differences in reaction. Pre-existing pathological changes are often sharply demarcated by colors that attest to abnormalities in the tissue reaction.

Methyl red is too susceptible to reduction for use during life; and brom cresol green, which possesses much the same range (yellow at pH 4.0; blue-green at 5.6), colors the tissues an intense blue-green, sufficient evidence that this range lies too far to the acid side for successful utilization.

The phenol indicators are excreted in large part through the bile; and the hue of the intestinal contents, which are stained in consequence, alters with the conditions at the different levels of the gut.

The information given by the indicators available at present for injection into living animals must be accepted with caution. Even the best of them is influenced by the substances with which it comes in contact; and little is known of the effects on the body of the majority of them. But the findings here set forth will serve perhaps to point the way to more conclusive studies. They emphasize the need for color methods whereby the manifold physiological differentiations within the living body can be disclosed with something of the certainty that now obtains for morphological ones.

Details of the work will appear in *The Journal of Experimental Medicine.*

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[2] Krogh, A., *J. Physiol.*, 1919, lii, 391.

DIRECT SYNTHESIS OF HIGHER FROM LOWER HYDROCARBONS[1]

IN examining the stability of gaseous ethane at normal pressure under the α-radiation of radon (radium emanation) mixed with it in a small glass sphere (1.7 cm diameter), a liquid phase appeared after the first day's radiation. Since nothing was initially present in the glass vessel except ethane confined over mercury (having contact with the ethane in a capillary connecting tube) and the infinitesimal quantity of radon (222.5 millicuries = 0.12 cubic millimeters and a pressure of 0.8 mm of foreign gas), it was evident that ethane was being converted into one or more of the higher hydrocarbons. The quantity of liquid hitherto obtained is too small for positive identification, but has about the vapor pressure of octane, which is the lowest member of the paraffin series that would form a liquid having the low vapor pressure observed at room temperature.

If the product is octane, the reaction which apparently takes place is $4C_2H_6 = C_8H_{18} + 3H_2$, which might take place in two stages with butane as the intermediate product. It is also not impossible that the product may be an unsaturated or a ring compound produced by splitting out more hydrogen.

The liquid was reddish-brown in color, most probably due to colloidal carbon, which shows that decomposition into carbon and hydrogen must also take place to some extent. Abundant hydrogen was shown to be present. After a few days, during which time the total pressure continued to increase, nothing remained except hydrogen and liquid generally distributed over the walls of the vessel in fine droplets, and forming a minute liquid column in the capillary tube at the bottom of the vessel. The pressure con-

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[1] Published with permission of the Director of the U. S. Bureau of Mines.

tinued to rise, indicating the liberation of further hydrogen by the direct action of alpha particles on the droplets of liquid. No sign of solid hydrocarbons appeared.

According to ionization the reaction mechanism may be interpreted as follows. The primary reaction is the removal by alpha particles of electrons from molecules of ethane:

$$C_2H_6 = C_2H_6^+ + 1\,e$$

The resulting active ethane ion forms complexes by addition of ordinary neutral ethane molecules:

$$C_2H_6^+ + C_2H_6 = (C_2H_6)_2^+$$

or

$$C_2H_6^+ + 3C_2H_6 = (C_2H_6)_4^+$$

Upon electrical neutralization by free electrons (from the original ionization) hydrogen would be split out, giving butane or octane as the case may be.

The reaction appears to possess interest from several angles: (1) It appears to confirm the hypothesis of complex formation by ions proposed by one of us at the Dayton meeting of the American Electrochemical Society (Trans. *44,* 63–71 (1923)). (2) It is the first instance of a method of directly synthesizing higher from lower hydrocarbons, by α radiation. (3) It will be of interest to see whether contact catalysis will be found to produce the same reaction in larger quantity. (4) The possibility is suggested that the same complex may break down in two or more ways, giving different products. It will be important to determine how these ways may be influenced or controlled, as having a possible bearing on the cracking of hydrocarbons. (5) Since α-radiation is present everywhere in the earth's crust, it is evident that a process is at hand in nature by which lower hydrocarbons could be stepped up to higher ones, as well as broken down. However, the complete absence of free hydrogen in natural gases and petroleum remains to be explained.

A more detailed study of this and similar reactions is under way, in which it will be undertaken to determine what fraction of the primary reaction results in higher hydrocarbons and what in complete decomposition to hydrogen and carbon.[2]

S. C. LIND,
D. C. BARDWELL

[2] The possibility of synthesizing higher from lower hydrocarbons by silent electrical discharge was long ago discovered by Berthelot (Comp. rend. *126,* 568 (1898)). Professor Boltwood (private communication) informs us that in work on the production of helium from radium he and Professor Rutherford had occasion to confine radon by a solid plug of paraffin. After several days large quantities of hydrogen were found to have been given off and the paraffin plug could no longer be melted, even by heating almost to the softening point of the glass.

NICOTIANA RUSTICA AS A SOURCE OF NICOTINE FOR INSECT CONTROL[1]

THE value of nicotine preparations for the control of aphids, leaf hoppers, red spiders and many other insects has long been recognized. The general interest in these preparations, however, has been greatly stimulated in recent years, owing to the experimental work of Smith[2] and many others on the use of natural and artificial nicotine dusts, with the result that more nicotine is used as an insecticide at the present time than ever before.

Nicotine for insecticidal purposes is derived almost entirely from stems, stalks and waste leaves of commercial types of tobacco of low nicotine content. This source of supply is dependent on the amount of tobacco wastes used for other purposes. Under the existing conditions, therefore, the cost of nicotine preparations, must, of necessity, be relatively high.

Realizing the importance of augmenting the natural supply of nicotine, the U. S. Bureau of Plant Industry, in cooperation with the Pennsylvania State College, started experimental work in 1914 on the practicability of cultivating tobaccos for their nicotine content alone. Various types of "high nicotine" tobaccos were used but were soon discarded, with the single exception of *Nicotiana rustica,* a leathery tobacco unsuited for the usual purposes of manufacturing and possessing an extremely high nicotine content. The nicotine content of these plants has since been increased by processes of selection.

In the fall of 1923, a number of carefully selected fairly mature plants of this type were sent to the Pennsylvania State College by Mr. Otto Olsen (expert in charge of tobacco investigations at Ephrata, Pennsylvania), with the request that studies be made on the whole plants relative to their nicotine content and utilization for insecticidal purposes. These plants came from Lancaster and Clinton Counties, Pennsylvania, and had received the same fertilizer treatment. Some of the plants had been topped, while others were kept free of suckers during their growing season. Several were both topped and suckered and the remaining plants were untreated. The whole plants, minus their root systems, were dried, weighed and analyzed for nicotine according to the method of Shedd.[3] The results obtained are given in the following table and are calculated on a water-free basis:

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[1] Published as Paper No. 12, Department of Agricultural and Biological Chemistry, the Pennsylvania State College.

[2] Smith, R. E., "The preparation of nicotine dust as an insecticide." Univ. Cal. Pub., Bull. No. 336. 1921. pp. 261–274.

[3] Shedd, O. M., "An improved method for the determination of nicotine in tobacco and tobacco extracts." *Jour. Agr. Res.,* Vol. 24, No. 11. 1923. p. 963.