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PART I.

ORIGINAL COMMUNICATIONS.

ART. XXI.—*High Explosives. T. N. T.: its Toxic action in Munition Workers. Detection of T. N. T. in Urine. With Experiments.** By WALTER G. SMITH, M.D. ; Ex-President, R.C.P.I. ; Ex-President, Royal Academy of Medicine in Ireland ; Physician to Sir P. Dun's Hospital.

THE Twentieth Century, even in its youth, is a witness to rapid and extraordinary advances made in all branches of Chemical Science. A new epoch has unfolded itself. What a change when we now know that the atom, the foundation stone of chemistry, is not an immutable indivisible entity, but is a complex microcosm liable to sudden and forceful disintegrations, and forming a storehouse of vast potential energy.

Surely we may hope that Chemistry will soon come into its own, secure the ungrudging support of Governments, and infiltrate the general public with a sense of its fundamental importance.

This colossal and lurid World War has been described—not untruthfully—as largely a war of applied chemistry.

* Read before the Section of State Medicine in the Royal Academy of Medicine in Ireland on Friday, April 13, 1917.

In this sphere of activity chemistry has been enlisted both lawfully and unlawfully. Lawfully, for the production of munitions of war and for the protection of human life in coping with the deadly chemicals employed by our adversaries. Unlawfully, and barbarously, for the maiming and torturing of humanity by death-dealing poison gases, by the poisoning of wells, and by other measures of ferocity in defiance of all hitherto recognised canons of international practice.

From sheer necessity—greatly against the grain—the British and their Allies have been compelled to adopt certain measures of offence and of reprisal which are foreign to their nature.

As examples of gases used as asphyxiating agents may be mentioned chlorine, bromine vapour, phosgene gas (COCl_2), and sulphur dioxide (SO_2).

In addition to these familiar substances there are now employed a number of complex organic compounds which give rise to offensive and toxic gases, and combine the properties of being asphyxiating and lacrymatory. It is unnecessary to give their names or formulæ.

One thought that carries some comfort with it is that while war makes men devils it also creates heroes and saints.

Furthermore, the war has led us to recognise some new and serious occupational diseases arising from the novel chemicals introduced. And once again malingering has been favoured by a curious property of one at least of the modern explosives.

In this latter connection I refer to picric acid. Soldiers have learned to simulate jaundice by swallowing picric acid, which turns the urine orange-yellow, independent of bile pigment, and tinges the conjunctiva yellow, properties not possessed by any other drug known to me.

Some time ago I made a few experiments on myself. I took, within ten hours, three powders of two grains of picric acid, in cachets, without any harm ensuing. Yet it is stated (Sollmann, *Text-book of Pharmacology*, 2nd edit.,

1906) to be very poisonous, causing destruction of red corpuscles, nephritis, convulsions, and death through paralysis of respiration. 0.06–0.60 grm. is said to be fatal to rabbits and dogs.

Ammonium picrate has been recommended in malarial fevers, in doses of $\frac{1}{8}$ to $\frac{1}{2}$ gr.

The picric urine assumed an orange yellow colour, and remained sweet for a number of days. It was free from albumen and bile pigment.

Mr. E. Werner recognised that my conjunctivæ were tinged yellow. This soon passed off, and I was none the worse for the venture.

To detect picric acid in urine, acidify and extract with ether; evaporate, and apply the tests for picric acid to the residue—*e.g.*, dyeing wool yellow.

I repeated these observations on the 11th of April, and took again 6 grs. of picric acid, in 2 gr. doses, at intervals of some hours. At 9 30 p.m.—*i.e.*, seven hours after the second dose—the urine was of a distinctly orange colour. The colour deepened on the 12th.

The urine was acidified with H_2SO_4 and extracted with ether. The ethereal solution was evaporated to dryness, and then dissolved in water, and a small skein of white wool left in it. The wool was stained pale yellow.

Let me now turn to the main subject of my communication—*viz.*, High Explosives.

The term “High Explosives” is of quite recent origin. The velocity of explosion in them is about 500 times greater than that of a “Low Explosive”—*e.g.*, gunpowder. It denotes compounds rich in N which, when detonated, furnish suddenly an enormous volume of heated gas, from 10,000 to 15,000 times the volume of the explosive. The amount of energy which will become available when explosion occurs depends mainly upon the percentage of N in the compound. All explosives contain N, a singular fact when we call to mind the chemically and physiologically inert properties of ordinary free N, which forms, as we all know, about 80 per cent. of atmospheric air.

The first explosive prepared by man was gunpowder, some form of which was used in the battle of Crecy in 1346, when, as the old chronicle relates, the guns "threw little balls of iron to frighten the horses." For a long time the employment of gunpowder was limited to cannon and muskets, and nearly 200 years passed before it was utilised for small arms—*i.e.*, pistols.

After this momentous innovation in warfare the history of explosives is a blank for nearly 500 years, and no new explosive was invented.

The starting point of modern explosives was made by a Frenchman, Braconnot of Nancy, in 1832. He prepared explosive nitro-compounds by the action of HNO_3 on starch, and wood-fibres—*i.e.*, from carbohydrates.

In 1845, Schönbein, of Basle, discovered guncotton. A year later (1846) a most important advance was made by an Italian chemist, Ascanio Sobrero, who discovered nitroglycerin, or, as he called it, pyroglycerin. But it was not until 1863 that nitroglycerin was brought into the sphere of practical utility by a Swede, Alfred Nobel—the founder of the munificent Nobel prizes.

After many experiments he found that by mixing nitroglycerin with *Kieselguhr* (a siliceous infusorial earth) a plastic and absorbent product was obtained which was safer to handle and more manageable. This mixture soon became universally known as dynamite, or giant powder, as the Americans call it.

Millions of tons of dynamite were used in the construction of the great Panama Canal. Likewise for the Suez Canal, and in the excavation of the Simplon and other long tunnels; in mines, quarries, &c.

In 1905, the steamer *Chatham* sank in the Suez Canal. Among other things the ship was laden with 100 tons of dynamite. Divers went down and placed electric detonators in position. The gigantic explosion forced a jet of water to rise 1,500 feet in the air, and a hole 73 feet in depth was punched out of the canal bed.

Picric acid was discovered nearly 150 years ago, but it

was not until 1867 that it was employed as a blasting powder mixed with NaNO_3 and K_2CrO_4 .

A mixture of picric acid and collodion compressed and molten is known as melinite, or lyddite, and was extensively used in the Boer War.

About twenty years later (1886) an entirely new departure was put forward by a French chemist, as "smokeless powder," and soon after, Sir Frederick Abel and Sir James Dewar introduced us to cordite.

Cordite is a mixture of guncotton and nitroglycerin dissolved in acetone, and thickened by the addition of 5 per cent. of vaseline. It is largely used in British ordnance.

The outcome of these successive discoveries is that the old black gunpowder, which held its ground for more than six centuries, has been practically superseded in military service, and may, before long, become a matter of history only, at least in military warfare.

What are the sources of High Explosives ?

The answer is simple. They are derivatives of the two great groups into which most organic compounds fall. I refer to (I.) The carbohydrates (fatty : aliphatic group), and (II.) The hydrocarbons of the aromatic group.

The organic products employed as explosives are either (a) true nitrates, or (b) nitro-compounds.

The difference between them is important, and consists in this :—

In an organic nitrite or nitrate (true ester) the nitric (nitrous) radical is attached indirectly to the hydrocarbon nucleus through the medium of oxygen—

In a nitro-compound the substituting NO_2 group is directly attached to the hydrocarbon radical—

These nitro-compounds are more stable, and are not

saponifiable by alkalis, whereas organic nitrates, being alcoholic salts or esters, are readily saponified.

Inorganic nitrates—*e.g.*, KNO_3 or NH_4NO_3 —are often added in order by supplying oxygen to intensify the effect of high explosives. Similarly, KClO_3 or KClO_4 may serve, as an addition to one of the aromatic explosives—*e.g.* Rack-a-rock : cheddite.

Of the carbohydrate group, the chief individuals which concern us are cotton, or cellulose $(\text{C}_6\text{H}_{10}\text{O}_5)_n$ and glycerin $\text{C}_3\text{H}_5(\text{OH})_3$

(a) By the graduated action of HNO_3 upon cellulose the degree of nitration can be so arranged as to yield products whose proportion of N ranges between 6 per cent. to 13.5 per cent. N. Pyroxylin, B. P. is Di-nitro-cellulose. Guncotton is Tri-nitro-cellulose. The term *nitro* is inapplicable to these bodies, for they are true nitrates—*i.e.*, esters. Practically, most violent propellants contain nitro-cellulose (guncotton) wholly or partly gelatinised. All smokeless powders consist largely of nitro-cellulose in some form. Guncotton, even when moist, can be exploded by mercury fulminate just as readily as when it is dry. Used for charging torpedoes and sea-mines.

(b) Glycerin, by the action of concentrated HNO_3 , is transformed into nitroglycerin, a heavy, oily-looking liquid. An alcoholic solution of nitroglycerin, 1 per cent., constitutes the Liquor Trinitrini B. P.

The term nitroglycerin is a chemical misnomer, for it has been shown that it is really a true ethereal nitrate $\text{C}_3\text{H}_5^n(\text{ONO}_2)_3$, and is readily broken up by alkalis—*i.e.*, saponified like other esters.

Gelignite is a mixture of nitroglycerin, nitrocellulose, wood pulp, and KNO_3 .

Most of us will remember that it was used by the rebels in the Dublin outbreak, April, 1916, and a quantity of it was found in the G.P.O.

Among the aromatic group we recognise three important parents of explosives, viz. :—

Derivatives	
Benzene (Benzol) C_6H_6	$\left\{ \begin{array}{l} \text{Trinitrobenzene, sometimes} \\ \text{used for filling shells ; also} \\ \text{trinitrocresol and trinitro-} \\ \text{naphthalene} \\ \text{Nitro-benzenes (mono-di-tri)} \\ \text{e.g., } C_6H_5NO_2 \end{array} \right.$
Toluene (Toluol) $C_6H_5CH_3$ methyl-benzene	$\left\{ \begin{array}{l} \text{Tri-nitro-toluene T.N.T.} \\ C_6H_2(NO_2)_3CH_3 \end{array} \right.$
Phenol (carbolic acid) C_6H_5OH	$\left\{ \begin{array}{l} \text{Picric acid or} \\ \text{Tri-nitro-phenol} \\ C_6H_2(NO_2)_3OH \end{array} \right.$

Derivatives of aniline have also been used—*e.g.*, tetra-nitraniline and tetranitromethylaniline (tetryl.).

The metallic picrates are more explosive than the free acid.

Lead picrate detonates suddenly and violently when heated. (Experiment shown.)

Picric acid is the oldest organic dyestuff, and colours animal tissues and fibres, such as silk or wool, but not cotton.

This dye test is useful for the detection of picric acid in organic fluids. (Experiment shown.)

Although picric acid solution is somewhat extensively used as a dressing for burns I have not heard of any ill effects ensuing. The only harmful result I can find which appears to have been due to picric acid is a case of a severe burn on the foot of a young infant. It was dressed with a dusting powder, containing from 7 to 17 per cent. of the acid. This was followed by vomiting and diarrhoea. T. 100° F. ; P. 100 to 150. A general erythema developed, and the child died on the twenty second day after the accident.—Martindale, *Extra Pharm.*, 16th edit., p. 64.

Within recent times picric acid and picrates have

receded in importance as explosive agents, and T.N.T. has come into the foreground, and has replaced picric acid as a filling for shells.

The reasons for the substitution are that T.N.T. has a lower M. P., is more stable, is insensitive to ordinary shock, and, being free from acidic properties, it does not attack metals or their oxides.

Furthermore, it is cheaper than picric acid, and is less poisonous.

T.N.T.

It is obtained by the graduated action of HNO_3 upon toluene, and is a true nitro-compound. Occurs in small yellow prismatic crystals. Insoluble in water; soluble in ether, acetone, and fixed oils. It is quite safe to handle. When heated in the open, it suddenly takes fire, without detonation. (Experiment shown.)

PHYSIOLOGICAL ACTION.

Absorption.—It can be absorbed by the skin, and is liable to cause dermatitis, followed by desquamation. Some persons are more susceptible than others. In my own case, I more than once rubbed in an ethereal solution on the back of my hand, and thereby caused slight punctiform erythema. I several times rubbed into the palms T.N.T. and liquid paraffin without result.

From observations of 1,100 workers Mr. Barnes considers that the main channel of absorption is the skin, especially if greasy, and the incidence of cases has been where the material was used, rather than where it was made.

Professor Benjamin Moore provoked toxic symptoms in himself by rubbing an oily preparation of T.N.T. into his palms. In a factory he had breathed fumes and dust systematically, but had not induced any symptoms of poisoning.

Digestive Troubles.—Munition workers who handle T.N.T. are liable to gastritis, abdominal pain, and persistent constipation.

Blood Changes.—T.N.T. absorption induces cyanosis and hæmolytic changes, and meta-hæmoglobin is demonstrable. The alterations in the blood are minutely described by Dr. M. J. Stewart in *The Lancet*, Jan. 27, 1917.

Liver.—T.N.T. brings about serious mischief in the liver. The lesion appears to lie somewhere between a subacute yellow atrophy and an ordinary multilobular cirrhosis of irregular distribution. Jaundice appears, and ascites sometimes supervenes, and hæmorrhages occur in various situations, in both skin and viscera.

Urine is dark, and may contain albumen as well as bile. Crystals of leucin and tyrosin have also been observed.

In 1916 about 50 deaths had occurred from toxic jaundice, a mortality among those exposed of 0.05 per cent. When death occurs it usually takes place about three weeks after the first appearance of jaundice, and is preceded by delirium and coma.

TESTS FOR T.N.T.

(a) *In the Free State* (M. P. 80° C.).—A weak solution (ethereal) diluted with water strikes a deep red with KOH, preferably in alcoholic solution. (Experiment shown.) Di-nitro-toluene yields a blue colour with KOH.

(b) *In the Urine.*—T.N.T. may be recovered unchanged from the fæces, but does not exist in the free state in the urine, except, perhaps, in minute amount. To detect it in urine, Webster's test is convenient (*Lancet*, Dec. 16, 1916). Add to urine (12.5 cc.) an equal volume of dilute H_2SO_4 . Pour the mixture into a separating funnel. Add about half its volume (10 cc.) of commercial ether. Shake up well and allow to settle. After a few minutes draw off the lower stratum of urine and acid. Now add about twice its volume (25 cc.) of tap-water to the ethereal solution, shake up again, and, after settling, run off the water. Finally, let the ethereal solution flow into a test tube and apply the KOH test, which at once strikes a bright red. (*Lancet*, Dec. 16, 1916).

In order to verify this test I made some experiments on myself.

On Sunday, March 18, I took three doses of 1 gr. each, of T.N.T., with a little sugar, at intervals of some hours—viz., 11.15 a.m., 1.5 p.m., and 6.30 p.m.

That night and next morning I collected some urine and tested the mixed specimen as above.

The urine was high-coloured, almost orange tint; acid in reaction, free from albumen, and gave no reaction with the iodine and chloroform test for bile. The ethereal extract from the acidified urine gave a bright red with the alcoholic solution of KOH.

The fresh urine, before treatment with H_2SO_4 , gave scarcely any reaction with KOH; very slightly deepened in colour, and slowly showed a pale red. A little T.N.T. added to normal urine reacts at once to the potash test, applied directly, or to the ethereal extract.

I repeated these observations yesterday, April 12, and took three doses of T.N.T., 1 gr. each, at 4.30 p.m., 9.30 p.m. and 10.30 p.m., with the same results.

ART. XXII.—*Tetanus*.^a By JOHN S. M'ARDLE, M.Ch. (*Hon. Causâ*), R.U.I. F.R.U.I.; F.R.C.S.I.; Professor of Surgery, National University of Ireland; Senior Surgeon, St. Vincent's Hospital; Consulting Surgeon, National Hospital, Holles Street, and Children's Hospital, Temple Street, Dublin. (Illustrated.)

IN 1881 I made my first endeavour to deal with tetanus, of which we then knew very little. For years, owing to the courtesy of the late L. Hunter, V.S., I had ample opportunity of seeing cases of tetanus in the lower animals. Every drug that seemed to offer any chance of help we employed extensively, and, sad to relate, with poor results.

The study of tetanus received a great impulse in 1884, when Rattone proved the characteristic symptoms of lock-

^a The substance of a Clinical Lecture.