AN EXHIBIT

Under the Auspices of

NATIONAL RESEARCH COUNCIL

Prepared by the

CHEMICAL WARFARE SERVICE

to Show the American People

WHAT THE CHEMIST HAS DONE

and

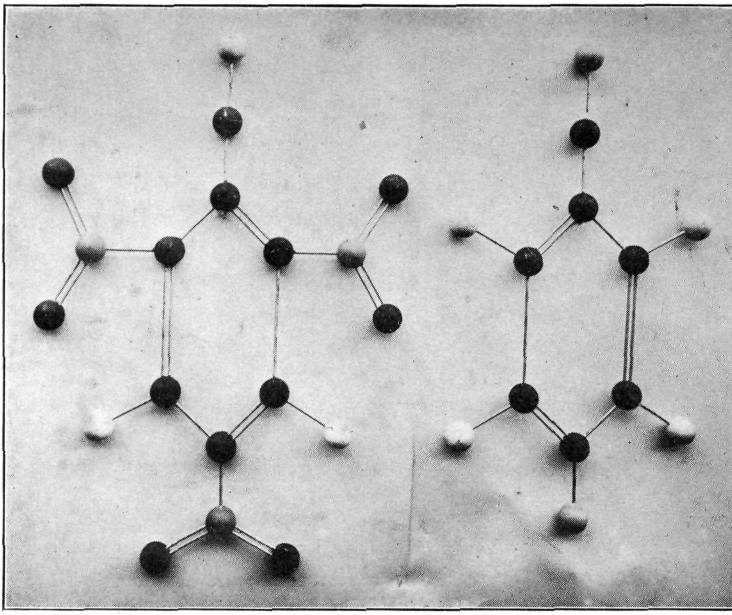
MAY DO FOR THEM

In War and Peace

THIS chemical exhibit is one in a series of popular scientific exhibits arranged under the auspices of the National Research Council, Washington, D. C., to emphasize the importance of fundamental research. It is the application of the results of such research by industry and the nation that leads to industrial progress and public welfare.

One of the greatest scientists has said:

"In our century science is the soul of the prosperity of nations and the living source of all progress. Undoubtedly the tiring daily discussions of politics seem to be our guide. Empty appearances! What really leads us forward are a few scientific discoveries and their applications."



PICRIC ACID CARBOLIC ACID

To the chemist these models represent the molecules of two well known organic acids. Such models or diagrams are to the chemist what blue prints are to the builder. The balls stand for atoms, and if the arrangement of these atoms is changed the character of the molecule changes and with it that of the compound. In synthesizing a new compound the research chemist must first work out the design and then devise processes to turn out the desired molecule. In a pound of a certain dye there are estimated to be more than 40,000,000,000,000,000,000,000 complicated molecules and all built exactly alike—a feat seldom, if ever, accomplished outside of chemistry.

In the phenol or carbolic acid molecule there is a hexagonal ring composed of six carbon atoms and to all but one a hydrogen atom is attached. To that one there is a hydroxyl group consisting of an oxygen with a hydrogen atom. Besides being a disinfectant and medicinal, phenol is an intermediate product in making picric acid. Note that the difference is that every alternate hydrogen atom of the phenol molecule has been replaced by a nitrogen atom to each of which in turn are attached two oxygen atoms. Any other arrangement, no matter how slightly different, would not be picric acid.

Picric acid is used as a high explosive and as a dye. It is an intermediate in the manufacture of the war gas chlorpicrin.

There are about 250,000 known organic chemical compounds and two million theoretically possible.

WHAT THE CHEMIST HAS DONE AND MAY DO IN WAR AND PEACE

The Great War forced America into a new industrial field, the manufacture of organic chemicals. When our soldiers met the enemy on the battlefields of France they had to fight fire with fire and poison gas with poison gas. At the same time the home folks found themselves without the dyes and drugs that they had hitherto obtained from Germany. It became necessary then to create chemical industries of all sorts from optical glass to nitrates and this was done, but with haste and waste for enterprises which should have been a gradual growth had to be extemporized in a year. But by the time the fighting was over the gigantic task was accomplished and the United States was for the first time "free and independent" so far as most of the essential chemical products are concerned.

Now that we have got this chemical industry the question is, what shall we do with it? Shall we again place the weapons needed for self-defense in the hands of possible enemies and shall we once more turn over to our commercial rivals the keys to our most important manufacturers?

The answer to this vital question can only be given by the American people and they will only be qualified to decide when they know the extent and importance of the chemical industry and how it may be kept at home. If now it had been a piece of land that we had acquired through the war, say the little island of Yap, we could have kept it by a few forts and ships. But science is more slippery. It does not stand still but keeps moving —and in the case of chemistry moving very rapidly. The only way to keep it is to keep ahead in it. The American dye maker now has at his disposal all the German patents, but the German chemists have not stopped using their brains and unless we use ours we shall soon be left behind. Of what value was the best patent on a flint-lock the day after the percussion cap was invented? As soon as the Germans found out how to make artificial indigo, the indigo crop of India lost its value. The chemical industry is the offspring of science and dies if weaned from its mother.

We say "the chemical industry," not "industries," for although chemical products appear in the most various forms they are so closely related that they stand or fall together. From coal tar alone come thousands of compounds; dyestuffs of more shades and colors than can be found in nature, perfumes more pleasing than the flowers produce; medicines adapted to counteract the particular disease and modified to suit the idiosyncrasies of the patient; explosives of unprecedented potency.

The elements out of which these innumerable products are made are the commonest that the world contains; carbon from coal, oxygen and nitrogen from the air, hydrogen from water. The distillation of common coal in coke-ovens gives these four already combined in the compounds of coal tar. To the "Big Four" just mentioned may be added chlorine from the salt lakes and sulphur from the sulphur wells and such other elements as may be needed.

The model on the table shows the sort of a plant that any manufacturing chemist might envy but could not easily find, where the coal, sulphur and salt are on his own premises together with the water power necessary to run the establishment. In the middle of the table are the factories where these raw materials are combined; four groups of buildings looking much alike because they are much alike, yet, as the labels state, the first may be turning out "Explosives," the second "Pharmaceuticals," the third "War Gases" and the fourth "Dyes."

This correlation of the chemical manufacturers is a fortunate thing for it means that while we are developing one of our essential home industries we are at the same time making the most effective provision for national defense. A warship is of no use except for war. But a chemical plant producing dyes may readily turn out explosives in an emergency and the making of medicines must go on in peacetime and wartime. Young men drilled in the art of presenting arms and forming fours may never have occasion to use this knowledge, but young men trained as chemists may make the most effective combatants as well as the most useful of citizens. The development of American chemical industry is a policy that commands the support of pacifist and militarist as well as of all the rest of us who come somewhere in between.

The cost of a single battleship, some $30,000,000, would endow an establishment for chemical research such as the world has never yet seen, and the expense of keeping the battleship in commission, some $3,000,000 a year, allowing for depreciation, would pay for the education of all the chemists the country could need. The modern battleship is made as invulnerable as possible but the men on it are not invulnerable. No armor can keep out air and a ship does not have to be sunk if the crew is suffocated. A sharpshooter wastes no more ammunition on a riderless horse. A single airplane with a couple of men may sail over a warship at an unassailable height and besprinkle its decks with a liquid so corrosive that three drops of it touching a man's skin at any part will kill him and so persistent that such little of it as may be caught in crevices will render the ship uninhabitable for days. A 14-inch shell pursues a single course and when it explodes that is the end of it. An ounce of diphenyl-chlor-arsine, an innocent looking white powder, will keep up its bombardment for weeks and its molecular projectiles will fly around corners and into the smallest cracks.

Armored with such liquids and solids the airman of the next war will not need a machine gun or even bombs to attack the enemy underneath. He does not have to take accurate aim and calculate the allowance for wind, height and velocity. All he need do is to attach a sprayer to the tail of his machine and rain down poison on the earth beneath as the farmer kills the bugs on his potato field. Mr. Bradner, Chief of Research of the Chemical Warfare Service, stated in a hearing before the House Army Appropriations Committee on February 1, 1921:

> One plane carrying two tons of the liquid could cover an area 100 feet wide by 7 miles long and could deposit enough material to kill every man in that area by action on his skin.
>
> It would be entirely possible for this country to manufacture several thousand tons a day, provided the necessary plants had been built.
>
> If Germany had had 4,000 tons of this material and 300 or 400 planes equipped in this way for its distribution the entire first American army would have been annihilated in 10 or 12 hours.

Evidently we are in the midst of a revolution in warfare as great as that when guns and cannon supplanted the bow and spear. War has been a branch of applied chemistry ever since the invention of gunpowder. The recent and rapid development of this branch during the Great War, the use of noxious gases, is merely the introduction of a new weapon, more effective and no more cruel than the use of explosive gases. The German poison gas caused fifty times as many casualties among the American soldiers as the pistol, saber, bayonet, hand grenade and aviation bomb, all combined. But of the soldiers admitted to the hospital from gas injuries only 1.7 per cent died, while of the soldiers admitted to the hospital from other wounds 7.8 per cent died. The percentage of complete recovery is also in favor of gas. Of the gas cases 3.62 per cent were given disability on leaving hospital, while of the other wounded 13 per cent were discharged as disabled. Last December there were still some 5,000 soldiers remaining in the hospital from other injuries but only 4 gas cases. The experience of the Great War has demonstrated that Captain Mahan, representing the United States at The Hague Conference in 1899, was right when he protested against the proposed rule against the use of asphyxiating gases in war and argued that gas shells would be no worse than torpedoes and firearms. The only effect of the rule, which was adopted in spite of the opposition of the British and American delegations, was that when the Germans first sent a cloud of chlorine into the allied trenches at Ypres on the fatal morning of April 22, 1915, it found the British totally unprepared and all that the poor soldiers could do was to hold handkerchiefs over their noses. Some regiments were wiped out and if the Germans had pushed the attack they might have reached the sea.

Before the war all countries were largely dependent upon the nitrate beds of Chile for the nitric acid necessary for the munitions, fertilizers and various other industries. But in 1913 Professor Haber developed a process for fixing the nitrogen of the air in the form of ammonia and nitric acid. This made Germany independent of external sources for all nitrogeneous compounds for she had in the home atmosphere an unlimited supply of the free gas. If this process had not been known Germany would hardly have dared to challenge the world to combat, or if she had been so rash she could probably not have held out more than two years after the coast had been blockaded by the British navy.

The situation with reference to many pharmaceutical preparations at the outset of the war was such that America was dependent exclusively on manufacturers in enemy countries. The emergency, of course, required prompt and effective work on the part of American chemical manufacturers and as a result of this the market was soon supplied with the needed useful remedies. The first example of this is arsphenamine, more widely known as salvarsan. This preparation is one of the most difficult to produce in the whole range of pharmaceuticals, and the Germans fully appreciated that we could not produce it. But in spite of real difficulties involving much experimental work no less than four American firms were producing the drug before the end of the war. Also America is now making her own aspirin, acetanilide, atophan, and other synthetic drugs for which we were formerly dependent upon Germany.

The lesson of it is that any country that hopes to hold its own in peace or war must have an active chemical industry guided by scientific research and backed by patriotic public opinion. The chemist is by profession a futurist. He is more an inventor than a discoverer. He foresees what no one has yet seen. He constructs in advance a diagram picturing the structure of the molecule that he proposes to make just as a builder prepares a blueprint of the house to be erected. A period of investigation and experimentation often extending over years must precede the commercial development of a new process or product. Commercial chemistry is an applied science and a science must exist before it can be applied. That is why the countries that have made greatest progress in the chemical industries, such as Germany, have spent most money on research and that is why America must have similar research establishments if she is to keep up with the procession.

EDWIN E. SLOSSON.

Science Service,
Washington

THE CHEMICAL EXHIBIT

The main feature of the exhibit is a topographic model, 7 feet by 12 feet, of an idealized group of chemical industries whose development and maintenance are essential for adequate national defense. The outer portion of the model shows the plants and equipment required for the production of some of the more important crude materials which are required by the chemical industries. This includes models of sulphur wells; a sulphuric acid plant; a coal mine with the usual equipment for sorting and handling coal; a by-product coke oven with stills and storage tanks for the various crude products obtained from coal tar; a hydroelectric power plant which supplies electric power to a plant for the production of nitric acid from atmospheric nitrogen and also to an electrolytic chlorine plant from which caustic soda and chlorine are produced by the electrolytic decomposition of salt; and salt wells which provide the salt for the chlorine plant.

The above group of plants surrounds what may be called the heart of the chemical industry; that is, the plants which produce the intermediate and finished chemical products. The group of buildings representing the production of the intermediate chemicals are situated near the center of the model. Radiating from the intermediate chemical plant are four separate groups of factory buildings. One group represents an industry for the manufacture of dyes; another for explosives; another for pharmaceuticals and medicinals; and another for war gases. All of these four industries use the same chemical intermediates for the production of their finished products.

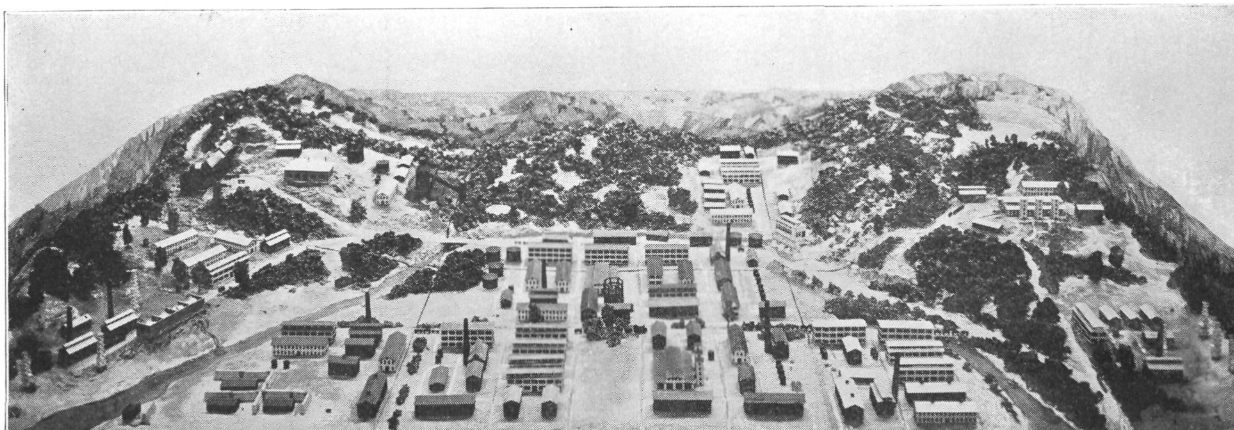
Back of this model are four charts showing some of the intermediates and finished products obtained from each of the four crude chemical materials—sulphur, salt, coal, and atmospheric air. On these charts actual samples of the chemical substances are attached.

Other features of the exhibit are: a group of the various appliances used in offense and defense chemical warfare; collections of some of the more important dyes; war gases; explosives, and pharmaceuticals derived from coal intermediates, and models to show the molecular structure of these chemicals. These models are the "blue prints" from which the research chemist works in so changing the molecules as to develop new dyes, war gases, medicinals, or explosives.

It may not be generally known that even our Government had to go begging to Germany for dyes following the outbreak of the European War so as to be able to continue the printing of its postage stamps. You remember how the shop men informed you that they would not guarantee the fastness of certain colors. Even today our textile trade is suffering because of the bad impression which it made in South America by exporting poorly dyed materials. But the American dye manufacturers have made wonderful progress, as the complete range of colors of American made dyes in this exhibit indicates. Dye patterns are also shown. The economic importance of the dye industry and its close relationship to many other industries have made the dyestuff industry a pivotal one whose reasonable safeguarding should have the assurance of the American people.

The Genealogical Table of the Chemical Industry

The following diagrams have been prepared to show how closely related are the various branches of chemical industries and how a few fundamental raw materials may be made into many useful products. The arrows indicate the order of synthesis, or the development that comes from special treatment or combinations. For example, from nitrogen, which comes from air, we get later by different processes an anaesthetic, an explosive, a war gas and a smokeless powder. Thus, by various reactions, thousands of products come from a few simple ones.



Topographic Model showing the Intimate Relation between the Coal Tar and other Industries.

PLAN OF BUILDINGS

Coal Mine By-Product Coke Ovens Nitric-Acid Plant Hydro-Electric Power Plant Chlorine Plant

Sulphuric Acid Plant Intermediates Plant Salt Wells

Sulphur Wells Explosives Pharmaceuticals War Gases Dyes

WHAT COMES FROM COAL, SULPHUR, SALT AND AIR

The photograph represents an idealized group of chemical industries such as are required in the production of dyes, war gases, pharmaceuticals and explosives. The model plants which produce the crude chemicals required are located on the outer portion of the topographic model, at the back and on the two sides, while the plants for the production of intermediates and finished products are in the center extending to the front of the model.

At the left hand lower corner of the model is represented a group of sulphur wells with the accompanying power houses and storage bins such as are found in Louisiana and Texas where native sulphur is pumped to the surface from deposits hundreds of feet under ground.

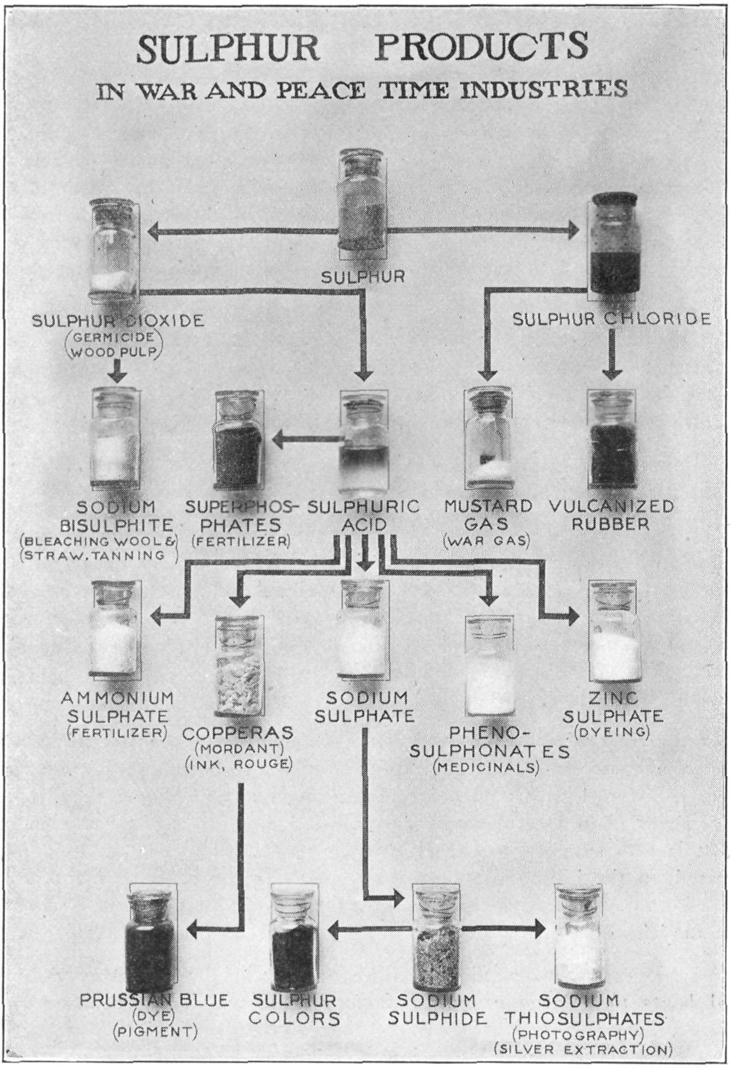
Adjoining the sulphur wells is a sulphuric acid plant where sulphur is burned to sulphur dioxide which in turn is oxidized in the presence of catalytic platinum to form sulphuric acid.

Back of the sulphuric acid plant in the far left hand corner of the photograph is a coal mine with a tipple and accessories which is the original source of coal tar crudes, the coal being distilled in the by-product coke ovens, located in the model at the right of the coal mine. The chief crudes obtained from the coal are xylene, benzine, toluene, napthalene, carbolic acid and anthracene.

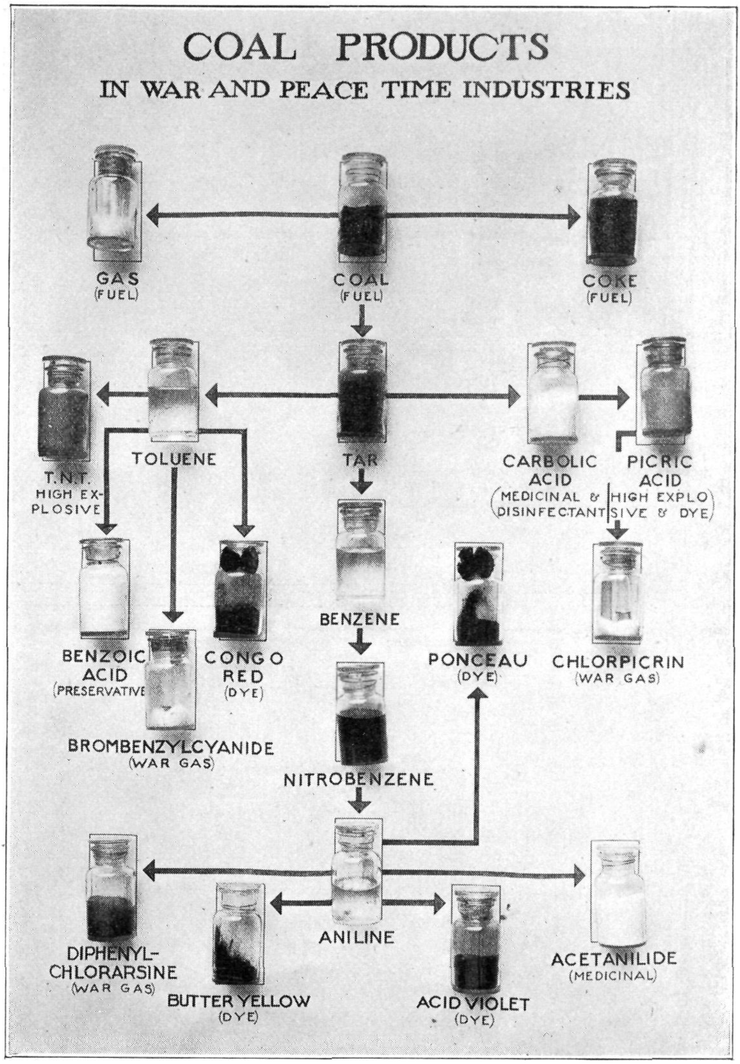
At the right of the coke oven is the fixed nitrogen plant where atmospheric nitrogen is converted into ammonia, nitric acid and ammonium nitrate. The electric power for this plant is supplied by the hydroelectric power plant located on the river below the falls. Power from this plant is also supplied to the electrolytic chlorine and caustic soda plant located on the hill to the right. The salt for the chlorine plant is obtained from the salt wells situated at the right hand lower corner of the model.

All of the crudes mentioned above are carried by miniature railways and boats to a large group of factory buildings in the center of the model where they are subjected to various chemical processes and thus transformed into the different intermediates.

Radiating from the intermediate plant are four smaller plants (in the front portion of the model) one for the production of explosives, another for pharmaceuticals and medicinals, a third for making war gases and the fourth for the production of dyes. All of these four plants use the same intermediate chemicals, but by using suitable combinations of the chemicals and subjecting them to the required processes, the four different types of finished products mentioned are obtained.

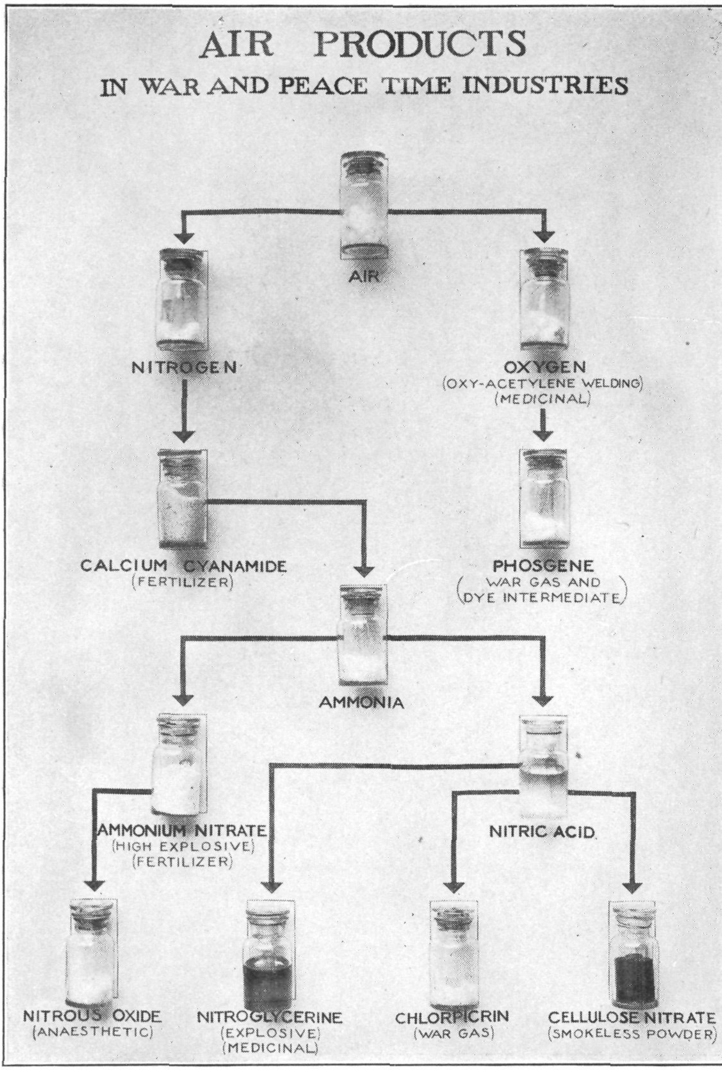


Sulphur enters into a large number of intermediates and finished products employed in the arts. By treating sulphur with chlorine we get a liquid, sulphur chloride, which is used in making the war gas, "mustard gas," and also in the vulcanization of rubber. Then, by burning sulphur in air sulphur dioxide is formed, useful as a germicide and employed in the manufacture of paper from wood pulp. By other chemical reactions we get products that are used in bleaching, tanning, photography, and in the manufacture of fertilizers, medicinals, dyes, inks, etc. The chart indicates merely a few of these.



Thousands of products are obtained from coal. By distillation comes coke, illuminating gas, and tar. The latter gives us a large number of what are called "crudes." By nitration we obtain from one of these, toluene, the high explosive trinitrotoluene (T. N. T.), by oxidation the preservative benzoic acid, and by other treatment the dyes, Congo Red and Patent Blue, or the war gas, brom-benzylcyanide. Benzene, by nitration, gives nitrobenzene and from that we get aniline, the base of various dyes, such as Butter Yellow and Acid Violet, the war gas diphenylchlorarsine and the medicinal acetanilide.

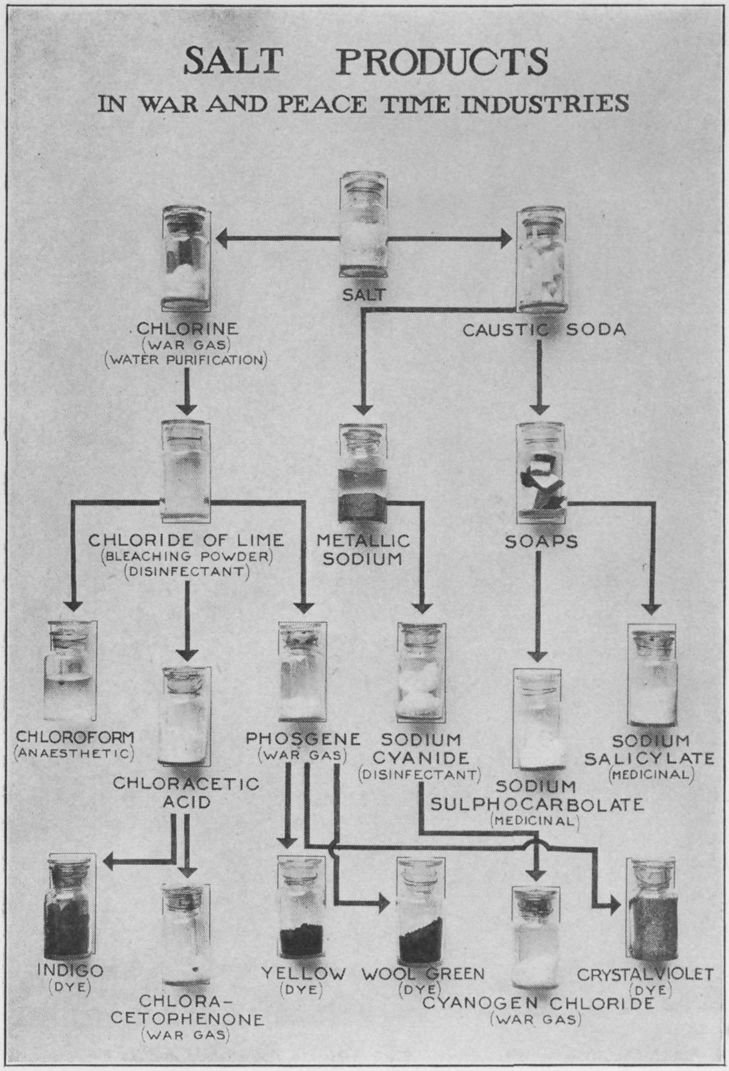
A large number of other products are obtained from the crudes shown on the chart, and an equally large number can be obtained from the other crudes, such as xylene, napthalene, etc.



When air is liquified it is readily separated into its two main constituents, oxygen and nitrogen. The accompanying chart illustrates a few of the uses for which these elements and their products are employed.

Oxygen is used in the oxyacetylene welding of metals, as a medicinal, and in the synthesis of phosgene, a war gas and dye intermediate.

Nitrogen combines with calcium carbide to form the fertilizer, calcium cyanamide, from which the important chemical, ammonia, is obtained. Ammonia in turn is used for the production of ammonium nitrate, a high explosive and fertilizer, from which the anaesthetic, nitrous oxide, is obtained, and nitric acid which is used for making explosives such as nitroglycerine and cellulose nitrate, the war gas, chlorpicrin, and in the synthesis of dye intermediates such as aniline.



The two main products of salt are chlorine and caustic soda, which are obtained by the electrolytic decomposition of brine (salt solution). Just a few of the products obtained from these and their use are indicated on the chart. One does not always associate the production of a deadly war gas with the extraction of gold or the manufacture of soap, but the arrows show the relation. Then, too, few people may think that the same chlorine which was one of the principle materials required in the war gas program has also wide use in drinking water purification and by various treatments gives us such important products as chloroform and synthetic indigo.

From

THE

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