

shore, the rise and fall lasting from half an hour to an hour or more. This has occurred during a comparative calm on some occasions, while on others, though a strong gale has been setting inshore, I have not noticed any difference in the lake's level; so it would seem that this occurrence is not altogether attributable to the wind backing up the water. Another curious feature is the periodical rise and fall, which, according to the natives, takes place every twenty-five years, and which is shown by the water marks on the shores. At the time of my visit the lake was between eight and nine feet below high-water mark, and the people told me that certain lands then under cultivation would again be flooded in due season, and that the peninsula on which my camp was pitched would again become an island. Similar changes of level have been noticed both in Lake Tanganyika and Lake Nyassa, and it is very desirable in the interests of geography as well as the development of the continent that continuous observations should be made, in order to discover what is the real character of these changes.

THE ORIGIN OF COAL AND PETROLEUM.*

By A. E. FORSTALL, of Newark, N. J.

THE average gas engineer finds his time so fully taken up by the routine of his position, or by investigations bearing directly upon the improvement of the processes with which he has to deal, that he has little leisure for original research in outside fields. When, therefore, the wisdom of the "powers that be" in the Western Association assigns such a subject as this for a paper, there surely can be no expectation of the development of any new and startling facts or theories. The idea must rather be to obtain a summary of facts and theories already known to and advanced by geologists, with a brief, succinct statement of the arguments for and against these various beliefs. It is from this standpoint that what follows has been written.

Geology is, from the nature of things, an indefinite science, in so far as it deals with the earlier periods of the earth's existence. Studying the effects produced by natural forces at the present day, it reasons that in the past similar effects argue the operation of the same forces. But even the record of these effects as contained in the portions of the earth's crust explored by the geologist is very incomplete, many gaps being left to be filled in by deduction, always liable to error. Any moment may bring forth some new fact, upsetting preconceived ideas and compelling a remodeling of theories. However, the theory as to the formation of coal now generally held is apparently as firmly founded as any geological speculation, and will probably never have to be materially altered. That in regard to petroleum is not so certain, but accounting satisfactorily for all the facts as known, must be accepted until some new and irreconcilable discovery is made.

Let us take up coal first. Almost all the coal known to and worked by man dates from the Carboniferous age division of the Paleozoic period, taking its name from the extent of its coal formations, and itself capable of subdivision into three minor periods; the Sub-Carboniferous, the Carboniferous proper and the Permian. It is in the measures of the second of these subdivisions that coal is principally found, in seams varying from a fraction of an inch to 40 or 50 ft. in thickness. Under each coal seam is a bed of fire clay; above it a covering of black bituminous slate. A pure, simple seam is rarely more than 5 to 10 ft. thick, the mammoth seams being formed by the running together of several seams through the thinning out of the intermediate strata, which are still to be found in very thin layers through these seams. Between the seams, with their accompanying clays and black slate, are layers of sandstone and limestone. A section through the coal measures shows a number of seams of coal, in some cases as many as 50 or 60, of various thicknesses and degrees of purity, separated from each other by intervening strata of sandstone and limestone. The vegetable origin of coal is no longer considered doubtful, and quoting from Le Conte's "Elements of Geology," we have the following as the principal evidence upon which is based the present scientific unanimity of opinion on the subject:

First.—The remains of an extinct vegetation are found in abundance in immediate connection with the coal seams, stumps and roots in the under clay and leaves and stems in the black slate in contact with the seam, and even embedded in the seam itself.

Second.—These vegetable remains are not only associated with the seam, but have often themselves become coal, though still retaining their original form and structure.

Third.—Not only these easily recognizable embedded fragments, but the embedding substance also, the whole coal seam, even the most structureless portions and the hardest varieties, such as anthracite, when carefully prepared in a suitable manner and examined with the microscope, show vegetable cells with characteristic markings.

Fourth.—A perfect gradation may be traced from wood or peat on the one hand, through brown coal, lignite and bituminous coal, to the most structureless anthracite and graphite on the other, showing that these are all different terms of the same series. In chemical composition, too, the same series may be traced.

Fifth.—The best and most structureless peat, by hydraulic pressure, may be made into a substance having many of the qualities and uses of coal.

These are, in brief, the main reasons for the belief in the vegetable origin of coal. Working on this hypothesis, how can we account for the different varieties of coal, classified according to their elementary composition; that is, according to the relative amounts of carbon, hydrogen and oxygen contained in them, these being the three elements forming a pure coal? The substance that makes up the mass of the cell membranes of all plants is called cellulose, and has a composition denoted by the chemical formula, $C_{12}H_{20}O_{11}$, signifying that each molecule is formed of 12 atoms of carbon, 30 atoms of hydrogen and 15 atoms of oxygen. When vegetable matter is protected from contact with air, as it may be by being covered with water, mud, or a growth of fresh vegetation above it, a slow decomposition takes place by mutual reactions among its

own elements. Carbon unites with hydrogen to form marsh gas, CH_4 ; also with oxygen, forming carbonic acid, CO_2 , while hydrogen and oxygen unite, producing water, H_2O . These reactions are proved to take place by the continual giving off of marsh gas and carbonic acid from the coal in mines, these two gases being the fire damp and choke damp, so dreaded by miners. Analysis also shows that the bubbles which rise to the surface when we stir up the decaying vegetable matter at the bottom of a pond are composed of these gases.

Starting now with 2 molecules of cellulose, or $C_{24}H_{40}O_{22}$, by subtracting 9 molecules of CO_2 , 3 of CH_4 , and 11 of H_2O , we have left $C_{15}H_{26}O$ —the formula for an average cannel coal. In the same way we obtain $C_{24}H_{40}O_{22}$ —the formula for average bituminous coal—by the subtraction of 7 molecules of CO_2 , 3 of CH_4 , and 14 of H_2O ; and finally, if we deduct 10 CO_2 , 10 CH_4 , and 10 H_2O , we have left C_8 , which is pure carbon or graphite. Thus reactions known to occur are shown to be capable of producing coal from vegetable matter—another strong argument in favor of this theory.

It is almost certain that bituminous coal has been formed in the manner indicated from the original vegetable matter, without the aid of heat, the strata found with it showing no signs of metamorphism. The extreme varieties of coal, anthracite and graphite, are always found, however, associated with metamorphic rocks, so that it is almost equally certain that in their case heat has played a part in the complete expulsion of the hydrogen and oxygen. Such heat need not be extreme, a temperature of 300° to 400° F. being sufficient to produce all the metamorphic effects found in the anthracite regions.

The origin of the coal thus determined, how can its accumulation in its present form of numerous seams throughout the coal measures be accounted for? This accumulation certainly took place in the presence of water. In no other way can the preservation of the original organic matter which would have decayed if left exposed to the atmosphere, the presence of interstratified layers of clay, sand and limestone, or the stratification of the coal itself, be explained. Besides, the plants found in connection with the coal seams are such as grow in moist ground. Opinion, however, is divided as to whether the growth and deposition took place on the same spot or whether the latter occurred at a distance from the original home of the plants, being brought about by the formation at the mouths of rivers of the so-called "rafts," an example of which is found at the mouth of the Red River. The theory of growth *in situ* seems most probable, agreeing better with the facts of the comparative freedom of coal from ash which is intermixed inorganic matter; the existence on top of the seams of numerous perfect specimens of the most delicate parts of plants and the number of stumps found apparently in the exact condition and position in which they grew in the under clay.

The study of the strata of the coal measures seems, also, to indicate that the forests from which the larger coal beds have been formed grew at the mouths of rivers, on low lands more or less marshy and subject to overflows from the rivers, with occasionally an incursion of the sea due to a gradual subsidence of the continent. The land area of the earth bearing then a much smaller proportion to the water than it does at the present day, the air was more saturated with moisture and consequently the climate was much warmer and more equable; water vapor, from its property of allowing luminous heat rays to pass almost untouched, while almost completely absorbing the dark rays radiated back from the earth, being one of the potent agents in storing up in the earth the heat coming from the sun. These conditions of constant moist warmth, coupled with the presence of an excess of carbonic acid in the atmosphere, produced a most luxuriant forest growth, continuing for years and forming a constantly thickening deposit of vegetable matter. Now and then an overflow of the river covered this deposit with a thin layer of sand and mud, on top of which a new seam began to form. At longer intervals an inrush of the sea put an end to vegetation and formed a stratum of limestone. But gradually the sediment brought down by the rivers built up on the sea bottom new deltas on which a new growth began and the process was repeated.

Thus by the alternate growth and submergence of vast forests, were the materials destined to produce these deposits of incalculable value formed and stored under the conditions necessary for their future transformation. Slowly, during the thousands of years of the Carboniferous period, did the energy of the sun transform the carbonic acid of the atmosphere into solid carbon; still more slowly through the succeeding eras came the changes bringing this carbon to its present form, and now, after ages of preparation, man is "unbottling the sunshine," modifying the rigors of winter and turning night into day with the rays apparently lost millions of years ago.

Turning to petroleum, we find opinion much more divided, and no such general knowledge of the subject as to warrant implicit belief in any particular theory. The various theories may be divided into two classes; those asserting a derivation from the chemical reactions of minerals or inorganic matter and those claiming an organic origin through the decomposition of vegetable or animal matter.

The theories of Berthelot or Mendeljeff are leading examples of the first group. According to the former, petroleum is formed by the action of water, carrying carbonic acid in solution, upon alkali metals existing in a free state and at a high temperature in the center of the earth, he having pointed out the reactions that would take place resulting in the formation of hydrocarbon compounds.

Mendeljeff's theory supposes the existence in the interior of the earth of metallic iron and metallic carbides at a high temperature, which, by contact with water, would generate metallic oxides and hydrocarbon compounds.

Both theories consider the production of petroleum as continuous, the vapors rising as they are formed and condensing to liquids in the porous strata of the oil fields, thus making the supply inexhaustible as long as the necessary minerals and water exist.

But these theories, though chemically perfect, are not generally accepted by geologists, since they do not accord with geological facts, which point more to the organic origin of petroleum; that is, to its derivation from the decomposition of vegetable or animal matter

originally contained in the rocks in which it is found, or in closely associated strata. As we saw in considering coal, the decay of vegetation at ordinary temperatures, when taking place out of contact with air, produces marsh gas. Peat bogs yield inflammable gases, and sometimes also members of the bitumen series closely allied to petroleum and asphalt, thus showing the decomposition of organic matter to be competent to produce petroleum.

There are two views as to this method of decomposition: One, that it is a primary decomposition of organic matter in or associated with the strata where the oil is found—the production, therefore, being *in situ*; the other, that a primary decomposition of the organic matter to hydrocarbon compounds first takes place, from which compounds oil and gas are derived by distillation and carried by hydrostatic pressure to the overlying porous strata, which act as reservoirs.

The chief exponent of the theory of primary decomposition is Prof. T. S. Hunt, who holds that petroleum is principally derived from animal remains contained in limestone rocks, though he admits a few cases of vegetable origin.

The theory of distillation is most fully stated by S. F. Peckham, in the report on petroleum contained in the tenth volume of the "Special Reports of the United States Census of 1880." He considers that petroleum was formed by distillation principally from beds of shale containing fossil plants and animal remains, with limestone as a minor source, basing this view upon the variations in composition of petroleum found in different portions of the same field, which he thinks can only be accounted for upon the theory of fractional distillation. In the case of the Pennsylvania oil field, the oil is derived principally from vegetable remains in rocks far below the present level of oil occurrence, the heat for its distillation having been supplied by the causes that resulted in the upheaval of the Appalachian mountain system, and the evidences of this heat are to be found deep down beneath the unaltered rocks in which the petroleum is now stored. Peckham also considers the occurrence of large veins of solid bitumen in fissures and metamorphic rocks as a further proof of the fact of distillation.

In Vol. VI. of the "Reports of the Geological Survey of Ohio," Prof. Edward Orton, the State Geologist, discusses the subject of the origin of petroleum quite extensively, reviewing the various theories given above, indicating their weak points, and stating his own views, derived from a special study of the Ohio fields in connection with a general study of the whole subject. Admitting the great want of definite information that prevents any theory from being accepted as perfect, he inclines toward the idea of primary decomposition as the great factor in the production of petroleum, a decomposition including both vegetable and animal matter, according to location. Thus the large amounts of nitrogen and sulphur in the Lima and California oils, the unstable character of the latter, and their presence in limestones filled with animal remains, are strong proofs of an animal origin. These limestone oils are dark and heavy, with a rank odor, and are easily distinguished from the oils of a probable vegetable origin, such as the Pennsylvania type, coming from bituminous shales and found in sandstones.

As an argument against the theory of distillation, Prof. Orton cites the fact that the study of the rocks underlying the Ohio oil fields, by means of borings carried 1,500 ft. below the oil-bearing strata, shows no signs of metamorphism, which, as this depth is below the only known sources of oil supply of the Pennsylvania type, would seem to condemn the idea of distillation. In favor of the theory of primary decomposition, he notes the fact that, at the present day, in Trinidad, beds of slate formed in comparatively recent times beneath the sea, but now raised above its level and containing abundant vegetable remains, are yielding petroleum in large quantities by direct decomposition of vegetable tissues, this petroleum passing into asphalt as a result of exposure to the atmosphere. But if the action took place where the petroleum could be stored out of contact with the air, it would remain as petroleum. This is what has happened in the oil fields. A tropical climate seems necessary for this action.

Applying the views derived from the foregoing facts to explain the origin of the oil of Eastern Ohio and Pennsylvania, the following theory is worked out: These fields were the site of a tropical sea, upon the floor of which the shales constituting the chief source of the oil were accumulated. The rivers emptying into this sea laid down sedimentary deposits of clay and sand, with occasional gravel bars. In the sea itself was a vast development of marine vegetation. Some of the especially abundant plants had very resinous spores and spore cases, which were set free in enormous quantities, and, in connection with other portions of these and similar plants, were carried to the bottom in a macerated condition, there to pass through the coaly transformation, resulting in the structureless carbonaceous matter that constantly characterizes black shales, and that can still be made to yield by destructive distillation members of the bitumen series. The shales thus slowly accumulated at the bottom of this gulf must have behaved as similar shales do now, petroleum and bitumen being formed as in the case of the Trinidad shales. The petroleum was absorbed by the particles of clay in contact with it, or if formed in the water, was caught by floating particles (clay possessing the property of absorbing oils in a marked degree), being carried by them to the floor of the sea as the sediment deposited. This process continued until the materials were exhausted, producing a shale much richer in petroleum than any portion of it is at the present time. Over this was laid a bed of porous sandstone, saturated with sea water and roofed in by a very fine-grained shale. Then, by a slow system of exchange between sandstone and shale, the oil reached its final reservoir.

Prof. Orton claims that this theory finds more support in the present processes of nature than that of distillation, as we see the bitumen series forming today by the apparent primary decomposition of organic matter under normal conditions, while on the other hand we do not find this series in any case open to observation and measurement as a result of secondary decomposition, unless the comparatively high temperatures of destructive distillation are reached. Still he admits that every theory in regard to petroleum is

* Read at the recent annual meeting of the Western Gas Association at Detroit.—*American Gas Light Journal*.

merely provisional, and none can be accepted as final. He summarizes his views as follows:

- First.*—Petroleum is derived from organic matter.
- Second.*—It is more largely derived from vegetable than from animal matter.
- Third.*—The oils of the Pennsylvania type result from the organic matter of bituminous shales; that is, they are of vegetable origin.
- Fourth.*—The oils of the Canada or Lima type are derived from the organic matter in limestones, and are, therefore, probably of animal origin.
- Fifth.*—Oil was produced at normal rock temperatures; that of the Ohio field at any rate certainly not being the result of a destructive distillation of bituminous shales.
- Sixth.*—The stock in the rocks is practically complete, for though the production is still going on, the rate is so slow as to make no appreciable increase in the amount already produced, in any ordinary space of time.

Prof. Orton's views have been given thus fully because he is the latest writer on the subject, and his ideas, being based upon a broad study of the whole field, are probably the most reliable. But according to his own statement the final word cannot yet be said as to the origin of petroleum.

From what precedes, it is seen that though coal and petroleum are of similar, they are not of the same origin; are not necessary correlative; nor is petroleum a product of the transformation of vegetable matter into coal. The difference in the product of the two operations, one being a solid in all stages of its transformation, while the other is a very volatile liquid, may account for the greater certainty with which the record of the first can be traced through all its successive steps, and the almost total absence of record in the case of the second. As more is learned, however, by the development of new oil territory, and a more systematic study of the facts revealed by the drill, the theories of the origin of petroleum may be put upon as firm a basis as those relating to coal. Until then the gas man must accept the dicta of geological oracles, and keep at the, for him, more important task of working out the best method for the destruction of petroleum, without being absolutely certain as to its origin.

THE following are the questions given to candidates for the Major examination in London recently, and to these we append model answers by an experienced "coach." Although the answers are, perhaps, somewhat fuller than the time actually allowed at the examination would have permitted, they make no pretensions to exhaust all that can be said on the various subjects.

EXAMINATION QUESTIONS IN CHEMISTRY AND PHYSICS.
WITH MODEL ANSWERS.

CHEMISTRY—(Morning).
(Three hours allowed.)

Question 1. Define isomerism and point out its various forms, giving examples.

Answer. When two or more substances are composed of the same elements in the same proportions, they are said to be isomeric with each other.

There are three principal varieties of isomerism—namely (a) Isomerism proper. This occurs when the substances not only contain the same elements in the same proportions, but also possess the same vapor density and exhibit similar behavior under the influence of various reagents. Such substances are recognized as being chemical individuals by differences in boiling or melting points, action upon polarized light, and the like. As examples of this kind of isomerism may be mentioned the three di-brom derivatives of benzene, all of which may be represented by the molecular formula, C₆H₄Br₂.

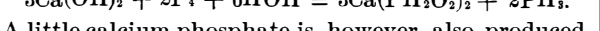
(b) Metamerism. In this the substances resemble each other in percentage composition and vapor density, but differ, not only physically, but also in their behavior with reagents. Examples: Propargyl and benzene, which have the common formula, C₆H₆.

(c) Polymerism. In this case the substances, while agreeing in percentage composition, have different vapor densities, and hence different molecular weights. Examples: Aldehyde, C₂H₄O; and paraldehyde, C₆H₁₂O₆.

Question 2. How is calcium hypophosphite prepared? Give the equation. Why is the gaseous product of the reaction spontaneously inflammable? Account for the basicity of phosphorous and hypophosphorous acids respectively by a reference to their constitutional formulae.

Answer. Calcium hypophosphite is prepared by boiling together phosphorus and milk of lime until the evolution of phosphine (PH₃) ceases, filtering the solution, passing a current of carbon dioxide through the filtrate to precipitate any excess of calcium hydrate, again filtering and evaporating with agitation, until a dry product is left.

The following equation approximately represents the reaction:



A little calcium phosphate is, however, also produced, and the evolved gas contains a trace of the vapor of the liquid phosphide of hydrogen P₂H₄, and it is to this circumstance that its spontaneous inflammability is due.

Phosphorous acid usually appears to be dibasic, only two of its three hydrogen atoms being replaced by metals under ordinary circumstances; but a sodium salt P(ONa)₂ has been obtained, and tri-ethyl phosphite, P(OC₂H₅)₃, is comparatively well known. Hence it is better to regard phosphorous acid as being really tribasic, and to give it the formula:

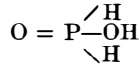


Hypophosphorous acid is generally represented as—



i. e., as phosphine in which two atoms of hydrogen have been replaced by hydroxyl. This formula, how-

ever, does not explain the fact that it always acts as a monobasic acid. If we regard the phosphorus as a pentad in this compound, and assign the following formula,



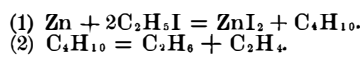
the basicity is explained.

Question 3. Give a process for the preparation of ethyl iodide, and describe the properties of the compound. What is its reaction with metallic zinc?

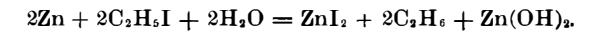
Answer. Ethyl iodide may be obtained by gradually adding iodine to a mixture of red phosphorus and strong alcohol placed in distilling flask with a suitable condensing apparatus attached. When the reaction is complete, the iodide may be distilled off, washed with water, and redistilled from calcium chloride.

It is a colorless liquid, becoming red on exposure to light; it is nearly twice as heavy as water, and boils at 72° C.

When ethyl iodide is heated with zinc alone, a mixture of ethane and ethylene is obtained, these bodies resulting from the decomposition of the butane at first produced. This is shown in the following equations:



In the presence of water zinc produces ethane only:

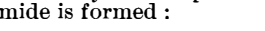


Question 4. What is ethylene, and to what class of bodies does it belong? Name its principal derivatives, and show how they may be prepared from it.

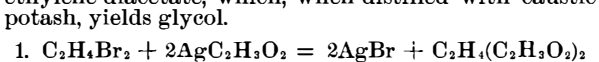
Answer. Ethylene is the name now usually given to the substance formerly known as "heavy carbureted hydrogen," or "olefiant gas." It has the formula C₂H₄, and is prepared by the action of dehydrating agents, such as sulphuric acid upon alcohol. It belongs to the unsaturated group of fatty hydrocarbons, and is a type of the olefine, or C_nH_{2n}, series.

Among the derivatives of ethylene may be mentioned:

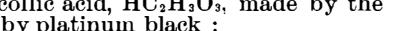
(1) The dihaloid compounds formed by direct addition. Thus, when ethylene is passed into bromine, ethylene dibromide is formed:



(2) Glycol C₂H₄(OH)₂, which may be made by treating ethylene dibromide with silver acetate, thus obtaining ethylene diacetate, which, when distilled with caustic potash, yields glycol.



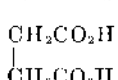
(3) Glycollic acid, HC₂H₃O₃, made by the oxidation of glycol by platinum black:



Question 5. Describe the sources, characters, and chemical constitution of succinic acid, and indicate its relation to tartaric acid.

Answer. Succinic acid may be obtained (1) from amber, in which it exists ready formed; (2) by the fermentation of a mixture of the juice of mountain ash berries, chalk, water, and decaying cheese, afterward decomposing the calcium succinate produced with dilute sulphuric acid; (3) by the fermentation of saccharine solutions, when a small quantity of this acid is always formed; (4) by the action of nitric acid upon many fatty substances; (5) by the reduction of tartaric acid by hydriodic acid. Succinic acid is a colorless crystalline body soluble in water and in alcohol, and melting at 80° C. Its salts give no precipitate with hydrochloric acid, but white barium succinate with barium chloride, and reddish ferric succinate with ferric chloride.

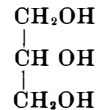
The constitution of the acid is represented by the graphic formula:



and its relation to tartaric acid is shown by describing the latter body as di-hydroxy-succinic acid, and regarding it as derived from succinic acid by the substitution of two molecules of hydroxyl (OH) for two atoms of hydrogen.

Question 6. What is the constitution of glycerine, and how has it been determined?

Answer. Glycerine is a trihydric alcohol and is represented by the formula



The following are among the considerations which have led to the view of constitution symbolized by the above formula.

(1) By the action of hydrochloric acid and pentachloride of phosphorus one, two or three atoms of chlorine can be substituted for one, two or three atoms each of hydrogen and oxygen, thus proving the existence in glycerine of three hydroxyl groups.

(2) Three classes of ethereal salts are obtainable from glycerine by treatment with acids, one, two or three molecules of water being set free in the reaction.

(3) The fact that two isomeric mono- and di-chlorhydrins exist is best explained by assuming the truth of the formula given above.

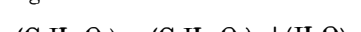
Question 7. Give a general account of the carbohydrates, showing the principle upon which they are classified.

Answer. A carbohydrate is defined as a body composed of carbon, oxygen and hydrogen, the two latter being in the proportion necessary to form water. They mostly occur naturally in animals and vegetables, and may be represented by one or other of three formulae, and hence fall naturally into three groups, which are:

- I. Glucoses. Formula C₆H₁₂O₆; the principal members being dextrose, levulose and galactose.
- II. Saccharones or saccharoses. Formula C₁₂H₂₂O₁₁. The principal members are cane sugar, or sucrose; milk sugar, or lactose; and malt sugar, or maltose. They are considered to be of an alcoholic nature, and may be regarded as formed by the union of two mole-

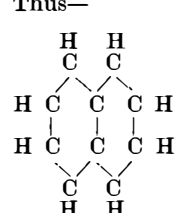
cules of a glucose with elimination of one molecule of water.

III. Amyloids or amyloses. Formula (C₆H₁₀O₅)_n. The principal members are starch, inulin, dextrin and cellulose. They may be looked upon as derived from n molecules of glucose with elimination of n molecules of water—



Question 8. Give the chemistry of naphthalene. What are its uses in the arts?

Answer. Naphthalene is a very frequent product of the action of high temperatures upon organic substances. Hence it is obtained during the destructive distillation of coal, and may also be made by passing the vapor of benzene and some other substances through a red-hot tube. From a careful study of the reactions of naphthalene and its derivatives, the molecule of this hydrocarbon is regarded as consisting of two benzene rings so arranged as to have two carbon atoms in common. Thus—



With chlorine and bromine it forms substitution derivatives and also certain additive compounds. With sulphuric acid two isomeric sulphonic acids are produced, called alpha and beta respectively. By the action of potash upon these, alpha and beta naphthols result, which bodies have the formula C₁₀H₇(OH), and bear to naphthalene the same relation that phenol bears to benzene. By the action of nitric acid nitro-naphthalenes are formed, by the substitution of the radical NO₂ for hydrogen, and, by the reduction of these compounds, naphthylamines, containing NH₂, can be obtained.

The principal products of the oxidation of naphthalene are dinaphthyl (C₂₀H₁₄), phthalic acid (C₈H₄(CO₂H)₂), and naphthoquinone (C₁₀H₆O₂).

Naphthalene is used (1) To increase the illuminating power of coal gas. (2) As a disinfectant, and to prevent moths and other insects from attacking articles of clothing and the like. (3) As a starting point in the manufacture of several dyes, e. g., Magdala red, campobello yellow, naphthazarin, etc. (4) In the manufacture of benzoic acid.

PHYSICS—(Afternoon).
(Three hours allowed.)

Question 1. State the law governing the diffusion of gases and describe an experiment in illustration of it.

Answer. This law may be formulated as follows: Gases diffuse into each other in the inverse ratio of the square roots of their densities. As an illustrative experiment a glass tube about a foot in length may be closed at one end by a plate of plaster of Paris, filled with hydrogen, and then placed in a vessel of water so that the open end dips below the surface. The density of air as compared with that of hydrogen is as 14.4 is to 1, therefore the rate at which the air will pass through the porous plate into the tube will be to the rate at which the hydrogen will pass through the plate out of the tube as sq. 1 is to sq. 14.4. The result of this will be that the tension of the gas in the tube will be diminished and the water will rise considerably in the tube. The experiment may be varied by putting air instead of hydrogen into the tube and then inverting over it a bell jar filled with hydrogen. This gas will pass into the tube more quickly than the air will pass out, and hence the level of the water in the tube will be depressed.

Question 2. Define specific and atomic heat, and give a process by which the specific heat of a solid may be determined.

Answer. The specific heat of a substance is the amount of heat required to raise unit mass through unit interval of temperature as compared with the amount required to raise the same mass of water through the same interval.

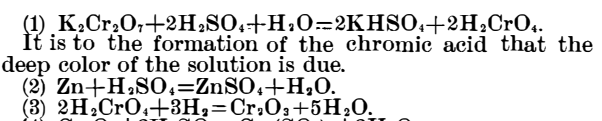
The atomic heat of an element is the product obtained by multiplying together its specific heat and its atomic weight. To determine the specific heat of a solid a known weight may be heated and then plunged into a known weight of cold water. If the initial temperatures of the solid and water be known, and the rise in temperature of the latter be accurately determined, the specific heat of the solid may be calculated by the use of the following formula:

$$\text{Specific heat} = \frac{M(T-t_2)}{m(t_1-T)}$$

Where M = weight of the water, m = weight of the solid, t₁ = initial temperature of the body, and t₂ = initial temperature of the water, and T = the final temperature.

Question 3. Describe the construction and principle of a bichromate battery cell, and represent the reactions which take place in it by equations.

Answer. A bichromate battery cell consists of a plate of zinc as the negative, and one of carbon as the positive pole. These are immersed in diluted sulphuric acid, in which bichromate of potassium is dissolved. The object of the bichromate is to prevent what is called internal polarization, i. e., the adhesion of evolved hydrogen to the carbon, which would tend to arrest the action of the battery. The method in which this polarization is prevented is apparent from the following equations, which show that the hydrogen, instead of being evolved in the free state, effects the reduction of the bichromate:



Question 4. Define the terms "electrode," "electro-