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FIRST LESSONS IN

COAL MINING

FOR USE IN PRIMARY SCHOOLS

BY

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WITH AN INTRODUCTORY NOTE BY

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AUTHOR'S PREFACE.

THOUGH there are many text-books, large and small, on Coal Mining, there is no work (so far as I know) which attempts to give a simple account, illustrated by diagram and experiment—suitable to the needs of a schoolboy—of the fundamental truths and principles with which this most important industry is concerned.

To give such a simple account has been the task I have here set myself. Without burdening my pages with unnecessary technical details, I have dealt with a few of the most important laws of Chemistry, Physics, and Geology, and have tried to show how these bear upon the collier's daily calling.

The lessons are modelled on the Syllabus recently issued by the Education Committee of the Glamorgan County Council, who have decided that instruction in subjects appertaining to Coal Mining shall be given in all Schools in Mining Districts within the County ; and I trust that my fellow-teachers in Glamorgan, and other mining districts where the like instruction may be prescribed, will find that my little book spares them the labour of hunting through more elaborate works, and gives them, in concise form, the information wanted for their classes. I hope, also, that it will be found useful as a Supplementary Reader to be put

into the hands of pupils in the upper standards or attending Evening Continuation Schools.

The experiments described in the book are such as may be demonstrated by any adult teacher, even though he may have had no previous experience in the manipulation of apparatus ; and in the Appendix will be found a list, with prices, of necessary apparatus and chemicals. The initial expense once incurred, an outlay of a few shillings a year should be sufficient, even in a large school, to cover the expense of renewals and replenishments.

I have to express my thanks to Mr W. F. TUDOR, who at very short notice has been good enough to draw the diagrams and illustrations for me.

<div align="right">WM. GLOVER.</div>

HIGHER STANDARDS SCHOOL,
    MAESTEG, GLAMORGAN.
        August 1906.

INTRODUCTORY NOTE.

EDUCATION is useful in so far as it enables a man to use his faculties rightly and efficiently. It has been well said by a French savant that the real aim of education is *l'aptitude à l'effort.* Education which trains children to think clearly, to remember distinctly, to observe accurately, to reason correctly, to express themselves adequately, which widens their mental outlook and stimulates their imagination, is certainly valuable. Memory, thought, observation, reason, imagination, are human faculties which undoubtedly may be strengthened and improved by right training. The practical question then arises, What subjects are best adapted to stimulate and strengthen the faculties which are latent in every child ? It seems evident that subjects which come within its sphere of life, its daily experience, are more likely to interest it usefully than subjects with which it is entirely unfamiliar. And if a subject, besides being of practical concern to the child, is one which is also well suited to exercise and call out its faculties, it is peculiarly fitted to be taught in the schools.

There are large and densely populated districts of the United Kingdom where the great bulk of the population depend entirely for their livelihood on coal mining. Nearly all the boys, as soon as they leave school, are employed at the collieries, and remain for the rest of their lives in this useful and well-paid employment. When a man takes an intelligent interest in his occupation, he becomes more

efficient, and is altogether a better and a happier man. Instead of his work being irksome drudgery to him, it exercises his higher faculties and is a source of interest.

As one of the great industries of the country—in fact, the basis of our material prosperity—coal mining deserves the best efforts of those engaged in it. It is now a well-ordered industry in which many of the latest developments of scientific research and mechanical invention are usefully employed. There is, perhaps, no other industry which requires some knowledge of such a variety of scientific subjects. Geology, chemistry, meteorology, electricity, mechanics, mathematics, are all laid under toll in the efficient working of coal mines. Moreover, it is an occupation so beset with dangers and difficulties that the safety of those engaged in it depends largely on the knowledge and skill of each individual. Coal mining is peculiarly suitable in every way to be a subject taught in the schools of mining districts, as a matter of most practical concern to the children, and as being well fitted to draw out their mental powers. And the dangers and difficulties which need to be encountered in the getting of coal, demanding as they do courage and self-devotion, supply that element of the heroic which will naturally appeal to a healthy-spirited boy, and call out the finer qualities of his nature.

The County Council of Glamorgan, a county famous for its valuable coal seams and large collieries, has given a good lead in resolving that lessons in subjects appertaining to coal-mining should be given in all schools in mining districts in the county. These subjects are specified as :— (1) Coal and how it was formed; (2) Coal mine gases and how they become dangerous; (3) The safety lamp and how to use it; (4) How a colliery is ventilated; (5) How the coal is worked in a mine; (6) Rules for the miners' safety. In order to induce teachers to qualify themselves, some

advantage in salary and in promotion is given to those who make themselves efficient in this subject. To encourage the pupils, certificates are awarded by the Inspectors of Primary Schools to those who have attended a full course of lessons in the subject, and who give evidence to the Inspector that they have profited by the course.

It is under these circumstances that Mr William Glover, the Headmaster of the Higher Standard Schools at Maesteg, has compiled these First Lessons in Coal mining. Mr Glover may be congratulated on his success in producing the right kind of book. Its simple but clear and attractive style, and the numerous practical experiments described and illustrated, are well adapted to stimulate the interest and attention of schoolboys. The experiments are excellent for training accuracy of observation and memory. The book confirms the high opinion of coal mining as a suitable subject of educational training. Brought before them in this way by a competent teacher, it can hardly fail to widen the mental outlook and strengthen the imagination of boys, and give them an intelligent interest in their future calling.

It is rightly confined to the fundamental principles of coal mining, and does not attempt too much.

It will be of much assistance to teachers wishing to give instruction in coal mining in Elementary Schools.

H. F. BULMAN.

Leazes Hall,
Burnopfield, Co. Durham.
16th August 1906.

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FIRST LESSONS IN COAL MINING.

LESSON I.

AN ANCIENT COAL FOREST.

When it grew.—We have all a pretty clear idea as to what is meant by a hundred years; but when we speak of a much larger number, such as a million, our notions are shadowy. A million, what is it? We know how to put it down in figures, and we know that it is built up of a thousand groups of units, each group of which is a thousand units strong, but we can form no real picture of it in our minds: for us, a million can only be expressed in symbols, and these symbols we call figures.

Many million years have passed since the ancient coal forests lived, flourished, decayed, and died; so many indeed that the mind is quite overwhelmed when it thinks of these vast periods of time.

Where it grew.—These forests grew in the districts which we now call the coal-fields; but we must remember that the country in those days had a very different configuration from what it has now. Right across what is now Central England, there stretched a barrier of mountains, but the rest of the country was almost flat. In Scotland and Wales, too, instead of mountain scenery there were great stretches of mud-flats, to many of which the tides had access: it was on these mud-flats that the ancient coal forests grew.

Climate.—Imagine for yourselves a place where the air was soft and balmy—neither very hot nor very cold—and

A

where the winters were nearly as warm as the summers. Such was the climate of these mud-flats.

A district that is low, marshy, and warm will be no stranger to fog and mist. Now the rich black mud of a forest is one of the best soils a plant could have : a warm, equable climate increases growth : and continual mists are better than the best of watering pots: so that we are not surprised when we learn in the next paragraph that—

Vegetation was wonderfully luxuriant. Almost every square inch of ground had its plant, and some of these plants grew to an immense size. What with the number of things that grew, and the size that some of them attained, the woods were so thick that in many places there must always have been the gloom of night.

And what *did* grow there? The oak, the elm, the ash, the beech, the hawthorn? No, you would not have found one of these old friends and favourites, not if you had searched the whole forest over. There were giant club-mosses, somewhat like those of our own moors and hills, but four or five feet in diameter and as much as fifty or sixty feet high ; thirty or forty different varieties of this club-moss (*Lepidodendron*) have been found. Then there were *Calamites* thirty feet high, huge copies of the familiar "horsetails" which now grow in swampy places and are seldom more than two feet high. Another tree was the *Sigillaria*, so-called from the seal-like impressions which occur in perpendicular lines on its fluted trunk ; the root of this plant is called *Stigmaria*, and is very often found in the clay that lies under a seam of coal. The space between these large trees was filled by ferns of many varieties and different sizes, and by quick-growing creeping plants.

If we could have looked upon such a wonderful forest, with its strangely marked tree-trunks, and its waving plumes —like great bunches of feathers rather than leaves—we should have been struck with the absence of bright colours. Greens, browns, and blacks were there of all shades and tints, but no reds, no blues, no brilliant yellows ; for, of all the three hundred different species of plants that have been

discovered as once growing there, not one ever bore a flower.

Animal Life.—The animal life was no less strange and wonderful than the vegetable. No deer bounded across the glades. No panther lurked in the shadows. Lions, tigers, bears, wolves, there were none. Creatures that roar, creatures that growl, creatures that bark, creatures that howl ; all these had yet to be born : their time was not yet. The place of these noisy, warm-blooded quadrupeds was taken by cold-blooded things that creep and crawl, out of whose jaws came no sound louder than a croak or a hiss. Tree lizards, not very much larger than those which now peep at us from sunny banks, and scurry away at our approach, climbed among the branches, and lived upon the marsh flies and beetles whose drowsy hum was never drowned by the song of birds—for there were no birds. A great creature (*Labyrinthodon*), something like a frog in shape, but a hundred times as big, abounded in Ireland and Scotland. In the former country—which now prides itself on having no snakes—there were several kinds of huge reptiles, something like a water serpent in shape, and able to live either on land or in water. Very often the salt-water mud-flats were visited by an alligator-like creature which came up from the sea. It has now a formidable name (*Archægosaurus*) : it had then a formidable appearance, its body being five or six feet long and covered with hard, horny scales.

In the shallower waters of the sea, and sometimes in the marine lagoons, there were multitudes of fish. Some of these were four or five feet in length, others were no bigger than the common stickleback ; nearly all were covered with enamel plates instead of horny scales. In some parts of Lancashire, in the shales which overlie the coal seams, these shining enamelled plates may be turned up by the thousand.

Of course there were no human beings. Men would have found it difficult, nay impossible, to live amidst such surroundings. The air, warm, moist, and reeking with decayed vegetation, would have bred terrible fevers. There was not, it is probable, in the whole swamp, a spot of firm

ground large enough for a hut to stand upon. There were no plants or berries fit for human food. Fishes were there, and lizards, but these would need cooking; and how was it possible to cook, when the fire must be built upon a puddle, fed by wet timber, and lighted in a vapour-bath?

LESSON II.

HOW THE FOREST CHANGED INTO COAL. I.

Movements of the Earth's Crust.—Yes, the earth has really and truly a crust. We stand upon it, we build our houses upon it, and we generally regard it as quite fixed and immovable; but we are mistaken. The solid rocks do not reach from the surface right down to the centre of the earth; but only form a hard crust, which rests upon an intensely hot liquid or spongy interior.

The cook places a layer of pastry on the top of a dish filled with fruit. When the pie goes into the oven the crust is spread out evenly; but, after baking, its contour is changed by the movements of solids, liquids, and gases in the dish; until, instead of a flat or slightly curved surface we have irregular hills and valleys of crust. So is it with what we may term that huge globular pie the earth; the movements of the intensely hot solids, liquids, and gases down below are continually causing changes in the crust, pulling it down in one place, lifting it up in another. When these movements are sudden and violent we have earthquakes and volcanic disturbances.

It is, however, the slow and gradual changes in level that are the most important; they have played a great part in the earth's history. Were it not for them we should have no seams of coal, and that is why I want you to note them well and remember them carefully.

On the coast of some parts of the British Isles there is a low, flat terrace, with the sea on one hand and an inland cliff on the other. This terrace is now raised above high-water mark, and in some cases towns have been built upon it, such, for instance, as parts of Glasgow and Leith. At the base of the inland cliff, now perhaps a couple of miles from the sea, there are caves that have evidently been hollowed out by the ceaseless pounding of the waves. Moreover, if you dig beneath the surface of this terrace, you will find everywhere sand and gravel, and here and there a number of shells. How can you explain these things? In no other way than by saying that the terrace is simply an old beach, and that the sea must have laid down the sand, the gravel, the shells, at the same time that it was scooping out the caves at the foot of the cliff. In fact we have here an instance of what is known as a "raised beach": land that was once at sea-level has been lifted above that level. Where a great many terraces occur, one above another, as in Norway, they show that the land has been raised up at intervals for a long period, the time when the land was stationary being marked by a terrace or raised beach.

We have other evidence to show that there are parts of of the world where the ground is slowly sinking.

When you think of these movements, you must think of them as slow, very slow, so slow as to be quite imperceptible to those who live on the spot, and they are also quite gentle. No houses are disturbed; the ground does not heave and toss. Giant forces are at work, but the giants are in gentle mood, and they do not seem to be in any particular hurry to finish what they are doing.

The Forest Sinks.—And now let us return to a consideration of our coal forest. This has gone on growing and flourishing. Individual trees and plants have died, have fallen to the ground, have there decayed, and helped to form the rich black mould upon which their successors have grown and fed. How long this process has continued we do not know; it may be a hundred years; it may be a hundred thousand. The longer the forest has lived, the

thicker will be the layer of dead plants upon which it rests. In some cases, if we are to judge by the thickness of the coal seams, the remains of thousands of generations must have accumulated before the forest was finally overwhelmed. By-and-by the ground sank.

Forest Buried.—As the ground sank, the waters of sea, river, or lake flowed over it and covered it with mud, clay, sand, or gravel. The thickness of this deposit would depend partly upon the amount of sediment in the water, but chiefly upon the length of time during which the land continued to sink ; the bed might be a foot thick or it might be a hundred.

Downward Movement Stops.—The sinking or subsidence did not last for ever. When it stopped, seeds were brought from afar by the winds, and dropped upon the new clayey, muddy, sandy, or gravelly swamp. Before very long a second forest grew up and flourished over the grave of the first.

Alternate Sinkings and Stoppages.—Sooner or later this second forest shared the fate of the first, and over the layer of sediment beneath which it lay buried grew a third. During countless ages this alternate growth and burial went on, until in some places, as in the South Wales coal-field, there are no fewer than one hundred different seams of coal, under each of which is a clay full of the roots and rootlets of a buried vegetation. In many parts of Britain the coal pits are more than a thousand feet deep ; and yet, down at the bottom of these pits lies the coal seam which we know is all that remains of an ancient jungle, swamp, morass, forest.

LESSON III.

HOW THE FOREST CHANGED INTO COAL. II.

Physical and Chemical Changes.—Before a forest becomes coal, there must evidently be great changes in it. Changes are of two kinds, physical and chemical, and before you proceed further you must understand what these terms mean.

Suppose a bar of iron rests upon a table. Somebody seizes the bar and tosses it up. It has changed from a state of rest to a state of motion, but it is iron all the same.

The bar may be magnetised. Now it will attract pins and needles ; formerly it would not do so. It has changed from a common iron bar to a bar magnet, but it is iron all the same.

By putting it into a fire you may so soften the hard metal that it may be bent into a circle or hammered into a round ball. Heat will make it glow, change colour, melt, nay, will even change it into a vapour or gas.

Iron in a state of rest; iron in a state of motion ; iron magnetised, iron non-magnetised ; iron hard, iron soft ; iron tough and fibrous, as in wrought iron ; iron brittle and crystalline, as in castings ; iron black, red, or white ; iron as a solid, a liquid, a gas ; but always iron, and always returning, when you let it alone, to its state of common everyday iron. These changes are *physical*.

But suppose that some magician could turn your bar of iron into, say, a fine powder, violet in colour, sweet to the taste, and giving out the scent of roses ; and suppose that this powder, no matter how long it stood there, never returned to its original form. This marvel you may take as an illustration of *chemical* change.

Observe for yourself, in the three following experiments, the difference between *chemical* and *physical* changes.

Experiment 1.—Take about a gram of mercury or quicksilver, and put it in a test-tube some five or six inches long. Heat the test-tube over a spirit lamp. The mercury will first boil. Then it will disappear from the bottom of the tube, and collect in tiny globules round the sides, where it will form a shining mirror-like surface. How has it got there? The heat has changed it into a vapour or gas; this gas has risen, and has been changed back into tiny drops of liquid by coming in contact with the comparatively cool sides of the tube.
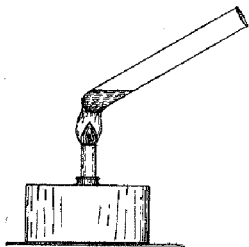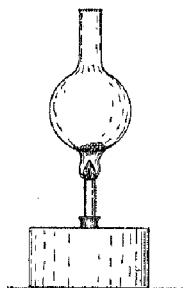

FIG. 1.   FIG. 2.

In this experiment you may either hold the test-tube in a test-tube holder or in your bare fingers.

Experiment 2.—Instead of a test-tube take a four-ounce Florence flask, and put into it about half a gram of crystals of iodine. Hold the neck of the bottle in your fingers, and heat the bottom very gently over your spirit lamp. The crystals will melt and become liquid. Then this liquid will change very quickly into a vapour or gas of a beautiful violet colour. Remove the flask from the flame, when the vapour will cool, and crystallise on the sides of the flask.

Now in these two experiments you see that heat can change a solid into a liquid, and a liquid into a gas; while

cold has just the opposite effect. But mercury is not turned into anything but mercury, and iodine is not turned into anything but iodine. Whether a liquid or a gas, mercury remains mercury still. Whether a solid, a liquid, or a gas, iodine is always iodine, and nothing else. Moreover, the changes are not lasting, permanent; they are, for the time being, temporary; for, once you leave your iodine and mercury alone, they soon return to the state in which you found them. In short, these transformations are only *physical.*

Experiment 3.—Place one gram of mercury with a gram and a quarter of iodine in a mortar, moisten them slightly with rectified spirit, and rub them together with a pestle. (The rectified spirit is added in order to induce the particles of iodine and mercury to come into more intimate contact.) As the spirit evaporates, a dry red powder will be formed. If this be heated in a test-tube it will collect on the sides in beautiful yellow crystals, which soon turn to a fine red colour. These red crystals will remain red crystals for as long as you wish to keep them.

A striking and very pretty variation of this experiment is to use only half the quantity of iodine. In this case the crystals obtained will be dark green.

Note what has been done here. The mercury and the iodine, mixed and pounded together, are mercury and iodine no longer; the two have joined together to form, *permanently*, one substance which is entirely different from either. This change is *chemical.*

You are now in a position to understand what is meant when it is said that the changes by which an ancient forest is turned into coal are both physical and chemical.

Buried beneath an immense weight, the mass of dead plants grew hot and turned black—in much the same way as a stack of hay does now when it has been packed in a damp state. It then became pulpy, and lost most of the traces of its vegetable origin; and, as the weight increased, the pulp was gradually squeezed and compressed until it became hard and jetty. These changes were largely physical.

Now for the chemical changes. To begin with, I must tell you the meaning of two terms very much used in chemistry. These terms are *element* and *compound*.

An element is a substance which chemists have failed to split up into anything simpler than itself. Thus iodine and mercury are elements. In all the world there are only about seventy of these simple substances, these elements; and all the thousands of different materials found in the earth and in the bodies of plants and animals are built up of different combinations and arrangements of these seventy elements. Just as, out of the twenty-six letters forming the English alphabet, you may build up thousands of different words, so out of the seventy elements are built up all the thousands of different substances found in the earth.

A Compound is a chemical combination of two or more elements. Thus the red crystals obtained in experiment 3 are a compound of iodine and mercury.

Now wood, bark, leaves, and seeds of plants are chemical combinations of the four common elements carbon, hydrogen, oxygen, and nitrogen, together with a small quantity of mineral matter. You will see for yourself presently what these four common elements are like; at present, I ask you to do no more than remember their names—carbon, hydrogen, oxygen, nitrogen.

When vegetable matter rots away under pressure, different gases—about which we shall speak in another lesson—are formed. These gases consist largely of oxygen and nitrogen, so that the solid part remaining becomes more and more like pure carbon.

As this process goes on and continues, we should naturally expect that the seams of coal which have been buried longest and deepest will be most like pure carbon, and that the seams of coal which have been buried the shortest time and under the least pressure will be least like pure carbon. Is this so? Do we find these things as we should naturally expect to find them? We do.

Note the following table :—

In 100 lb. of wood there are 50 lb. of pure carbon.

,,	peat	,,	60	,,
,,	lignite	,,	68	,,
,,	coal	,,	85	,,
,,	anthracite	,,	94	,,

Peat, formed in bogs, marshes, swamps, and occurring in beds varying from one foot to forty feet in thickness, is found at or near the surface.

Lignite, or brown coal, is found deeper than peat but not so deep as coal.

Coal is found deeper than lignite; but is not of such ancient formation, and has not been subjected to so great a pressure as anthracite.

While **Anthracite,** which is jet black, has a brilliant lustre, is difficult to light, gives off intense heat with little or no smoke, and is denser, harder, and more brittle than ordinary coal, is found in the deepest formations of all.

LESSON IV.

PROOFS THAT BEDS OF COAL ARE REALLY BURIED FORESTS.

THE chemist has examined coal, and has found it to consist of very much the same materials as wood and peat. We did not expect he would say it was made of *exactly* the same materials, in the same proportions—for we know now that wood undergoes chemical and physical changes before it becomes coal. We are quite satisfied when he says it is made of nearly the same. Our statement, therefore, that beds of coal are really buried forests, is not opposed by the chemist. On the contrary, he says that, as far as he has

been able to observe, everything is in favour of the theory that coal is only vegetation which has been pressed together and gradually changed into the black substance now used as fuel.

We cannot here repeat the difficult experiments by which the chemist arrives at his conclusions : we must be content with something much simpler, and much more rough-and-ready.

Experiment 4.—Take a hard glass test-tube, *a*, about six inches long and one inch in diameter, and fit it with a cork. Bore a hole through the cork with a cork-borer, and insert a piece of glass tubing. Let the glass tubing project about a quarter of an inch through one end of the cork and three
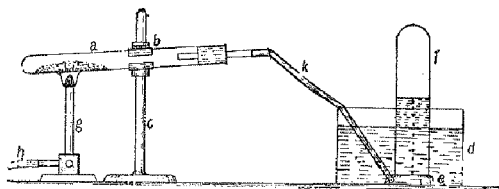

FIG. 3.

or four inches through the other. You can cut your tubing to the required length by notching it with a triangular file and then breaking it with your fingers. Slip a piece of india-rubber tubing about eighteen inches long on the end of the glass tubing that projects three or four inches.

Now fill the test-tube one-third full of powdered coal, and fix it in a horizontal position by means of a clamp, *b*, to a retort stand, *c*. Insert the cork.

Next take your glass pneumatic trough, *d*, and pour in sufficient water to cover the beehive shelf, *e*. Fill another tube, *f*, with water, close its mouth with your thumb or a piece of paper, invert the tube, and place it on the beehive shelf. When the mouth of the tube is below the level of the water, remove thumb or paper. The test-tube, *f*, is now full of water.

Apply heat to the coal by means of a Bunsen burner, *g*, attached by india-rubber tubing, *h*, to a gas bracket. See that the holes at the base of the Bunsen are open.

Gas will begin to come off. When enough of this has escaped to drive out the air that was previously in the test-tube, *a*, insert the delivery tube, *k*, in the hole in the side of the beehive shelf, *e*. The gas that is still coming off will bubble up through the hole in the top of the beehive shelf into the test-tube, *f*, and displace the water there. When all the water has been driven out, lift up the test-tube, and apply a light to the gas you have collected ; it burns with a yellowish-blue flame.

Continue to heat the coal until no more gas is produced. Observe that a tarry liquid and coke are left behind—in addition to the drops of water which you will already have seen to collect on the sides of the tube.

The coal gas used in our towns is made in the way we have just explained. But instead of a test-tube to hold the coal-dust, large ovens, called retorts, are employed ; instead of a few pinches of coal, many thousands of tons are made into gas ; instead of a test-tube in which to collect the gas, huge gas-holders made of iron plate are used. Besides gas we get many other useful things from coal :—Coke, tar, pitch, and what is more wonderful, those splendid bright violet and crimson colours, mauve, and magenta, which we see ticketed as aniline dyes in the shop windows.

Experiment 5.—Repeat Experiment 4 with this difference, that instead of coal dust you use chips of wood. Observe that a tarry liquid, charcoal, and water are formed, in addition to a gas which burns with a yellowish-blue flame.

Now, by heating the coal we obtain coke, a tarry liquid, water, and a gas ; and by heating wood we have obtained charcoal, a tarry liquid, water, and a gas. As coke and charcoal are different forms of the element carbon, you see how very similar our two results have been.

The Microscopist has also examined coal. He has taken slices of it, rubbed them down till they were thin enough to be transparent, fixed them on glass, and then

put them under his microscope. His observations have shown him that coal contains an immense number of tiny seed-vessels, once round, but now flattened by pressure. In appearance these are very much like the seed-vessels shed by the club-mosses of our own moors, except that they are larger, and, as we have just said, flattened instead of round. Should we be far wrong if we were to conclude that the tiny seed-vessels seen by the microscopist in the coal had, really and truly, been dropped by the mosses of an ancient coal forest, and dropped so thickly as to form a deep mould?

It would be too much to ask you to prepare your own slices of coal; that delicate process requires tools and skill somewhat beyond you at present. But those slices, or sections, can be bought ready to your hand, and they are not very expensive. If you are fortunate enough to have a good microscope at your school, ask your teacher to obtain a coal-section for you. When you examine this you will be able to see for yourselves the little seed-vessels about which you have been reading.

The Geologist.—What of him? A man whose special business it is to study the rocks, should be able to tell us something about the formation of coal. What does the geologist say?

He says he usually finds that a seam of coal rests upon a layer of *under-clay.* This is a dark clay, with many branching streaks like roots, spreading through it, and he can trace these branching streaks, upwards till they are lost in the coal itself. The more he examines this *under-clay* the more he is convinced that it is really an old soil; the branching strings were formerly roots, and coal is the remains of a dead-and-gone vegetation.

The evidence of the *under-clay* is supported by that of *fossils* generally.

Your dictionary will tell you that a *fossil* is "the petrified remains of an animal or vegetable found embedded in the earth's crust." The only word likely to puzzle you in this definition is " petrified," and when you learn that this means " turned to stone," the whole will be quite clear.

The beds of coal abound with these stone-like remains of animals and plants. How did they come there? They could not very well have flown there from far-off lands, and nobody supposes that they have been placed there by the hand of man. No, they must have lived, grown, died, and decayed on the spot where we now find them; and their presence is a clinching proof that beds of coal are the remains of buried forests.

It is chiefly by a careful study of *fossils* that geologists have been able to reconstruct for us the landscape of these bye-gone times—such a landscape as I tried to picture in Lesson I. Somebody once said of Professor Owen, that if you were to show him one small bone he would be able to give you a full and particular description of the animal of which it had once formed a part. Now the geologist has much more than one small bone to help him, for the coal measures are rich in hints, clues, suggestions as to what has once existed. Consequently, when the geologist describes a coal forest, we believe his description is true to nature, is based upon solid facts and not upon cloudy fancies.

LESSON V.

COAL MINE GASES.

Introductory.

WE stated in a previous lesson that during the process of converting an ancient forest into a seam of coal many chemical changes went on, and different gases were formed. These, together with the breath of men and horses, and the foul air from burning lamps, find their way into the underground workings.

The four most important of these coal mine gases are carbonic acid, carbonic oxide, sulphuretted hydrogen, and carburetted hydrogen. We shall treat each of these separately, and in doing so we must make use of words which

as yet convey no clear and distinct meaning to your minds. Before going on further, therefore, it would be well to explain these new words, and, if possible, show you the objects for which they stand. Our new words are oxygen, hydrogen, and nitrogen.

Oxygen.

Experiment 6.—Fit up and arrange an apparatus like that shown in Fig. 4. You will see that it is very similar to the one we used in Experiment 4. Fill the hard glass tube *a* about one-fifth full of red oxide of mercury. Heat the tube gently at first, but afterwards more strongly. When you judge that the gas which is given off by your red powder has driven out all the air that was previously in the tube,
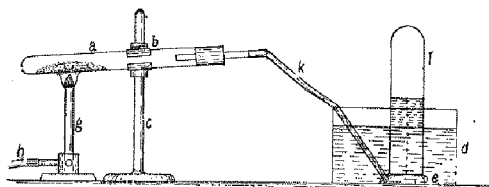

FIG. 4.

collect at the pneumatic trough the pure gas, which is coming off freely: you will see it bubbling up through the water in the test-tube. Take the india-rubber tube out of the water before you stop heating the powder.

When the test-tube is full of gas, place a ground glass disc over its mouth, and remove from the trough. Slip the disc aside for a moment and sniff the gas: it has no smell. Apply a lighted taper: the gas will not burn. Light a long chip of wood, and blow it out again, leaving it glowing at the end. If you now plunge into the test-tube the glowing spark, the latter will rekindle, and flame up furiously.

The gas you have collected is the element oxygen. You have observed that it has no colour, and no smell: it will not burn, but a light will burn very brightly in it.

Hydrogen.

Experiment 7. — Take a 6-ounce flask, *a*, with a flat bottom, and fit it with a cork. Through the cork bore two holes. Through one of these holes thrust a thistle funnel, *b*, until it reaches to within half an inch of the bottom of the flask: through the other push a piece of glass tubing, allowing it to project about an inch below and a couple of inches above the cork. On the outer end of this latter tube slip a piece of india-rubber tubing some eighteen inches long. Pour water into the pneumatic trough until the beehive shelf is covered. Fill two gas jars with water, cover them each with a ground glass disc, and place them on the table beside you.
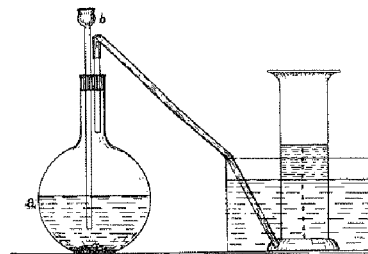

FIG. 5.

Remove the cork from the flask, and introduce about 10 grams of granulated zinc: to avoid the risk of breaking the glass, incline the flask and let the zinc slide gently down the sides. Replace the cork, pour water down the thistle funnel until the lower end of it is covered half-an-inch deep. Make sure that the flask and its fittings are quite air-tight.

Pour dilute sulphuric acid (one part of sulphuric acid to seven of water) down the thistle funnel until a brisk effervescence is set up. If at any time the action slackens add more acid.

After pouring in the acid, allow the gas to escape for a

B

minute or two, as the first portions of it are mixed with air. Before collecting the gas in jars fill a test-tube with it : do this by hanging the test-tube mouth downwards on the end of the delivery tube. Close the mouth of the tube with the thumb, and, keeping the mouth downwards, light the gas. When a sample of it burns quietly and without explosion, you may begin to collect the gas in your jars. In all your experiments with this gas, bring no lights within a yard of your generating flask.

In a manner similar to that in which you collected coal gas, fill your two jars with that which is now issuing from the Florence flask. As each is filled, close with a ground glass disc, remove from the trough, and place mouth downwards on the table.

Now fix a small piece of candle to a piece of copper wire by twisting the latter several times round the candle ; leave a straight piece of wire about six inches long projecting downwards. Take up one of your two jars, and, keeping it mouth downwards, apply a lighted candle. The gas burns with a very hot blue flame where it meets the air. Thrust the lighted candle up into the jar. The candle goes out, but as you withdraw it, it is relit as it comes to the burning gas.

Now take your second jar of the gas and pour it *upwards* into one containing only air. Do this in the following manner :—Invert the jar containing air. Keep the jar of hydrogen mouth downwards at first, then hold it so that its mouth projects a little across that of the inverted jar. Gradually bring the lower jar into a vertical position, with its mouth upwards and directly under the upper jar. When you apply a lighted taper to the jar which formerly contained air, you will see that you have poured your gas upwards : mixed as it is with air it will explode.

The gas with which you have been have experimenting is the element hydrogen. It has no colour, and no smell ; here it resembles oxygen. But—here it is quite the opposite to oxygen—it will itself burn, but will not allow a candle to burn in it. It is also very light ; in fact, it is the lightest gas known.

Nitrogen.

Experiment 8.—Pour water into your pneumatic trough to the depth of a few inches. Take a stoppered bell-jar, and, having first removed the stopper, place the jar in the trough, and mark the height of the water by sticking a piece of gummed paper on the outside of the jar. Take a stick of phosphorus, place it in a basin of water, and while it is under the water cut off a piece about the size of a pea. Do not on any account touch phosphorus with your fingers. With the point of your knife pick up the piece you have cut off ; then dry it with blotting paper, place it on a small
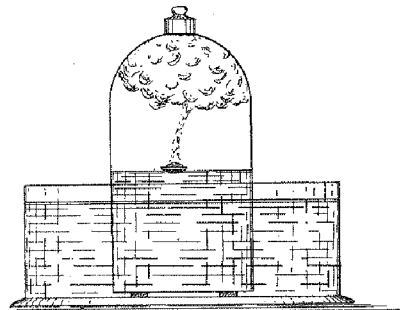

FIG. 6.

china dish, and put the china dish to float on the water of the pneumatic trough and under the bell-jar. Light the phosphorus by touching it with a hot wire thrust down through the opening at the top of the bell-jar. Quickly withdraw the wire and replace the stopper.

The phosphorus burns for some time and then goes out. After the burning has ceased wait for the white fumes inside the jar to dissolve. Observe that the volume of air in the jar has diminished, and water has risen up to fill the vacancy.

Pour water into the trough until the levels inside and outside the bell-jar are the same. Remove the stopper and

plunge a lighted taper into the gas left ; the taper is put out, the gas will not burn.

This gas is nitrogen. It is colourless and has no taste or smell ; it will not burn ; it will not allow a taper to burn in it.

We will conclude this chapter with a few facts about—

The Air We Breathe.—In our last experiment we burnt phosphorus in air. This burning was simply the chemical union of phosphorus with the oxygen in the air ; joined together the two formed a white vapour which soon dissolved ; the colourless gas remaining was nitrogen.

Air, then, is a mixture of oxygen and nitrogen. Notice that we say it is a *mixture*, not a *chemical compound*. If we pound together sand and sugar in a mortar, we make a mixture ; the fine particles of sand and sugar are only *mixed* ; if you were to examine them with a microscope you would see the crystals of sugar and the grains of sand quite distinct and separate. If we pound together mercury and iodine, with a few drops of rectified spirit, these two join chemically to form red crystals. Air, then, is a mixture of oxygen and nitrogen ; roughly speaking, there are four parts of nitrogen to one of oxygen. Oxygen is the gas that enables tapers and animals to burn and live ; nitrogen simply dilutes, and so weakens the effect of, the very vigorous oxygen.

In an average sample of air there is, however, another gas present—carbonic acid. There is not much of it, only about four parts of carbonic acid in ten thousand parts of air, but its presence is very important. We speak about this important gas in the next lesson.

LESSON VI.

COAL MINE GASES.

Carbonic Acid.

Experiment 8.—Fit up apparatus similar to that used in *Experiment* 7, for the preparation of hydrogen. Instead of zinc, however, use chips of marble, or the common lime-stone which is used in some districts for mending the roads, and instead of sulphuric acid use hydrochloric. Collect four jars of the gas which comes off. As each jar fills, close the mouth with a ground glass disc, and place, mouth up-wards, on the table. Observe that the gas is colourless.

Experiment 9.—Take one of the jars, remove the disc, and insert a burning taper. The gas will not burn, neither will it allow a taper to burn in it.

Experiment 10.—Take the second jar, and pour the contents into a beaker in just the same way as you would pour water. You cannot see the gas passing down, but you can see that it has done so if you test with a lighted taper. This experiment shows that the gas upon which you are experimenting is heavier than air.

You can show this in a still more striking way by putting into one of the scales of a balance a beaker, and accurately balancing it by weights (sand will do). Then pour the gas into the beaker ; the scale pan on which this is placed will go down.

Experiment 11.—Take the third jar, and pour into it a little clear lime water. Replace the glass cover and shake the jar. The lime water becomes milky. Would it have become milky if you had shaken it up in a jar containing air alone? Try it, and you will see that the lime-water remains clear. The lime-water test is an excellent one for detecting the presence of this gas ; remember this.

The following experiment shows us of what our gas is composed :—

Experiment 12.—Take a piece of magnesium ribbon,

about eighteen inches long, and flatten it out. Light one end, and while this is burning brilliantly plunge it into your fourth jar of gas, where it will continue to burn. Withdraw from the jar what remains of the magnesium ribbon, before the flame comes near enough to burn your fingers.

Now look at your jar, when you will see in it, on the sides and at the bottom, little specks of black. You will also see a little white powder.

Pour into the jar a few drops of hydrochloric acid, which will dissolve the white powder and allow the black specks to be seen more plainly.

The explanation of these striking changes is interesting. Magnesium has what we may term a very strong liking for oxygen, and, when it meets with oxygen, seizes it, combines chemically with it, and the two together form a white powder. This process of seizing and combining is called burning or combustion, and gives rise to the brilliant light we have observed. Now when we first lit the magnesium ribbon it burnt brilliantly in the air, because in the air it found the oxygen which it loves; and when we plunged it into our jar of gas, it continued to burn because there also it found oxygen. The gas we have prepared, therefore, evidently is made up, in part, of oxygen. But what are these black specks? They look very much like tiny pieces of charcoal. In fact they *are* tiny pieces of charcoal or carbon. Formerly they were united with oxygen, to form the heavy invisible gas with which we had filled our jar; but when the vigorous magnesium seized the oxygen, the poor carbon was left out, as it were, in the cold, and it appeared to us as specks of black.

The gas, then, upon which we have been experimenting, is made up of carbon and oxygen. Chemists call it carbonic acid, and, in their own shorthand, write it down as CO_2, meaning thereby that it contains one part of carbon to every two parts of oxygen.

Experiment 13.—Place a small piece of charcoal in a deflagrating spoon, and heat in a Bunsen flame till the charcoal glows. Then plunge the spoon containing the burning charcoal into a jar containing air. After the glow

has quite died away withdraw the spoon. Pour lime-water into the jar, close with a glass disc, and shake. The lime-water becomes milky; this shows that carbonic acid has been formed.

Now charcoal is nearly pure carbon, and we see from the above experiment that when carbon burns in air carbonic acid is produced. Coal also is made up largely of carbon, therefore the burning of coal means the manufacture of carbonic acid.

Experiment 14.—Pour a little lime-water into a beaker. Blow bubbles of your own breath into this through a glass tube. The lime-water becomes milky; human beings, and indeed all animals, breathe out carbonic acid.

FIG. 7.

Let us now sum up what our experiments have taught us concerning carbonic acid :—

1. It has no colour.
2. It will not burn.
3. It will not allow a taper to burn in it (and where a taper will not burn a man cannot live).
4. It is heavier than air.
5. It is made up of carbon and oxygen (one part of carbon to every two parts of oxygen).
6. Lime-water is the detective officer that always finds it out.
7. It is formed by the action of an acid (here hydrochloric) on a carbonate (here marble or limestone, the chemical name of which is carbonate of lime).
8. It is formed by the burning of coal.
9. It is formed by the breathing of animals.

We could say very much more about carbonic acid, and give many experiments to prove our statements, but we must for the present be content with the two following brief remarks about this most interesting and important gas :—
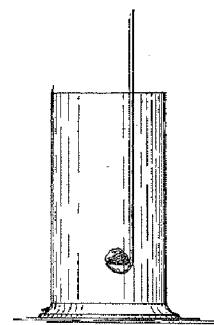
I. When present in the air in large quantities it is very injurious, often fatal, to all animals; 10 per cent. will put out a light and cause death.

II. It is present in small proportions in the atmosphere—four parts in every ten thousand—and here it acts as the chief food of plants.

How is it given off in Mines ?—The animals and men employed breathe it out. It oozes from cracks and crevices in the coal. It is formed by explosions, when, joined with other gases, it forms a heavy, deadly mixture known as after-damp, black-damp, choke-damp. Being heavier than air, it is often found in low places, on the floor of the seam, or in workings that dip downwards.

How is its Presence Detected ?—(1) By the light of the lamp being dimmed, or put out. (2) By the way in which it affects people who breathe it, for it produces a drowsy feeling, and causes pains in the head and limbs, followed in extreme cases by prostration and death. (3) By testing with lime-water.

LESSON VII.

COAL MINE GASES.

Carbonic Oxide and Sulphuretted Hydrogen.

Where Carbonic Oxide occurs in Nature.—This gas is given off when carbon burns in an insufficient supply of air. It is sometimes formed in mines by the explosion of some blasting agent, or after an explosion of fire-damp. Miners call it white-damp or sweat-damp.

What it is Made of.—Like carbonic acid, it is formed by the union of carbon and oxygen, but it only

contains half as much oxygen as carbonic acid. Thus in the shorthand of chemistry we write down carbonic acid as CO_2, but carbonic oxide as CO.

Its Properties.—It has neither colour, taste, nor smell. It burns with a blue flame, and then it changes into carbonic acid. It cannot be poured downwards like carbonic acid, neither does it rise quickly like fire-damp, for it has just about the same weight as air.

It acts as a strong poison even when breathed in small quantities. In France, where charcoal fires are sometimes burnt in the middle of a room, death too often takes place owing to the breathing of the carbonic oxide produced. The effects of carbonic oxide on the human body are headache, weakness, drowsiness, insensibility, death. If it is suspected that a person is suffering from carbonic oxide poisoning, the first thing to do is to remove him into the open air, and induce him to breathe freely; in extreme cases it is necessary to compel him to inhale oxygen for some time. Recovery from carbonic oxide poisoning is much more difficult than from that caused by carbonic acid, because the former, unlike carbonic acid, unites directly, by way of the lungs, with the red colouring matter of the blood, from which it can with difficulty be driven off, even by pure oxygen. It is dangerous to breathe air which contains as little as one part of carbonic oxide to two hundred parts of air.

Preparation.—It will not be advisable for you, yourself, to meddle with this highly dangerous gas; but your teacher can, with perfect safety, perform for you an experiment by which carbonic oxide is produced in small quantities.

Experiment 15.—Heat a few fragments of potassium ferrocyanide with a little *strong* sulphuric acid in a test-tube. Carbonic oxide comes off, and can be lit at the mouth of the tube.

A glass rod moistened with lime-water, and introduced into the tube before the gas is burned, is not coated with chalk; after the carbonic oxide has been burned, again

introduce the glass rod, and notice how it whitens—an action due to the presence of carbonic acid.

Where Sulphuretted Hydrogen occurs in Nature.

—It is found dissolved in certain mineral springs, is given off by volcanoes, and is produced by the decay of animal or vegetable matter. In mines it is given off by the decomposition of iron pyrites (which miners sometimes call "brass," though there is no brass about it) in damp workings, and is sometimes found in the water that trickles through the rocks. Often it is found in old workings which contain water. It goes by the name of *stink-damp*— and a very good name for it too.

Preparation.

—We said in the preceding paragraph that sulphuretted hydrogen was produced (1) by the decay of animal or vegetable matter, (2) by the decomposition of iron pyrites.

That it is produced by the decay of animal matter is easily perceived. An egg is well known to be rich in sulphur; it is the sulphur that blackens the spoon with which an egg is eaten. When an egg is kept too long it decomposes, and the sulphur is changed into sulphuretted hydrogen. It is this sulphuretted hydrogen that chiefly gives off the unpleasant smell which we associate with a bad egg.

In the next experiment we will prepare the gas, not indeed from iron pyrites, but from a substance very much like it and made up of the same two elements, iron and sulphur.

Experiment 15.—Fit up a flat-bottomed flask with a cork and delivery tube as shown in Fig. 8. Now take a second flask, cork it tightly with a cork having two holes, and fit it up as you did the first—with this exception, that the tube which dips down nearly to the bottom must not have a thistle funnel at the top. Connect, by means of a short piece of india-rubber tubing, the delivery tube of the first flask with the long tube of the second. Fill the second flask about two inches deep with warm water. Introduce into the first flask a few fragments of sulphide of iron, then enough water to cover them; and, having replaced the cork, pour a

little strong hydrochloric or sulphuric acid down the funnel tube. Let it be only a *little*, as it is easier to put more in than to take any out. Gas soon begins to come off; this gas is sulphuretted hydrogen. It bubbles up through the liquid in the first flask, and passes through the connecting tube into the second flask; where it again bubbles up— this time through the warm water—and passes out through the delivery tube of the second flask. Having first allowed time for all the air that was in the apparatus to escape, collect two jars of the gas over water, as in experiment 7. Do not use a pneumatic trough of japanned tin, as the gas discolours most paints and acts on the metal. Let the water
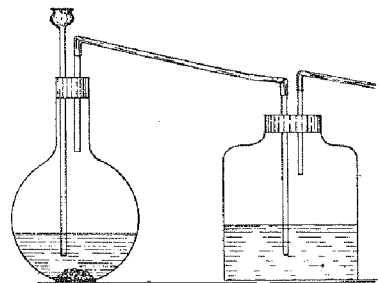

FIG. 8.

in the trough be warm: water dissolves sulphuretted hydrogen, but warm water dissolves less than does cold.

Experiment 16.—Take the first jar, and observe that it is colourless, and has a peculiar and most unpleasant smell. While the jar is standing upright on the table take off the disc and apply a light. The gas burns, and while this is going on a little yellow sulphur separates on the side of the jar. Wash off this sulphur at once; if you allow it to dry you will have trouble in cleaning the jar.

When you set fire to the gas, plunge your taper deep into the jar. The taper goes out, and is relit when you bring it out again to the burning gas.

Experiment 17.—Take the second jar, and try to pour the contents downwards into another dry jar. Apply a light: the gas in the lower jar burns: therefore sulphuretted hydrogen is heavier than air.

While the gas is burning notice the pungent smell (not at all like that of sulphuretted hydrogen). Also hold a dry disc over the mouth of the jar: drops of water are formed.

Wash thoroughly every piece of apparatus you have used.

The explanation of the changes we have just observed is instructive, and not very hard to understand. Try to follow them :—

Sulphuretted hydrogen is made up of the two elements sulphur and hydrogen, one part of sulphur to every two parts of hydrogen. Chemists write it down as SH_2.

This burns when it comes in contact with the air, that is at the mouth of the jar. Another name for burning is oxidation, that is a combining or joining chemically with oxygen. Where does the sulphuretted hydrogen get the oxygen with which it burns? Of course from the air.

The sulphur joins with the oxygen of the air to form a very pungent gas called oxide of sulphur. This oxide of sulphur escapes into the air, and when you have once smelt it you will not easily forget it.

The hydrogen joins with the oxygen to form water. This escapes into the air as invisible steam, which, however, you can collect as tiny drops of water on the glass disc held over the burning gas.

When the oxygen has any difficulty in finding its way to the sulphuretted hydrogen, the hydrogen alone burns, and the sulphur is deposited on the sides of the jar.

Properties.—Summing up what we have learnt from the above experiments, we now know the following things about sulphuretted hydrogen :—

1. It is colourless.
2. It has a peculiar and most unpleasant smell.
3. It burns.
4. It does not allow a taper to burn in it.
5. It is heavier than air.

6. It is made up of sulphur and hydrogen, one part of sulphur and two parts of hydrogen. Chemists write it down as SH_2.

We may add that it is a poison, so great care must be used in its preparation. We must not prepare more than we require, and to this end must regulate the supply of acid which we pour down the funnel. If the gas is still coming off when we have filled our two jars, it is well to remove the generating apparatus into the open air.

LESSON VIII.

COAL MINE GASES.

Carburetted Hydrogen—After-Damp—Summary.

WE now come to the most abundant, and by far the most dangerous, of all the coal mine gases.

Where Carburetted Hydrogen occurs in Nature.— Light carburetted hydrogen, fire-damp, marsh gas—for it is known by all these names—may often be found in marshy ground, where it bubbles up through stagnant pools. It is also found in coal seams; where these, however, are at a moderate depth, or are covered by porous rocks, much of the gas may have escaped; in this case the seams are said to be *non-fiery*, and can be worked with naked lights.

It is given off wherever the miner has laid bare a surface of coal, and often comes out in large quantities from faults, and from cracks in the roof and floor. As a rule it is discharged gradually and regularly, oozing out in silence from the pores of the coal; but sometimes it bursts forth in *blowers*, or sudden outrushes, with a noise like escaping steam. These blowers may be exhausted in a few minutes, or they may continue for years.

Preparation.—In nature's great laboratory of the coal

measures, carburetted hydrogen is prepared on a vast scale, under great heat and pressure, and by processes which the cleverest chemist can perhaps only guess at. In our own little chemical workshop we shall prepare it on entirely different lines, but remember that it will be carburetted hydrogen for all that.

Experiment 18.—We shall require first of all some sodium acetate : if we do not have this in stock we can prepare it in the following manner :—Place a few grams of common crystallised carbonate of soda in an evaporating dish with some water. Put the dish on a piece of wire gauze which rests upon an iron tripod, as shown in Fig. 9, and heat it nearly to boiling point over the flame of a Bunsen burner. When the carbonate of soda has all dissolved, add acetic acid or vinegar, a few drops at a time, until effervescence stops.
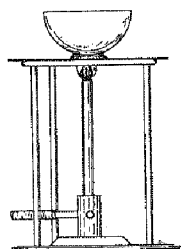
Evaporate the solution you have now obtained to dryness. You can best do this by means of a sand bath, which is a shallow dish or tray filled with sand. On this sand place the evaporating dish ; then put the tray on the tripod over the Bunsen burner. The process goes on much more slowly than when a wire gauze only is used, but the liquid does not "spit."

FIG. 9.

When all the water has been driven off, sodium acetate remains behind in the dish.

Experiment 19.—Take about two grams of sodium acetate, and mix with six or seven grams of soda lime (a mixture of caustic soda and lime). As the heat required will be greater than an ordinary flask might stand, it is better to use a combustion tube of hard glass, or—to be perfectly safe from breakages—one of iron. Take a combustion tube, about six inches long and three-quarters of an inch in diameter, and closed at one end, and put in the mixture of sodium acetate and soda lime ; then fit into the open end a cork with delivery tube. Fasten the combustion tube to a retort

stand by a clamp, as shown in Fig 10, and place over the flame of a Bunsen burner. Carburetted hydrogen will be given off, and may be collected in jars over water in the pneumatic trough. Collect four jars full, then remove the
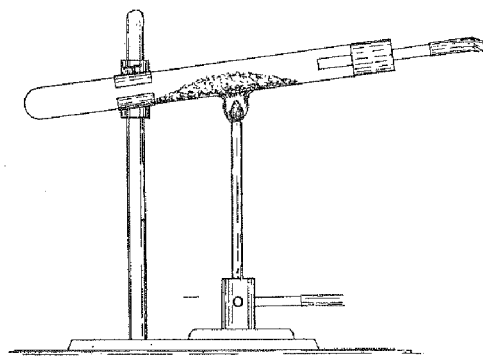

FIG. 10.

delivery tube from the water, and afterwards take away the Bunsen burner.

Experiment 20.—Now dry the end of the delivery tube and connect it with a bulb tube. Fill this tube with small
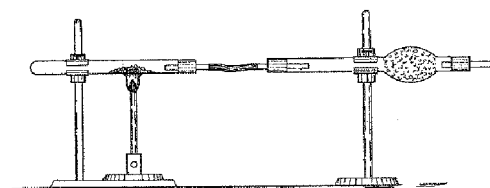

FIG. 11.

lumps of calcium chloride, and close it at each end by a cork through which passes a short piece of glass tubing. This arrangement is shown in Fig. 11. Light the Bunsen burner again, and continue to heat the combustion tube. The gas

will come off as before, pass through the calcium chloride tube—where it will leave any watery vapour that may have come off with it, for calcium chloride is a capital trap to catch moisture—and come out pure. When you are quite sure that all the air that was previously present in the apparatus has been driven out (make sure first that your corks are all quite tight), light the gas that issues from the drying-tube. Hold over the flame a cold glass disc or a Florence flask full of water; the disc, or the outside of the flask, becomes wet; water has been formed. Water, as we know already, is made up of oxygen and hydrogen. Where does the oxygen of the water on the disc or plate come from? From the air. Where does the hydrogen come from? It must come from the carburetted hydrogen. In this experiment, then, we have proved that carburetted hydrogen contains hydrogen.

Experiment 21.—Take one of your jars of gas, slip the cover aside for a couple of seconds, and pour in a little lime-water. Replace the cover, and shake the jar. The lime-water does not become milky, therefore carbonic acid is not present.

Experiment 22.—Take a second jar of the gas, invert it (mouth downwards), slip off the glass disc, and apply a light; the gas burns with a brighter flame than that of hydrogen. When the burning is nearly over, close the mouth of the jar with a glass disc and place the jar mouth upwards on the table. Slip aside the disc, pour in a little lime-water, replace the disc. Shake the jar; the lime-water becomes milky; carbonic acid is present. We see then that when carburetted hydrogen burns (or explodes, for an explosion is only a very sudden and violent burning) in air, carbonic acid is formed. Where does the carbon of the carbonic acid come from? Evidently from the carburetted hydrogen.

This experiment has shown us that carburetted hydrogen is made up in part of carbon. Experiment 20 showed us that it was partly composed of hydrogen. Carburetted hydrogen, therefore, is made up of the two elements, carbon and hydrogen — one part of carbon to four of hydrogen. Chemists write it down as CH_4.

Experiment 23.—Hang an inverted beaker by a piece of string a few inches above the scale-pan of your balance. Now put weights in the opposite pan and exactly balance the beaker. Take another jar of your gas, and pour it *upwards* into the beaker. The scale-pan over which hangs the beaker rises. The light carburetted hydrogen, trying to escape upwards, gives a lift to the beaker and so decreases its weight. This experiment shows us that carburetted hydrogen is lighter than air.

Experiment 24.—Take a stout soda-water bottle and fill it about one-sixth full of water. Put a piece of wet paper on its mouth, invert, and place it, mouth downwards, in the water of your pneumatic trough. The bottle is now one-sixth full of water and five-sixths full of air.

Decant into this bottle, keeping its mouth under water, upwards from your remaining jar enough carburetted hydrogen to drive out the water and fill the bottle. You will best do this by using a funnel. The sketch in Fig. 12 will show you the method.
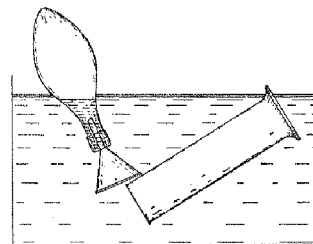

FIG. 12.

You have now in your bottle a mixture of air and carburetted hydrogen—one part of carburetted hydrogen to five parts of air.

Wrap the bottle lightly in a towel, remove from the pneumatic trough, and quickly apply a light. An explosion takes place, due to the quick and violent union of carburetted hydrogen with the oxygen of the air in the bottle.

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Properties.—We have now found out the following things about carburetted hydrogen :—

1. It is colourless, and has no smell or taste by which we may detect its presence.

2. It is made up of carbon and hydrogen—one part of carbon to four of hydrogen.

3. When it burns or explodes it forms water and carbonic acid.

4. It is lighter than air.

5. It will not allow a candle or taper to burn in it; but, when pure and unmixed with air, it burns quietly and with a flame brighter than that of hydrogen.

6. Mixed with air it explodes. Mixed with five times its own volume of air it explodes feebly.

The explosive force is increased by adding more air to it, and when the mixture reaches the proportions of ten volumes of air to one volume of the gas the greatest explosive force is reached. By adding more air the explosive force is reduced, until the mixture becomes so diluted that it will not burn at all.

How detected in Mines.—Being lighter than air, this gas is always found high up, where it floats near the roof, and lodges in holes and hollows. Its presence may be detected by the use of the safety lamp. When not much of it is there, it causes the flame to flicker a little, vertically; when a larger quantity is present, the flame grows larger and longer, and sometimes a blue halo or cap is found on the top of the flame. Much practice is required in exploring for carburetted hydrogen, and no unskilled person should be allowed to undertake the work. It is highly important that the lamp used should be well fitted and securely locked : the smallest neglect here may cause terrible consequences.

After-Damp.—What is known as the after-damp is often more fatal than the actual explosion. If you wish to understand what it is, follow carefully each step of this explanation :—

Before the explosion there is in the pit a mixture of

carburetted hydrogen and air. Carburetted hydrogen is made up of carbon and hydrogen. Air is made up of oxygen and nitrogen.

Let us write this down in another way :—

Before Explosion.	{ Carburetted Hydrogen . .	{ Carbon. ⟨ Hydrogen.
	{ Air	{ Oxygen. ⟨ Nitrogen.

In the explosion a sudden and violent chemical change takes place.

Part of the carbon joins with part of the oxygen to form carbonic acid. The rest of the carbon joins with part of the oxygen to form carbonic oxide. Part of the oxygen joins with the hydrogen to form water. The nitrogen remains unchanged.

The following table will make this clear :—

After Explosion.	Carbonic Acid	{ Carbon. ⟨ Oxygen.
	Carbonic Oxide . . .	{ Carbon. ⟨ Oxygen.
	Steam	{ Hydrogen. ⟨ Oxygen.
	Nitrogen	Nitrogen.

These four gases, carbonic acid, carbonic oxide, steam, and nitrogen, make the deadly mixture known as *after-damp* or *choke-damp*. Being heavy, after-damp sinks to the floor; but where the air space is small, it sometimes fills the whole passage where it is found.

Summary.—We will conclude this Lesson with the Table on the following page, in which you may see at a glance the properties, &c., of the coal mine gases of which we have spoken :—

Name of Gas.	Chemical Symbol.	Weight compared with Air.	Taste.	Colour.	Smell.	Does it support life?	Will it burn?	Element, Compound, or Mixture.
Hydrogen	H	Much lighter	None	None	None	No	Yes	Element
Oxygen	O	Slightly heavier	None	None	None	Yes	No	Element
Nitrogen	N	Slightly lighter	None	None	None	No	No	Element
Air	N_4+O	Same	None	None	None	Yes	No	Mixture
Carbonic acid, Choke-damp, Black-damp	CO_2	Heavier	Slightly acid	None	None	No	No	Compound
Light carburetted Hydrogen, Marsh gas, Fire-damp	CH_4	Much lighter	None	None	None	No	Yes	Compound
Carbonic oxide, White damp	CO	Slightly lighter	None	None	Very slight	No	Yes	Compound
Sulphuretted Hydrogen	SH_2	Heavier	Sweetish	None	Very strong	No	Yes	Compound

Carbon dioxide [handwritten annotation beside Carbonic acid row]

LESSON IX.

THE SAFETY LAMP—PRINCIPLES OF ITS CONSTRUCTION.

BEFORE we proceed with our next experiment I wish you to have clear notions about two things.

First.—I want you to understand what is meant by the terms " good conductor " and " bad conductor."

If you put into the fire a short poker, and let it remain there for some time, on attempting to take it out again you will find that the end farthest from the fire has also become hot. How has the heat got from the fire to the end of the poker which is not in the fire? You will reply at once, and quite correctly, that most of the heat from the fire has travelled along the poker. The iron has "conducted" the heat from the fire to the projecting end of the poker, and it is true to say that iron is a " good conductor " of heat.

If you had three pokers, one made of iron, one of copper, and one of glass, and were to place them side by side in the fire, you would find (provided the glass did not break) that the projecting end of copper became hot more quickly than that of iron, and the iron more quickly than the glass. Copper is a better conductor of heat than iron, and iron is a better conductor of heat than glass. Copper and iron are " good conductors," glass is a " bad conductor."

Second.—A gas that will burn, refuses to light until it is heated to a certain point. How hot it must be before it will burst into a flame depends upon what gas it is: some light at a much lower temperature than others.

Why does the gas you burn in your houses not ignite at once when you turn on the tap? Because it is not hot enough. It must be hot before it will light, and so you bring a lighted match to it in order to heat it to what is called its "ignition point."

Have you ever seen your mother make a furniture polish of beeswax and turpentine? She shreds the wax into a jar containing turpentine, and then warms the mixture until the wax dissolves; but she is, or should be, careful how she warms it, for turpentine requires careful handling.

Once, a housewife who was thus making furniture polish put her jar into a hot oven and closed the door. The turpentine, as it grew hot, gave off turpentine vapour or gas, which soon filled the oven. This turpentine vapour grew hotter and hotter until it reached the point at which it was ready to burst into flame—its ignition point. But it could not burn in the oven, because the oven was full of turpentine vapour, and things which burn must have oxygen to burn in. There was plenty of oxygen in the air, but the turpentine vapour was separated from this by a

tightly fitting door of iron. It awaited its opportunity, and the opportunity soon came. The housewife opened the oven door. Turpentine and oxygen met. There was a violent explosion, the flame of which leaped out more than a yard into the kitchen. A little knowledge of chemistry would have saved that housewife much subsequent suffering. Now we are ready for—

Experiment 25.—Roll a piece of thick copper wire tightly round a lead pencil, so as to make a close coil about half an inch long, leaving a piece of straight wire to act as a holder. Lower the coil carefully into the flame of a candle so that the coil encloses the wick. The flame is extinguished, and white smoke issues out of the top of the coil. Why is this? Well, consider what was going on in the candle before you put the flame inside the coil. A stream of melted tallow was passing up the wick, and this tallow, as it reached the flame, was turned into vapour. The vapour was heated by the flame until it reached ignition point: then it burst into flame. You enclosed the flame in the copper coil. Copper is a good conductor, and it conducted away so rapidly the heat of the flame, that the tallow vapour became too cool to burn : in fact it was cooled below its ignition point, and you saw the cooled vapour going up as a white smoke.
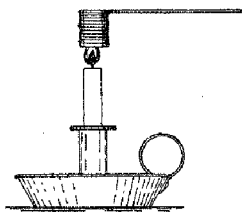
FIG. 13.

Experiment 26.—Heat to redness in a Bunsen flame the copper coil, and then repeat Experiment 25. The candle continues burning : the copper coil must conduct away, and give off into the surrounding air, much of its own heat before it can give its attention to the heat of the candle flame.

Experiment 27.—Close the air-holes at the base of your Bunsen burner, light the gas, and press down on the flame a piece of fine wire gauze about six inches square. The flame flattens out under the gauze, but does not burn above

it. Why is this? Does none of the gas come through the meshes of the gauze? Strike a match, and put the light above the gauze. Now you have gas burning both above and below, and the flame is no longer flattened out. Evidently then, when we began the experiment, gas *was* coming through the meshes but it did not burn. Why did it not burn? Because the iron gauze conducted away the heat of the flame so rapidly that the gas which came through was cooled below its ignition point.

Repeat the above experiment with the air-holes of the Bunsen burner open. For some time you get the same result as before ; but presently—for your flame is now much hotter than it was before—the gauze cannot conduct away the heat quickly enough, and the gas rushes through the meshes at a temperature above its point of ignition.

Put out the flame, turn on the gas again, and this time light it *above* the gauze. This time the gas burns above, and not below. Why is this? Again that good conductor, iron, is responsible for what has taken place.

Experiment 28.—Set fire to a little methylated spirit in a basin, hold the basin with a pair of crucible tongs, and pour the burning liquid through a piece of wire gauze slightly hollowed in the middle, into another basin. When it falls into this second basin it is no longer burning. The iron wires have conducted away so much heat that when the drops of methylated spirit fall through the gauze they are no longer hot enough to burst into flame.

The experiments in this lesson have led us up to a study of the safety lamp, invented in 1816 by Sir Humphrey Davy. This was, and is, an ordinary oil lamp, with a cylinder of wire gauze surrounding it. When it is brought into an explosive mixture of carburetted hydrogen and air, the mixture burns inside the lamp, but in ordinary cases the flame cannot pass through the gauze ; when it tries to do so the gauze cools the gas below the point at which it can take fire.

Experiment 29.—Take a cork an inch and a half in diameter, and a piece of fine brass wire gauze six inches square. Roll the gauze into a cylinder of such a diameter that the

cork will fit tightly into one end of it. Cut out of the same kind of gauze a circle a little larger in diameter than the cylinder. Take out four or five of the horizontal wires at the top of the cylinder, so that the straight wires are left projecting upwards. Cover the top of the cylinder with the circle you have just cut out, passing the projecting straight wires through the meshes near the circumference of the circle, and fixing them tight by bending them over. Now fix a small piece of candle to the cork by means of a little melted wax. When you have lit the candle and replaced the cork securely you have a complete safety lamp.

To show how it acts, hold a strong, wide-mouthed bottle inverted over an ordinary gas-burner, turn the tap, and partly fill the jar with gas so as to form an explosive mixture of air and gas. Pass the safety lamp, which you can hold by a wire pushed into the cork from below, up into the bottle. The explosive mixture passes through the meshes of the gauze into your safety lamp, and burns inside it, but the flame does not pass out; there is no explosion. You may afterwards push a lighted taper into the jar to show that an explosive mixture is really there.

We will conclude this lesson by asking you to remember this important fact:—The gauze of a safety lamp has its limits of endurance; it cannot conduct away an unlimited amount of heat. If it is held in an explosive mixture too long, the wires become hot enough to allow the burning gas inside to pass through, and set fire to that which is waiting so eagerly outside. Then comes an explosion.

LESSON X.

THE SAFETY LAMP—KINDS—HOW TO USE IT.

The Davy Lamp.—This lamp consists of a small vessel, *b*, for holding the wick and oil, while *f* is a pricker for trimming the wick. The cylinder of wire gauze, *a*, made double at the top, and supported by iron rods, *c*, terminates

in the cover *d*, to which is attached a handle for carrying the lamp. The cylinder of gauze is about one and a half inches in diameter, and seven inches long, with wires giving 784 openings to every square inch. Through these openings or meshes air enters to keep the lamp burning. The
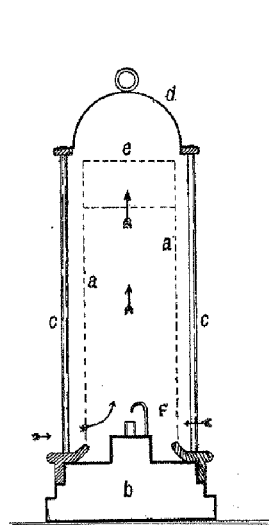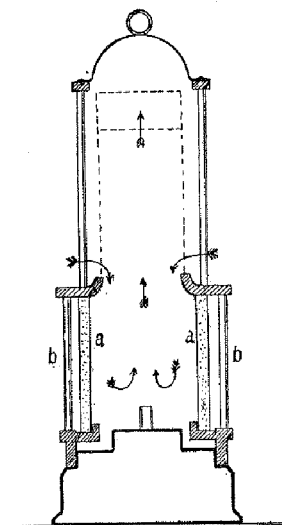

FIG. 14.—Davy Lamp.   FIG. 15.—Clanny Lamp.

direction of the air currents may be seen from the arrows in the accompanying sketch.

The old-fashioned Davy lamp has two disadvantages:—(1) It gives a very poor light; (2) it is found to be unsafe in a current of air. When the speed of the current is more than six feet per second, the flame is liable to be blown through the gauze, and thus may set fire to any inflammable gas outside.

The Clanny Lamp.—This lamp is similar in construc-

tion to the Davy lamp, but has a glass cylinder, *a*, instead of the lower part of the gauze, and this enables it to give a much better light, and to be more safely carried in a current of air. But it is unsafe in draughts of air which have a speed of more than eight feet per second. The supply of fresh air to f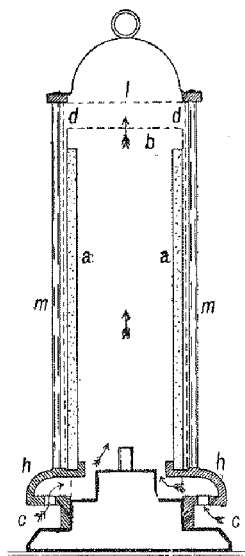eed the flame enters through the gauze at the top of the glass cylinder, passes down on the inside of the glass, and the products of combustion ascend, and escape through the upper part of the gauze. Some of these products of combustion mix with the feed air as it enters, and are thus carried to the flame. It is this circumstance which accounts for the light of the Clanny lamp not being so good as might otherwise be expected.

The Stephenson Lamp.—

This lamp differs from the Davy as follows:—In the Davy the flame is simply surrounded by a wire gauze through which the air passes. In the Stephenson—sometimes called "The Geordie"—there is first of all the usual cylinder of gauze, *d*, within which is a cylinder of glass, *a*, covered at the top with a cap of copper gauze, *b*. The lamp is supplied with air through numerous little holes, *c*,

FIG. 16.—Stephenson Lamp.

in a metal ring, *h*, which passes round the bottom. The air passes through these holes, finds its way through the meshes of the outer cylinder, *d*, and under the bottom of the glass cylinder, *a*. After feeding the flame, the air rises through the copper cap of the glass cylinder, and passes out through the upper covering of gauze *l*. *m, m* are metal rods which hold the lamp together and make the framework rigid.

This lamp burns well—if the holes in the metal ring are kept free from dirt—but as the light has to pass through both gauze and glass it is very dim indeed outside. The Stephenson may be carried in currents of air the speed of which is twelve feet per second, and in this respect it is better than either the Davy or the Clanny.

The Marsaut Lamp, which was invented by a Frenchman, is very much like the Clanny. Its chief point of difference is that instead of having a single gauze, like the Clanny, it has two, or sometimes three. These gauzes fit close together at the bottom, but gradually diverge as they proceed upwards. Thus :—
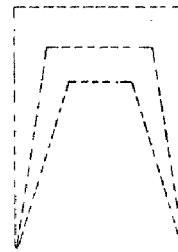

FIG. 17.—Arrangement of Gauzes in the Marsaut Lamp.

The Marsaut lamp is much used in England and Scotland, and when the outer gauze is surrounded by a tin bonnet or shield may be carried with safety in currents of air having a speed of forty feet per second.

The Mueseler Lamp, of Belgian invention—is, like the Marsaut, a modification of the Clanny. It has the glass cylinder round the flame in the same way, but instead of having two or three gauzes it has only one, with a conical-shaped chimney of metal fitted inside. The principle will be easily seen from the sketch on next page.

A Mueseler lamp is safe when the draught of air in the mine is not more than twenty-one feet per second, a

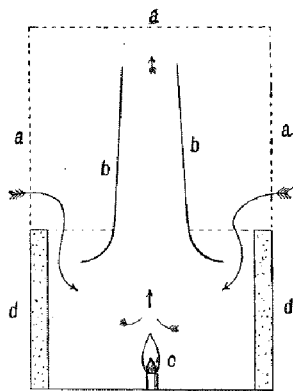bonneted Mueseler when the speed is as much as forty feet per second.

Fig. 18.—Showing Principle of Mueseler Lamp. *a*, outer gauze; *b*, metal chimney; *c*, flame; *d*, glass cylinder. Direction of air currents shown by arrows.

The Tin Can Davy.—This is an ordinary Davy lamp enclosed in a tin can or case which has a circular glass front for the light to pass through. This lamp is very dim but very safe.

The Bonneted Clanny.—This is an ordinary Clanny lamp with the gauze covered by a tin shield or bonnet. It is very safe, and is much used.

There are many other varieties of safety lamp, but we have mentioned those which are perhaps most largely used. We will, however, close our list with a brief description of yet another. It deserves our notice well, for it is by far the best of all lamps. It is called—

The Perfect Lamp.—Here are its chief points :—
1. It is very cheap.
2. It is very strong.

3. It is so simple and scientific in construction that it is almost impossible for it to get out of order.

4. It goes out of its own accord in an explosive mixture of gases.

5. It gives a brilliant light, which burns with a strong, steady flame, and never, unless under great provocation, suddenly leaves a miner in the dark.

Alas! the Perfect Lamp has not yet been invented.

And now read the following :—

Practical Rules for those who use Safety Lamps.

1. When you receive your lamp from the fireman or other person appointed for the purpose, examine it carefully to see that it is clean, in proper repair, and securely locked.

2. If at any time you detect any appearance of fire-damp, at once try to put out your lamp by drawing the wick into the tube with the pricker. Should the light still continue in the inside of the lamp do not try to put out the light by any other means, but instantly remove the lamp with the greatest possible care, and return with it to the lamp station, walking very slowly, with the lamp as near to the ground and to the centre of the roadway as possible. When you arrive at the lamp station at once give notice of what has occurred.

3. Should your light be lost or put out, take it before it is again used, to the lamp station, and deliver it there to the person appointed to open and lock lamps. If, after he has examined it, he relights it, locks it, and returns it to you, see for yourself that it is in perfect order before you take it from the lamp station.

4. Do not interfere in any way whatever with your lamp beyond the necessary trimming of the wick with the pricker, except to put it out in the presence of fire-damp, as explained in Rule 2.

5. Be careful to hang your lamp when you are working, so as to avoid the risk of its being struck by a tool.

6. If you should observe that your lamp, or the gauze

mesh, is injured or out of order, or that it is unlocked, or in any way unsafe, instantly put it out by drawing down the wick into the tube with the pricker. Then take the lamp to the lamp station as before.

7. Never try to hide from the person in charge of the lamp station any damage that may have been done to your lamp.

These seven rules are taken from the Government regulations for the management of mines, and all are worthy of your most careful attention.

LESSON XI.

A TALK ABOUT ROCKS.

MEN who make a special study of rocks are called Geologists, and the science which they thus study is called Geology.

Geologists have many interesting things to tell us about rocks, but we shall only be able to find room for a very few of these interesting things here.

In all parts of the world geologists have been at work, exploring, digging, and examining the edges of the rocks, laid bare in quarries and mines and along the slopes of the mountains. These rocks, many hundreds in number, they have sorted, and arranged in three classes. To these classes they have given the names of—

1. Stratified.
2. Unstratified.
3. Metamorphic.

Stratified Rocks, such as sandstone, limestone, slate, and coal are arranged in beds, layers, strata, and can be split up more or less easily into flat plates or slices. Sometimes they are called *aqueous rocks,* because they have as a rule been formed under water; and sometimes they go by the name of *sedimentary,* because they have generally been

formed by the accumulation of a sediment at the bottom of the water.

Unstratified Rocks, such as granite, basalt, and lava,
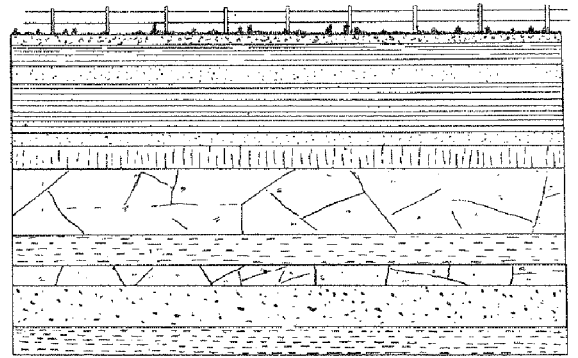
FIG. 19.—Quarry in Stratified Rocks.

consist of vast irregular masses; they are not arranged in beds or strata; and they cannot be split up into plates or slices. They were formed by the melting (under intense
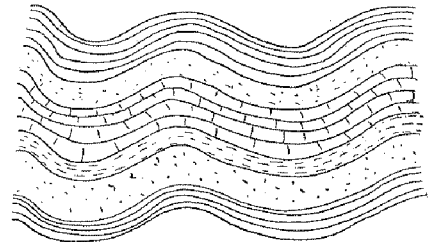

FIG. 20.—Showing Bending of Stratified Rocks.

heat), and subsequent cooling of rocks older than themselves. Sometimes they are glassy in appearance, and sometimes they are built up of crystals.

Metamorphic Rocks, such as marble, are stratified rocks which have been made crystalline in structure by subterranean fires.

The most important and by far the most plentiful of the rocks of which we have been speaking are the sedimentary. At first these were laid down in flat layers, but the movements of the earth's crust have bent, twisted, tilted, and broken them in a wonderful manner.

In Fig. 20 you see an illustration of the way in which they have been bent.

In Fig. 21 you see an illustration of the way in which the rocks have been tilted; they are in this case said to incline or "dip."
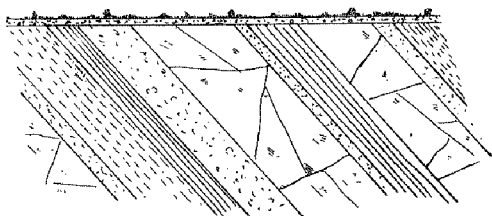
FIG. 21.—Quarry showing "Dip" of Sedimentary Rocks.

Sometimes strata have been actually broken through, and so displaced, that they do not correspond on opposite sides of the fracture, those on one side having a higher elevation than those on the other. Such a fracture or displacement is called a *fault*. Coal miners, in following some particular bed or seam, find it suddenly come to an end on reaching a fault. They must then seek the continuation of the seam on the other side of the fault, at a higher or lower level; and they call the fault an *upthrow* or a *downthrow*, according to whether they have to rise or descend. In Figs. 22 and 23 you see illustrations of faults.

Sometimes masses of unstratified rocks have pushed their way in between the strata; they appear to have been thrust upwards while in a molten state, and to have filled any

spaces, such as fractures, which they found. Fig. 24 shows three cases of such intrusion.
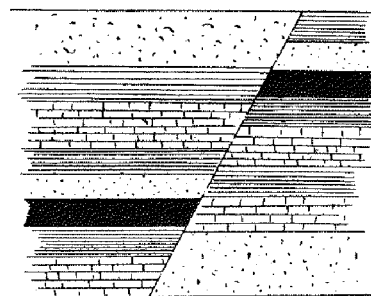

FIG. 22.—Showing Fault and Displacement of Coal Seam.

From what has been said, it will be seen that the art of coal-mining is attended with difficulties—so many, indeed,
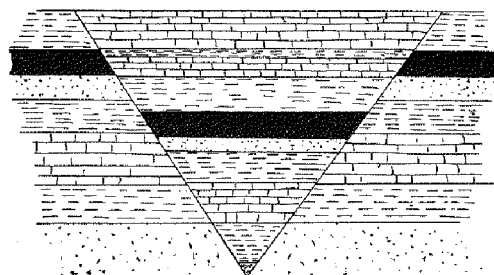

FIG. 23.—Showing Trough Fault.

that a successful manager must be a first-rate geologist, able to read the signs of the rocks, able to track a seam of coal

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through all its vagaries and pranks, and able to find it when, by means of a fault, it plays its merry game of hide-and-seek.
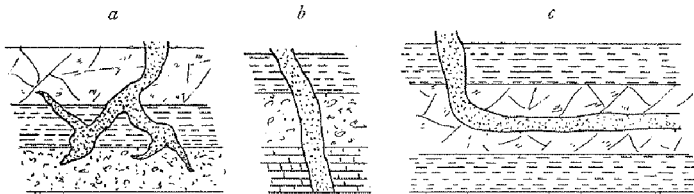

FIG. 24.—Intrusive Unstratified Rock. *a, b, c,* are the intruders.

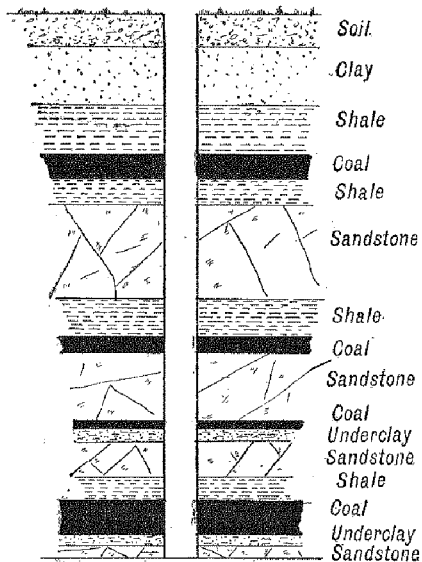Fig. 25 shows a section of the rocks passed through by a typical coal shaft.

FIG. 25.—Section of a Coal Shaft.

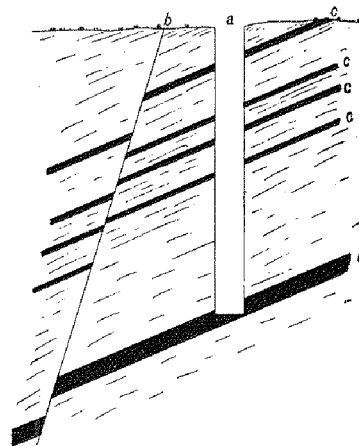Here is another picture of a coal shaft.

FIG. 26.—Section of the Strata in a Coal Pit. *a,* is the shaft ; *b,* shows the line of a fault ; *c, c,* are seams of coal.

LESSON XII.

METHODS OF WORKING THE COAL.

I.—Pillar and Stall System.

JUST as the boundary between two farms is marked off by fences, and no farmer has a right to pasture his cattle on his neighbour's land, so the limits within which we are allowed to work underground are strictly laid down. But, you say, people cannot put fences through the solid rock down there in the darkness, as they do in the fields above. That is true enough ; there are no fences down below, but it is possible to measure distances so accurately, that the

manager of the colliery may know to an inch when he has
reached his boundary line. If he goes beyond that line and
takes away coal, he is stealing ; and though he may go on
undetected for some time, he is pretty sure to be found out
and severely punished before long. The area of coal which
the owners of a colliery are entitled to work we may term
our underground farm.

We will suppose that we have secured our farm, and have
sunk two holes right down to the seam of coal which we
intend to work. One of these holes is called the *downcast
shaft*, the other the *upcast*. The former, as its name implies,
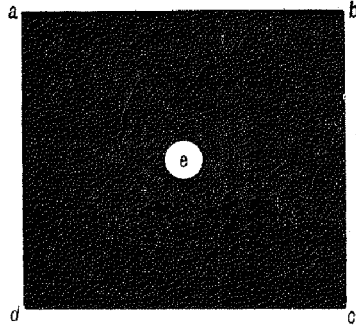
FIG. 27.—Downcast Shaft *e*, and Shaft Pillar *a b c d*.

will be used for supplying the mine with a current of air fresh
from the surface ; up the latter will escape the air foul from
the workings. Either shaft may be used as the highway of
traffic. We will employ the downcast, though we will put
the upcast in order, so that, in case of need, we may ascend
and descend by that also.

To prevent the sides of our shafts from falling in we must
be careful to meddle as little as possible with the coal
immediately around the bottom, for it is very necessary that
our shafts should rest on solid foundations.

This unworked coal is termed the *Shaft Pillar*, and its

size depends chiefly upon the distance of the seam from the
surface. In diameter it should be about half the depth of
the shaft ; so that if the shaft goes down a hundred yards
below the surface, the diameter of the shaft pillar—from *a*
to *b*, or *b* to *c* (Fig. 27)—should be fifty yards. In the
diagram, Fig. 27, the shaft pillar is shown black, and the
upcast shaft white.

Here we are, then, at the bottom of the shaft, and ready
to begin opening out the pit. How shall we start?

We will first of all tunnel out two main levels or roadways
from the bottom of the shaft towards the boundary of our
farm, and we will connect these with each other by narrow
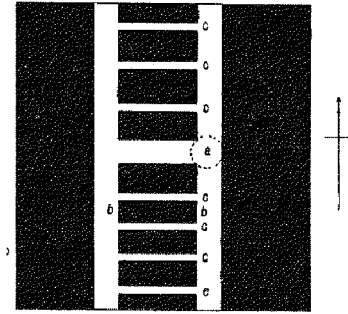openings for ventilation. In Fig. 28, *a* is the shaft, *b b* are

FIG. 28.

the main roadways, and *c c c c c c* are the cross cuts for
ventilation. As the pit is opened out the main road-
ways will be driven further and further until they reach the
boundary.

From these two main levels *b*, *b*, roadways are now cut
out at right angles, *d d d d d* (Fig. 29). They are sometimes
called "endings." In Fig 29, therefore, we have the down-
cast shaft *a*, the two main levels *b*, *b*, the cross cuts for
ventilation, and the "endings" *d d d d d*. The endings in-
crease in number, and grow longer as the pit is opened up.

In this and the following diagrams the shaft pillar, for purposes of simplification, is omitted.
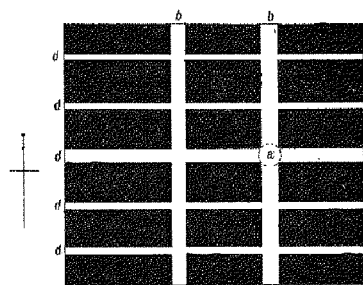

FIG. 29.

From the endings *d d d d*, "bords" *e e e e* are cut at right angles, as shown in Fig. 30. You see that the coal is gradually being worked out, though not nearly so quickly as it
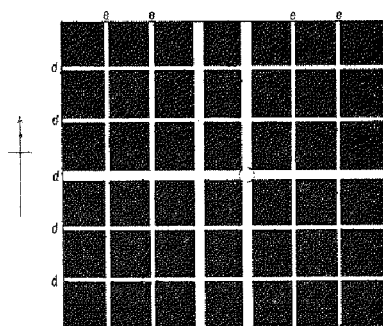

FIG. 30.

would seem from the diagram, where the roads appear much wider in proportion than they really are. So far, then, the seam of coal has been mapped out into huge rectangular

blocks, though I must again warn you that this mapping out process is not fully completed before the work has been still further subdivided as shown in Fig. 31.

From the bords *e e e e* "bord stalls" *f f f f f f* are cut, as shown in Fig. 31. In this figure observe that we have once more the rectangular blocks of coal still remaining in the seam, though these are now much smaller than before the bord stalls were tunneled out.
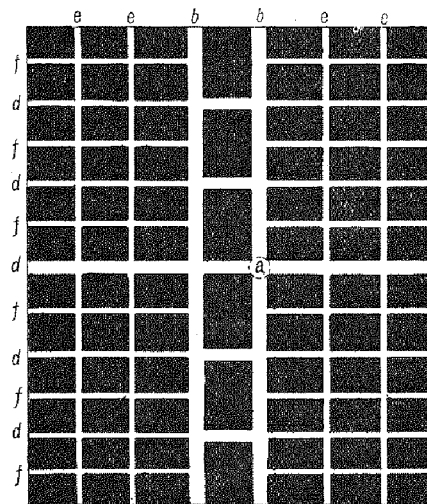

FIG. 31.

Before proceeding further, look well at Fig. 31, *a* is the downcast shaft; *b b* are the *main levels*; *d d d d d* are the *endings* cut from, and at right angles to, the main levels; *e e e e* are the *bords* cut from and at right angles to the endings; and *f f f f f f* are the *bord stalls* cut from, and at right angles to, the bords.

There are variations to the system of bord and stall which

forms the subject of this lesson, but they all aim at one thing :—to leave behind rectangular blocks of coal termed " pillars."

So far, we have only spoken of what is called *first working* of the coal, and this first working has left behind, as we have just seen, rectangular blocks of coal. They are very useful where they are, for they act as supports for the roof. Their size will depend chiefly upon two things (1) the pressure from above, (2) the nature of the coal of which they consist. The deeper the seam, the larger will be the pillar ; and if the coal is soft and friable it will require a larger pillar than if it had been hard and firm. In some collieries the pillars are about thirty yards long and twenty yards wide ; in some they are more ; in some they are less.

The following is a table that is sometimes used for regulating the proportion of coal to be left in the pillars :—At a depth of 100 yds., 50 per cent. of the seam is left behind.

From 100 to 200 yds. 65 ,,   ,,   ,,
From 200 to 300 yds. 75 ,,   ,,   ,,
From 300 to 500 yds. 80 ,,   ,,   ,,

To leave all this coal behind seems a pity ; and, as a rule, it is *not* left behind, but is removed by a process known as the *second working*. The pillars are sliced away bit by bit until little or nothing is left ; then, when the timber supports are withdrawn, the immense weight of rock sinks down and fills the cavity where the coal once lay.

This second working is the most dangerous part of the pillar and stall system ; for the miners aim, not only at removing the blocks of coal, but also at carrying away the strong timbers which they had previously put up to help to support the roof. They wish to take away these timbers for two reasons—(1) because if left behind they would tend to make the overlying strata settle unevenly, and so throw a slanting pressure on the surrounding workings and cause derangement there, (2) because timbers are expensive, and may be used again.

All supports being removed, down comes the roof.

In this and succeeding lessons we have, for the sake of

simplicity, assumed that the downcast shaft alone is used as a highway of traffic : as a matter of fact, both shafts are so used.

The same desire for simplification has influenced us in drawing our diagrams ; in a colliery, the workings are not arranged so symmetrically as we have made them appear— though they are arranged on *the same general principles*.

LESSON XIII.

METHODS OF WORKING THE COAL.

II.—Longwall.

LONGWALL is of two kinds :—

1. Longwall advancing, or working away from the shaft.
2. Longwall retreating, or working back from the boundaries towards the shaft.

Longwall Advancing.—Consider Fig. 32, *a* is the downcast shaft.

From the downcast shaft *headings* are tunneled out, say, as in our diagram, directly east and west. It will not be necessary to use shading here if you will remember that
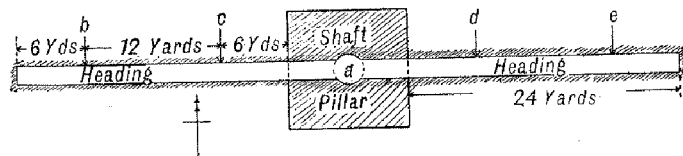

FIG. 32.

everything is black coal except the downcast shaft and the two headings.

When the headings have been driven out, each twenty-four yards beyond the shaft pillar, eight gangs of men may

be set to work, two at *b*, two at *c*, two at *d*, and two at *e*. Of the two at *b*, one is to work north and the other south ; the same arrangement is carried out at *c*, *d*, and *e*. The point *c* is six yards from the boundary of the shaft pillar, and *b* is twelve yards from *c* and six yards from the end of the heading. The point *d* is six yards from the boundary of the shaft pillar, and *e* is twelve yards from *d*, and six yards from the end of the heading.

Our eight gangs are to cut away the whole seam as they go, leaving no pillars of coal, as in the pillar and stall system, but filling up empty spaces with the rock other than coal obtained in the mine. These spaces, when thus packed, are called the *gob* or *goaf*. It is necessary, however, that
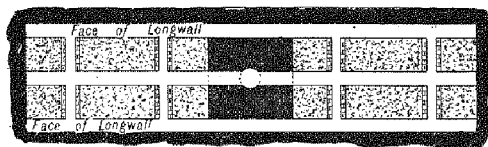
FIG. 33.

the men should leave behind them roads communicating with the headings ; these roads are called *gateways*.

After our eight gangs have been cutting coal for some time, they have changed the aspect of the workings, which now appear, as shown in Fig. 33.

In the above figure the dotted portions are the gob or goaf. The gateways are seen lined with substantially built *packwalls*. Observe that the miners have taken away *all* the coal as far as they have gone. Every day they are at work on the face of the longwall, cutting out the coal, and putting it in tubs or trams, which are then drawn by horses down the gateways, to the headings, and thence to the bottom of the upcast shaft. From the bottom of the upcast shaft it is drawn by the engines up to the surface.

Fig. 34 is a plan showing *a*, face of longwall; *b*, goaf or gob ; *c*, packwalls, and a tramway laid along the gateway, and then

branching off at right angles along the face of the longwall. This tramway along the face of the longwall, where the miners are at work, is necessary when the distance between the gateways is long ; if this distance is only twelve yards,
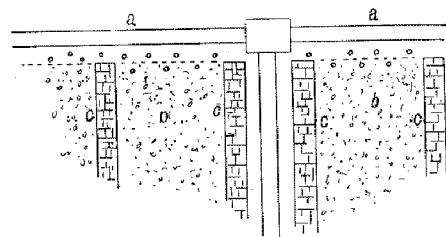
FIG. 34.

then the miners can easily carry the coal to the mouth of the gateway where the tubs or trams are then stationed ; but it is sometimes as much as sixty yards, and then a tramway along the face is necessary. The little circles between the tram lines and the goaf are timbers supporting the roof.
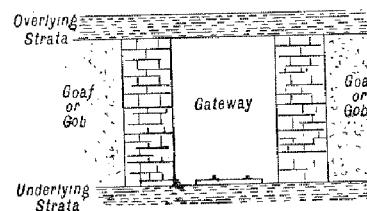
FIG. 35.

The packwalls need to be very strongly built, for the pressure upon them is enormous. In Fig. 35 we see a section of a gateway with the packwalls just built, and before the weight from above has had time to settle fully upon them.

In Fig. 36 the roof has settled down, crushed the pack-

walls and gob, and reduced the height of the gateway, so that horses can no longer pass. To remedy this, it has been necessary to rip down part of the roof, in order to give more head-room. In Fig. 36 we see this change; we also note that the sides and the roof of the gateway are supported by additional timbers.
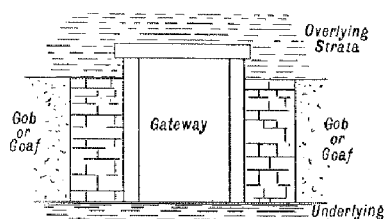

FIG. 36.

In many parts of England the side supports are vertical, and are fitted into the cross piece in the manner shown in Fig. 36*a*.

In Wales, however, they are often made sloping, and are fitted into the cross-piece in the manner shown in Fig. 36*b*.
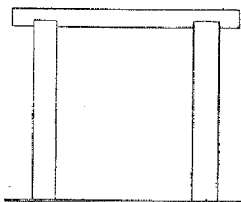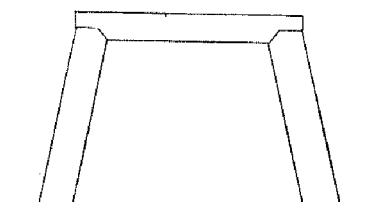

FIG. 36*a*.   FIG. 36*b*.

When several of these gateways have been driven a considerable distance, it is a matter of great difficulty and expense to keep them all in good repair; so one alone is maintained, and the rest are abandoned. This arrangement, however, makes a *cross gateway* necessary. Thus in Fig.

37 we see that six gateways have been driven through the coal. These have been joined by a *cross gateway*, and this enables the five shaded with oblique lines to be dispensed with, while the one nearest the shaft is kept open as a *main gateway*.

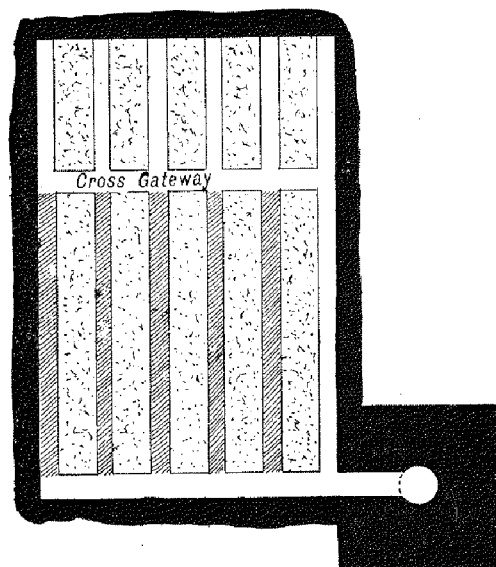And now let us sum up, in a very few words, what we

FIG. 37.

have learnt in this lesson. From the bottom of the upcast shaft two headings are driven through the seam, say, for the sake of simplicity, one due east and the other due west, and these headings are prolonged until, at length, they reach the eastern and the western borders of the area to be worked. Gangs of men are stationed, at intervals varying from twelve to sixty yards, along the headings, and these men drive

gateways to the north and to the south until they reach the northern and the southern boundaries. In this way the whole of the coal is worked out. When the gateways become too long to be easily kept in repair, most of them
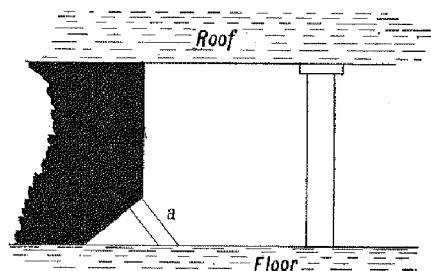

FIG. 38.

are abandoned; to enable this to be done, cross gateways are necessary.

At the face of the longwall the miners work out the coal in a very methodical manner. First they cut out the bottom
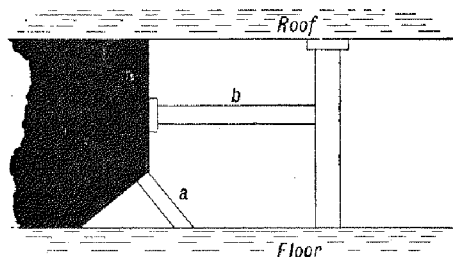

FIG. 39.

of the seam, as shown in Fig. 38; the cutting is in the form of a wedge, and varies in depth from three to six feet. While the men are thus "holing out," they are protected from a fall by short props, *a*, set not more than six feet apart.

When the coal is soft and friable, the props are supplemented by further supports, *b*, Fig. 39. The main body of the coal below can now be brought down by wedging or blasting.

Longwall Retreating.—Longwall retreating differs from longwall advancing chiefly in this:—In the former, the main headings are first driven right to the boundaries, and the gateways are begun there. In this way the coal is worked out from the boundaries towards the shaft, instead of from the shaft towards the boundaries as in longwall advancing.

The roads which communicate with the shaft being already made, as the coal is cut out no roads whatever are maintained through the goafs, for there is no longer a use for them. To protect the miner while working, the face is timbered as in longwall advancing, but the timber is withdrawn as the workings are abandoned. Longwall retreating has thus one great advantage over longwall advancing:—In the latter, expensive gateways must be maintained through the goaf; in the former, these gateways can soon be finally abandoned.

LESSON XIV.

HOW A MINE IS VENTILATED.

I. First Principles.

Experiment 30.—Take a Florence flask, and close the mouth with a tight-fitting cork. Now place it on one scale of your balance, and counterpoise it with sand. What have you counterpoised? Evidently a bottle, a cork, and a flask full of air at the temperature of the room.

Uncork the flask, and heat it over the flame of your spirit-lamp. When the flask—and of course the air inside it—is quite hot, cork it again, and put it on the scale.

What do you see? The scale containing the sand descends. What do you conclude? That a flask full of hot air, you say, is lighter than the same flask full of comparatively cool air. You are quite right, though there are conditions in this experiment that interfere with the accuracy of your determination. Try to think what these conditions are.

How do you explain what you have just witnessed? Look at Experiment 31; it should supply you with an answer.

Experiment 31.—Take a Florence flask fitted with a cork and delivery tube, and allow this tube to dip under water in a beaker. Heat the flask. Bubbles of air will pass through the water. When these have come off for about half a minute, nip the delivery tube tight, and take away your spirit-lamp. You have now a flask full of hot air, and remember that it is *full.* But there is not so much air in it as there was at first; you yourself saw the bubbles of air escaping. Do you not see now why a flask full of hot air is lighter than the same flask full of cool air? When you apply heat some of the air escapes, and thus when you come to the second weighing *there is not so much material to weigh.*

Experiment 32.—Take a little ice or snow, and pound it it up in a mortar with about half the quantity of salt.

Now take a Florence flask and counterpoise it as before. When you have done this, uncork, and place the flask to stand in the intensely cold mixture you have just made. After it has stood there for two or three minutes, replace the cork, wipe the flask quite dry, and replace it on your balance. You see that the flask is now heavier than it was before; a flask full of intensely cold air is heavier than the same flask full of a warmer air. Why? Because cold has an opposite effect to heat. Heat drove out air from your flask; cold drew more air in. In fact, you might compare air to hay; you can spread it out loose and light, or you can press it together firmer and heavier; heat spreads it out, cold compresses it.

Let us sum up the conclusions we have arrived at concerning air :—

1. It has weight.

2. It can be made to expand, and thus, volume for volume, become lighter.

3. It can be made to contract, and thus, volume for volume, become heavier.

In our last three experiments we have used heat and cold to arrive at our results, but there are other agents that would have served our purpose equally well—as you will see before we finish with the subject of ventilation.

Experiment 33.—Take two pieces of glass tubing, each about six inches long and half an inch in bore, and join them
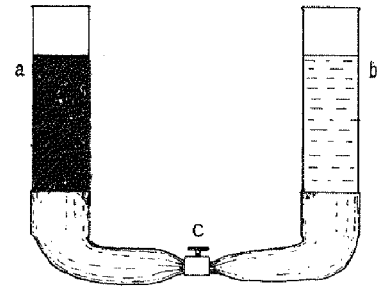

FIG. 40.

by a piece of india-rubber tubing some six inches in length. Now clip the middle of the india-rubber tubing tightly by a screw clip, and, holding the glass tubes upright, pour mercury into one and water into the other until both are about three-fourths full. You have now an arrangement of apparatus such as that shown in Fig. 40, where *a* and *b* are glass tubes, *a* containing mercury and *b* containing water, while *c* is the clip which cuts off the mercury from communication with the water.

Unscrew the clip. What happens? At once the water begins to well up, and soon it overflows. It has been forced out by the heavier mercury.

Experiment 34.—When you have emptied and dried the

E

apparatus used in Experiment 33, clip it again, as before. Both tubes are now full of air.

Now let the flame of your spirit-lamp play gently upon tube *b* until this becomes quite hot. Then unscrew the clip, and, as you do so, blow a little smoke gently over tube *a*. You will see the smoke descend tube *a* and come out of tube *b*. The hot, and therefore lighter, air in *b* has been forced out by the cooler, and therefore heavier, air in *a*.

Now the ventilation of a mine depends exactly upon the principle we have just explained. Of course in a mine there are many complications, but we shall treat of these presently. It is enough here to state that instead of the glass tube containing mercury or cold air we have the
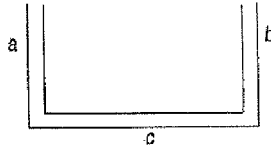
FIG. 41.

downcast shaft *a*, Fig. 41, instead of the glass tube containing water or hot air we have the upcast shaft *b*, and instead of the india-rubber tubing we have an underground passage *c*, connecting *a* and *b*. The downcast shaft is used for traffic, and for supplying fresh air; the upcast shaft is used for getting rid of the foul air; and the underground passage conducts the fresh air by roundabout ways to the face of the coal before discharging its current into the upcast shaft.

LESSON XV.

HOW A MINE IS VENTILATED.

II. Methods of Increasing the Density of the Air in the Downcast Shaft.

IN order to ventilate a mine it is necessary, as we have just seen, that there should be a current of air up the upcast shaft and a current of air down the downcast shaft. In some mines there is a natural difference between the two shafts, the air in the upcast being, from natural causes, lighter than that in the downcast; where this difference exists there is a system of what is termed *natural ventilation*. But these instances are rare, and, where they do exist, are not always satisfactory in their working.

The current is generally produced by artificial means— either the density (weight, volume for volume) of the air in the downcast shaft is increased, or that of the air in the upcast shaft is decreased.

The density of the air in the downcast shaft may be increased in five different ways :—

1. By an Air-Pump.
2. By a Wind-Cowl.
3. By a Waterfall.
4. By a Trompe.
5. By a Blowing-Fan.

The Air-Pump.—Air is pumped into the downcast shaft. Packing the air more closely makes it heavier, volume for volume, and so a current of air is made to flow from the heavier downcast to the lighter upcast.

The Wind-Cowl is fixed at the top of the downcast, and a pipe is carried from it for some distance down the shaft. Fig. 42A is a diagram showing the principle of a wind-cowl. Any wind that may be blowing on the surface enters the wide mouth *a*, and passes down the narrower pipe *b* into the downcast shaft. The top of the cowl can

be moved round so that the wide mouth may face any wind that blows. It is evident that a wind-cowl is quite useless on a calm day.

The Waterfall.—Small mines which have an outlet near the bottom of the shaft to conduct away the water and discharge it again at the surface, are sometimes ventilated by a waterfall. Such a mine is shown in Fig. 42B, where *a* is the downcast shaft, and *b* a natural underground channel, by which any water at the bottom of the shaft drains away and comes out at *c* as a spring. Here the shaft has been sunk near the slope of a hill.
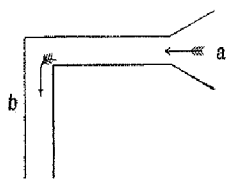
FIG. 42A.

The water is scattered from the top of the shaft by a species of watering-pot, and falls like rain ; in its descent it produces a downward current of air.
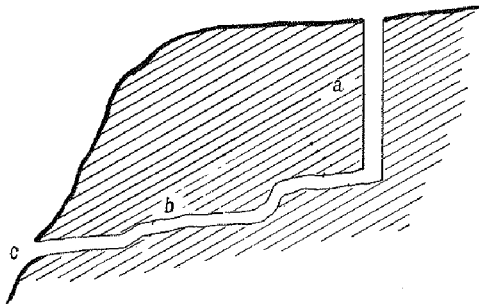
FIG. 42B.

The Trompe.—Here water is conducted through a pipe, *a* (Fig. 43) into an upright pipe, *b*, which is made to contract a little just below the top, as shown at *c*. Immediately below this narrow part there are small holes, *d*, through which air is drawn from outside and carried down with the rush of the water.

The water falls upon what is called a dashblock, *e*, in a cistern at the bottom, and passes away at the overflow, *f*. The air—which fails to find a way of escape with the water —passes along the air-pipe, *g*, in the direction shown by the arrows, and is conducted into the downcast shaft.

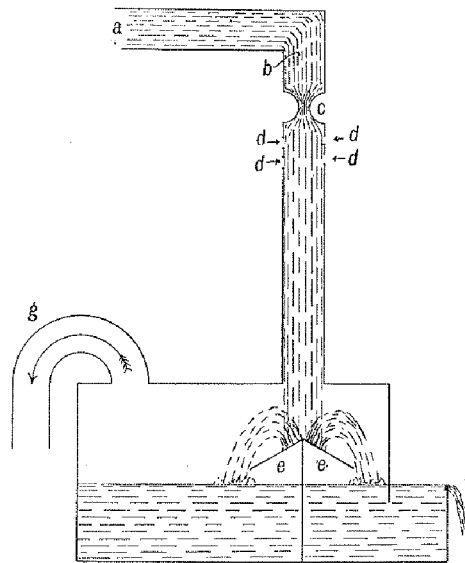**The Blowing-Fan.**—This is another apparatus for

FIG. 43.

forcing air into the downcast ; but as the principle of the fan is treated in one of the succeeding lessons, it is not necessary to say more about the matter here.

The method of producing a current of air by increasing the density of the column of air in the downcast shaft is very little used in this country, though it has been largely adopted

in America. Of the five systems we have mentioned in this lesson, the air-pump and the blowing-fan are the most important; the remaining three—the waterfall, the trompe, and the wind-cowl—are sometimes useful for supplementing other means of ventilation, but are seldom, if ever, used alone.

LESSON XVI.

HOW A MINE IS VENTILATED.

III. Methods of Decreasing the Density of the Air in the Upcast Shaft.

WE now come to the second method of producing a difference of density in the two shafts, viz., that of decreasing the density in the upcast. This may be done—

1. By a Furnace.
2. By a Steam Jet.
3. By an Exhaust Fan.

The Furnace.—This is placed near the bottom of the upcast shaft. Its action may be seen from the plan shown in Fig. 44; *a, a,* are the fire-bars of the furnace, which is lined with walls of fire-brick, *b, b;* *c* is the upcast shaft. When the furnace is situated in or near the seam of coal, it is necessary that air-ways, *d, d,* should be left at each side, and these again are lined with brickwork, *e, e.* The air to feed the furnace is drawn from the workings, enters the furnace at *f,* and, escaping at *g,* goes into the air-way surrounding the upcast, and finds its way into the shaft through an opening in the brickwork at *h.* The direction of the current is shown by the arrows.

When the stream of hot air enters the shaft it warms the air there, which expands, and so becomes lighter. There is consequently now a difference in density between the air in the downcast shaft and that in the upcast, and a current is therefore set up from the downcast to the upcast.

Fig. 45 is a section across the furnace, where *a* is the actual furnace, *b* is a fire-bar on which the coals burn, *c, c* are the side air-ways.

When the furnace is situated some distance from the seam of coal, and when there is no danger of the latter taking fire, the side air-ways are not necessary.
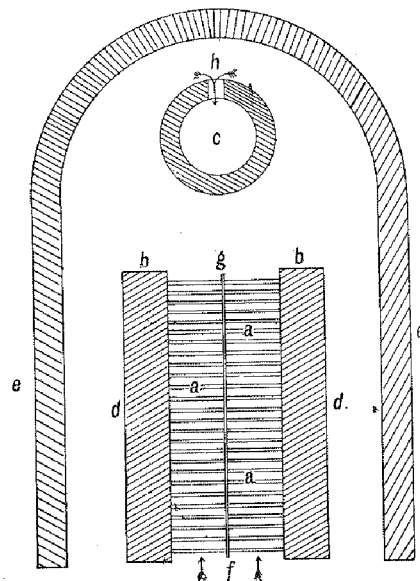

FIG. 44.

Where the foul air from the workings is charged with explosive gases, it would be unsafe to bring these gases into the furnace, so they are conducted by a passage called a *dumb drift* straight into the upcast shaft some fifteen or twenty yards from the bottom, where they cannot come in contact with the fire. In this case the furnace is fed with

air straight from the downcast shaft. In Fig. 46, *a* is the upcast shaft, *b* is the furnace, *c* is the roadway which admits air straight from the downcast shaft, *d* is the dumb drift which conducts the foul air from the workings into the up-
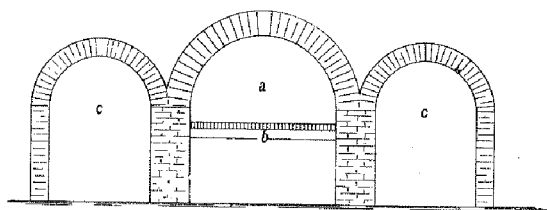

FIG. 45.

cast shaft. When it is necessary to use a dumb drift, the ventilating current, *d*, is not nearly so strong as when the furnace is fed with the return air from the workings.
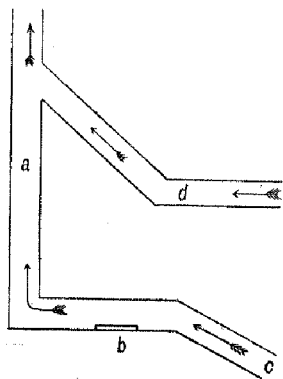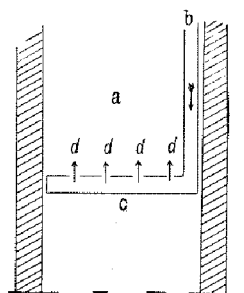

FIG. 46.   FIG. 47.

Furnaces were much used some years ago : now they are regarded as out of date, and their place is largely taken by fans.

The Steam Jet.—This is an arrangement by which a pipe, *b* (Fig. 47), from the steam boiler is carried for some distance down the upcast shaft. This pipe, *b*, is connected with another, *c*, which passes round the shaft. On the top of *c* are small holes, *d*, through which the steam rushes in small jets.

Like the furnace, the steam jet heats the air in the upcast shaft, and so produces an upward current. It has this advantage, too, that it gives an upward push to the air, and thus makes the current due to the difference in the densities stronger than it otherwise would be. Another recommendation is that it cannot set fire to any explosive gases that may be present. It is, however, useless, or worse than useless, in a wet shaft, because the steam at once condenses, falls down the shaft as rain, and so makes the air heavier instead of lighter. Sometimes the steam jet, though not in constant use, is fixed ready for an emergency, and proves useful when the ordinary arrangements for ventilation have been damaged.

The Fan—*Experiment* 35.—Take a box of thick, strong cardboard, and out of it cut two circular discs each eight inches in diameter. In the middle of each disc cut a hole half an inch square.
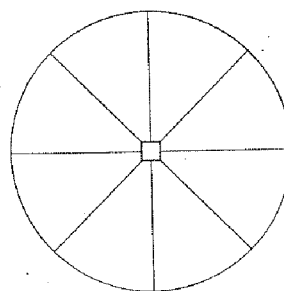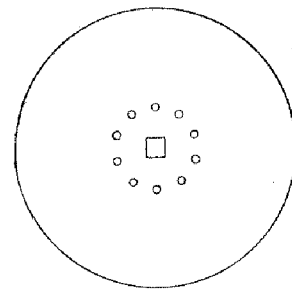

FIG. 48.   FIG. 49

Divide the circumference of one of these discs into eight equal parts, and rule straight lines from each of the eight points in the direction of the centre. Your disc will now look like Fig. 48.

We will call this disc No. 1.

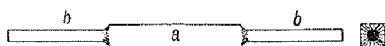Now cut out of your cardboard eight oblongs each six-

FIG. 50.—*a* is square in section ; *b, b* are circular in section.

and-a-half inches long and an inch broad. Take these eight oblongs and fix them, by means of glue or strong gum, upright on their long edges, each resting on one of the eight lines you have drawn on disc No. 1.
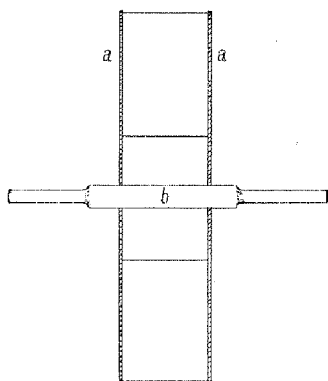

FIG. 51.—*a, a*, discs ; *b*, axle.

Cut nine or ten holes, each about one-eighth of an inch in diameter in disc No. 2, just outside the square hole in the middle, as shown in Fig. 49.

Fit disc No. 2 on the top of disc No. 1, centre to centre.

Wait till the gum or glue has dried.

You have now got a wheel made of two discs joined together, the space between them being crossed by eight vanes radiating from the centre.

You now require an axle. Take a piece of wood about five inches long, each end of which is a square of half-an-inch side. With your penknife cut the two ends round, as shown in Fig. 50.

This piece of wood is to be your axle. Insert it, as shown in Fig. 51.

Your fan is now ready, but if you are of a mechanical turn you can fit the ends of the axle into two supports, and by winding a string round one of these axles, and then pulling the end of the string, you can cause your fan to revolve very rapidly. If you are not dexterous enough, or patient enough, for this, take the ends of the axle in your hands and twirl the fan as quickly as you can. When you hold it to your face you will feel that the blades are wafting out a current of air ; and if you blow a little smoke near the holes round the centre of disc No. 2, you will see that the smoke is drawn into these holes and then wafted out of the periphery.

The little model you have just made is on the principle of the *Waddle Fan*, though you have not imitated all the details of its construction. For instance, in the real Waddle fan the vanes are curved, and of the discs one is flat, while the other—the one through which air is admitted —bulges outwards towards the centre.

Exhaust fans are placed near the top of the upcast shaft, not immediately over it, but some distance away, so that the mechanism may not be damaged in case of an explosion. The upcast shaft is covered at the top to prevent any surface air from being drawn in, and a passage or *drift* connects the shaft with the fan, like this :—

There are several other varieties of exhaust fans, such as the *Guibal*, the *Schiele*, the *Capell*, and the *Walker*. But though differing in construction, they all do the same kind of work :—they draw out, or exhaust air from the upcast shaft. In other words they take out weight—for air has weight—from the upcast, the air there becomes conse-

quently lighter, less dense, and a current flows in from the denser downcast shaft.
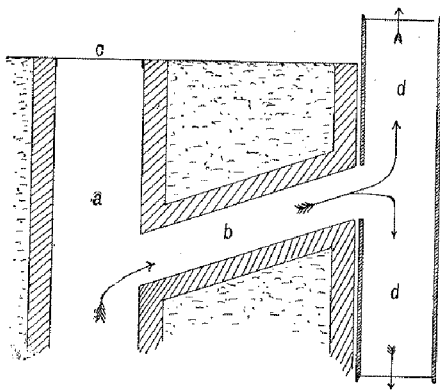

FIG. 52.

a, upcast shaft ; *b*, fan drift ; *c*, covering of upcast shaft ; *d*, fan. The arrows show the direction of the air current.

LESSON XVII.

HOW A MINE IS VENTILATED.

IV. Distributing the Air.

LOOK at the diagram shown in Fig. 53. *a* represents the upcast shaft, *b* the downcast ; *c* and *d* are two main road-ways or drifts joined by cross roads *e, f,* and *m* ; *f* is closed by an air-tight brick wall at *g*.

As it is advisable to be able to get from one shaft to another without making a long rounding, the cross road *e* is not closed like *f*, by a simple air-tight wall, but by two walls, *h* and *i*, in each of which is a closely-fitting door.

These doors are generally fixed a short distance from each other, so that when one is opened for men or horses to pass through, the other is kept shut to prevent a sudden rush of air (the intake current) from the downcast shaft into the return current travelling towards the upcast. Doors which are intended for men only to pass through are called *man-hole doors*, and should be securely locked. The doors on main roads are made large enough for the passing of horses and tubs, or trams : boys are placed in charge here, and are called *door boys* or *trappers*.
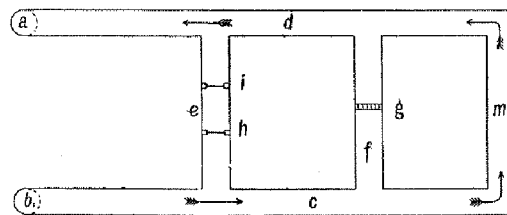
FIG. 53.

In Fig. 53 the air comes down the shaft *b*, and, having passed round the two main roadways in the direction shown by the arrows, leaves the pit by the upcast *a*. In this way the part of the mine here represented is well ventilated. If, however, the doors at *h* and *i* were not quite air-tight, or if they were carelessly left open, much of the intake current would rush through the cross-cut *e* straight to the upcast *a*, and the rest of the pit would receive a very poor supply of fresh air. Doors are of vital importance.

In former times mines were ventilated by one continuous air-current, which travelled from the downcast shaft, along the main roadways, into the headings and stalls, round the face of all the workings, and then returned, heavily laden with gases, to the upcast shaft. There was only one intake, and from this the air branched, and branched again, and passed round the whole of the face where the miners were

at work. Consequently, a man who was working in the intake current near the place where it entered the pit would receive his air fresh; while one who worked in the return, near the upcast shaft, would receive his air charged with all the impurities it had gathered during its long and round-about journey. Also, when there was only one current, very many doors were required in order to turn the air into the various workings; and as the opening of these doors inter-fered with the course of the air-current, the ventilation was often deranged, and explosions were common.
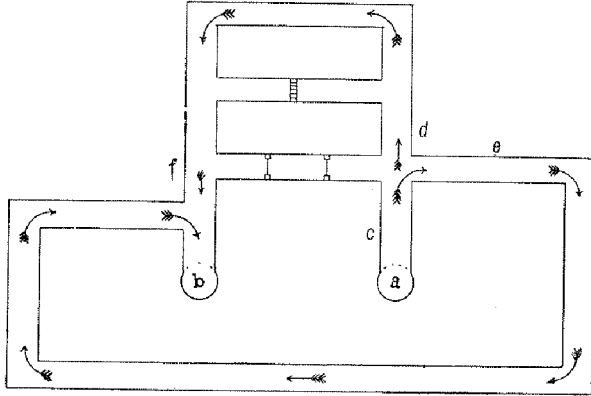

FIG. 54.

Now, it is usual to have separate intakes for each district of the mine, and each intake begins as near as convenient to the bottom of the downcast. The total volume of air entering the downcast is split up where the main intakes branch off, and each portion travels along its own separate intake to the face of the workings of the district, and returns along a separate airway to be joined again to the other splits near the bottom of the upcast shaft.

This system of *Splitting the Air* is illustrated in Fig. 54. The downcast is *a*, and *b* is the upcast.

The air from the downcast proceeds along the main road *c* until it reaches the junction of the two roads *d* and *e*. At the junction it splits into two portions, one going north along the road *d*, and the other east along the road *e*. The northern current supplies all the northern district, and the eastern current the eastern district. The return air from the north joins that from the east at *f*, and the conjoined currents pass straight to the upcast. The eastern and the northern intakes may, in a similar manner, be split again and yet again to supply new districts as these are opened out.

FIG. 55.

In many mines the quantity of air passing into the different splits must be regulated, and that for three reasons:—

1. Because otherwise the districts near the downcast shaft would take too much air, and those a long distance off would not receive their fair share.

2. Because some districts, being larger than others, require a proportionately larger supply of air.

3. Because some districts give off more inflammable gas, and so require a correspondingly stronger current to sweep these gases away.

The supply of air is regulated by fixing in each return air-way where required a *slide door* called a *regulator*, by means of which the size of the air-passage can be reduced to such dimensions as will allow only the required quantity of air to pass through.

FIG. 55A.

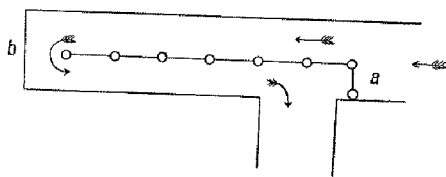In most underground workings there will be places that require air to be conducted to them by means of *bratticing*, which is a kind of coarse, strong, tarred canvas.

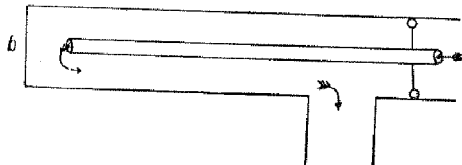Thus, in Fig. 55 we see a representation of such a case.

FIG. 55B.

Men are at work at *a*, *b*, and *c* cutting tunnels or drifts, and pushing them further to the north, west, and south respectively. The little circles dotting the middle of the drifts are props supporting the roofs. The *brattice-cloth* is fixed to wooded boards, called *brattice-boards*, which are nailed to the tops of the props, close to the roof, and also to the bottoms of the props, close to the floor. In Fig. 55, the direction of the air-currents is shown by arrows.

Fig. 55A gives another illustration of the use of brattice-cloth. At *a* is a brattice-door, which, however, does not

extend quite across the road, but allows the current to pass in the direction shown by the arrows. In this way the men working at *b* are supplied with air.

In Fig. 55B still another arrangement for ventilation is
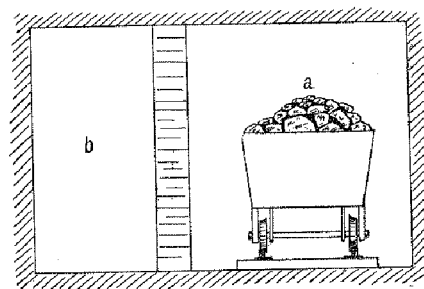
FIG. 56.

shown. The brattice-door extends quite across the road, but is pierced by a pipe, generally six inches in diameter, through which the supply of air rushes to the men at *b*. The direction of the air-currents is shown by arrows.

Sometimes, instead of a partition of brattice-cloth, one of
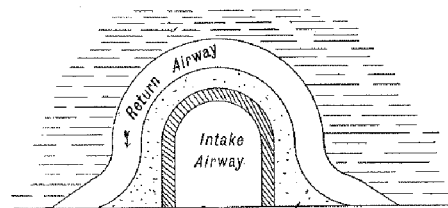
FIG. 57.

brickwork is used. Such a partition is shown in Fig. 56. The supply of air comes along *a* and returns by way of *b*.

When two currents, an intake and a return, have to cross each other, an *air-crossing* will be required (see Fig. 57).

F

Usually the return air-way is taken over the intake, in which case the air-crossing is called an *overcast*; sometimes it is taken under the intake, when it is termed an *undercast*.

The best kind of air-crossing is a *natural air-crossing*. This is one made in such a manner that the two air-ways are separated by a barrier of solid rock. Natural air-crossings are expensive, but they will survive explosions of fire-damp that would wreck the common, artificial kinds.

LESSON XVIII.

ATMOSPHERIC PRESSURE.

On the deck of a ship that is out in mid-ocean stands a group of men. At their feet lies a cubical box, made of tin-plate, and in size and shape somewhat resembling an ordinary biscuit-tin. But this particular tin has no lid, and is sealed up so carefully that the air outside cannot get in; neither can the air inside—and there is nothing but air in it—get out. Heavy weights are fastened to hooks at the bottom, and a very long cord is tied to a ring projecting from the top.

Presently, one of the men takes up the box, and, holding fast to the cord, lowers the curious apparatus overboard. As it sinks deeper and deeper beneath the surface, the cord runs rapidly through the fingers of the man who holds it. When this process has gone on for some time, the man grips the cord firmly and begins to haul in his line.

This is not a method of deep-sea fishing—as one might be pardoned for supposing—but an experiment showing the effect of water-pressure. When the box comes to the surface, it is cubical no longer; for it has been squeezed out of shape by the weight of the water in which it has been immersed, and the deeper it has sunk the more it has been squeezed. Note also that not only the top has been bulged in, but the bottom and all the sides.

It is by experiments similar to this that scientists have established the truth of the two following laws:—

1. Objects immersed in water are pressed upon from every direction.

2. The pressure varies, growing greater and greater as the object sinks deeper and deeper.

Now just as fishes move in an ocean of water, we move in an ocean of air; and inasmuch as air and water are both fluids they are both subject to the laws of pressure just stated. We live at the bottom of an air-ocean 200 miles deep, and upon every square inch of the surface of every object there is a pressure of about 15 lb. This pressure comes from every direction, so that we are free to move without any sense of burden.

Here is an experiment showing in a striking manner the power of atmospheric pressure.

Experiment 36.—Take a cylindrical can of thin tin-plate, a can having a narrow neck. In this place a little water, and boil over the Bunsen burner. When steam has come off freely for some time, and has quite driven out all the air, cork the can tightly and remove from the flame. In a few minutes a very curious thing happens; the can crumples up as though some giant were squeezing it between his powerful fingers.

What has taken place is simply this:—As the steam cooled, it condensed in drops of water on the sides of the can; and the pressure of the air outside, having no pressure to oppose it from inside, did just what you saw it do.

A still more simple experiment is this:—

Experiment 37.—Fill a tumbler quite full of water, and cover with a disc of paper. Place one hand lightly yet firmly on the paper, and with the other quickly invert the tumbler. When you remove your hand from the paper, the latter adheres to the tumbler, and the water does not fall out. This is because the upward pressure of the air is more than the weight of the water.

But what, you may perhaps ask, has atmospheric pressure to do with a colliery? Well, the two are very closely connected indeed. You have been told that out of crack,

and crevice, and pore, the gases with which the coal is charged are constantly finding their way into the roadways of the mine. But there is something that is always trying to force them back, and that something is atmospheric pressure. The gases are pressing outwards in their endeavour to escape from their dark prison-house, and the atmosphere—with a force of about 15 lb. to every square inch—is trying to shut the door of escape. If the atmospheric pressure were increased, less gas would succeed in escaping ; and if it were decreased, the gas would come off in greater volume.

Now, as a matter of fact, the atmospheric pressure varies from day to day ; sometimes it is a little more than 15 lb. to the square inch, and sometimes a little less ; and the volume of escaping gas varies with this varying pressure.

If only a colliery manager could know of these variations of pressure, he would know when to guard against an extra outrush of dangerous gases, and when to expect a time of comparative safety. Is there any means of supplying him with this highly useful information? There is. Science has furnished us with an instrument called a barometer, which measures and records each variation of pressure. You can see now why it is that the Government regulations insist upon a barometer being kept at every colliery. We shall speak of the barometer in our next lesson.

LESSON XIX.

THE BAROMETER.

THE barometer is, as its Greek name implies, an instrument for measuring weight—in this case, the weight of the atmosphere. There are two kinds, the mercurial and the aneroid. The one in common use is the mercurial, and we will confine our attention to this. We shall best understand its construction by making one for ourselves.

Experiment 38.—Take an oblong piece of board, *a, a, a,*

a, about 40 inches long and 4 inches wide. Rule a line, *b, b,* across this, 3 inches from the bottom. Rule lines 28, 29, 30, 31, and 32 inches above *b, b,* as shown in the figure.
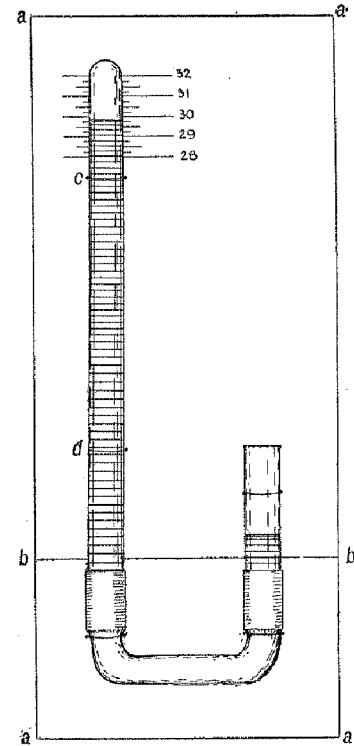

FIG. 58.

Each of these inch divisions should now be divided into ten equal parts.

Now take a barometer tube, 36 inches long, open at one

end and closed at the other. Fill this with mercury, and shake well, so as to dislodge any bubbles of air that may be clinging to the sides.

Fit a short piece of india-rubber tubing on the open end of the tube, and slip a glass tube some six inches long into the free end of the india-rubber. Tie the india-rubber very securely to the glass tubes.

Fix this apparatus to the board you have just prepared. You can do this by boring two holes through the wood at *c*, and two at *d*, and into these pushing copper wires, which, after passing round the barometer tube, you may twist securely behind the board. Do not fasten the wires too tightly, for the tube must be allowed free play of an inch or so.

You have now completed your barometer. Examine it. What do you see? The mercury has dropped for some distance, and has left an open space of a few inches in the top of the tube. What does this space contain? Evidently, not air, for you took pains to dislodge every particle of air at the beginning; it contains nothing but a little of the vapour of mercury.

Now mercury, like other liquids, will, unless forcibly prevented, always find its own level; and there must be some force which keeps the mercury in our long tube at such a higher level than that in the short one. That force is atmospheric pressure, which, acting on the free surface of the mercury in the short tube, prevents the liquid from running out and coming to the same level in the two tubes.

Increase that pressure by slipping a piece of india-rubber tubing on the open end of the short tube, and then blowing down it. The mercury in the long tube rises; and, by increasing the pressure, it would be possible to force the column completely to the top. If, instead of blowing down the tube, you suck the air up, you may cause the mercury to sink.

In order to take a barometric observation, move the arrangement of tubes into such a position that the top of the mercury in the short tube is on a level with the line *b, b*; then read off the height of the mercury in the long tube.

If this level is much below 30 inches the atmospheric pressure is low, and an outrush of gases may be looked for in the roadways of the mine; if it is much higher than 30 inches there will be a corresponding decrease in the escape of gases.

From what has just been said, it will be readily seen that, at a colliery, the barometer is a very useful instrument indeed; for it is a faithful sentinel that tells us of the presence of special danger. From time to time, the Government, not content with trusting the matter to individual colliery managers, issues warnings when low barometrical pressure is observed. In one year nineteen of these warnings were sent out, and fourteen of them were followed by explosions costing altogether more than 200 lives. How many of these explosions were due to neglect of special precautions, and how many to an outrush that defied precautions cannot be computed; but the explosions actually took place, and their occurrence surely justified the warnings.

LESSON XX.

EXPLOSIVES.

MUCH of the work of cutting coal and making roadways in a mine is done by the "pick"; but there are occasions when some more powerful agent is required. This is found in the process known as "blasting."

Blasting is carried out by means of substances known as explosives. There are many different kinds of these, but they all depend for their success upon one and the same principle. A hole is bored in the rock to be blown down. At the bottom of this is placed the explosive, tightly packed and embedded in position. When the shot is fired, the substance of which the explosive is composed is suddenly changed into gas. As this gas is many thousands of times

the volume of the original substance, it requires room for its expansion, and it makes this room for itself by breaking the rock with which it is surrounded.

Explosives are generally put up in the form of cartridges, and are fired either by safety fuses or by electricity.

Safety fuses look something like thick cord. Down the middle runs a core of gunpowder, surrounded by flax, cotton, or other material; and the outside is protected from damp by a coating of gutta-percha or other waterproof substance. One end of the fuse is inserted in a little copper cap filled with fulminate of mercury, which is embedded in the body of the cartridge; the other end projects some distance from the hole. The man who fires the shot applies a light to the end of the fuse, and then quickly retires to a place of safety. The fuse burns slowly and regularly until the fire comes to the fulminate of mercury. The latter then ignites, detonates, and causes the cartridge to explode.

The better and safer way, however, of firing shots is by electricity. Two wires are laid from the source of electric supply to the cartridge, and joined by a thin wire of platinum, which becomes red hot by the passage of the electric current and sets fire to the charge.

In treating of the different kinds of explosives, it would perhaps be advisable for us here to make very few experiments with such dangerous substances. We may, however, safely do a little in the way of experiment with gunpowder.

Experiment 39.—Take about a teaspoonful of gunpowder and place it in a beaker. Add four or five teaspoonfuls of water, stir well, and then warm over a spirit lamp until the water is nearly boiling. Filter the mixture through a filter paper, and catch the clear liquid that runs through in a second beaker. Put the contents of this second beaker into an evaporating dish; and, after driving off the water by evaporation, you will find crystals of saltpetre left behind.

Scrape off the black powder left on the filter paper, dry it at a gentle heat, and place in a test tube. Pour in carbon bisulphide, and shake well. Filter. A clear liquid will run through, and a black powder will remain on the filter paper. Pour the clear liquid into a large watch glass; it will quickly

evaporate (do not heat it or bring it near a light), leaving behind beautiful, needle-shaped crystals of sulphur.

The black powder left after the second filtration is charcoal.

From this experiment we have learnt that gunpowder is made up of saltpetre, charcoal, and sulphur. If we had carefully weighed each of these as we separated them, we should have found about 75 per cent. of saltpetre, 15 per cent. of carbon, and 10 per cent. of sulphur.

A far more powerful explosive than gunpowder, is nitro-glycerine, a light-yellow oily liquid, a little heavier than water. As this is extremely dangerous to handle, its use in a pure state is forbidden in Britain. Several varieties of explosive are, however, manufactured from it, and the best known of these is dynamite.

Dynamite is made from a spongy earth called *Kiesulguhr*, found in Germany, mixed with three or four times its own weight of nitro-glycerine. It is of a reddish-brown colour, and is of a plastic nature like putty. It is generally prepared in the form of cartridges wrapped in parchment paper. When thrown on the fire it burns quickly; if struck, or subjected to shock, it explodes.

As it freezes at a higher temperature than water (in which state it is difficult to explode), it is best to keep it in a warm dry place. Another reason for keeping it warm is, that when it reaches a temperature near its freezing point, it is extremely sensitive to shock, and so is particularly dangerous to handle. If it should happen to freeze, it should on no account be thawed except in warming pans supplied by the makers.

There are two great drawbacks to the use of gunpowder and the nitro-glycerine compounds:—1. The flame of their explosion may set fire to the fire-damp in the pit. 2. The immense volume of noxious gas they give off in exploding is in itself a source of danger. There are, however, now manufactured cartridges where the explosive is surrounded by some flame-extinguishing material, though these do not always justify the claims of their inventors.

Many other explosives, besides those we have mentioned,

are now in use. Each has its advantages and its disadvantages, for not one is perfection. Before any one of these is put on the list of "permissible explosives" issued by the Government authorities, it has to pass through a series of thorough and rigid tests.

APPENDIX I.

RULES FRAMED FOR THE MINERS' SAFETY.

THE Coal Mines' Regulation Act, 1887, gives thirty-nine *General Rules* to be observed so far as is reasonably practicable in every mine. The following is a synopsis of these Rules:—

1. **Ventilation.**—This must be constant and adequate, and the quantity of air in each current or split must, at least once in every month, be measured and entered in a book to be kept for this purpose at the mine.

2. When a fire is used for ventilation, a dumb drift must be used if the gases are inflammable.

3. Fans, &c., shall be so placed that they will not be injured in case of an explosion.

4. **Examination of Mine.**
   (*a.*) *Before each Shift Commences Work.*—A competent person shall examine, before each shift commences work, every part of the mine in which workmen are to work, or through which they are to pass; and no workmen shall pass into any part of the mine that has not been so examined. The person making this examination shall at once enter his report in a book that is accessible to the workmen.
   (*b.*) *During Working Shift.*—A similar inspection shall be made in the course of each shift.

5. **Machinery.**—A competent person shall, once at least in every twenty-four hours, examine the machinery in use, and shall at least once in every week, examine the state of the shafts by which persons ascend or descend, and shall, without delay, enter his report in a book to be kept for the purpose at the mine.

6. **Fencing.**—Every entrance to any place which is not in actual use shall be fenced off so as to prevent persons inadvertently entering the same.

7. **Dangerous Places.**—If at any time it is found by the person in charge of a mine that any part of the mine is dangerous, every workman shall be withdrawn from the dangerous part, and shall not be re-admitted into the dangerous parts until the same is stated by the person in charge of the mine not to be dangerous.

8. **Naked Lights.**—No lamp or light other than a locked safety lamp shall be allowed in any place in a mine in or near which there is likely to be any quantity of inflammable gas sufficient to render the use of naked lights dangerous.

9. **Safety Lamps.**—These shall be so constructed that they may be safely carried against the air current ordinarily prevailing in that part of the mine where they are used, even though such current be inflammable.

10. **Locking Lamps.**
    I. A competent person shall be appointed to examine lamps, and no lamp shall be taken into the workings until it has been examined by him and found in safe working order and securely locked.
    II. A safety lamp shall not be unlocked except either at the appointed lamp station or for the purpose of firing a shot.
    III. A person, unless he has been appointed either for the purpose of examining safety lamps, or for the purpose of firing shots, shall not have

in his possession any contrivance for opening the lock of any safety lamp.

IV. *Lucifers.*—A person shall not have in his possession any lucifer match, or apparatus for striking a light, except within a completely closed chamber attached to the fuse of the shot.

11. **Lamp Station.**—This shall not be in the return air-way.

12. **Shot Firing.**

(*a.*) Explosives shall not be stored in the mine.

(*b.*) Explosives shall not be taken into the mine except in cartridges in a secure case or canister containing not more than five pounds.

(*c.*) A workman shall not have in use at any one time in any one place more than one of such cases or canisters.

(*d.*) In the process of charging or stemming for blasting, a person shall not use or have in his possession any iron or steel instrument for stemming, nor shall he make use of coal-dust for stemming.

(*e.*) No explosive shall be forcibly pressed into a hole of insufficient size, and, when a hole has been charged, the explosive shall not be unrammed, and no hole shall be bored for a charge at a distance of less than six inches from any hole where the charge has missed fire.

(*f.*) In any place in which locked safety lamps are used, or which is dry and dusty, no shot shall be fired except under the direction of a competent and duly appointed person, and he shall not fire it until he has examined the place itself where the shot is to be fired, and all neighbouring accessible places of the same seam within a radius of twenty yards, and has found such place safe for firing.

(*g.*) If at any inspection under Rule 4, inflammable gas has been reported in the ventilating district, the shot shall not be fired

(1) Unless a competent and duly appointed person report that the gas has been cleared away, or

(2) Unless the explosive is of such a nature that it cannot inflame gas.

(*h.*) If the place where a shot is to be fired is dry and dusty, the shot shall not be fired unless

(1) The dusty places within a radius of twenty yards are watered, or

(2) The explosive is of such a nature that it cannot inflame gas.

(*i.*) Defines "ventilating district" and "main haulage road."

(*j.*) When a mine is not divided into ventilating districts, the provisions of this Act relating to ventilating districts shall be read as though "seam" were substituted for "ventilating district."

13. **Water.**—Where a place is likely to contain a dangerous accumulation of water, special precautions, such as bore-holes, &c., shall be used.

14. **Refuges on Underground Planes worked by Machinery.**—These, in the form of manholes, shall never be more than twenty yards apart.

15. **Refuges on Horse Roads.**—These shall never be more than fifty yards apart.

16. **Refuges must be kept clear.**

17. **Horse Roads.**—These must be of sufficient height to clear the horse.

18. **Fencing.**—Shafts not in use must be kept securely fenced.

19. **Shafts in use.**—These also must be fenced.

20. **Shaft to be cased.**—Where the strata are not safe, every working or pumping shaft must be cased.

21. **Security of roof and sides.**—The roof and sides of every travelling road and working place shall be safe.

22. **Propping timber.**—Suitable timber for this purpose shall be provided, and the distance between the sprags or holing props shall not exceed six feet.

23. **Use of downcast shaft.**—Where there is a downcast and a furnace shaft to the same seam, and both shafts are provided with apparatus in use for raising and lowering persons, every person employed in the mine shall have the option of using the downcast shaft.

24. **Competency of engineers.**—Engineers appointed for the purpose of working the machinery employed in lowering and raising persons must be competent, and not less than twenty-two years of age. Engineers employed on underground work alone must be competent and not less than eighteen years of age.

25. **Signalling.**—There shall be an efficient system of signalling in every working shaft.

26. **Overwinding.**—If the winding apparatus is not provided with some self-acting contrivance to prevent overwinding, then the cage, when the men are coming up, shall not be wound up at a speed exceeding three miles an hour after the cage has reached a point in the shaft to be fixed by the special rules.

27. **Cover for Cage.**—A sufficient cover overhead shall be used for every cage employed in lowering or raising persons.

28. **Chain.**—A single linked chain shall not be used for lowering or raising persons except for the short coupling chain attached to the cage.

29. **Winding Drum.**—This shall have appliances sufficient to prevent the rope from slipping.

30. **Winding Breaks: Position of Cage.**—There shall be attached to every machine used for lowering or raising persons an adequate break, and a proper indicator showing to the person who works the machine the position of the cage in the shaft.

31. **Fencing Machinery.**—Every exposed and dangerous part of the machinery in or about the mine shall be kept securely fenced.

32. **Steam Boiler.**—Each steam boiler shall have attached to it a proper steam gauge and water gauge, to show respectively the pressure of steam and the height of water in each boiler.

33. **Atmospheric Pressure and Temperature.** —A barometer and a thermometer shall be placed above ground in a conspicuous position near the entrance to the mine.

34. **Ambulances** or stretchers, with splints and bandages, shall be kept at the mine.

35. **Safety Contrivances.**—No person shall remove or damage any of the safety contrivances mentioned in this act.

36. **Obedience to Orders.**—Every person shall observe such directions as may be given to him with a view to comply with this act.

37. **Books.**—The books mentioned in these rules shall be provided by the owner, shall be kept at the office at the mine, and shall be open to inspection.

38. **Inspection on Behalf of Workmen.**—The workmen may appoint two persons to inspect the mine at least once every month.

39. **Coal Getter working alone.**—No person shall be allowed to work as a coal getter in the face of the workings until he has had two years' experience of such work.

APPENDIX II.

THE following is a list of Apparatus and Chemicals required for performing the experiments described in the preceding pages :—

Apparatus.

	£	s	d
1 doz. hard glass test tubes, for boiling, 6 in. by 1 in.	£0	1	6
1 spirit lamp with ground glass cap	0	0	9
1 wooden test tube holder	0	0	6
3 four-ounce flat bottomed flasks, for boiling	0	1	0
3 six-ounce ,, ,, ,,	0	1	3
1 porcelain pestle and mortar, 3 in. diameter	0	0	8
Corks, assorted	0	1	0
1 set of cork borers	0	0	10
1 balance	0	10	6
1 set of weights, 20 grams down to 1 centigram	0	3	0
Glass tubing, assorted, $\frac{1}{8}$ in. to $\frac{1}{2}$ in.	0	1	6
Triangular file	0	0	4
6 ft. india-rubber tubing, $\frac{1}{4}$ in. internal diameter	0	2	0
10 ft. india-rubber tubing, $\frac{5}{16}$ in. diameter, for connecting bunsen burner with gas bracket	0	4	2
1 foot india-rubber tubing, $\frac{1}{2}$ in. diameter	0	0	10
1 bunsen burner	0	2	6
1 retort stand	0	1	0
1 strong stoneware pneumatic trough, diameter 11 in., depth 5 in.	0	2	0
1 beehive shelf for pneumatic trough	0	0	5
1 retort stand clamp for holding tubes and fixing on retort stand	0	2	0
$\frac{1}{2}$ doz. ground glass plates, 4 in. diameter	0	0	4
4 gas cylinders, 6 in. by 1$\frac{1}{4}$ in.	0	1	8
2 thistle funnels	0	0	4
$\frac{1}{2}$ lb. copper wire, assorted	0	0	8
1 stoppered bell-shaped gas jar, 30 oz.	0	1	3
3 porcelain evaporating basins	0	1	0

	£	s	d
1 nest of hard glass beakers	£0	1	0
1 deflagrating spoon	0	0	3
2 glass rods	0	0	2
1 common wide-mouthed bottle, about 16 oz.	0	0	2
1 iron tripod	0	0	4
2 iron wire gauzes, 6 in. by 6 in.	0	0	5
2 brass wire gauzes, 6 in. by 6 in.	0	1	4
1 sand bath dish, 6 in. diameter	0	0	2
1 iron combustion tube, 6 in. by $\frac{3}{4}$ in., closed one end	0	0	8
2 calcium chloride tubes, one bulb	0	0	4
2 cylindrical tin cans for showing atmospheric pressure	0	1	0
2 funnels, glass	0	0	4
1 barometer tube, straight, 36 inches long	0	1	0
Strong, wide-mouthed bottle for exploding gases	0	0	9
1 screw clip for I.R. tube	0	0	9
	£2	11	8

Chemicals.

	£	s	d
Mercury	£0	5	0
1 quart methylated spirit	0	1	0
$\frac{1}{2}$ oz. iodine	0	0	8
Rectified spirit	0	0	6
2 oz. red oxide of mercury	0	0	10
1 lb. granulated zinc	0	0	6
3 lbs. pure sulphuric acid	0	1	3
3 lbs. pure hydrochloric acid	0	1	3
1 oz. phosphorus	0	0	5
$\frac{1}{2}$ lb. marble	0	0	6
Calais sand	0	0	2
1 pint lime water	0	0	6
$\frac{1}{2}$ oz. magnesium ribbon	0	1	0
Charcoal	0	0	2
3 oz. potassium ferrocyanide	0	0	6

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Iron sulphide -	-	-	-	-	£0	0	3
Carbon bisulphide	-	-	-	-	0	1	0
3 oz. sodium acetate	-	-	-	-	0	0	6
Sodium carbonate	-	-	-	-	0	0	3
1 lb. acetic acid	-	-	-	-	0	0	5
Soda lime	-	-	-	-	0	0	6
1 lb. calcium chloride for absorbing water		-	0	0	5

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