For any liquid, the absolute temperature T of the boiling under a pressure of p atmospheres is determined by the same general law slightly specialized as follows:—

$$T = Y_1 + Y_2 \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (4)$$

where

$$Y_1 = K_1[1 \cdot 4 + \log p] \quad . \; . \; . \; . \; . \; . \quad (5)$$

and

$$Y_2 = K_2[\log \pi - \log p]^2 \quad . \; . \; . \; . \; . \quad (6)$$

The logarithmic limits of all liquids intersect in the same absolute zero point determined by $T = 0 = -273°$ C. and $\log p = -1 \cdot 4$. For each individual liquid this limit extends upwards to the critical point of the liquid, $p = \pi$ and $T = \theta$. For many liquids the critical point can be theoretically calculated, as well as the value of the parameter. It is understood

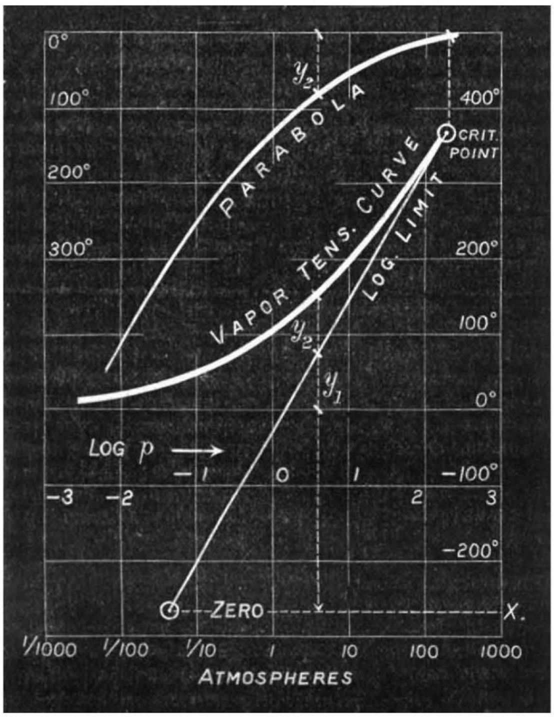


FIG. 2.

that the parabolic curve is tangent to the logarithmic limit at the critical point.

It hardly needs to be said that the tension of dissociation, and even the solubility of solids, are subject to the same general law.

The fusing points are obtained by simply changing the sign in (1) to

$$t = y_1 - y_2 \quad . \; . \; . \; . \; . \; . \; . \; . \quad (7)$$

so that the parabolic curve will be placed below the logarithmic limit.

One of the most remarkable results of this research is the mechanical determination of the true position of the carbon atoms in organic serials, and the complete explanation of the difference in fusing point between compounds containing an even and odd number of carbon atoms.

It should also be understood that the change in fusing point produced by change in pressure is expressed by the same general law.

Putting $\log a = x$, $\log p = z$, and $\log \alpha = \xi$, $\log \pi = \zeta$, the formulæ (1) to (7) will become

$$t = y_1 \pm y_2, \; y_1 = k_1(x - \xi), \; y_2 = k_2(\xi_2 - x)^2 \,. \quad (8)$$
$$T = Y_1 + Y_2, \; Y_1 = K_1(z - \zeta), \; Y_2 = K_2(\zeta_2 - z)^2 \,. \quad (9)$$

These formulæ strikingly show the simplicity of the laws stated, and also determine the surfaces formed by the co-ordinates x, t, and y in general.

In subsequent notes special topics covered by this general law will be taken up, and the complete concordance of the law with the results of observations will be shown.

Porpoises in African Rivers.

IN reference to Mr. Sclater's letter in NATURE of June 11 (p. 124), the following may be interesting to your readers:—

The skull of a Delphinoid Cetacean from Cameroon has lately come into my hands, through the kindness of Prof. Pechnel-Loesche. The sender, Mr. Edward Tëusz, gave the following information concerning it. The animal to which it belonged was caught in Kriegschiff Bay, after very heavy rains, and was being devoured by sharks. The contents of the stomach consisted of grass, weeds, and mangrove fruits. None of the natives had ever seen the animal before. In preparing the skull, Mr. Edward Tëusz noticed that the nostrils projected above the surface of the forehead.

I am preparing for publication a detailed description of the skull, and must here confine myself to remarking that, though the animal belongs to the genus Sotalia, it differs in several essential points from all the species of that genus hitherto described. I have no doubt that it is a new species. There are twenty-seven teeth on each side in each jaw. Their form, in that they are not pointed, but worn down, indicates, as also do the contents of the stomach, that the animal is herbivorous. It therefore seems certain that it is a fresh-water animal. It is well known that other Sotalia live in rivers.

Jena, June 20. WILLY KÜKENTHAL.

PHYSICAL SCIENCE FOR ARTISTS.[1]

I.

I THINK it right that I should begin by explaining how it is that I am here to-day, to lecture to you on a subject which touches art as well as science. It happens in this wise. Some years ago, while studying a certain branch of optics, it became important for me to try to learn something of the exact sequence of colours at sunrise and sunset; and being, like you, busy all day in a large city, I thought it would not be a bad idea, and that it would save a little time, if I studied pictures representing these phenomena *en attendant* the happy holiday time that I should spend in the country. So I went to the Academy and other picture galleries, and endeavoured to get up the information from pictures which I could not at that time get from Nature herself. I then had, as I have still, such an extreme respect for art and artists that I was perfectly prepared to take the pictures as representing truthfully what I wanted to see. The result, however, brought me face to face with a difficulty that I was not long in finding out. I was driven to the conclusion that artists could be divided into two distinct classes—those who studied Nature and Nature's laws, and gave us most exquisite renderings of this or that, and those who apparently considered themselves far superior to any such confining conditions as would be imposed by any law; and that, unfortunately, made me a little doubtful as to the results.

My friend, and your friend, Dr. Russell, happens to know this little bit of my experience, and hence it doubtless is that he requested me to come down to-day to say a few words to you, his plea being that this College is one of the very few institutions of its kind in the world where there is a studio and a physical laboratory side by side.

That, then, is the reason I am here, and what I want to impress upon you to-day is that the highest art can only be produced by those who associate the study of physical science with the study of art, and that therefore the possible producers of the highest art can only be looked for in such an institution as this if training of any kind has anything to do with it.

[1] A Lecture delivered at Bedford College, by J. Norman Lockyer F.R.S. on June 10, 1891.

I think that the *general* conditions of art training as they exist at present absolutely bar any sufficient knowledge of the laws and conditions of natural phenomena on the part of art students.

The *best* art of the time has always been on a level with the best science of the time, and if it had not happened that the first schools and the first Universities clustered round medical schools and schools of anatomy, I do not think that so much attention would be given to-day to anatomical science to the exclusion of all other branches.

You see, then, it comes to this. It is conceded by the art world that in a certain direction the phenomena of Nature require to be studied, otherwise that tremendously exuberant literature on Anatomy for Artists would not have been written, and more than half of the time of students of art would be spent in studying something else rather than those things which they do study.

It is on that ground that I would venture to say that in other institutions, as in this one, the study of physical science should be added to the other branches already recognized by the art world.

I am not an artist. I am not an art critic. I am almost unacquainted with the language usually employed by those who write on art subjects. I shall not deal with opinions, the algebraical sum of which in relation to the qualities of any one picture I have often noticed is zero; but what I shall try to do is to stick as closely as I can to the region of fact, and endeavour to show you, by two or three individual instances, how a student who wishes to become a great artist—as some of you no doubt do—will find his or her ambition more likely to be realized if the study of physical science be combined with that of "Art as she is taught" to-day.

In looking at the Academy Catalogue this year one finds the motto, "La mission de l'art n'est pas de copier la nature, mais de l'exprimer," and this is a true motto. But let us analyze it a little. To "express" suggests a language; a language suggests a grammar, if it is to be perfect, satisfying. But what can this grammar be, in the case we are considering, but the laws underlying the phenomena the "expression" of which, in his own language, constitutes the life-work of the artist. Should he be content to show himself a bumpkin? Are solecisms to be pardoned in his expressions because, so far, scientific training and thought are so limited? Is he justified in relying upon the ignorance of mankind, and, if so, is the highest art always to remain divorced from the highest knowledge?

Now it so happens that the branch of physical science which is above all things the thing to be studied by artists, is the branch of it which is already familiar to you—namely, optics. There could be no art without light; no artists without light; and the whole work of an artist, from the beginning to the end of his life, is to deal with light. Now we live in a world of white light. We might live in a blue world, or a green world, and then the condition of things would be different; but we can, in our laboratory, make our world red or green for the moment; but sometimes, indeed, when we do not seek to make this experiment, we find the world changed for us by the means which we employ for producing artificial lights, such as candles, gas, or the electric light; since in these, colours are not blended in the same way as in a sunbeam.

We thus come to the question of the radiation of light, and the way in which this light, whatever its quality, is reflected by natural objects; it is by this reflection that we see them. Everything that an artist paints which is white, is painted white by him for the simple reason that it reflects sunlight complete. It is perfectly clear that any reflecting surface can only reflect the light which it receives, although all surfaces do not reflect all of it—we have red walls and green trees; the direction of the light is not changed, except in the way of reflection, and you are already acquainted with the imperative law of optics —that when light falls upon a body and is reflected, the angle of reflection is equal to the angle of incidence.

To us this drastic law is of the very highest interest. We can apply it to art in a great many ways, but I will only take two very simple ones. Oftentimes it is our fortune to be in the country by the side of a river, or at the seaside. In both cases we see things reflected in water, and at first sight it would seem that here the artist ought to find perfectly free scope; but the worst of it is that, though he has free scope, sometimes his picture becomes very unpleasant to people who are acquainted with the law I have stated. I find here some diagrams, prepared by the kindness of some of our friends, which will show you the intimate connection between art and science in this direction. In the pictures which you will see in the Royal Academy and the New Gallery, I fancy you will see some which, if you care to study them from this point of view, will be found not to agree with the law.

In the diagrams we have a surface of water and observers at the top and bottom of a cliff. We have on the other side of this surface of water a tree. Now, what anyone would do who disdains to "copy" Nature, and who paints without thinking, is this: he would paint what he saw on the bank, and then turn it upside down and paint it again. But you see that will not do, because the conditions are as you see them here. The higher spectator, No. 1, the angles of incidence and reflection being equal, although he can see the upper part of the tree and part of the trunk, will not be able to see it all completely reflected in the water. You see that the lower part of the tree cannot be seen in the reflection, because any light reflected by it first to the water and then to the eye is really cut off from the eye of the spectator by the bank; if you greatly vary your distance from the other side of the water, you will find the reflection as represented in the other diagram. Now, to anyone who has studied optics, if such a matter as this is represented wrongly in a picture, it becomes an intolerable nuisance, and when you go away you feel sorry that the artist did not do justice to what he wished to represent. A good example of truth to Nature in this respect is to be seen at the German Exhibition—No. 205—in one of the landscapes, which I saw last night; it is a beautiful instance of careful study, and is absolutely true in this respect. The artist has shown how a mountain side, with high lights upon it, reflected on the surface of a lake, appears very different in the reflection, in consequence of an intervening elevation near the edge of the water. When you have thought out the difference of the appearances on the lake and on the hillside, you will appreciate the truth and skill of the artist enormously.

Another serious fault arising from the neglect of this same law is to be found in very many pictures in which we get the reflection of the sun or moon in water.

Obviously, if the water is disturbed, the reflection upon the water must depend upon the direction of the disturbance. I need not say more than that to you. You will quite understand what I mean; but if you look at the pictures in the Royal Academy this year—Nos. 677, 1071, and 1155—you can see how very admirably this reflection can be rendered; and if you look at 165 and think the conditions out, you will wonder how the artist should trouble to paint something that is absolutely opposed to the physical law.

You know that, in those instances where you get a natural reflection, if the light source be beyond the object which reflects the light, the nearer it is in a line with it the more light will be reflected. You see that that rule relates to almost every landscape or seascape that is painted, for the reason that our air is filled with particles which reflect light. If it were not so, our atmosphere would be absolutely black.

It therefore follows that the light of the sky must increase in intensity as the sun or moon is approached—

that is to say, in a sun-setting or moon-setting, if you paint an unbroken sky, there must be an increase of intensity towards the light source. I am almost ashamed to make such a statement, because it is so obvious to you as students of science, but to the artist who is not a very strict observer, why should it strike him? The fact remains that it has not struck a great many artists. If you study the pictures Nos. 650, 989, 1144, in the Royal Academy, and No. 39 in the New Gallery, you will find there indications of a neglect of this law. Now the sky is far more luminous than it ought to be by the light indicated by the landscape. Again, the setting sun is not so bright as the clouds which it is supposed to illuminate, and in some cases there is absolutely no grazing reflection indicated, and, if anything, the sky is rather less luminous where the sun is than further away!

A good rule, and one which a student of physical science would be certain to act upon with considerable care, would be never to show anything as reflected which was not there.

An interesting example of this kind was exhibited in the Academy some years ago. It so happened that a French man of science wrote a book on physical phenomena, beautifully illustrated. Among the illustrations was a coloured copy of a photograph of a soap bubble. Now the laboratory in the Collège de France, in which the photograph was taken, was, like yours, very well lighted by many windows, and the soap bubble was blown in the middle of it. A translation of this book appeared in English, and the illustrations were reproduced.

An artist had a most excellent idea. He thought he would paint a picture of a garden, which he did admirably. The foreground looked bare, so he thought he would put children playing in it. It next struck him, apparently, that the children did not seem to be quite sufficiently occupied, so he painted one blowing soap bubbles. But, alas! less fortunate than you, the artist had no laboratory in which he could blow and study soap bubbles for himself; so what did he do? He copied the bubble which was riddled with windows, although there were no windows in the garden. He thought that the nature of bubbles was windowy.

Then, again, in the matter of reflection, it would not be right that I should fail to remind you that, besides things terrestrial, we have the moon, which rules the night, and rules the night because it reflects the sunlight to us. Now, in a little talk like this I must not take up much time with astronomy, but it is fortunate that books on astronomy can be got for 6*d*. or 1*s*. which will tell us, say, in half an hour, the chief points about the moon which we need consider in the present connection. The moon is lighted by the sun. The sun can only light one half at a time. If we are on the side of the moon which is lighted by the sun, we must see the complete lighted half which we call a full moon. If we see a full moon, we must have our back to the sun. When the position of the moon with reference to the earth is such that we can see half the lighted portion of the moon, we generally find that the part of the moon which is turned to the sun is lighted up.

But none of these things are so in art. Last year a picture in the Academy was absolutely disfigured by the dark part of the moon being turned to the sun. Surely it was not worth the artist's while to paint a moon if he did not know how to do it. But the moon has been treated, if possible, worse than that. Some years ago a friend who knew I was interested in astronomy had another friend who had painted a picture, and he wished me to look at it to see if the moon was right. I went and saw the picture, and had to say that the moon was wrong. It was perfectly clear that the picture was intended to represent the sun setting on the right, beyond the part of the landscape included in the picture, so that the moon rising on the left, and shown in the picture, must be full. My friend said to me he knew this, and that as a matter of fact the artist had painted a full moon to start with, but he had altered it because it "destroyed the balance of his picture." That you see was where art came in. And then he added that the painter was not satisfied with the moon as it stood! I told my friend to say that I regretted that the full moon destroyed the balance of the picture, and that even a delicate crescent did not make things quite right, and I suggested that the effect of two or even three moons, of different sizes if needs be, should be tried. The artist said that this was nonsense; I replied that I did not consider it greater nonsense than the moon as he had represented it, and so the matter ended.

I am sure that the students of this College will know that such things as these are to be avoided, even if there were difficulties caused by the non-existence of a book on astronomy. No artist need paint a moon in a picture if he be too ignorant to paint it properly.

Everything that you paint in a picture, which you paint because it reflects light, should be painted its proper size in relation to the other objects. It seems, however, that the moment a body which reflects light does not happen to be on the surface of the earth, you may, in art, make it as large as you please. I do not think that the moon's distance from the earth gives us any right to treat it in this way.

An eminent American astronomer some years ago looked at the pictures in the New York galleries from this point of view. The moon subtends a certain angle. Everything else in a picture can be expressed in this way the moment you put a moon into it. This astronomer took the trouble to get out a statistical table of the heights of the different mountains and hills as drawn by American artists in pictures of places taken from other places (the distances being therefore known) with a moon thrown in. The maximum height was 105 miles, and the lowest 13!

Next, permit me to say a few words on another point, in order to show that the student of art will delight more and more in his work as he or she knows more and more of physical science. I now take refraction. You know that refraction can be divided into deviation and dispersion. The phenomena of deviation teach us that when a beam of light, whatever its colour, passes out of one medium into another its course is changed. An experiment, which is easily performed and which is more a home experiment than a laboratory one, is to put a coin into a basin and look over the edge in such a direction that the coin is just invisible: then fill it with water, the coin appears. Another experiment is to insert a straight body, such as a pencil, into this bowl of water: it appears to be broken; refraction, then, appears to make water shallower than it really is. If you look at 1094, you will find that this deviation has been made to act the wrong way.

It is rather a bad thing to attempt to paint a nymph partly in and partly out of *clear* water, because her body, if the picture be truly painted, would follow suit with the pencil.

Passing from deviation to dispersion we come to rainbows. You have learned, and perhaps seen demonstrated by experiment, that we deal with a beam of white light coming from the sun and refracted at the front surface of a rain-drop. It is next reflected and again refracted down to the eye, so that the eye sees a bow, with all the spectrum colours due to the dispersion. If the light be strong enough, we get what is called a supplementary bow, and, in consequence of internal reflections, the two reds are brought together.

The point is that in this dispersion, brought about by the rain-drops, the effect is produced in a plane passing through the sun, your eye, and the rain-drop; your eye being in the centre, so that if you see a rainbow at all, you must have your back to the sun. The bow is always circular, and high or low according to the height of the sun. Those are, of course, conclusions which a very restricted study of physical science will make perfectly clear: why you get the two reds together when two bows are visible; why the blue is inside, and the red outside the single bow, also follows from a demonstration which your teacher will give you, or which you can get from a book. The main point is that a rainbow is produced by a physical cause; so that, if you once grasp the idea of the cause of a rainbow, its whole anatomy will remain for ever with you.

It is quite impossible for you to see a rainbow in prospective, or projected on the sky as an ellipse. That will be quite clear, I think. Still, both these are recognized art-objects. I am sorry to say that in this year's Academy there is one case in which you will find that the fundamental condition of having your back to the sun has been neglected or forgotten by the artist. In No. 395 a most exquisite stump of rainbow is seen, most beautifully painted, and you naturally think, of course, that you have your back to the sun, but the artist has not been contented with painting the rainbow, he has painted cattle as well, and their shadows sweep across the picture. Another rainbow, 595, is excellently painted. The artist not only knows a great deal about rainbows, but wishes you to know that he knows, an umbrella being emphatically *en évidence*.

(*To be continued.*)

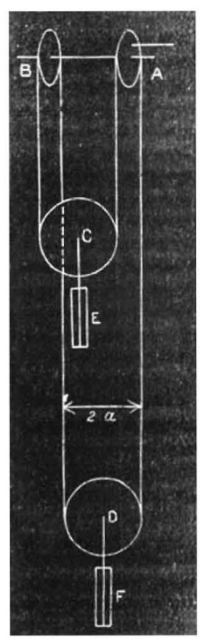
THE FARADAY CENTENARY.

ON Wednesday, June 17, at the Royal Institution, Lord Rayleigh delivered a lecture in connection with the hundredth anniversary of Faraday's birth. The Prince of Wales presided.

Lord Rayleigh said that the man whose name and work they were celebrating was identified in a remarkable degree with the history of that Institution. If they could not take credit for his birth, in other respects they could hardly claim too much. During a connection of fifty-four years, Faraday found there his opportunity, and for a large part of the time his home. The simple story of his life must be known to most who heard him. Fired by contact with the genius of Davy, he volunteered his services in the laboratory of the Institution. Davy, struck with the enthusiasm of the youth, gave him the desired opportunity, and, as had been said, secured in Faraday not the least of his discoveries. The early promise was indeed amply fulfilled, and for a long period of years by his discoveries in chemistry and electricity Faraday maintained the renown of the Royal Institution and the honour of England in the eye of the civilized world. He should not attempt in the time at his disposal to trace in any detail the steps of that wonderful career. The task had already been performed by able hands. In their own Proceedings they had a vivid sketch from the pen of one whose absence that day was a matter of lively regret. Dr. Tyndall was a personal friend, had seen Faraday at work, had enjoyed opportunities of watching the action of his mind in face of a new idea. All that he could aim at was to recall, in a fragmentary manner, some of Faraday's great achievements, and if possible to estimate the position they held in contemporary science.

Whether they had regard to fundamental scientific import, or to practical results, the first place must undoubtedly be assigned to the great discovery of the induction of electrical currents. He proposed first to show the experiment in something like its original form, and then to pass on to some variations, with illustrations from the behaviour of a model, whose mechanical properties were analogous. He was afraid that these elementary experiments would tax the patience of many who heard him, but it was one of the difficulties of his task that Faraday's discoveries were so fundamental as to have become familiar to all serious students of physics.

The first experiment required them to establish in one coil of copper wire an electric current by completing the communication with a suitable battery; that was called the primary circuit, and Faraday's discovery was this: That at the moment of the starting or stopping of the primary current, then, in a neighbouring circuit, in the ordinary sense of the words, completely detached, there was a tendency to induce a current. He had said that those two circuits were perfectly distinct, and they were distinct in the sense that there was no conducting communication between them, but, of course, the importance of the experiment resided in this—that it proved that in some sense the circuits were not distinct; that an electric current circulating in one does produce an effect in the other, which is propagated across a perfectly blank space occupied by air, and which might equally well have been occupied by vacuum. It might appear that that was a very simple and easy experiment, and of course it was so in a modern laboratory, but it was otherwise at the time when Faraday first made it. With all his skill, Faraday did not light upon truth without delay and difficulty. One of Faraday's biographers thus wrote:—"In December 1824, he had attempted to obtain an electric current by means of a magnet, and on three occasions he had made elaborate and unsuccessful attempts to produce a current in one wire by means of a current in another wire, or by a magnet. He still persevered, and on August 29, 1831—that is to say, nearly seven years after his first attempts—he obtained the first evidence that an electric current induced another in a different circuit. On September 23rd, he writes to a friend, R. Phillips: I am busy just now again with electro-magnetism, and think I have got hold of a good thing, but cannot say; it may be a weed instead of a fish that, after all my labour, I at last haul up." We now know that it was a very big fish indeed. Lord Rayleigh proceeded to say that he now proposed to illustrate the mechanics of



the question of the induced current by means of a model (see figure), the first idea of which was due to Maxwell. The one actually employed was a combination known as Huygens's gear, invented by him in connection with the winding of clocks. Two similar pulleys, A, B, turn upon a piece of round steel fixed horizontally. Over these is