

PROCEEDINGS
OF THE
AMERICAN PHYSICAL SOCIETY

MINUTES OF THE PASADENA MEETING, MARCH 7, 1925.

The 132nd regular meeting of the American Physical Society was held in Pasadena, at the California Institute of Technology, in the Norman Bridge Laboratory of Physics, on Saturday, March 7. The presiding officer was Professor R. A. Millikan.

The session consisted of 28 papers, of which abstracts of 27 are given in the following pages. An **Author Index** will be found at the end.

The attendance was 120.

DAVID L. WEBSTER
Local Secretary for the Pacific Coast

ABSTRACTS OF PAPERS

1. The Compton effect with hard x-rays. D. L. WEBSTER and P. A. ROSS, Stanford University.—Graphs of ionization spectra are presented, supplementing the authors' statement at the December meeting that the Compton effect exists for tungsten K-series rays and the adjacent continuous spectrum. In glass the Compton shifted component is several times as strong as the unshifted, and in graphite still stronger. In silver, the fluorescent rays were very strong but the scattered too weak to measure. The wave-length shifts confirm Compton's theory within limits of error (about 0.03 angstrom).

2. Characteristic x-rays from lithium. G. K. ROLLEFSON, University of California.—A method which has been described previously (Phys. Rev. **23**, 35, 1924) has been used to determine the critical potentials corresponding to the excitation of characteristic x-rays of lithium. Definite critical potentials have been obtained at 39.2, 43.05 and 46.0 volts, and it is shown by comparison with the known energy levels for three electron systems that these correspond to the differences $1_1 \rightarrow 2_1$, $1_1 \rightarrow 2_2$, and $1_1 \rightarrow 3_1$ respectively. Some evidence has also been obtained for a higher critical potential which probably represents ionization of the 1_1 level. The 2_2 to 1_1 transition corresponds to the $K\alpha$ line of lithium. Using this value for Li and Lukirsky's value for the $K\alpha$ line of carbon, it is possible to extend the Moseley curve for the $K\alpha$ line and obtain the values for the other light elements by interpolation. The following are the ν/R values for the light elements: Li, 3.18; Be, 6.86; B, 12.25; C, 18.60; N, 27.46; O, 37.21; F, 48.44; Ne, 61.31.

3. Unusual x-ray reflections on spectral photographs. LINUS PAULING, California Institute of Technology.—On a photograph of the molybdenum K-radiation reflected from planes (001) of the orthorhombic crystal $\text{UO}_2(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, several weak lines were found which did not give the same value of d/n as the strong reflections. These lines were not due to reflection in the usual way from other planes, for they persisted even after a change in orientation of the crystal and the use of a slotted screen. The explanation of their origin is that previously advanced by Dickinson in explanation of diffuse spots on Laue photographs, that there are present in or on an easily deformed crystal minute crystals whose axes make small angles with those of the large crystal, the number of these being greater the smaller the angles. A strong photograph made with a water-cooled tube showed this predicted sort of powder pattern being focused to produce the unusual lines. Similar lines have been found with other crystals, notably KI. These lines may have introduced errors in the interpretation of spectrographic and spectrometric measurements.

4. The series spectra of two-valence-electron atoms of phosphorus (P_{IV}) sulphur (S_V) and chlorine (Cl_{VI}). I. S. BOWEN and R. A. MILLIKAN, California Institute of Technology.—With the aid of the irregular and the regular doublet laws which we have previously found useful for the prediction of the spectra of stripped atoms (atoms denuded of all valence electrons save the one which in moving back and forth between energy levels gives rise to the observed radiation) we have now been able to make similar identifications for a new series of atoms, of like electronic structure but containing in each case two electrons in the outer shell instead of one. Thus we have definitely identified 23 lines and 12 term-values of P_{IV}, 17 lines and 8 term values of S_V, and 6 lines of Cl_{VI}. It has further been found that the pp' group follows the irregular doublet law, and with the aid of this law this group has been traced from Mg_I to Cl_{VI}. That this group follows the irregular doublet law means that all jumps involved must be between orbits of the same total quantum number, viz., 3 in the case of the Mg to Cl sequence, and 2 in the case of the Be to O sequence. This definitely eliminates any jump involving d levels in the latter sequence and hence renders Wentzel's explanation and selection principle unacceptable.

5. The series spectra of three-valence-electron atoms of phosphorus (P_{III}) sulphur (S_{IV}) and chlorine (Cl_V). R. A. MILLIKAN and I. S. BOWEN, California Institute of Technology.—By the methods mentioned in the preceding abstract, 21 lines and 10 term values of P_{III} have been definitely identified; also 20 lines and 10 term values of S_{IV}; also 10 lines of Cl_V. Further, a quadruplet pp' group, in which the $p_1'p_2'$ separation is about two-thirds of the p_1p_2 separation, has been discovered and traced from P_{III} to Cl_V and from C_{III} to O_{IV}. This new pp' group also follows the irregular doublet law. Again, the triplets arising from atoms of similar electronic structure but varying effective nuclear charge have been everywhere found to follow the fourth power relativity law as closely as do the doublets.

6. The widening phenomena of spectrum lines as related to temperature classification and energy levels. ARTHUR S. KING, Mount Wilson Observatory.—A close parallelism is found between the temperature classification of electric furnace lines and that based on widening effects in sources of high electrical excitation, such as the disruptive spark, pole of the arc, and the thousand-ampere arc. In the latter sources, low-temperature lines remain nearly symmetrical, while those responding to higher temperatures are distinguished by increasing degrees of dissymmetry and diffuseness. It follows that the "multiplet" groups, whose selection and assignment to energy levels are based largely on the temperature classification, show in the discharge sources a definite increase in sensitiveness to wave-length disturbance as higher energy levels are

involved. About fifty multiplets of iron, examined in the high-current arc, illustrate this clearly. The tendency to widening, usually with dissymmetry, does not result necessarily from large difference of energy levels passed through, but depends on the initial stage, as if the larger electronic orbits were especially sensitive to perturbation caused by high excitation. Iron multiplets starting from the three lowest levels are affected but slightly, while those from higher levels show increasing degrees of dissymmetry. Lines of a given multiplet are affected nearly alike, so that the differences in widening effect supplement the temperature classification as a means of grouping the high-level lines.

7. Standard wave-lengths in the spectrum of iron. HAROLD D. BABCOCK, Mount Wilson Observatory.—With the apparatus and methods previously described, the investigation reported last June has been continued. Interferometer measurements on about 150 lines distributed through the visible spectrum have been secured, confirming and extending the preliminary results. Systematic differences are found between the new measurements and the adopted system of secondary and tertiary standards, amounting to about 0.002 Å for $\lambda < 5500$ Å, but averaging about 0.008 Å in the red, the new measures being shorter than the old. Although this accords with the work of other observers in showing that the adopted system is too high, there are definite systematic differences between the measurements made at Mount Wilson and those at the Bureau of Standards, amounting to 0.003 Å for the red lines, which are dependent on differences in the iron arcs used. The distinguishing features of the adopted type of iron arc are illustrated.

8. The absorption spectrum of oxygen to 1240 Å. J. J. HOPFIELD and S. W. LEIFSON, University of California.—The intense continuous spectrum of hydrogen discovered by Lewis was used as a background in a part of the region $\lambda 2000$ —1250. With 2.5 cm of oxygen at atmospheric pressure, sixteen clearly resolved bands appear between $\lambda 1950$ and 1760. This is the first verification of the work of Schumann, who found 14 bands at $\lambda 1850$. This appears to be the first time that the wave-lengths of these bands have been determined. They may be accurately measured on our spectrograms. The approximate wave-lengths of the heads are $\lambda 1950, 1929, 1908, 1888, 1869, 1851, 1836, 1821, 1808, 1797, 1788, 1780, 1773, 1768, 1764$, and 1762. A fine structure of these bands has also been observed. The great absorption band at $\lambda 1750$ —1300 is of course registered on our plates. The vacuum grating spectrograph previously employed by one of us was used in this work. Preliminary investigations on other substances are now in progress.

9. A preliminary report on the application of the combination principle to the bands of the Swan group of carbon. J. D. SHEA, University of California.—These bands are found in the spectra of stars of spectral class R and N. Vibration quantum numbers previously assigned by Birge to the various bands of the Swan group have been tested by means of the combination principle. The existing series for the four bands with heads at $\lambda 5165, 5129, 5635$, and 5585 have been extended and improved. These particular bands correspond to vibration quantum changes in emission of 0 to 0, 1 to 1, 0 to 1, and 1 to 2, respectively. The origin of these bands has been located. Thus for the $\lambda 5165$ band it is 14 lines or 4.8 Å from the head. The combination principle has been successfully applied to these four bands. Since it is not possible to resolve the line in the vicinity of the head, it is possible to obtain only an approximate value for the moment of inertia as follows, $J' = 16 \times 10^{-40}$ gm cm², $J'' = 17 \times 10^{-40}$ gm cm². These values give a separation of the two atoms forming the molecule of 1.3×10^{-8} cm, when the molecule is assumed to be C₂. The values given are undoubtedly accurate to the number of figures given.

10. The band spectra of coupled systems. H. KAHLER, National Research Fellow, California Institute of Technology.—The spectra of the crystals containing uranium oxide as a constituent consist of bands in the blue side of the spectrum having an approximately constant frequency interval and associated bands in the longer wavelength region with a different frequency interval. It is shown that such results are to be expected when the cross product terms involving the quantum numbers of the nuclear and electronic vibrations are taken into consideration. The effect of coupling is shown to lead to a formula which represents the data of Henri on the spectra of polyatomic gases. The multiple linear terms of Henri were hardly reconcilable with previous considerations.

11. Behavior of bright hydrogen lines in stellar spectra. PAUL W. MERRILL, Mount Wilson Observatory.—Among the hotter stars the bright hydrogen lines are usually double with a separation of 2 to 4 angstroms. In one star the violet component of $H\beta$ varies periodically in intensity, while the other component remains unchanged. In all hot stars the intensities of the bright lines decrease from $H\alpha$ toward shorter wavelengths and the ultra-violet lines are frequently dark in the same spectrum in which $H\alpha$ is bright. Among the long-period variable stars at the lower end of the stellar temperature sequence the bright hydrogen lines are nearly monochromatic. In the titanium oxide variables their relative intensities are very different from those observed in the laboratory, $H\gamma$ and $H\delta$ being many times as strong as $H\alpha$ and $H\beta$. Since the temperatures (and presumably the pressures) are low it should be possible to reproduce these effects in the laboratory. A curious phenomenon in red stars is the decided weakness of $H\epsilon$ compared to $H\delta$ and $H\zeta$. This may be due to the absorption of calcium since $H\epsilon$ lies within the broad calcium line H. A definite laboratory problem is to find a condition in which calcium vapor is nearly opaque to the hydrogen line $H\epsilon$.

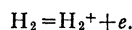
12. Indirectly excited fluorescence spectra. STANISLAW LORIA, California Institute of Technology.—Franck and Cario's experiments on fluorescence spectra of some metallic vapors mixed with mercury vapor and excited by radiation absorbed only by the latter, have been repeated with a result confirming the statements of previous observers. The spectrograms of Tl-fluorescence contain all lines recorded by Cario and also the lines 2922 ($4d_2-2p_1$), 2768 ($3d_2-2p_2$) and 2580 ($2s-2p_2$), which are to be expected theoretically but could not be found on Cario's plates. The investigation of the influence of inert gases on the intensity of "sensitized" fluorescence confirmed in general the results obtained by K. Donat (Zeits. f. Phys. **29**, 345, 1924); the admixed gas weakens the intensity of mercury lines but intensifies the fluorescence of the indirectly excited vapor. The effect is different for different lines. An attempt is being made to perform this last experiment under well defined conditions of pressure and temperature for all components of the mixture, so as to obtain data sufficient for the determination of the time during which a mercury atom may (under various conditions) persist in its metastable state.

13. The effect of minute surface impurities upon the photo-electric long wavelength limit of mercury. HUGH K. DUNN, California Institute of Technology.—The definite establishment by C. B. Kazda of a sharply measurable long wave-length limit for a perfectly clean surface of flowing mercury has rendered possible for the first time the determination of the effect of minute traces of impurities upon such a limit. In the present work the long wave-length limit of flowing mercury is again found at Kazda's value of 2735 Å, with an uncertainty of not more than 10 Å. The cleanest obtainable stationary surface of mercury has yielded, however, a value of 2860 Å, the change from the first to the second values upon stopping the flow being strikingly reproducible. Certain types of impurities are found to push the limit down below the

2537 line. The effect of hydrogen impurity upon this limit has been especially investigated.

14. Secondary emission from nickel surfaces due to positive ion bombardment. A. L. KLEIN, California Institute of Technology.—The apparatus used consisted of a number of concentric nickel cylinders surrounding a central positive ion emitter. The cylinders are pierced with slots in such a manner that they act as grids, shields, and collectors. The observations were taken by running saturation curves for the various voltages of acceleration of the positive ions. The velocity of emission of the secondary electrons was obtained from the point of maximum slope of the saturation curve, and the amount of the emission from the saturation value. Secondary emission was obtained for primary velocities as low as fifty volts.

15. The ionization of hydrogen by electron impact as interpreted by positive ray analysis. T. R. HOGNESS and E. G. LUNN, University of California.—The method of positive ray analysis has been applied to the study of the processes of ionization of hydrogen by impact electrons. The results of experiments on the relative amounts of H^+ , H_2^+ and H_3^+ ions as a function of the pressure, show that the only process occurring when an electron of sufficient energy collides with a hydrogen molecule is that represented by the equation:



The H_2^+ thus formed is energetically unstable, and on collision with a neutral molecule disrupts to form H^+ and H ; the H^+ may attach itself to a neutral molecule forming H_3^+ . This conclusion has been verified by studying the ionization in mixtures of helium and hydrogen. The *ionization potential of hydrogen* was found to be 16.0 volts. In *mixtures of hydrogen and helium* the ion HeH_2^+ and one which is probably HeH_3^+ were observed in addition to H^+ , H_2^+ and H_3^+ . The bearing of the above conclusions upon the various interpretations of the ionization potentials and ionization processes is discussed. The discrepancy between the ionization potential calculated from the heat of dissociation and from theoretical ion models and that experimentally determined is pointed out.

16. Ionic mobilities in ether as a function of pressure. L. B. LOEB, University of California.—Mobilities of positive and negative ions were measured in ethyl ether as a function of the pressure using the Franck modification of the Rutherford alternating current method with a square wave alternating current. The mobility reduced to N.T.P. for positive ions was 0.19 cm/sec. at 340 mm pressure and rose to 0.22 cm/sec. at 5 mm pressure. The latter value was the same as that for the negative ion at 340 mm which was 0.223 cm/sec. Thus the positive ion in ether shows the two types of mobility observed by Erikson (Phys. Rev. **20**, 117, 1922; **24**, 622, 1924) and Wahlin (Phys. Rev. **20**, 267, 1922; Proc. Nat. Acad. Sci. **10**, 475, 1924), new ions having a mobility equal to that of the negative and aged ones having a lower value. The age of the high mobility ions was about .001 sec.; that of the low .02 sec. Below 80 mm the negative mobility rose rapidly because of the effect of electrons that had not formed ions, dual curves of the type observed by Wellisch (Phil. Mag. **34**, 199, 1917; Am. Jour. Sci. **44**, 1, 1917) for such ions being found at 40 mm. Great care must be used in deducing mobilities from such curves because of the smooth asymptotic feet of the curves caused by the gauze and auxiliary field. Care must be taken to avoid changes in mobility produced by changes in the value of the auxiliary field alone.

17. The theory of the range of α -particles. EDWARD CONDON and L. B. LOEB, University of California.—The theory of the range of α -particles which has been developed by Henderson (Phil. Mag. **44**, 680, 1922), discussed by Fowler (Proc. Cambr.

Phil. Soc. **21**, 521, 1923), and tested by Bates on rare gases (Proc. Roy. Soc. **A106**, 622 1924) leads to the equation

$$-MVdv/dx = (8\pi e^+ N/mV^2) \sum n_s \log(2mV^2/T_s)$$

for the rate of loss of energy of an α -particle along its path. Here n_s is the number of electrons having the ionization potential T_s . This paper points out two errors in the argument leading to this equation. (1) The assumption is tacitly made that multiple ionization in a given shell can take place with the same ionization potential as single ionization from the same shell. (2) The calculation also assumes that processes will happen in the atoms of the gas corresponding to multiple ionization of the gas by single impact. This is in direct contradiction with the results of Millikan's studies of ionization by α -particles, except in the case of helium. It is shown that the effect of making these corrections to the theory is to increase the existing discrepancy between this theory and experiment, indicating that this line of attack on the problem is inadequate.

18. Conductivity of gases during chemical reaction. A. KEITH BREWER, California Institute of Technology.—In preceding papers it has been shown that when gas phase reactions were allowed to take place between gold or platinum electrodes a current was detected which was proportional to the quantity of material reacting and to the applied voltage over the field investigated (0 to ± 2700 volts per cm). It has since been shown that a conductance is observed when various oxidizable vapors are mixed with oxygen at temperatures well below that of the ignition temperature. The temperatures at which the conductance begins fall in about the same order as the ignition temperatures. In each case the conductance increases exponentially with the temperature; on the average the conductance doubles for a rise in temperature of 10°C . Experiments are presented to distinguish between reactions taking place on the surface of the electrodes, and reactions throughout the body of the gas.

19. Remark on the dielectric constant of gases. PAUL S. EPSTEIN, California Institute of Technology.—The recent measurements of A. Glaser (Ann. der Phys. **75**, 459, 1924) show that the diamagnetic susceptibility of gases varies as a function of the pressure and of the magnetic strength of field. The theoretical explanation of this effect is not quite known. On the other hand, the theory of the action of an electric field presents no difficulties and it is possible to predict an analogous change of the dielectric constant with the strength of field. For monatomic hydrogen we can carry through the computations completely. For weak and normal electric fields the dielectric polarization is considerably higher than for extremely high values of the strength of field. This drop is due to the gradual development of the Stark effect leading to a change of the orbits and to an orientation of the atoms in the direction of the field.

20. Electrolysis through glass as a sodium voltameter. R. C. BURT, California Institute of Technology.—An electric light bulb is immersed (with filament lighted) in molten sodium nitrate, and sodium is driven electrolytically through the glass wall. From the weight of sodium thus deposited and the time integral of the current, Faraday's laws are checked, it is believed, to 0.2 per cent. Further experiments are in progress to verify this more precisely. This makes available another form of voltameter.

21. The theory of the radiometer. H. E. MARSH, E. CONDON and L. B. LOEB University of California.—In a recent number of the Zeits. f. Phys. (**27**, 1, 1924) there appeared an article by A. Einstein in which the radiometric pressure observed on vane radiometers where the pressure is such that the mean free path is less than the dimensions of the vane, is ascribed to a region of the vane along its edges of width of the order of a mean free path at that pressure. If this theory is correct it should be expected that the determining factor in the operation of such radiometers depends on the length of the

edge of the vane rather than the total area of the vane as hitherto supposed. This was tested experimentally by constructing two types of vanes whose areas and area moments were equal on two sides of a vertical axis but in which the edge moments on one side were four times as great as they were on the other. On placing such vanes in a uniform beam of light it was found that the side of the vane having the greater edge moment was universally more strongly acted upon than the other side. The effect however was not nearly as great as theoretically anticipated from the ratio of the edge moments. The deviation was ascribed to the greater cooling produced on the vane having the larger edge moment. On a thicker vane where this effect was assumed to be minimized results more nearly in quantitative accord with the theory were observed.

22. Adaptation of the phonelescope as a precision pitch indicator, and an application as a detector of pitch variation in vocal tones. L. E. DODD, University of California, Southern Branch.—By permitting the vibrating beam from the phonelescope to fall upon a suitable stroboscopic screen in motion, an immediate direct indication of the frequency of the beam and of the constancy of this frequency, is obtained. The test is an objective one, since the detection of pitch, particularly of pitch variation, is not dependent upon the ear, but upon the eye, so that change in loudness or in quality of the tone cannot possibly be interpreted as a pitch wandering, or conversely, a pitch wandering cannot possibly be interpreted as a variation of intensity or of timbre. The particular practical application was to test the effect upon pitch, of external local pressure gradually applied to the throat at different designated points during the sounding of a vocal tone by the subject. Under such circumstances variations in pitch, either upward or downward depending upon the place where the pressure was applied, and often great enough to be detected easily by ear, were obtained. Such data are of value in a physiological study of the action of the muscles controlling the vocal cords. In the cases of more pronounced pitch change, the method always served as an objective confirmation of the evidence by ear, and in all cases it constituted the sufficient test of a pitch change.

23. The interfering effect of tones and noise upon the quality of speech in an auditorium. V. O. KNUDSEN, University of California, Southern Branch.—Speech-articulation tests are being conducted to determine the effect of noise upon the quality of speech in an auditorium. The tests are conducted in a quiet room, having a volume of 15000 ft³ and a time of reverberation of 1.3 seconds. Tests with pure tones as the interfering disturbance, indicate that tones of low and medium pitch, below 2000 d.v., produce a greater interference than tones of high pitch. Thus, tones of 256 d.v. and 4096 d.v., each having an energy equal to 10⁶ times the energy for its minimal audible tone, reduced the word, vowel, and consonant articulations to 45, 81, and 69 percent and 80, 98, and 89 percent, respectively. This is consistent with the data of Fletcher, Wegel and Lane on the auditory masking of one tone upon another. Low tones disturb both vowels and consonants, whereas high tones disturb only the consonants. Tests on typical hard of hearing individuals who claim that in the presence of a noise they hear better, indicate that they actually hear not as well.

24. A recording acoustic marine depth-sounder. LEO P. DELSASSO, University of California, Southern Branch (introduced by J. M. Adams).—Preliminary tests were conducted aboard a U. S. battleship during a full-power run, to investigate the disturbing effect of incidental noises and to compare the waves direct from the source with those reflected from the bottom, as to intensity and form. The oscillograms obtained indicate a wide variation of the echo in both respects over various bottoms. The results of these tests made it possible to complete a mechanism which by a selective multistage amplifier records the time of transit of a sound wave from the source to the bottom and back,

on a paper chart. Tests with this recorder aboard the U. S. S. Maryland indicate that, with few modifications, it should be possible to record automatically on the bridge of a ship all depths that will contribute to her navigation.

25. New evidence for a sharply bounded and very rigid core in the earth. JAMES B. MACELWANE, University of California.—The existence of a clearly defined shadow zone on the surface of the earth and therefore of a sharply bounded, refracting core within, as maintained by Wiechert and Gutenberg and denied very generally outside of Germany, is proved conclusively by the seismographic records of the South Pacific earthquake, June 26, 1924. The energy of the direct longitudinal group of waves is very great at all stations up to arcual distances approaching 103° , but beyond this point becomes almost zero. At 142° a second longitudinal group which appears in this shadow zone begins to increase slightly in amplitude and at 144° becomes very large indeed. The rigidity of the deep interior has been denied by Knott and others on the basis of absence of shear waves. Transverse waves transmitted by the core seem to be present on the records of this earthquake at many stations from an arcual distance of 132° onward. Their speed is such as to make Poisson's ratio in the core approximately $\sigma = \frac{1}{4}$. In that case the core is very rigid and the density increases suddenly at the boundary.

26. The relative importance of wind, humidity, and solar radiation in determining evaporation from lakes. N. W. CUMMINGS, California Institute of Technology.—Hourly determinations were made of evaporation and temperature of the water contained in a Dewar jar 15 cm in diameter and approximately 25 cm deep. Simultaneous determinations of radiation from sun and sky were made with a copper disk pyranometer. The jar was packed in sawdust and it had previously been found that the rate of leakage of heat through the walls for one degree difference in temperature was extremely small. The radiant energy per square centimeter integrated over any time interval was equal to the heat represented by the change in temperature of the water plus the heat represented by the evaporation per square centimeter during the same time interval, plus a relatively small correction to be determined empirically. This correction appears to depend on atmospheric conditions.

27. Dynamical Einstein space-times which contain a conformal-euclidean three-space. H. P. ROBERTSON, California Institute of Technology.—The manifolds here examined are those having a line element of the form $ds^2 = f(dx^2 + dy^2 + dz^2) - gdt^2$ where f and g are functions of x, y, z , and t . The problem of the integration of the cosmological equations for such fields is found to involve the integration of sets of first order equations which are linear and homogeneous in the derivatives. One of these sets is not completely integrable, but particular integrals are found. The space coordinates being isotropic the fundamental velocity is the same in all directions from each point. The interpretation of the solutions is as yet incomplete, but among those that have been interpreted are found theorems like the following: If "stationary" observers in such a manifold find that their proper-time does not depend on their position in space, then space-time is itself conformal-euclidean, i. e. a hypersphere.

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