

An Examination
of Certain Body Fluids
by means of their Ultra-
Violet Emission Spectra

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Introduction

The application of spectroscopic methods to the analysis of various chemical and biological substances, although of comparatively recent date, has met with considerable success. In the field of inorganic chemistry, emission spectra have been used, while the absorption spectrophotometer has been of great service in organic chemistry and biology. This difference, aside from certain practical difficulties, is no doubt due to the fact that inorganic chemical analysis is concerned chiefly with elements, and hence with their atoms which produce characteristic emission spectra by means of which they may be identified. In the biological field, however, the analyst is dealing with aggregates of atoms, that is complex molecules, which give rise to distinctive band spectra, and these may in general be more readily studied by absorption methods.

However, it has been found that minute quantities of metallic elements in organic substances such as plant or animal tissues may have effects out of all proportion to their relative amounts. Since metallic elements are readily detected by their emission spectra it follows that analysis of biological materials by emission spectra might have interesting and valuable results.

Statement of the Problem

An analysis of certain body fluids by means of their ultra-violet emission spectra.

Sample Materials

The body fluids studied were blood serums and urine and were supplied by the Manitoba Medical College. The blood serum itself was used and also the residue obtained by evaporating the serum to dryness. The urine was analysed as a solid residue only.

General Method

Complex spectra consisting of lines due to the elements in the residue and the copper electrodes were obtained and by comparison with the spectrum of pure copper the residue lines were identified. Using wavelength tables the elements corresponding to these lines were then determined.

Both the visible and ultra-violet spectra were studied. The investigation in the visible region was carried out by Mr. Herman Johnson, B.Sc.(Hons.), and that in the ultra-violet by the writer.

C O N T E N T S

Part I - Development, Theory and Classification of Spectra.

- Historical
- Extension of the Spectrum
- Wavelength Standards
- Classification of Spectra
- Series in Line Spectra
- Origin of Spectra

Part II - Spectroscopic Analysis

- Qualitative Analysis
- Quantitative Analysis
- Applications of Spectroscopic Analysis

Part III - Method and Apparatus

- General Procedure
- The Spectrograph
- Electrical Apparatus
- Electrical Circuit
- Auxiliary Apparatus

Part IV - Data and Results

- Calibration Curve
- Analysis of Urinal Residue
- Analysis of Blood Serum

Conclusion

Appendix I - Persistent, Ultimate and Sensitive Lines.

Appendix II - Chemical Analysis of Urine

Part I

Development, Theory and Classification of Spectra

Historical

Newton in 1666 observed that a beam of white light when passed through a prism was separated into a band of colors which he called the spectrum. Further, he showed that Snell's Law of Refraction held only if the rays considered were of the same color, since the deviation varied, so that the red was the least and the blue most refracted. This discovery of the composite nature of white light marked the origin of spectroscopy.

Newton found that better spectra were produced if a lens were used between a slit aperture and the prism, but apparently did not notice the presence of dark lines in the solar spectrum. This discovery was made later by Wollaston, who, however, did not pursue the investigation.

Fraunhofer after a thorough study and with improved methods of obtaining the spectrum, was able to show that these dark lines were fixed in position and indicated that the light from the sun was not homogeneous but was deficient in certain rays.

Sir William Herschel (1822) observed, that when metallic salts were fed into a flame, and the flame examined through a prism, the light was resolved into single rays, and thus bright lines were visible on a dark ground, that is, discontinuous spectra were produced. Fraunhofer noticed that the yellow line from the flame of common salt corresponded with one of the dark lines of the solar spectrum, and that the "line" in both cases consisted of a close pair of lines of equal intensity.

Foucault in 1848 observed the phenomenon of absorption lines by passing light from an arc through a sodium flame. Kirchhoff investigated and explained this phenomenon and in 1859 published his famous law which states, "that the relation between the powers of emission and powers of absorption for rays of the same wavelength is constant for all bodies at the same temperature". On the basis of this law and the absorption effect Kirchhoff suggested that there was a layer of vapors of different substances around the sun which absorbed their own characteristic radiations from the sun's light, the process being known as "reversal". The reversed or Fraunhofer lines therefore furnish evidence as to the elements present in the solar atmosphere.

Bunsen and Kirchhoff continued this work and mapped out the spectra of many substances, some of which were identified in the solar spectrum.

The solar spectrum soon became the standard for spectroscopic work and A. J. Ångström measured the wavelengths of a very large number of the lines and made a map of the spectrum in which each line was placed according to its wavelength. The measurements covered all the visible region and were expressed in ten millionths of a millimetre. This unit, now called the Angstrom, has since been used as the standard for all wavelength determinations.

The publication in 1868 of this map, the Normal Solar Spectrum, placed the science of spectroscopy on an accurate basis as it provided a general reference table coordinating all data and enabling the wavelengths of unknown lines to be determined by a simple interpolation process.

Extension of the Spectrum

The term "spectrum" was originally applied only to the band of light of various colors obtained when white light was passed through a prism. It was soon found, however, that the spectrum extended beyond the visible in both directions. The chemical action of rays below the violet on silver chloride was discovered by Scheele and Stokes extended this ultra-violet region to 1900 A.U. Schumann using fluorite prisms and lenses in rarefied hydrogen to eliminate absorption went down to 1000 A.U., and Lyman and Millikan with modifications of the Schumann vacuum

spectrograph reached 600 A.U. and 144 A.U. respectively.

The infra-red region discovered by Sir William Herschel in 1801 was further investigated by methods involving the use of bolometers, thermopiles and radiometers as detecting devices. Langley traced the rays to 182,000 A.U., and Rubens to 610,000 A.U. In the infra-red as in the ultra-violet and visible regions, gratings replaced the prisms where great dispersion was desired.

Thus the term "spectrum" is now used in an extended sense to cover the whole range of rays, not only visible, but also ultra-violet and infra-red rays, wireless waves, X rays and gamma rays, the range being from 0.001 A.U. to 10,000 kilometres in wavelength.

Units and Methods of Measurement

Spectral measurements are usually made in terms of wavelength or frequency and the wavelength is expressed in meters or some submultiple thereof, depending on the region of the spectrum. The various units in common use are as follows:

the micron,	symbol μ = 10^{-4} cm. (10^{-6} meters)
the millimicron,	symbol $m\mu$ = 10^{-7} cm.
the Angstrom,	symbol A.U. = 10^{-8} cm.
the X unit,	symbol $x.u.$ = 10^{-11} cm.

Michelson introduced the use of the interferometer for wavelength measurements and in 1895 measured the length of the standard metre in terms of the wavelength of the red cadmium line. This wavelength 6438.4696 A.U., has been accepted as the primary standard and subsequently secondary and tertiary standards have been adopted so that measurements of wavelengths in the visible and near visible part of the spectrum are now possible with an absolute accuracy (in terms of the cm.) of considerably better than one part in a million.

The frequency ν of radiation in vibrations per second is theoretically more fundamental than wavelength and the frequency may be computed from the wavelength by the relation:

$$c = \nu \cdot \lambda$$

where c = velocity of light

Since the frequency involves very large numbers, it is sometimes more convenient to use the number n of waves per centimetre, which is proportional to the frequency and is the reciprocal of the wavelength.

Classification of Spectra

Spectra may be classified according to the method of production as emission and absorption spectra or according to appearance as continuous, band, and line.

Continuous Spectra: Are those containing the whole range of wavelengths between certain limits, depending on various controlling influences. Such spectra are usually given by solid substances, the limits of continuous emission depending on the temperature.

Band Spectra: Appear under low dispersion as diffuse bands, but under high power these may be resolved into groups of lines, each group having a "head", that is, the lines of each group are so ordered that in one direction either towards the shorter or longer wavelengths, they set closer and closer together until they form a sharp edge or head. A number of these heads with their attendant lines form a group of bands, and several related groups form a system. More than one such system may be present in a single spectrum.

These band spectra are due to changes in molecular energy which has in general three components:

- (1) Rotational energy of the molecule due to the rotation of the molecule as a whole about some axis of symmetry.

- (2) Vibrational energy due to the relative vibratory motion of the constituent atoms with respect to each other.
- (3) Energy of the electronic system associated with the molecule.

Corresponding to these are three types of band spectra:

- (1) Pure Rotation spectra -- in the extreme infra-red.
- (2) Rotation-vibration spectra -- in the near infra-red.
- (3) Electronic spectra -- in the ultra-violet or visible.

Line Spectra: Are those consisting of more or less sharply defined lines which are generally distributed without any apparent regularity, although characteristic groupings are often visible, but never any repeating structures such as distinguish the band spectra.

Emission Spectra: Are produced by the excitation of atoms or molecules so that they emit their characteristic radiations.

Absorption Spectra: Are a result of the selective absorption by a substance of particular rays of the radiation passed through it.

Sources of Emission Spectra

As the spectra considered in this investigation were of the emission line type, some more detailed attention may well be paid to this kind of spectrum.

Emission spectra are divided into groups according to the source of the radiation as follows:

Flame and Arc Spectra: Are similar in that the arc acts very much as a hot flame and it has been found that with an oxy-acetylene flame practically the complete arc spectrum may be produced.

The High Temperature Furnace: As exciting agent provides spectra which approximate to the arc in the number of lines and these spectra are usually considered with the flame and arc types.

The Electric Spark: Provides a very strong excitation and many intense lines are found which belong to series not prominently represented in the arc spectrum. Those which appear faintly in the arc in addition to the true arc lines being the so-called "enhanced lines", that is, lines whose intensity is enhanced in the spark.

Fluorescence and Phosphorescence Spectra: Are due to the luminescence of liquids or solids, not vapors, as are the other types.

Vacuum Tube: The spectra of gases are obtained by submitting them under reduced pressure to the action of a discharge between metallic electrodes, the spectra being practically devoid of lines due to the electrode materials.

Structure of Spectra

Plurality of Spectra

In general, with a given element a number of different spectra may present themselves according to the circumstances.

- First, - There is the spectrum due to the molecules, which will be a band spectrum.
- Second, - The spectrum of the free or neutral atoms; which will be a line spectrum of the type characteristic of the relevant chemical family. This spectrum will be of the flame, arc, or other type depending on the conditions of production as mentioned above.
- Third, - The enhanced spectra of the ionized atoms which will be of the spark type.
- Fourth, - Absorption or reversed lines.

Structure of Spectral Lines

If a "line" is examined by means of an instrument of high resolving power, such as an interferometer, it is usually found that each line is composed of a number of radiations differing very slightly in wavelength from one another. This phenomenon is the "fine line" structure referred to subsequently.

It may be noted that the lines from gases in vacuum tubes are nearly always narrow and sharply defined, although variations in gas pressure will change their character considerably.

In arc and spark spectra distinction may be drawn between four types of lines:

- (1) lines which are sharply defined on both sides.
- (2) lines which are sharp only on the long wavelength side.
- (3) lines which are sharp only on the short wavelength side.
- (4) lines which are diffuse on both sides.

That this distinction is of importance was soon realized when it was found that lines belonging to the same series are always of the same type.

Length of Spectrum Lines

It was discovered by Lockyer¹ that if the image of an arc or spark be thrown on the spectroscope slit that each part of the line, or lines obtained, corresponded to a different region of the source. In this way the long lines correspond to the whole source from pole to pole and the short lines correspond to a short distance in the neighborhood of the poles. Lockyer showed that there is no necessary connection between length and intensity but that with metallic salts the longest lines appear easiest and are the most persistent when the concentration of the element is decreased. This is in accord with the well known fact that the potential gradient between the poles of an arc is greatest at the anode, a minimum in the central region and larger again at the cathode. The long lines are produced throughout the region, while the short lines require the greater potential difference near the poles for excitation.

1
Lockyer Phil.Trans. 163; 253, 269. (1873)
164; 479, 805. (1874)

Width of Spectral Lines

The width of the lines has been found to depend upon several factors. Michelson¹ has shown that the width varies with the pressure but the lines do not become infinitely narrow when the pressure falls to zero.

Besides the broadening effect due to pressure, there is also the temperature, or Doppler effect, and in an approximate way the width varies inversely as the molecular weight and directly as the temperature. A more theoretical consideration of the temperature effect will be given subsequently.

Reversal of Lines

If a beam of light from an incandescent body be passed through the vapor of a substance, the absorption or reversed lines are seen upon a continuous spectrum as background.

This phenomenon may also occur in the arc, for example, when the centre of a glowing mass of vapor is at a greater density than the outer layers. In this case the central portions emit a broadened line due to the increased density, while the outer layers absorb some of these rays and they form a very fine absorption line. So the effect produced is a very fine black line in the centre of a broader bright line.

¹ Michelson Phil. Mag. 34; 280 (1892)
Astrophys. Journ. 3; 251 (1896)

Effect of External Physical Conditions on Spectral Lines

Temperature Effect

The application of the Doppler Principle to atomic motion leads to the conclusion that the observed frequency of a spectral line may be increased if the motion of the atom is towards the observer, and decreased if the motion is directed away from the observer.

It is interesting to note that the measurement of the radial velocity of stars is based on an analogous application of this principle.¹

Now since it is known that the atoms of a luminous gas are moving with a Maxwellian distribution of velocity, increasing with temperature, it is evident that a spectral line emitted by a gas comprises a range of frequencies symmetrically distributed about the true frequency of vibration for the atom at rest. The breadth of the line will depend on the temperature, the distribution of intensity throughout the width of the line being determined by Maxwell's Law.

Michelson² and Fabry and Buisson³, using interferometer methods have confirmed these conclusions.

¹ J. S. Plaskett Pub. Dominion Astrophys. Obs. II, 1, p7, (1921)

² Michelson loc.cit.

³ Fabry and Buisson Journ. Phys. 2; 442 (1912).

Pressure Effect

Interference fringes can be produced when the difference in the path of two light beams is as much as several hundred thousand wavelengths and it is inferred that the wave train sent out by a particular atom is continuous (that is, without change of phase) for at least that number of vibrations.

Hence the mean free time between collisions with other atoms must on the average exceed the time required to emit a complete wave train, since it is assumed that a collision would cause either a change of phase or excessive damping.

Now atomic collisions are proportional to the pressure for a given temperature. The higher the pressure then, the shorter should be the wave train and more frequent the abrupt changes of phase. At higher gas pressures there should be therefore a broadening of the spectral line due to the increasing frequency of phase change resulting from collisions. This will be in addition to the increase in width due to the Doppler effect.

This effect due to variation in pressure has also been confirmed by Michelson.

Stark Effect -- Due to Electric Field

Stark¹ discovered that if a stream of "canal" or positive rays be allowed to pass between a plate cathode and another plate terminal, and a field of 20,000 volts or higher be applied between them, then the lines of the spectrum of the rays viewed transversely will be split up into numerous components, some polarised parallel to the field and others perpendicular to it. Nicholson and Merton² have shown that the Stark Effect may operate to an appreciable extent in an ordinary vacuum-tube discharge causing a broadening of the lines.

Zeeman Effect -- Due to Magnetic Field

In 1896 Zeeman³ discovered that spectral lines are split into components when the source emitting them is placed in a very strong magnetic field; and further, that these components are polarised.

In the so-called Normal Effect, if the line be viewed at right angles to the magnetic field, the line is seen to be triple with the lines of longer and shorter wavelength plane polarised parallel to the magnetic field, and the line of the same wavelength as the original polarised in a plane at right angles to the magnetic field.

¹ Stark (1913) Die Atomionen chemischer Elemente und ihre Kanalstrahlenspectra.

² J. W. Nicholson and T. R. Merton Phil. Trans. A.
Vol. 216. P. 459 (1916)

³ Zeeman Phil. Mag. Vol. 43, P. 226 (1897)

If the line be viewed in a direction parallel to the magnetic field only two components, lines of longer and shorter wavelengths, circularly polarised in opposite directions are observed.

In the Abnormal Zeeman Effect, the number of components may be four or more and the shift of any component is proportional to H , the magnetic intensity. The "pattern" is symmetrical as to number, distribution, and intensity of lines about the position of the line in zero field. Two groups of components are recognized, the " π " components plane polarised parallel to H , and the " σ " components polarised at right-angles to H .

Series in Line Spectra

Spectral Series Formulae

The extensive accumulation of accurate wavelength measurements soon led to the search for possible relations between and within the spectra and for formulae to express these relations in terms of line frequencies or wavelengths.

The first successful effort was that of Hartley who in 1883 was able to enunciate a law giving a relationship between the components of doublets or triplets in the spectrum of a given element. This helped to simplify the task of sorting out the lines of a spectrum into groups.

In 1885 Balmer discovered that the nine lines of the hydrogen spectrum could be related by the formula:

$$\lambda = h \frac{m^2}{m^2 - 4} \dots\dots\dots(1)$$

where h = a constant, the numerical value of which to give λ in Angstroms is 3645.6

and m = a variable integer which takes the successive values 3, 4, 5,.....for respectively the 1st, 2nd, 3rd,.....line in the spectrum beginning in the red.

In terms of wave number this formula may be written as:

$$m = \frac{N_H}{a^2} - \frac{N_H}{m^2} \dots\dots\dots(1a)$$

where $N_H = \frac{a^2}{h}$ = Rydberg constant for hydrogen,

and $a = 2$

Balmer was also able to correctly predict from the formula that no lines longer than H_γ (6562.10) would be found and that the series would converge at $\lambda = 3645.6\text{\AA}$ since the fraction approaches unity as m increases.

Balmer's formula supplied the basis and inspiration for subsequent work on series relations and the problem was taken up by many investigators, chief of whom

were Kayser, Runge, and Rydberg.

Balmer had suggested that his equation might be a special case of a more general formula and Rydberg found by an examination of the data for the sharp and diffuse series of sodium that a satisfactory expression for the frequency of a spectral line was given by:

$$\nu_m = \nu_\infty - \frac{N_\infty}{(m + \mu)^2} \dots\dots\dots (2)$$

where ν = frequency of line in wave numbers

m = ordinal number

N_∞ = a universal constant for all series of the same type and all substances.

ν_∞ & μ = constants characteristic of each substance.

ν_∞ = convergence frequency. (i.e., when $m = \infty$)

As expected Balmer's formula was found to be a special case of this equation and from the Balmer form the value for N was determined, namely;

$$N_\infty = 109,720 \text{ cm.}^{-1}.$$

This is known as the Rydberg (wave number) constant.

Series Notation

Four types of series are recognized and may be represented by the following formulae of the Rydberg type, using the notation given by Fowler¹; this form being

¹ Fowler -- Report on Spectral Series

of fairly general acceptance and very convenient to use, although other systems have been devised.

$$P(m) = P_{\infty} - \frac{N_{\infty}}{(m + P)^2} \quad \begin{array}{l} \text{Principal Series} \\ m = 1, 2, 3, \dots \end{array}$$

$$S(m) = S_{\infty} - \frac{N_{\infty}}{(m + S)^2} \quad \begin{array}{l} \text{Sharp Series} \\ m = 2, 3, 4, \dots \end{array}$$

$$D(m) = D_{\infty} - \frac{N_{\infty}}{(m + D)^2} \quad \begin{array}{l} \text{Diffuse Series} \\ m = 2, 3, 4, \dots \end{array}$$

$$F(m) = F_{\infty} - \frac{N_{\infty}}{(m + F)^2} \quad \begin{array}{l} \text{Fundamental Series} \\ m = 3, 4, 5, \dots \end{array}$$

In these formulae the $P(m)$, P_{∞} , and P , of the Principal Series, for example, stand for the n_m , n_{∞} and respectively of Rydberg's general formula.

Each of these series may consist of singlets, doublets or triplets.

For the singlet series, the letters P , S , D , & F , are used.

For the doublet series, the letters π , σ , δ , & ϕ are used with subscripts 1 and 2.

For the triplet series, the letters p , s , d , & f , are used with subscripts 1, 2, & 3.

For example:

$$P_1(m) = P_{1\infty} - \frac{N}{(m + p_1)^2}$$

represents the series made up of the first and strongest component of the principal series of triplets.

The whole H term may also be abbreviated

For example:
$$m\delta_2 = \frac{H_\infty}{(m + \delta_2)^2}$$

hence the series may be written

$$p_1(m) = p_1^0 - mp_1$$

or

$$\delta_2(m) = \delta_2 - m\delta_2$$

Particular lines may be written in the form $p_1(2)$, for example, which represents the strongest line (subscript 1) in the triplet (lower case letter), the value of which is obtained by putting $m = 2$ the equation for the principal (p) series.

On the other hand, $1p_1$ is the value of the term $\frac{H_\infty}{(m + p_1)^2}$, which is obtained by putting $m = 1$.

The two quantities on the right hand side of the equation for a series are referred to as the "terms" of the spectral series formulae. It will be noticed that each series is given by the difference of two kinds of terms.

Series Relations in Line Spectra

Various relations within and between the series have been discovered and although the work has been largely empirical, it aided in sorting the lines and series and bringing some order from the apparently unsystematic arrangement of the lines, which was due to overlapping of the series.

Relations between doublet series, between triplet series, and interrelations between the principal, sharp, diffuse and fundamental series have all been discovered, and typical of these relations is the "Rydberg-Schuster Law" which states that the wave number of the first line in the principal series is equal to the difference between the convergence wave number of that series and the common convergence wave number of the S and D series.

Doublets and triplets in the diffuse series are in many instances accompanied by faint companion lines called "Satellites", which cause the lines to appear diffuse under low dispersion.

Ritz discovered that other combinations of terms than those giving the four chief series might correspond to spectral lines observed to be present in spectra but not belonging to the series. Such are called "Combination Lines or Series".

The Significance of Spectral Series Terms

The phenomenon of combination lines serves to emphasize the importance of the terms in the series formulae and more particularly of the fact that the wave number of a line is given by the difference between two terms.

Applying Planck's quantum theory to the equation for a spectral line gives an interesting result. For example:

$$\pi_2(3) = \pi_{2\infty} - \frac{N_{\infty}}{(3 + \pi_2)^2} \dots\dots\dots(3)$$

Multiply by ch :

$$ch.\pi_2(3) = ch.\pi_{2\infty} - ch. \frac{N_{\infty}}{(3 + \pi_2)^2} \dots\dots\dots(4)$$

$$\text{But} \quad h.n.c. = hv \quad \dots\dots\dots(5)$$

where h = Planck's constant

and by his theory hv = a quantum of energy

and v = frequency = $n.c.$

where c = velocity of light

and n = wave number

Now comparing (4) and (5) it is evident that the quantity on the left side of equation (4) becomes a quantum of energy corresponding to the frequency of the emitted line, and the two terms on the right hand side must be quantities of energy, such that their difference gives the energy represented by this line.

To generalize then, all the formulae for spectral lines may be written as

$$h\nu = W_1 - W_2 \dots\dots\dots(6)$$

This equation (6) is a generalization from the empirical data on line spectra extended by the aid of Planck's quantum hypothesis.

The quantum of energy $h\nu$ corresponding to a spectral line of frequency ν is equal to the difference between two energy terms W_1 and W_2 the numerical values of which are computable from the terms in the spectral series equations by multiplying these terms by $c.h.$

On the basis of the Law of Conservation of Energy we might consider W_1 as being the quantity of energy possessed by an atom at a certain stage, and that this amount might be decreased to a lower value W_2 by some event, with the result that an amount of energy $h\nu$, equal to the difference $(W_1 - W_2)$ is emitted.

Enhanced or Spark Spectra Series

The series considered in the foregoing discussion of series relations consist of lines in the arc or flame spectra.

Similar series and relationships have been discovered in the spark lines, and the same types of formulae apply with the change that the Rydberg constant R_∞ is replaced by a constant which is very nearly equal to $4R_\infty$.

The Origin of Spectral Lines

It was early realized that the production of spectra was associated with changes within the atom or molecule and hence the attempt to find a satisfactory theory of the origin of spectral lines became identified with the problem of atomic and molecular structure.

Thomson Atom Model

The first significant attempt at a solution of the problem was the atom model of J. J. Thomson, which however failed when applied to the phenomenon of γ ray scattering.

Rutherford Atom Model

Rutherford¹ (1911) proposed a new type of atom in which the positive charge, instead of being uniformly distributed throughout a sphere of atomic dimensions as in Thomson's atom, is concentrated in a very small region less than 10^{-12} cm. in diameter, at the centre of the sphere, with the electrons surrounding this nucleus in some sort of configuration.

Now the Rutherford atom while it satisfied the demands of the γ ray scattering effect did not possess the stability which was characteristic of the Thomson model.

¹ Rutherford Phil. Mag. Vol. 21, P669. (1911)

Equilibrium could not be secured if the electrons were at rest under the operation of electrostatic forces alone. If the electrons were assumed to move in orbits around the nucleus, mechanical equilibrium could be attained, but in accordance with the laws of the electromagnetic theory, the revolving electron being subject to constant acceleration would continuously radiate energy, and would approach the nucleus on a spiral path as its energy decreased, giving out a radiation of constantly increasing frequency.

Bohr Atom Model

The theory of Nils Bohr expounded at this juncture is essentially an extension of Planck's theory of quanta, applied to the Rutherford nuclear atom in an attempt to explain the origin of the characteristic spectra of the elements.

Now Planck's Quantum Hypothesis states that if a particle vibrates with simple harmonic (linear) motion about a centre with a frequency ν , then the oscillator can have energy only in multiples of $h\nu$:

that is

$$W = T h \nu$$

where

W = energy of the system

T = an integer

h = Planck's constant ($= 6.55 \times 10^{-27}$ erg.sec.)

ν = frequency of vibration

In other words, under the restrictions of Planck's quantum condition, the angular momentum of an electron moving in a circular orbit around a massive positively charged nucleus may take on only those values which are integer multiples (τ) of $h/2\pi$.

This quantum restriction on the angular momentum is incorporated in Bohr's First Postulate which states that "the values of the angular momentum, and therefore of the radii of the orbits are restricted to certain discrete values and that therefore only a limited number of orbits are possible; further that these orbits are stable orbits and that the motion of the electron in them is governed by the ordinary laws of mechanics and electrostatics, but is not subject to the requirements of the electromagnetic theory". (that is, while moving in these orbits the electron does not radiate.)

Now, it may be shown that the radii 'a' of the orbits are given by:

$$a = \tau^2 \frac{h^2}{4\pi^2 m e^2} \dots\dots\dots (7)$$

where τ = an integer 1, 2, 3,

m = mass of electron

e = neg. charge of electron

E = + charge on nucleus

h = Planck's constant

That is, the radii 'a' of the successive privileged orbits are proportional to the squares of the integers 1, 2, 3, .. These integers are called the Quantum Numbers of the respective orbits.

Corresponding to each of these orbits the system has a definite amount of energy W which is readily evaluated for W will be the sum of the kinetic and potential energies; (obtained by applying the inverse Square Law to a nucleus of charge +E and Mass M with an electron, charge -e, mass m, in a circular orbit of radius 'a').

$$W = \frac{Ee}{2a} - \frac{Ee}{a} = -\frac{Ee}{2a} \dots\dots\dots(3)$$

and substituting the value for 'a' from equation (7)

$$W_{\gamma} = -\frac{2\pi^2 m E^2 e^2}{\gamma^2 h^2} \dots\dots\dots(9)$$

Thus the larger the value of γ , the smaller numerically but the larger in absolute value is the energy of the system. Hence the lowest value of W_{γ} is that corresponding to the first orbit, and therefore this orbit should be the most stable, and is the one which the electron normally occupies in the atom.

The question of stability and definiteness in the atom is thus solved by applying the quantum condition to the orbits of the electrons in the atom, and by assuming that the electron does not radiate while revolving in these orbits.

Now, since an atom is known to radiate energy, the conclusion is reached that energy of an amount W_R is emitted when an electron changes its orbit in some way from an outer to an inner one, that is, "drops" from an orbit of high energy to one of lower energy. That is,

$$W_R = W_{\gamma_2} - W_{\gamma_1} \dots\dots\dots(10)$$

where W_{γ_2} = energy of the outer orbit of quantum number γ_2

and W_{γ_1} = energy of the inner orbit of quantum number γ_1

Now the resemblance between this equation (10) and the equation (6) derived by introducing Planck's quantum hypothesis into empirical data on spectral series viz, $h\nu = W_1 - W_2 \dots\dots\dots(6)$

lead Bohr to enunciate his Second Postulate "that when an electron drops from an outer to an inner orbit, an amount of energy W_R equal to the difference ($W_{\gamma_2} - W_{\gamma_1}$)

between the energy in the respective orbits is radiated as a quantum of energy of frequency ν given by the equation

$$h\nu = W_{\gamma_2} - W_{\gamma_1} \dots\dots\dots(11)$$

It is evident that the "terms" of the empirical spectral series equation may now be regarded as the amounts of energy possessed by the atom in its various

"stationary states"; this expression referring to the condition or state of the atom when its electrons are revolving in their several privileged orbits.

By substituting in equation (11), the values of τ given by equation (9), the formula for the frequency ν of a spectral line is obtained:

$$\nu = \frac{2\pi^2 m e^2}{h^3} \left\{ \frac{1}{\tau_1^2} - \frac{1}{\tau_2^2} \right\} \dots\dots\dots (12)$$

$$\text{or } n = \frac{2\pi^2 m e^2}{ch^3} \left\{ \frac{1}{\tau_1^2} - \frac{1}{\tau_2^2} \right\} \dots\dots\dots (12a)$$

where n = wave number

Bohr Theory Applied to the Hydrogen Atom

It was at once realized that this formula (12a) would be identical with the Balmer equation (1a) for the hydrogen atom (where $E = e$), if

$$\tau_1 = a = 2$$

$$\tau_2 = m = 3, 4, 5, \dots\dots$$

$$\text{and } M_H = \frac{2\pi^2 m e^4}{ch^3}$$

On evaluating M_H , the Rydberg constant for hydrogen, by using the appropriate values for m, e, c , and h , the result (109,300) is found to be with $1\frac{1}{2}\%$ of Balmer's value (109,679).

It was also found that the Bohr formula for the radii of the orbits, gave as the value for the diameter

of the smallest orbit, 10^{-8} cm. which is exactly the order of magnitude of the diameter of atoms, computed from the kinetic theory of gases.

Further, the Bohr theory furnished a picture of the atom and of the process whereby the spectral series originate, and how they differ, while the Bohr formula gives the frequencies of the lines of the series with amazing accuracy.

Thus in the diagram (1) the Lyman series is seen to correspond to electrons going from the 2nd, 3rd, 4th....orbits to the first orbit. Theoretically an infinite

number of series are possible, but practical limitations due to convergence and increasing wavelength, prevent the recognition of more than a few lines and series.

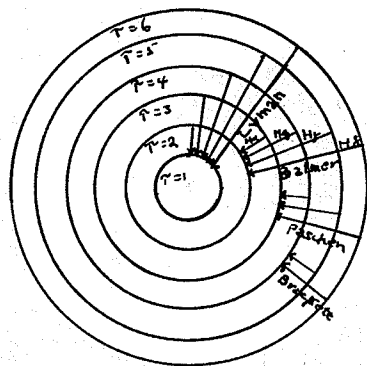


Fig. 1

Variation of Rydberg Constant with Atomic Number

Bohr's theory was found to predict the existence of such phenomena as the Combination series and the various relations between and within series, and the Bohr formula gave quantitative results in excellent accord with experimental and empirical data.

When the theory was applied to the helium atom which has lost one electron, a slight discrepancy in the value of the Rydberg constant for helium as compared to hydrogen was noticed.

A new general equation (13) of a spectral series in the nuclear type of atom was derived in which the mass of the nucleus was not, as previously, considered infinite with respect to the mass of the electron.

$$n = Z^2 \frac{2\pi^2 me^4}{ch^3} \cdot \frac{M_Z}{M_Z + m} \left(\frac{1}{r_1^2} - \frac{1}{r_2^2} \right) \dots\dots\dots (13)$$

where Z = atomic number of the element

(and $Ze = E$ of equation (12))

M_Z = mass of nucleus of element of atomic number Z

The Rydberg constant is thus seen to depend on the atomic number of the element, and for the heavy elements the values approach the calculated value R_0 , which is the Rydberg constant for atoms with nuclear mass practically infinite compared to the mass of an electron.

From the ratio of the Rydberg constant for helium and hydrogen, the ratio m/M_H is found to be $1/1846$ which value is practically identical with that determined by other methods.

Elliptical Orbits and the Fine Structure of Spectral Lines

In the discussion of the Bohr theory so far, the orbits have been considered as circular, but the theory has been extended by Sommerfeld¹ to the more general case of the electron moving in an ellipse with the nucleus at one focus.

The position of the electron at any time may be given in terms of the polar coordinates r and ϕ , and corresponding to these there will be a radial momentum and an angular momentum. Applying the quantum condition gives the respective quantum numbers τ_r and τ_ϕ . These may have any integer values but their sum must always be τ - the total quantum number, and hence the extension to elliptical orbits will introduce no new frequencies.

Now on the assumption that the electron does not radiate while revolving in the orbit, and that the mass of the electron remains constant, it may be shown that for a given quantum number all orbits will have the same energy.

But when the variation of the mass of the electron with its continually varying velocity is considered, the formula for the energy of the system has an added term which involves the ratio of the total quantum number $(\tau_\phi + \tau_r)$ to τ_ϕ .

This means that an ellipse of given total quantum number τ represents an orbit of lower energy level

¹ Sommerfeld, - Atomic Structure and Spectral Lines

than the corresponding circle; and the greater the eccentricity of the ellipse the lower the energy level.

If, for example, an electron transition is from a state of higher energy level to the state given by $\tilde{\tau} = 2$, then the electron may "drop" into the ellipse $\tau_l = 1, \tilde{\tau}_n = 1$; or into the circle $\tau_l = 2, \tilde{\tau}_n = 0$. The energy change involved will be slightly different in the two cases and so the observed 'line' would appear as a fine doublet.

Thus Sommerfeld was able to give a quantitative explanation of the observed fine structure associated with spectral lines when studied with instruments of high dispersive power.

The Selection Principle

It was found that all the mathematically possible line components were not produced, and in the case of the H_α line for example, although six components are to be expected, since the line arises from a transition from the state $\tilde{\tau} = 3$, to $\tilde{\tau} = 2$, only three components are present.

A Selection Principle which governs these transitions, was enunciated by Rubinowicz and Bohr, who arrived at the same statement by quite different arguments. The principle states that only those interorbital transfers are possible for which the change $\Delta \tau_l$ of the azimuthal quantum number is given by: $\Delta \tau_l = \pm 1$

Absorption of Energy

When the electron is revolving in any of the outer orbits, the atom is said to be in the excited state, and the process of moving an atom from an inner to an outer orbit is called Excitation.

With sufficiently intense excitation the electron may be completely removed from the nucleus, and the atom is then left with a surplus positive charge and is called a positive ion, the process being referred to as Ionization.

Excitation is obviously the converse of radiation and must involve the absorption of energy, either from radiation, or by electron impact.

Critique of the Bohr Theory

Some mention has been made of specific cases of the successful application of the Bohr quantum theory, and in general it may be said that, this theory brought order out of the apparent chaos of the extensive accumulation of experimental and empirical data. In fact, the extraordinary accuracy of the prediction and results obtained, completely overshadowed any discrepancies or difficulties that existed in the wholesale adoption of Bohr's atom model.

Some of the predictions were not found accurate, however, and the theory could not give a complete explanation of such things as the abnormal Zeeman effect, and

the relative intensities of the spectral lines. Also half-odd integers were necessary in the theory of the structure in X ray spectra.

It was found that the quantum theory of radiation was apparently irreconcilable with the wave theory of light, and that light rays could act either as particles or waves depending on the conditions.

These difficulties lead to a new attack on the problem of atomic structure, and the closely related matter of the nature of radiation and energy. The question was considered from two points of view, and these may now be considered briefly.

Heisenberg-Matrix Mechanics

Heisenberg proposed that in a theoretical discussion of physical phenomena only observable quantities should be considered and further stated that there is a fundamental indefiniteness and a fundamental discontinuity associated with all these quantities.

Thus in the case of a moving electron, its position and velocity cannot both be determined without error, and the greater the accuracy of one determination the less accurate will be the other. Further the product $p \cdot q$ of the error in determining the position and momentum of a particle is of the order h and according to Bohr and Heisenberg this is the real significance of Planck's constant.

This problem was attacked by Heisenberg using the Matrix Mechanics and by Dirac using Quantum Mechanics with similar results.

Schrödinger-Wave Mechanics

It was pointed out by Hamilton that there must be a wave theory associated with mechanics corresponding to the wave theory in optics. De Broglie and Schrödinger recognizing the importance of this in atomic physics effected this extension of dynamics called Wave Mechanics which opens up a new field analogous to diffraction in optics, and which has already had practical applications in the problem of atomic structure. On this basis matter as well as radiation is seen to have a wave as well as a corpuscular nature. But here no adequate model or picture is available.

General Consideration

It is of interest that the two theories lead to the same result, but it must be remembered that Wave Mechanics is essentially an extension of classical theory, and is based on conceptions of continuity, while the new Quantum Mechanics of Bohr, Heisenberg and Dirac are, on the contrary, based on the fundamental concept of discontinuity. It is as yet too early in the development of these theories

to express judgment or preference. The difference between the theories is well represented by their respective interpretations of the wave function ψ . Schrodinger associates it with the density of charge in a system consisting of a continuous distribution of charge while Bohr and Heisenberg consider it as a probability factor.

Some attempt has recently been made at the development of a new comprehensive theory of physical phenomena on the basis of a five-dimensional continuum which will include the quantum phenomena that seem to have no place in any four-dimensional system. It appears possible that the discovery of discontinuity in nature is due to the habit of describing physical phenomena on a space-time, or four-dimensional basis.

For the sake of completeness mention may be made here of the Spinning Electron theory of Goudsmit and Uhlenbeck which gives an alternative explanation of fine line structure; and of the Static atom model of Lewis and Langmuir designed to satisfy the needs of the chemists for a stable, rather than a dynamic atom.

Part II

Spectroscopic Analysis

Historical

Spectroscopic analysis had its origin very early in the history of spectroscopy. It dates from the discovery by Kirchhoff of the significance of the Fraunhofer lines. He realized that the lines indicated the presence in the solar atmosphere of the vapors of elements, which absorbed certain radiations and that these were characteristic of the elements in question. Bunsen and Kirchhoff proceeded to map out the spectra of many elements some of which were identified in the solar spectrum. The attention of many investigators was then directed to the possibilities of chemical analysis by means of spectra.

Definition

It may be mentioned here that some confusion seems to exist regarding the terms "spectrum analysis" and "spectroscopic analysis". In general, it may be said that the former refers to the process of investigating relations within and between spectra, such as series and

fine line structure; while the latter concerned with the use of characteristic spectra of the elements to determine their presence or absence in a given substance. However this distinction is by no means rigid and such authorities as Twyman and Smith of Adam Hilger Ltd. use the term "spectrum analysis" in the sense opposite to that given above.

Analysis by Absorption Spectra

Both Emission and Absorption spectra have been used for purposes of analysis but as this investigation was carried out with the former type, the latter will be dealt with only briefly.

Much of the work done with absorption spectra has consisted of obtaining absorption curves for various substances in the form of solutions. These curves give the relative absorption with respect to the wavelength of the light, and are characterized by quite definite maxima and minima. The curves for various elements and compounds are quite distinctive and by comparing the graph for an unknown substance with standard curves the analysis may be made. It has been found that organic compounds in particular lend themselves to this method, and practical application of absorption spectrophotometry, as this branch is called, has been accordingly, chiefly in the field of biochemistry.

Analysis by Emission Spectra

Emission spectra on the other hand have been used mainly in inorganic analysis, and with particular success in the qualitative and quantitative estimation of metallic constituents. Atlases and wavelength tables of the characteristic line spectra of most of the elements are now available and render the identification of unknown lines in a spectrum comparatively easy.

Qualitative Analysis

Qualitative analysis has in general two types of problems.

- (1) The detection of the presence of a particular element in a sample.
- (2) The determination of all the elements present in a given sample.

The former problem is, of course, much more simple and it is usually sufficient to obtain the spectrum of the sample in juxtaposition to that of the desired element. Any lines common to the two spectra will be those of the element, and thus the element is present in the sample if there are such common lines, and absent if there are none. Care must be taken that air and electrode lines are not mistaken for those due to the

element; but if necessary, a third spectrum of the electrodes alone will show these lines separately.

If a permanent record is desired then the spectra are obtained on a photographic plate, one immediately below the other, by moving the plate between exposures, or by using a Hartmann diaphragm, or the one may be superposed on the other so that the spectra are of different lengths but on the same part of the plate.

The process may be carried out visually by using a small comparison prism, which may be attached immediately in front of the slit of the spectroscope.

The problem of determining what elements are present in a given sample has been the subject of considerable research and a number of methods of attack have been employed, and the most important and general of these will now be considered.

(a) A Calibration Curve for the instrument is obtained by plotting the positions of the lines of a known spectrum against their corresponding wavelengths. Then the wavelength of any line in a spectrum may be determined by measuring its position and reading off the corresponding wavelength from the graph. Having determined the wavelengths of the lines due to the elements in a sample, these elements may be identified by consulting tables which give all the lines due to each

element, or tables which have the lines listed according to wavelength and the corresponding elements assigned to them.

(b) The wavelength of the unknown lines may be found by interpolation, using either known standard lines (eg. those due to electrodes) in the same spectrum or lines in an immediately adjoining spectrum. The interpolation may be direct if there are sufficient reference lines very close to the unknown ones, or the Hartmann interpolation formula may be used if such is not the case. Having determined the wavelengths, the procedure is as above. (Method a)

(c) When the spectrograph is equipped with a wavelength scale, the approximate wavelength which it gives will be sufficient to identify prominent lines, but for faint lines or when several elements have lines in a particular region a series of comparison spectra of suspected elements may be used to complete the identification.

(d) Another very convenient method of identification of lines is based on the fact that a mixture of elements or their salts may be prepared in which they are in such proportions that the spectrum of the mixture contains all the most characteristic lines of the elements present, that is, those lines which are produced with minimum excitation. Such a mixture is the R.U. powder developed by J. W. Ryde and H. G. Jenkins at the General Electric

Company research laboratories at Wembley. The powder consists of small quantities of fifty elements incorporated in a base material composed of zinc, magnesium and calcium oxides. Only the more sensitive and persistent lines, about seven per element appear in the spectrum. When used as a comparison spectrum all the elements in a given sample may be readily recognized as enlargements of the R.U. spectrum with the origin of each line marked, are supplied with the powder. It will be noted that in this case no wavelength determinations are necessary.

Rares Ultimes and Persistent Lines

Mention may well be made here of the important work of de Gramont, Hartley, Leonard and Pollok, since it forms the basis of much of the subsequent research on spectroscopic analysis. They found that certain of the lines of each element in the sample persisted as the amount or concentration of the element decreased, and they prepared tables giving the wavelengths of these lines for many elements.

The last three worked chiefly with aqueous solutions of metallic salts, while de Gramont used solutions and also metallic alloys of known composition, and employed the oxy-hydrogen and oxy-acetylene flames as well as the electric spark for excitation. The more persistent

or sensitive lines he called the "raies de grande sensibilité" or "raies sensibles". The lines which persisted when the concentration of the element was reduced indefinitely, that is, as long as any of the element was present he called the "raies ultimes". It is these lines that appear in the spectrum of the R.U. powder. Obviously if the raies ultimes of an element are not present in a spectrum, then the element is not present in the sample. De Gramont made the following important general observations:

- (1) That the sensitive lines are unaffected by the use of the self-induction coil.
- (2) That these lines appear both in the arc and spark spectra of the element, and that they are generally very intense in the former and not necessarily so in the latter.
- (3) That they are also present in the flame spectra as given by the oxy-hydrogen and oxy-acetylene flames.

Quantitative Analysis

In order to make a quantitative analysis it is necessary to find some spectroscopic quantity which varies with the amount of the element present in the sample, and then some means of measuring this quantity.

The following is a list of the variable quantities used by different investigators together with their methods of measuring these quantities and some of their applications. This is by no means a comprehensive survey of the field of quantitative spectroscopic analysis, but is fairly representative and will serve to indicate the wide variety of the problems considered, and the ingenious manner in which they have been attacked.

1. Length of the lines of the element in spark discharge.

Lockyer¹ discovered that the length of a line (that is, the distance from each pole at which the line is visible) decreases with the amount of the corresponding element. Occhialini has used this fact in developing a new system of quantitative analysis.

2. Number of lines of the element recorded on a plate after a standard exposure.

3. Time taken for the disappearance of the lines of a volatile element.

Hill and Luckey² have applied this method to the analysis of alloys by measuring the time taken for a line to disappear when a given weight of an unknown mixture is burned in the crater of an arc. The volatility of different constituents of the alloy will vary.

¹ Lockyer Phil.Trans. 164, 479. (1874)

² Hill and Luckey Trans.Amer.Electrochem.Soc.
32, 335, (1917)

4. Some Intensity Comparison Methods

(a) Exploded Wire Method

A special method for the analysis of fine wires, such as filaments in lamps and valves was devised by J. W. Ryde. A bank of condensers is discharged across a spark gap and the wire is placed in series with the gap, with the result that the filament is immediately vaporized and the spectrum produced by the discharge through the vapor is so intense that a single explosion is often sufficient to record the spectrum. The method is made quantitative by preparing tables giving the relative intensities of sensitive lines of the impurities in terms of neighboring lines due to the chief constituent of the wire for various quantities of impurities present, as determined by examination of spectra of standard wires containing known quantities of impurities.

(b) De Gramont Method

Intensities of the lines of an element as registered on a spectrogram from a sample are compared with those of the same lines on a spectrogram taken from standard specimens of known composition.

Although the comparison is visual, considerable accuracy is obtained. This is the method used by A. de Gramont in his extensive researches.¹

¹ De Gramont — Reports contained in a series of papers published in Comptes Rendus between 1907 and 1922.

(c) Internal Standard Method

Gerlach and Schweitzer¹ made the comparison with lines of the main constituent within the one spectrum, thus eliminating errors due to difference of exposures etc.

Heggers, Kiess and Stinson² have applied the de Grauwet method to the analysis of tin, assay of gold etc.

(d) Solution Method of F. Löwe

Löwe³ prepared an atlas of the spark spectra of the solutions of salts containing elements in concentrations of 1%; 0.1%; 0.01%; 0.001%. A drop of the solution was placed in the lower electrode and the spectrogram compared with the standards, visual comparison of the intensities giving quite accurate results.

(e) "Testverfahren" Method. — K. Thurnwold.

This ingenious method is described by Thurnwold as follows, "to the solution to be examined is added the requisite amount of a solution of another metal

¹ Gerlach and Schweitzer — Zeits.f.Anorg.Chemie.
143,393,(1925) 164,127,(1927)

² Heggers, Kiess, and Stinson—Bureau of Standards Scientific Paper No. 444 (1922).

³ Löwe — "Atlas der Letzten Linien der wichtigsten Elemente". (1922)

to give equality of intensity between the "raies ultimes" of each element. The amount of "test" solution added thus gives an indication of the percentage content in the sample solution".

(f) Intensities of Lines matched with the brightness of an electrically heated tungsten wire.

This method was used by Meggers, Keiss, and Stimson in the estimation of minor metallic constituents of tin, gold, and platinum.

5. Persistence of Lines

The order of persistence of the lines in a spectrum was the basis of a quantitative method developed by Hartley, Leonard and Pollok, and Whelan¹.

Hartley found that all the lines of a metal in a solution of its salts do not persist at the same dilution, and the same lines always disappear at the same dilution, providing the sparking conditions remain constant.

¹ Hartley Phil.Trans. 175; 49, 325 (1884)
 Proc.Roy.Soc.A. 69, 283 (1902)

J. H. Pollok Proc.Roy.Soc.A. 11, 184 (1907)

J. H. Pollok & A. G. G. Leonard Proc.Roy.Soc.A.
 11, 217, 229, 257 (1907)

A. G. G. Leonard Proc.Roy.Soc.A.
 11, 269 (1908)

J. H. Pollok Proc.Roy.Soc.A.
 11, 331 (1909)

A. G. G. Leonard & F. Whelan Proc.Roy.Soc.A.
 15, 274 (1913)

Tables were prepared of the 'persistent' lines of the elements, classifying them according to the minimum dilution at which they were visible. The system had the following symbols for the various classes.

τ	lines obtained with the metal, but not with strong solutions.
σ	" " " strong solutions, but not with 1% "
φ	" " " 1% " " " " 0.1% "
χ	" " " 0.1% " " " " 0.01 "
ψ	" " " 0.01% " " " " 0.001 "
ω	" " " 0.0001% solutions.

The solution was contained in a U shaped capillary tube through which passed a gold wire to project just above the tube into the cup at the end; a piece of thin glass capillary tubing was placed over the wire to draw up the liquid.

6. Measurement of Intensity

a. Microphotometric Measurement of Line Intensity

- (i) Wall registering microphotometer.
- (ii) Galvanometer and photoelectric cell.
- (iii) Nutting Photometer.

b. Logarithmic Sector Method

A rotating logarithmic sector is placed in front of the slit so that a variation of exposure time is

caused along the length of the slit. The height of the line is then a measure of its intensity, and by a comparison of the heights of neighboring impurity and main constituent lines under a travelling microscope, the analysis may be effected with considerable accuracy.

A. A. Fitch has applied this device to the quantitative analysis of many minerals, and the method, modified somewhat, has been applied to the analysis of solutions obtained in leaching processes for copper ores.

Scheibe and Neuhäusser¹ originally developed this method.

c. Barratt Method

Depends upon the photometric comparison, visual or photographic, of one or more lines of the element being estimated when excited simultaneously in the "unknown" and in a standard comparison material; two spark gaps in series being used to insure the same electrical conditions.

Applications of Spectroscopic Analysis

(1) Chemistry

The use of the spectroscope or spectrograph in chemistry is usually confined to the detection of metals but phosphorous, arsenic, carbon, boron,

¹ Scheibe and Neuhäusser Zeits.f.Angewandte Chemie (1923)

silicon and tellurium give both arc and spark spectra, and fluorine, chlorine, bromine, iodine, nitrogen, oxygen, sulphur, and selenium, show spark spectra.

Flame spectra are of very limited use, but the oxy-hydrogen and oxy-acetylene flames have been used in the analysis of minute precipitates on filters.

Powders, precipitates or residues may be placed in the crater in the lower electrode of a carbon arc, or in a cavity in the lower copper electrode of a spark.

If a conductor, the sample may of course, be used as the electrodes, or as one of them, the other giving standard comparison lines.

Solutions may be dropped on to a hot carbon electrode to saturate it, or may be examined by the method of Hartley or De Gramont, the liquid being put in a glass cup and drawn up to the surface of the electrode by a glass capillary tube, or by using coiled gold foil, or twisted platinum wires as the electrode. Also pure graphite or carbon rods cut in a fluted or channelled wedge shape serve as good electrodes for solutions.

Special cases such as the analysis of stains in cloth, or of different types of glass indicate the diversity of the problems to which spectroscopy is applicable.

(2) Metallurgy

The detection of metallic impurities in metals and alloys, and of the very small amounts of some minor constituents of alloys and special steels is rendered comparatively simple by the use of the spectrograph. A number of examples of this type of problem might readily be given, such as the determination of impurities in zinc and copper; rhodium, iridium and palladium in platinum; aluminum in brass; tin and chromium in steels; and the constituents of ores, spelters, slags etc. The detection of base metals in bullion and platinum is an excellent illustration of the convenience and economy of the spectroscopic analysis, since only a very small sample is required and in some cases the metal itself could be used as electrodes without injury. H. G. Lloyd of the U.S. Bureau of Standards at Washington has found that the spectroscopic estimation of small quantities of such elements as niobium and molybdenum in steel is more reliable than the chemical analysis.

(3) Mineralogy

In mineral analysis, rare elements whose properties are incompletely known may often be detected only by means of the spectrograph.

De Cramont was the first to use this instrument in this field and obtained many valuable results

such as the detection of the presence of titanium in biotite and euxenite; vanadium in lauxite and laterite, etc. He was also able to show that goyazite was a strontium, not a calcium mineral as expected, although only 0.01 gm. was available.

(4) Biology

The use of emission spectra for the analysis of organic substances has been rather limited partly because of exceptional difficulties in dealing with these materials, and also because considerable success has been attained by using absorption spectrophotometric methods, as previously mentioned.

However some attempts have been made, such as those of H. Ramage, who has applied the oxy-hydrogen flame with carbon arc to the quantitative analysis of vegetable and animal substances and oils, and of Mottram who has investigated the presence of alkali metals in animal tissues and blood.

Spectroscopic methods have been applied to the problem of the control of purity in foodstuffs, and it is found that metallic compounds added as preservatives or coloring matter may readily be detected; for example, 0.06% zinc and 0.05% copper are quite detectable in peas.

In general it may be said that spectroscopic methods are of particular value in the estimation of minor constituents and small amounts of impurities and in many cases are far more simple and economical than the chemical analyses, and further, that the field is now being enlarged to include major constituents, and a greater variety of sample materials.

PART III

Method and Apparatus

Introduction

In order to facilitate the discussion of the procedure and the apparatus used in this investigation a general description of the method including mention of the chief instruments will first be given to lend continuity and clarity to the subsequent more detailed account of the devices used in the analysis.

After some preliminary experimentation satisfactory copper spectra were obtained by using a 20,000 volt transformer, an induction coil and a condenser to produce a condensed spark.

The copper rods which formed the electrodes were conveniently held in a Gramont arc and spark apparatus, the gap being about 2cms., and about 12cms. from the slit of the quartz spectrograph on which the light from the spark was focussed by means of a quartz condensing lens.

From the spectrograms and tables given in "Atlas Typischer Spektren" of Eder and Valenta, sufficient of the prominent copper lines were identified so that a temporary calibration curve was obtained relating the wavelengths of the lines to their respective positions in

the spectrum, these positions being measured with a traveling microscope.

When the preliminary curve had been obtained identification of practically all the other copper lines became an easy matter, and a new and more accurate curve was then prepared, using the data for the copper lines (and some of other elements principally aluminum and iron).

Using this Calibration Curve, the wavelength of any line in a spectrum could be read off as soon as its position was determined.

The next step was to obtain the spectrum of a body fluid, a Urinal Residue being first used. This was done by placing a small quantity of the substance in cavities bored in copper electrodes, the holes being concentric with the rods.

The spectrum obtained then consisted of the copper lines plus those due to the elements in the residue. After finding the positions of all the lines in the spectrum and determining their respective wavelengths from the graph, the copper lines were readily distinguished.

In order to discover which elements had produced the other lines, various tables of spectral lines were referred to, including the following:

Eder and Valenta	Atlas Typischer Spektren
Kayser	Handbuch der Spektroskopie
	Tabelle der Hauplinien der Linienspektren aller Elemente
Twyman	Wavelength Tables for Spectrum Analysis
Baly	Spectroscopy Volume II

It was found that all the lines from the residue seemed to be produced by four elements. In an endeavor to obtain more lines of these elements, and to detect the lines of other constituents of the residue various modifications were tried such as variations in the amounts of induction, capacity, material used, exposure times, and electrode shape. Also blood serums in liquid state and the residue obtained by their evaporation to dryness were investigated. The results obtained will be subsequently considered.

The Spectrograph

Before proceeding to a discussion of the particular spectrograph used it may be well to consider the general characteristics of the spectroscope, the essential parts, the way in which it produces a spectrum, and such special devices as may be relevant to this problem.

Refraction Through a Prism

As is well known the velocity of light varies with the medium, and the path is thus straight as long as the ray travels in one medium, but when passing from one isotropic medium into another, the change in velocity causes a bending, or change in direction, known as Refraction. The new path is a straight line at a certain angle of deviation to the original path.

The amount of deviation depends upon the relative velocities of the light in the two media; and also the angle at which the ray falls on the boundary surface.

In general, a ray is refracted towards the normal to the surface when going from a rare into a dense medium, and conversely away from the normal when going from a dense into a rare medium. The ratio of the velocities in the two media is equal to the ratio of the sine of the angle of incidence to the sine of the angle of refraction. This ratio is found to be a constant and is called the index of refraction.

For practical purposes it is necessary to deal with at least two surfaces and when these are parallel, the ray on emerging pursues a path parallel to its original path. When the two boundary surfaces are not parallel to one another but are inclined at some angle, the deviation produced by the refraction at the first surface is not counteracted at the second surface, but is

always increased.

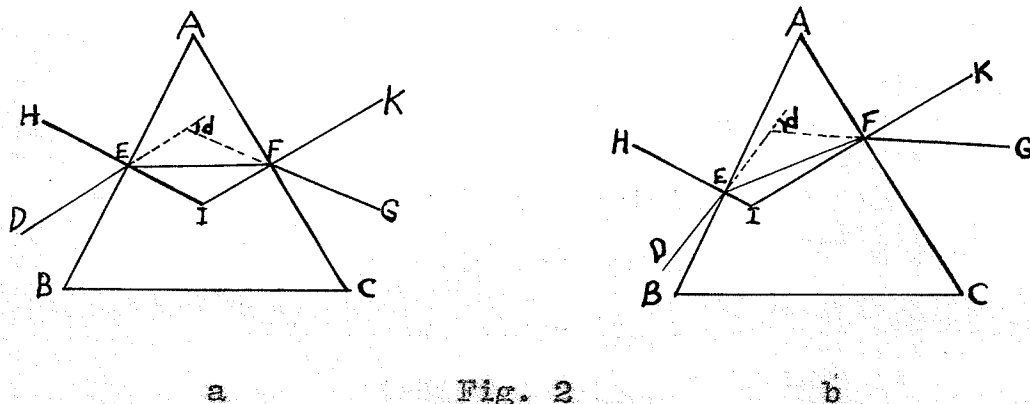


Fig. 2

Let AB and AC in figure 2 represent two refracting surfaces of a prism ABC inclined together at the angle BAC.

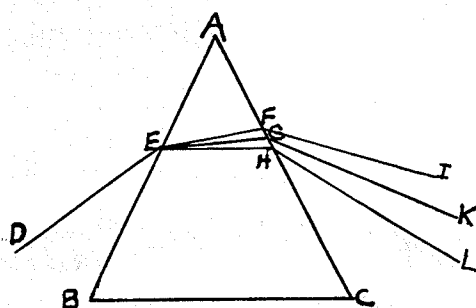
Then if the ray DE fall on the surface AB making an angle of incidence DEH, part will enter the prism and follow the path EF which makes an angle of refraction FEI. The relation between the angles DEH and FEI is defined by the value of the index of refraction. The ray EF on reaching the second surface AC is refracted away from the normal and passes along the path FG.

It is evident that the deviation in the path of the ray DE produced by the refraction at the first face is increased still more by that which occurs at the second face, and the total deviation is then shown by the angle 'd' which is obtained by prolonging the paths of the incident and emergent rays. It will readily be seen that this angle 'd' has the lesser value in the first case

(Fig. 2a) and indeed it can be proved that the total deviation is a minimum when the ray passes symmetrically through the prism, that is, when angle $DEB = \text{angle } GFC$, and it will be noted that the path of the ray EF in the prism is parallel to the base BC , if the prism is isosceles.

Formation of the Spectrum

In the above treatment of the refraction of light passing through a prism a tacit assumption was made that the rays of light were homogeneous, that is, that they consisted of light of only one color or wavelength. Since Newton by his discovery of the composite nature of white light showed that rays of different colors suffer different amounts of refraction, it becomes necessary to take a wider view of the phenomenon.



Let ABC represent a prism and DE an incident pencil of white light.

Fig. 3

The refraction at E will be different for every ray of different color in the pencil and therefore every ray will pursue a different path in the prism, three such rays being indicated in the figure as EF, EG, and EH. All the rays are again refracted at the second face and their paths become still more divergent as shown by the three rays FI, GK, and HL. The different colors are thus all separated by the prism and if they were received on a screen a band of colors would be produced in which each color would be placed according to its index of refraction. For example, blue would appear at the end nearer the base of the prism (at L) while the red would appear at the other end I, while the middle position would be occupied by green.

The indices of refraction for light of different colors have been measured for many substances and these measurements are of great significance in spectroscopy. In the first place they are important with reference to the use of prisms and lenses in spectroscopes, and secondly the refractive indices of a substance are intimately connected with its power of absorbing light.

Curvature of Spectrum Lines as produced by Prisms

It will always be found that the spectrum lines as seen in a prism spectroscope are curved with the convex side turned toward the red end of the spectrum. This is due to the fact that only the rays from the centre of the slit pass through a principal plane of the prism; a principal plane being a plane perpendicular to the plane of the refracting edge of the prism. Hitherto the refraction has been dealt with on the assumption that the rays pass through a principal plane. In order that the deviation be a minimum, two conditions must be satisfied. First that the angles of incidence and emergence be equal, as already stated, and second that the rays pass through a principal plane. Since the rays from other than the central portion of the slit do not pass through such a plane, they suffer a greater amount of deviation, an amount which increases with the distance of the ray from the centre of the slit. The lines are therefore curved, as may be observed if the slit be sufficiently long, but if only the central portion is used, the lines will be sensibly straight.

Refracting Angle of a Prism

This is the angle between the two refracting faces and is equal to half the angle between rays

reflected from the two surfaces when the light is incident upon the refracting angle. It determines to a great extent the amount of deviation produced in the path of the beam.

Dispersion

If a comparison be made between the values of the indices of refraction possessed by different substances for the same rays of light, it will at once be noticed that the ratios between the indices are by no means the same. That is, a change in wavelength in one medium may produce a greater change in deviation in that medium than another (eg. $C S_2$ and glass)

The ratio $(d\theta/d\lambda)$ of the change in the deviation to the change in the wavelength for any substance is called the dispersion or dispersive power of the medium.

The dispersion is also a function of the refracting apparatus, that is, it depends upon the number and refracting angles of the prisms employed.

The variation in dispersion has made possible the construction of Compound Prisms, which cause a particular ray to pass through undeviated and Achromatic Lenses, by means of which all the rays are brought to the same focus without destroying the deviation.

Index of Refraction Determined from a Prism

Fraunhofer showed that the index of refraction of a substance could be found by passing a ray through a prism of the substance at the critical angle, when the index 'n' would be given by

$$n = \frac{\sin \frac{A + D}{2}}{\sin \frac{A}{2}}$$

where

A = refracting angle

D = angle of deviation

Resolving Power of a Prism

The ratio $\lambda/\delta\lambda$ between the mean wavelength of a pair of lines which can just be separated in a spectroscope, and the difference between the two components is called the Resolving Power.

. The resolving power is the product of the linear (effective) aperture and the dispersion. The theoretical resolving power varies inversely as the cube of the wavelength.

In order that two lines may be separated in a prism spectroscope, it is necessary that the total

thickness of the base of the prism or prisms be equal to the quotient of the wavelength by the difference in the indices of the two lines.

$$\text{i.e.} \quad t = \frac{\lambda}{\delta n}$$

From the above it follows that all possible prisms constructed on the same base will give equal resolving power.

Dimensions of Prisms

The length of the refracting faces should be greater than their height to accept all of the beam from the collimating lens, and the height should be equal to the diameter of the lens.

Materials for Prisms

Many substances have been used for prisms but only glass and quartz are common, the other materials being applied where special properties are wanted. The following list contains practically all the substances now used.

Glass	—	Has the advantage of being cheap, tough, and may be had in a wide variety of dispersive powers.
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Uviol Glass — Far more transparent to ultra-violet rays than ordinary glass, and is considerably less expensive than quartz. Three types are available —

PK ₁	Phosphate crown
BK ₅	Borosilicate crown
ZK ₅	Zincosilicate crown.

Calcite — (Iceland Spar) — transparent down to λ 2100.

Quartz — transparent to λ 1850.

Fluorite — transparent to λ 1200, but dispersion is small.

Rock salt and Sylvine — High transparency to infra-red but soluble in water, and hence are readily affected by adverse atmospheric conditions.

Carbon Bisulphide — Has high dispersive power, but being a liquid is difficult to handle.

Cornu Prism

When quartz or calcite is used for the prism material certain precautions must be taken, since both these substances are doubly refracting, and would ordinarily cause a doubling of the spectrum lines. However the prisms may be cut so that the rays will pass along the optic axis of the crystal, this being the direction along which double refraction does not take place.

In addition the optic axis should lie in a principal plane and be parallel to the base, so that the rays at minimum deviation will not undergo double refraction.

Quartz, beside producing two plane polarised refracted rays has also the power of rotating the plane of polarisation. The two rays circularly polarised to the right and left respectively possess different velocities and so will be separated and a doubling of the image will result.

Now it has been found that there are two kinds of quartz crystals, the right-handed crystal in which the dextro-polarised ray suffers the least deviation, and the left-handed crystal in which the laevo-polarised ray is less deviated. Hence by joining two equal portions of left and right-handed crystals the doubling effect in the first half is then destroyed in the second. The optic axis must also be parallel to the base in each half. This method of cutting is due to Cornu, and the prism of the

spectrograph used was of this type.

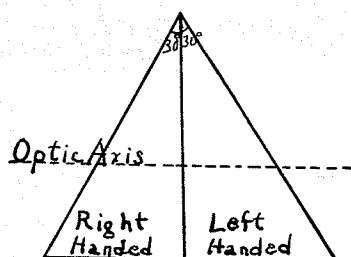


Fig. 4

The Lenses

If the beam of light passing into the prism is very convergent or divergent, considerable disturbances arising from aberration tend to appear which militate against good definition in the spectrum.

Fraunhofer first introduced the use of the Collimating Lens, to correct for this effect by collecting the rays coming from the slit and throwing them as a parallel beam on to the prism face.

There is then needed a lens to collect the rays leaving the last prism face and to bring them to a focus at the eyepiece or photographic plate.

Generally speaking, if quartz lenses are used alone, it will be found that the foci lie on a curve. It is possible, however, to cut the quartz prism and lenses in such a way that the focal curve is almost flat, although it lies at an acute angle with the axis of the telescope lens.

The focal length of a lens differs for every ray of different color and thus a single lens must give with white light a series of colored images of different sizes distributed along the axis.

Either a quartz-fluorite or quartz-calcite achromatic combination will counteract this defect but the former is very expensive, and the latter is not transparent to the far ultra-violet, so that they are not commonly used except where great accuracy is necessary.

The Quartz Spectrograph

The instrument used in this investigation was a small Hilger Quartz Spectrograph (E31).¹ This is of all metal construction except for the plateholder and slide.

The optical system consists of a collimating and a telescope lens both of 203 mm. focus, and a Cornu prism. These are cut in such a way that the focal curve is practically flat, although it lies at an angle of 27° with the axis of the telescope lens.

The instrument is designed to give good definition over the whole spectrum from 8000 A.U. to 1850 A.U. on one plate ($3 \frac{1}{4}'' \times 4 \frac{1}{4}''$), the spectrum being about 85 mm. long.

The spectrograph is in permanent adjustment and is thus very simple to operate, as its chief use is as a student laboratory instrument.

The length of the spectrum, measured on a plate in centimetres from $\lambda 8000$ is as follows:

λ in Angstroms	Length in cms.
8000	0
5000	0.8
4000	1.5
3500	2.1
3000	3.0
2500	4.5
2000	7.5

¹ Catalogue numbers of Hilger apparatus are given.

The Slit F25

The only adjustment possible on the instrument is that of the slit. The width is controlled by a fine screw adjustment with a drumhead, which is divided into mms., although the scale seems arbitrary. The total effective slit length is 7 mms., but only the centre portion, about 2.5 mms. was used.

Auxiliary Apparatus

Measuring Micrometer

The position of the lines of the spectra were determined by means of a Hilger Measuring Micrometer (L1).

This consists of a microscope mounted on a slide which accurately works in grooves and is actuated by a micrometer screw; the length of travel of the slide being about 6 inches. The micrometer screw is mounted on the frame of the instrument and turns in bearings so that it cannot move backwards or forwards. It is provided with a divided drumhead and a handle for moving the plate rapidly through comparatively long distances. The drumhead is divided into a hundred divisions, which can easily be read to the tenth of a division, so that with the screw cut to 1 mm. pitch, the movement of the microscope can be read to a thousandth of a millimetre.

The whole is fixed to a massive stand in order to have the instrument as rigid as possible.

Under the microscope is a support on which the plate rests, and a travelling mirror is provided for illumination purposes. The microscope itself is of quite low power, as higher power causes the spectrum lines to become too magnified and difficult to measure, since the edges will become diffuse, and the central portion so enlarged that accurate measurement of either the centre or edge is impossible. The eyepiece is of course fitted with cross-hairs.

The Electrodes

During the course of the investigation various materials for electrodes were tried including copper, steel, aluminum, zinc and carbon; but the copper proved the most suitable as it was obtainable in pure form without great expense and provided a convenient, definite, and not too crowded spectrum.

Hilger Spectroscopically Pure Copper Rods (F127) were used, these rods being 5 mm. in diameter and 17.5 cm. long.

The sample material was at first just packed into holes, a few mms. deep in the ends of these electrodes. Later it was found that if lengths of about 2 cms.,

bevelled at one end, were drilled completely through, and the material pressed in from the other end that more lines were obtained since the spark tended to pass through the substance which protruded past the ends of the copper.

These electrodes could be recharged and used several times, but in general new pairs were made up for each series of spectra.

For the spark spectra of the blood serum, a special type of lower electrode was devised.

The liquid was put in a U shaped glass tube through which passed a thick copper lead wire which made contact with a thin copper tube, so placed that the liquid just covered the copper. When the spark was then passed, from an upper copper electrode to this one, the liquid vaporized and the spectrum was thus obtained. The glass tube was wide at the open end so that the glass would not be affected by the discharge.

Electrode Stand

The Gramont Arc and Spark Apparatus (F449) was found to be a very convenient electrode holder, since it permits easy and accurate adjustment of the position of the electrodes with respect to each other, and also enables both electrodes to be moved vertically simultaneously. The adjustments may be made while sparking is in progress, if

necessary to keep the light focussed on the slit of the spectrograph.

This device as described in the Hilger catalogue has the following properties:

1. All the exposed metal parts are of stainless steel.
2. The clamps take any size of rod from 4 to 10 mm. diameter.
3. Spring clips are provided for holding small metal specimens or pieces of conducting substances.
4. The insulation is of non-inflammable zylonite and is sufficient for tensions up to 20,000 volts.
5. The main rod moves up and down by rack and pinion thus permitting the arc or spark to be adjusted in position while running.
6. A separate rackwork is provided for adjustment of the width of the gap.

Special brass holders were made for the short copper electrodes since it was found that they did not fit rigidly into the clamps without them.

Condensing Lens

A quartz spherocylindrical condensing lens (F.11), which gives a line of light from a point source was used to focus an image of the source on the slit so that more light was obtained, and the exposure times thereby reduced considerably.

The Electrical Apparatus

Transformer

A Thordarson transformer, type R, No. 14788 was used, which gave 20,000 volts in the secondary on open circuit with 110 volts, 60 cycles alternating current in the primary.

A resistance of about 23 ohms in the primary circuit cut down this voltage somewhat to produce a smoother discharge.

Condenser

A Thordarson oil-immersed condenser of about 0.01 microfarad capacity was connected across the spark gap to produce an oscillatory discharge.

Self-Induction Coil

A self-induction coil was made by winding a single layer of bell wire on a cardboard tube, the coil being in five sections which could be used separately or groups of as many as desired.

The circumference of the coil was 16 cms. The turns of the coil were approximately 3 cms. apart. The specifications for the coil were as follows:

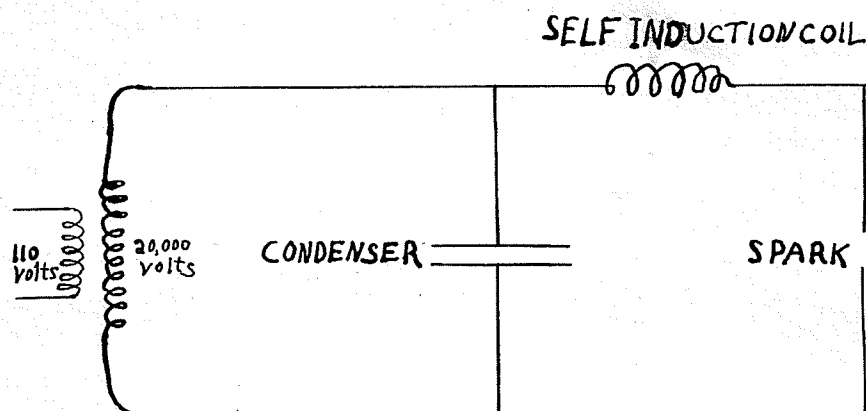
Coil	No. of Turns	Resistance (ohm)	Self-Induction (henry)
1	20	.030	.000017
2	40	.174	.000034
3	70	.273	.000059
4	170	.612	.00013
5	80	.260	.000043
Total	380	1.41	.00033

Electrical Circuit

The source of illumination throughout this research was the electric spark obtained by the discharge of the high potential current from a transformer with a condenser in parallel with the spark gap.

The condenser charges up until the potential is sufficient for a spark to pass, when, if the right conditions obtain between the capacity of the condenser, the self induction of the coil, and the resistance of the circuit formed by condenser, self induction and spark gap, an oscillatory discharge passes around the latter circuit yielding a brilliant and explosive spark.

The arrangement of the apparatus is indicated in the following diagram and the spark is caused to pass between electrodes of the metal or compound under investigation.



The capacity of the condenser determines the quantity of electricity which passes in each individual spark, that is, the intensity of the spark, and as mentioned before, the stage of the ionization present depends on this intensity.

Now the transformer used must be of suitable size to charge the condenser to a sufficient potential, so that it will discharge across the gap of desired length, in this case about 2 mm. Hence the transformer is determined by the condenser capacity, and in fact the two are usually designed together to give the proper results.

In an oscillating circuit the three essentials are (i) capacity; (ii) self-inductance; (iii) a spark gap; and the resistance must be small.

The oscillations arise because of the self-inductance of the circuit, by reason of which the current once set up tends to go on so that the first discharge more than empties the condenser, and charges it the opposite way; then follows a reverse rush which also overdoes the discharge and charges the condenser as originally and so on. Each successive oscillation is weaker, so that the discharge finally dies away, due to waste of energy by resistance, or to energy being radiated away in waves, this effect being known as "damping".

The condition for oscillation is thus given by:

$$R < \sqrt{4L/C}$$

where C = capacity of condenser in farads
 R = resistance of circuit in ohms
 L = inductance of circuit in henries
 and $L = \frac{4\pi S^2 A}{l} \times 10^{-9}$ henries

where S = no of turns
 A = area of each turn
 l = length of coil

and the frequency 'n' of the oscillations will be such that,

$$2\pi n = \sqrt{\frac{1}{CL} - \frac{R^2}{4L^2}} = \sqrt{\frac{4L - CR^2}{4CL^2}}$$

and if R is small

$$n = \frac{1}{2\pi \sqrt{CL}}$$

Hemsalech and Schuster¹ have found that the mechanism of the spark is evidently as follows: "the spark first passes extremely rapidly through the air, a single discharge; this vaporises the metal, which then spreads across the spark gap, conveying the current. The velocity of travel

¹ Hemsalech and Schuster Phil. Trans. A 193, 189 (1900)
 Hemsalech Comptes Rendus 122, 285 (1899)

of the metallic vapor varies with different metals from 1300 - 400 metres per second, and appears to be quicker with metals of low atomic weight, but it varies for different lines of the same metal".

They also investigated the function of the self-inductions and found that in addition to eliminating the air lines, the self-induction also renders the spectrum lines much narrower and causes certain new lines to appear.

Photography of the Spectra

The maximum sensitivity of a normal photographic emulsion, containing silver bromide or mixtures of silver bromide and iodide, lies at or near $\lambda = 4500$.

On the red side of this maximum the sensitivity falls off rather rapidly to a small value near $\lambda = 5200$, this being due to the decrease in absorptive power and hence in the photochemical activity of the silver halide with increase in wavelength. On the short wavelength side the sensitivity falls off more slowly to about $\lambda = 2400$, after which it decreases with considerable rapidity due to the absorptive power of the gelatine, which protects the silver halide from the direct action of the light. Thus the ordinary photographic plate of commerce may be used within the limits of $\lambda = 5000$ and $\lambda = 2400$.

In general, however, special plates are used in spectroscopic work to obtain the best possible definition, as the two desired conditions, fineness of grain and strong contrast, are not obtainable with ordinary plates where soft lights and shades are required.

Silver bromide in the absence of gelatine appears to be sensitive to light of the shortest wavelength yet reached, and quartz spectrographs working in air will give the spectrum down to $\lambda = 1850$. Consequently there is a gap between $\lambda = 2400$ and $\lambda = 1850$ which has a feeble action on ordinary plates due to the absorptive effect of the gelatine.

Two practical methods of solving this difficulty have been devised by Duclaux and Jeantet¹.

The first consists in the removal of the gelatine from the film of an ordinary glass photographic plate by means of sulphuric acid, thereby leaving film of silver bromide. This film is quite regular and very sensitive to the rays of short wavelength, but it is very fragile.

The second method depends upon the fluorescence of a substance when excited by light of wavelengths between $\lambda = 2400$ and $\lambda = 1850$. There are many oils which

¹ Duclaux and Jeantet J.Phys.Radium 2, 154, (1921).

under stimulation by these rays fluoresce with emission of light of wavelength longer than $\lambda = 2400$. Hence, if an ordinary plate is coated with a thin film of one of these oils, wherever the extremely short wave light falls on it, the fluorescence will produce the latent image at that point. Excellent sensitivity is obtained by this method, the only fault being a tendency to broaden the spectrum lines owing to irradiation, but this is less than 0.05 mm. Lyman¹ has used this process with his vacuum spectrograph down to $\lambda = 580\text{\AA}$.

Clear paraffin oils, such as nujol are suitable for this purpose, but they must be removed before developing the plate. This is done by dissolving the oil with acetone.

Schumann² has used plates coated with silver bromide containing little or no gelatine, the amount being sufficient to bind the bromide but exerting no appreciable absorption of light.

The photographic plates used by the writer were Eastman Kodak special ultra violet spectroscopic plates, type 3P and size $3\frac{1}{4}'' \times 4\frac{1}{4}''$. These plates are the fluorescent type mentioned above, and were washed

¹ Lyman Nature 112, 202, (1912).

² Schumann Wiener Berichte 102, II, A, 994, (1893)
Ann. der Physik 3, 349, (1901)

in acetone before developing. The plates give excellent definition of the spectrum from $\lambda = 8000\text{\AA}.$ to $\lambda = 1850\text{\AA}.$ and are of very fine grain. They are packed in pairs, the gelatine sides together, and then wrapped in black paper. When one of a pair was removed for use the other had to be covered with a glass plate, as the black paper produces fogging if in contact with the emulsion.

Eastman Kodak X-ray Fixer and Developer were used and it was found that best results were given by five minutes developing, and approximately six minutes fixing. The plates were washed in acetone for two minutes first, and finally were washed in running water for about forty minutes and then dried.

The process was carried out in complete darkness until the plates had been fixed for about two minutes, the time and order of procedure being as follows:

acetone	- 2 minutes
distilled water	- 2 minutes
developer	- 3 minutes
distilled water	- 2 minutes
fixer	- 6 to 7 minutes
running water	- 40 minutes
rack drying	- 1 to 2 hours

Part IV

Data and Results

Preliminary Calibration Curve

As mentioned previously a preliminary calibration curve was obtained to assist in the identification of all the copper lines. The positions and wavelengths of the prominent lines in spectrum 10, of plate 1 were used for this purpose.

The spectrum was that of the copper electrode rods between which passed the discharge from a 10,000 volt transformer, with a Leyden jar and small self-induction coil in the circuit. The gap was 2 mm. and was placed 10 cms. from the slit of the spectrograph, the width of which was set at .5 on the slit scale. The time of exposure for this spectrum was 60 secs. In the following table giving the data for the calibration curve, the lines were numbered from the first and most prominent copper doublet, the characteristic 3274, 3248 pair, and the positions as determined by the travelling micro-

meter were read off from this same starting point. The wavelength is only approximate as it was determined by identifying the prominent lines by means of the Eder and Valenta "Atlas".

The fourth column records various observations of particular lines or groups, which serve as landmarks.

Table 1

Preliminary Calibration Curve

Copper Spectrum

Number	Position (mms.)	Wavelength A.U.	Description
1	20.95	3274	1st line of 1st prominent doublet.
2	21.45	3248	2nd line of 1st prominent doublet.
3	32.52	2770	Heavy solitary line.
4	34.05	2722	1st line of 1st group.
5	34.23	2719	2nd line of 1st group.
6	34.625	2702	3rd line of 1st group.
7	35.02	2690	4th line of 1st group.
8	38.06	2600	Lone line.
9	40.14	2545	1st line of 2nd group.
10	40.73	2528	2nd line of 2nd group.
11	41.62	2507	3rd line of 2nd group.
12	42.325	2486	4th line of 2nd group.
13	42.46	2486	5th line of 2nd group.
14	46.09	2404	1st line of 2nd doublet
15	46.26	2400	
16	47.76	2370	2nd line of 2nd doublet.
17	51.63	2294	Lines from here on are the heavy
18	52.63	2276	lines of approximately equal in-
19	53.29	2264	tensity forming a long series
20	54.26	2247	near the end of the spectrum.
21	54.54	2243	
22	55.38	2228	
23	56.00	2218	
24	56.47	2210	
25	57.06	2200	
26	57.23	2192	faint doublet
27	57.75	2190	heavy
28	58.41	2179	heavy
29	58.66	2175	faint
30	59.26	2165	very faint
31	59.49	2161	very faint
32	60.16	2152	faint
33	60.43	2149	heavy
34	61.36	2135.5	
35	61.94	2125.5	
36	62.19	2123	
37	62.55	2117	
38	63.00	2112	

Preliminary Calibration Curve

Copper Spectrum

Number	Position (mm.)	Wavelength A.U.	Description
39	63.50	2105	
40	63.88	2100	faint
41	64.68	2086	faint
42	65.33	2079	faint
43	67.26	2055	
44	68.15	2043	
45	68.76	2036.	
46	69.05	2031	
47	69.57	2026	
48	71.84	2000	
49	72.67	1989	faint
50	73.55	1979	faint

Final Calibration Curve

The final calibration curve was plotted from data for spectra 8 and 9 of plate 2, the former being an aluminum spectrum, and the latter pure copper as in Table 1. It was found that the aluminum contained copper and other impurities and all the lines identified were used, points being added to the curve from time to time as other spectra were examined. Obviously the more points plotted, the more accurate the curve.

The data for Plate 2 is as follows:

Table 2

Spark from 10,000 volt transformer with Leyden Jar and Inductance.
Gap 2 mms. Slit at 1.
Electrodes as indicated below.
Position here refers to the positions of the spectrum on the plate.

Number	Position	Exposure	Electrodes
1	6	60 secs.	Copper
2	10	20 "	Steel Rods
3	14	40 "	and
4	18	60 "	Urinal
5	22	2 mins.	Residue
6	26	4 "	
7	30	30 secs.	Steel Rods
8	34	30 "	Aluminum
9	38	60 "	Copper
10	42	30 "	Steel Rods
11	46	5 mins.	Steel Wedges
12	50	20 "	Carbon
13	54	60 secs.	Aluminum
14	58	2 mins.	Aluminum
15	62	30 secs.	Al. / U.R.
16	66	60 "	Al. / U.R.
17	70	5 mins.	Al. / U.R.

Table 3

In this table the lines used in the final calibration curve are listed. The more prominent lines are numbered as 1,2,3,.... for the copper lines and (1),(2),(3).....for the aluminum lines. The second column records the number of the spectrum in which the line was observed, and in some cases the line was present in both spectra. The approximate wavelengths as determined from the preliminary curves are given in the next column, with the corresponding element in the fifth column. The exact wavelengths and arc and spark intensities from the "Atlas Typischer Spektre" shown for reference in the sixth and seventh columns respectively. Insufficient care in handling the copper electrodes was probably responsible for the few lines due to impurities.

Calibration Curve Data

Spectrum 8 Aluminum
Spectrum 9 Copper

Number	Spectrum	Position (mm.)	λ (approx.)	Element	λ (exact)	Intensity arc spark	
1	8, 9	25.05	3274	Cu	3274.09	20	10
2	8, 9	25.55	3246	Cu	3247.65	30	15
	8, 9	27.21	3162	Cu	3160.09		3
	8, 9	27.65	3147	Cu	3159.85		
	8, 9	27.65	3147	Cu	3146.93	2	
(1)	8	28.53	3093	Al	3092.89		10
(2)	8	28.73	3082	Al	3082.50		8
	8	29.12	3065	Al	3066.40		3
	8	29.12	3065	Al	3064.55		3
	8	29.29	3057	Al	3057.40		4
	8	29.45	3050	Al	3050.50		3
	8, 9	30.39	3010	Cu	3010.93	4	3
	8	30.95	2986	Fe	2985.55		4
	8	30.95	2986	Fe	2984.97		6
	8, 9	31.51	2962	Cu	2961.30	10	6
	8	32.35	2928	Al	2927.9		3
	9	33.57	2880	Cu	2877.97		4
	9	34.28	2852	HS	2852.29	10	8
				Na	2853.00	6	4

Calibration Curve Data

Spectrum 8 Aluminum
Spectrum 9 Copper

Number	Spectrum	Position (mms.)	λ (approx.)	Element	λ (exact)	Intensity arc spark	
	9	34.70	2634	Cu	2637.68		3
	9	35.05	2624	Cu	2624.43	4	5
(3)	8	35.29	2616	Al	2616.41		10
	8, 9	35.65	2602	Hg	2602.81	8	10
	8, 9	35.87	2798	Hg	2798.12	1	5
3	9, 8	36.63	2770	Cu	2769.59		8
	8	37.03	2755	Fe	2755.80	6	10
	8	37.29	2748	Fe	2749.41	4	10
				Cu	2740.07		2
					2737.65		2
	8	37.52	2739	Fe	2739.63	5	10
4	9	38.17	2719	Cu	2719.01		5
5	9	38.35	2713	Cu	2713.77		7
	9	38.73	2703	Cu	2703.45		6
					2701.30		9
7	9	39.11	2690	Cu	2689.56		8
(4)	8	40.05	2660	Al	2660.50		5
(5)	8	40.31	2653	Al	2652.60		3
(6)	8	41.04	2632	Al	2631.83		6
	8	41.21	2626	Fe	2623.39	4	8
					2625.79	4	4
	8	41.74	2612	Fe	2611.97	4	8
	8	41.94	2606	Fe	2607.17		8
					2606.57		2
8	9, 8	42.19	2600	Cu	2600.53		7
					2599.13		4
	8	42.40	2594	Mn, II	2593.73	10	10
				Fe	2592.80	4	4
	8	42.67	2586	Al II	2586.95		6
(7)	8	43.05	2575	Al I	2575.22	6	4
(8)	8	43.32	2568	Al II	2568.11	5	3
	8	43.51	2563	Fe	2563.57		5
					2562.65	5	5
9	9	44.23	2545	Cu	2545.09		10
10	9	44.83	2523	Cu	2523.61		7
	8	45.25	2516	Cu	2516.54		3
11	9	45.75	2507	Cu	2506.51		9
12	9	46.43	2489	Cu	2489.72		7

Calibration Curve Data

Spectrum 8 Aluminum
Spectrum 9 Copper

Number	Spectrum	Position (mms.)	λ (approx.)	Element	λ (exact)	Intensity arc spark
13	9	46.58	2485	Cu	2486.57 2485.99	4 4
	9	47.10	2473	Cu	2473.50	5
	8	48.27	2448	Fe I	2447.71	4 2
	8	48.78	2437	Cu	2436.02	3
	8	49.25	2425	Cu	2424.69	3
	8	49.85	2412	Cu	2412.46 2412.23	2 2
	8	50.11	2406	Fe Cu	2406.66 2406.82	6 4 3 2
14	9	50.20	2404	Cu	2403.58	8
15	9, 8	50.37	2400	Cu	2400.23	3 7
	8	50.56	2396	Fe II	2395.63	3 8
	8	51.18	2382	Fe II Al I	2382.04 2378.52	3 10 5
(9)	8	51.62	2373	Al I	2373.36 2372.11	4 4 9 5
				Al	2370.50 2369.36	2 4 4
(10)16	8, 9	51.78	2370	Cu	2369.95	5 10
					2368.20	2
(11)	8	51.91	2367	Al I	2367.70 2367.18	8 2 4
	9	52.46	2356	Cu	2356.70 2355.24	4 3
	8	52.84	2348	Fe II Cu	2348.13 2348.90	4 5 2
	8	53.07	2343	Fe II	2343.50	4 7
17	9, 8	55.65	2294	Cu	2294.44	2 6
18	9, 8	56.64	2276	Cu	2276.30	2 5
(12)	8	57.03	2269	Al I	2269.15	8 4
(13)19	9, 8	57.34	2264	Cu Al I	2263.89 2263.50	2 2 8 4
20	9, 8	58.30	2247	Cu	2247.08	2 6
21	9	58.55	2243	Cu	2242.68	6
22	9, 8	59.27	2228	Cu	2228.94	3
		59.35	2227	Cu	2226.94	2
23	9, 8	60.00	2218	Cu	2218.18	5

Calibration Curve Data

Spectrum 8 Aluminum
Spectrum 9 Copper

Number	Spectrum	Position (mm.)	λ (approx.)	Element	λ (exact)	Intensity arc spark
	9	60.20	2215	Cu	2215.36 2214.60	2 2
24	9, 8	60.48	2210	Cu Al I	2210.36 2210.15	4 2 4
25	9, 8	61.13	2200	Cu	2199.76	2
26	9, 8	61.38	2195	Cu	2195.86	3
27	9, 8	61.59	2192	Cu	2192.36 2191.2	4 2
	9, 8	61.73	2190	Cu	2189.69	4
28	9, 8	62.39	2179	Cu	2179.45	4
29	9	62.68	2175	Cu	2175.14	3
30	9	63.38	2165	Cu	2165.14	2
31	9	63.58	2161	Cu	2161.44	2
32	9	64.21	2152	Cu	2151.95	2
33	9, 8	64.40	2149	Al Cu	2150.69 2149.05	1 3
34	9, 8	65.30	2135	Cu Al	2136.05 2134.51 2134.81	4 2 2
35	9, 8	65.96	2125	Cu	2126.09 2125.26	4 2
36	9, 8	66.18	2123	Cu	2123.06	3
37	9	66.60	2117	Cu	2117.14	3
38	9, 8	66.95	2112	Cu	2112.19	4
39	9, 8	67.47	2105	Cu	2104.66	3
40	9	67.94	2100	Cu	2098.51	2
41	9	68.75	2088	Cu	2088.12	3
	9	68.93	2086	Cu	2085.39	3
42	9	69.43	2079	Cu	2078.63	2
	9, 8	70.70	2066	Cu	2067.58 2066.46	1 1
43	9, 8	71.23	2055	Cu	2055.05	3
44	9, 8	72.12	2043	Cu	2043.64	3
45	9, 8	72.67	2037	Cu	2037.16	2
	9, 8	72.76	2036	Cu	2035.93	2
46	9	73.22	2031	Cu	2031.08	2
47	9, 8	73.61	2025	Cu	2025.53	2
48	9	75.86	2000	Cu	1999.71	3

Calibration Curve Data

Spectrum 8 Aluminum
Spectrum 9 Copper

Number	Spectrum	Position (mm.)	λ (approx.)	Element	λ (exact)	Intensity arc spark
(14)	8	76.68	1990	Al	1989.90	8
49	9	76.78	1989	Cu	1989.20	2
50	9	77.70	1979	Cu	1979.27	2
(15)	8	81.77	1935	Al	1935.29	7
(16)	8	82.24	1930	Al	1930.4	2
(17)	8	89.56	1862	Al	1862.20	4
(18)	8	90.04	1858	Al	1857.56	1
(19)	8	90.51	1854	Al	1854.09	3

Table 3 (a)

Calibration Curve Data for Visible Region

Some prominent air lines were obtained in this region and are recorded in the table. The dispersion was much less here, and consequently the accuracy is decreased so that the region was of little use although many of the sensitive lines of the elements occur in the near ultra-violet.

Spectrum	Position	λ (approx.)	Element	λ (exact)	Intensity arc spark
	13.05	4275	Cu	4275.38 4275.30	4 5
	13.30	4190	O II	4189.79	8
	13.36	4185	O II	4185.45	6
	14.35	4119	O	4119.22	8
	14.55	4097	H O II	4097.3 4097.2	3 3
		4076	O II	4075.87	10
	14.60	4072	O II	4072.16	10
		4070	O II	4069.90	10
	15.10	4042	Cu	4043.47	3
	15.51	3995	H II	3995.0	10
8	15.86	3962	Al I	3961.54	8

Calibration Curve Data for Visible Region

Spectrum	Position	λ (approx.)	Element	λ (exact)	Intensity arc spark	
8	16.06	3944	Al I	3944.02	8	
	16.31	3919	H	3919.0	7	
8	19.85	3615	Al III	3612.55	4	
8	20.02	3602	Al III	3601.62	10	
8	20.24	3587	Al II	3587.06	8	
				3586.55	10	
	23.41	3366	Cu	3365.51	3	
	24.04	3330	H II	3331.85	4	
			H	3329.3	5	
9	24.44	3308	Cu	3308.07	5	3
9	24.74	3290	Cu	3290.67	4	4

Analysis of Urinal Residue

The first body fluid to be dealt with was Urinal Residue, various samples of which were analysed. Spectra of copper and steel rods containing this residue were obtained by the procedure described in the method.

Table 4

The data for plate 3 on which these spectra were obtained are given in Table 4, in which Urinal Residue is represented by U.R.

Number	Position	Exposure	Electrodes
1	10	60 secs.	Copper
2	12	60 "	Copper and U.R.
3	14	30 "	Steel
4	24	60 "	Copper
5	26	60 mins.	Copper and U.R.
6	28	30 secs.	Steel
7	38	60 "	Copper
8	40	30 mins.	Copper and U.R.
9	42	30 "	Steel and U.R.
10	44	30 secs.	Steel
11	54	60 secs.	Copper
12	56	30 "	Steel and U.R.
13	58	30 "	Steel
14	68	60 "	Copper
15	70	5 mins.	Copper and U.R.
16	72	5 "	Copper and U.R.

Table 5

Table 5 indicated the lines in two of the spectra of the copper with Urinal Residue. In this and succeeding tables the intensity is that obtained by a visual comparison of the relative strength of the lines.

Plate 3, Spectrum 3, Cu / U.R.

Plate 3, Spectrum 5, Cu / U.R.

Position	λ	I	Element	Position	λ	I	Element
23.44	3366	6	Cu	23.42	3366	7	Cu
24.06	3330	f	Mg	24.05	3330	f	Mg
24.51	3304	1	Cu Na	24.50	3305	1	Cu Na
24.93	3290	1	Cu				
25.05	3275	8	Cu	25.05	3274	9	Cu
25.40	3253	2	Fe				
25.52	3249	8	Cu	25.55	3248	9	Cu
27.22	3161	3	Ca Cu	27.22	3161	6	Ca Cu
27.70	3135	1	Na	27.69	3136	4	Na
27.79	3131	fff	Na, K	27.88	3126	f	Cu
28.08	3116	fff	Cu	28.05	3116	f	Cu
28.40	3100	f	Cu				
28.58	3091	f	Na Mg	28.59	3090	1	Na Mg
29.05	3069	1	Fe	29.01	3060	ff	Na
29.14	3065	f	Cu	29.16	3062	5	Cu
29.27	3058	ff	Fe				
30.19	3020	ff	Cu	30.38	3010	ff	Cu
30.65	3000	ff	Cu				
31.04	2984	ff	Na, K				
31.15	2980	f	Na	31.16	2978	5	Na
31.41	2968	ff	Fe O				
31.51	2964	1	Cu	31.55	2892	5	Cu
31.59	2960	ff	Cu	31.73	2955	5	Fe
31.73	2955	1	Fe				
32.08	2942	fff	K, Mg				
32.36	2930	fff	Mg				
33.10	2900	fff	Na				

Position	λ	I	Element	Position	λ	I	Element
				33.43	2886	ff	Cu
33.57	2881	fff	Cu	33.60	2880	ff	Cu
33.65	2870	fff	Fe				
34.28	2854	f	Na	34.30	2852	2	Na
			Mg				Mg
34.67	2839	fff	Cu				
35.02	2825	ff	Cu	35.07	2824	2	Cu
35.31	2815	ff					
35.60	2804	2	Mg	35.68	2801	6	Mg
35.73	2800	1	Mg				
35.84	2795	3	Mg	35.88	2794	6	Mg
37.59	2738	1	Cu	36.63	2770	2	Cu
37.93	2727	f	Fe				
				36.17	2719	1	Cu
				36.35	2713	1	Cu
38.68	2704	f	Cu	36.73	2702	2	Cu
39.06	2691	ff	Cu	39.11	2690	1	Cu
39.45	2679	ff	Na	39.44	2680	fff	Na
				39.83	2667	fff	Cu
				40.50	2647	1	Cu
				42.18	2600	1	Cu
				42.46	2592	fff	Na, Cu
				42.66	2586	fff	Fe
43.20	2571	1	Cu				
				44.21	2545	5	Cu
44.86	2529	ff	Cu	44.85	2528	5	Cu
45.74	2507	ff	Cu	45.74	2507	3	Cu
				46.40	2490	ff	Cu
				46.60	2486	ff	Cu
				47.11	2473	ff	Cu
				47.34	2468	ff	Cu
50.06	2407	f	Cu				
				50.20	2404	4	Cu
50.38	2400	f	Cu	50.37	2400	4	Cu
50.74	2392	ff	Cu				
51.09	2386	fff	Fe				
51.48	2375	fff	Cu				
51.71	2371	8	Cu				
51.77	2370		Cu	51.78	2370	8	Cu
52.21	2361	ff	Fe	52.19	2361	ff	Fe
52.43	2356	ff	Cu	52.44	2356	ff	Cu
52.70	2351	fff	Cu, K				
55.63	2294	8	Cu	55.68	2294	8	Cu
55.94	2289	ff	Cu				
				56.03	2286	fff	Cu
56.65	2276	8	Cu	56.64	2276	8	Cu
57.37	2263	f	Cu	57.34	2264	2	Cu
				57.79	2255	fff	Cu

Position	λ	I	Element	Position	λ	I	Element
58.30	2247	9	Cu	58.30	2247	9	Cu
58.56	2243	9	Cu	58.55	2243	9	Cu
				59.27	2229	9	Cu
59.37	2230	6	Cu	59.35	2228		
				59.51	2226	ff	Cu
59.91	2220						
60.03	2218	8	Cu	60.00	2218	8	Cu
60.20	2215	1	Cu	60.20	2215	2	Cu
60.41	2212						
60.49	2210	9	Cu	60.48	2210	8	Cu
61.07	2200						
61.15	2199	7	Cu	61.13	2200	7	Cu
61.52	2193			61.31	2197	ff	Cu, Cu
61.65	2191	10	Cu	61.59	2192	8	Cu
61.70	2190			61.73	2190	8	Cu
61.78	2189	7	Cu				
62.25	2181	2	Cu				
62.35	2180			62.39	2180	9	Cu
62.44	2178	8	Cu				
62.70	2175	ff	Cu	62.68	2175	2	Cu
63.08	2169	fff					
63.34	2165	2	Cu	63.58	2165	2	Cu
63.63	2160	2	Cu	63.58	2161	2	Cu
64.26	2151	fff	Cu	64.40	2151		
64.44	2149	9	Cu	64.49	2149	8	Cu
65.25	2136			65.28	2136		
65.35	2135	10	Cu			9	
65.42	2134	1	Cu	65.41	2134		Cu
65.71	2130	ff	Cu				
65.91	2127	1					
65.95	2126	2	Cu	65.96	2125	8	Cu
66.00	2125	2	Cu				
66.06	2124	2					
66.11	2124	1					
66.15	2123	2		66.18	2123	8	Cu
66.22	2122	1					
66.50	2118	ff					
66.61	2116	ff	Cu	66.60	2117	5	Cu
66.89	2112	1	Cu				
66.99	2111	1	Cu	66.95	2112	8	Cu
67.43	2105						
67.51	2104	7	Cu	67.47	2105	8	Cu
67.93	2098	fff	Cu	67.94	2098	1	Cu
68.40	2092	fff	Fe				
68.77	2087	fff	Cu	68.75	2088	1	Cu
				68.93	2086	1	Cu
				69.43	2078	1	Cu

Position	λ	I	Element	Position	λ	I	Element
69.61	2074	fff					
71.16	2055	8	Cu	71.23	2055	8	Cu
71.29	2054						
71.70	2049	ff					
72.07	2044						
72.20	2042	8	Cu	72.12	2044	8	Cu
72.60	2038						
72.70	2037	10	Cu	72.67	2037	7	Cu
72.85	2035	f	Cu	72.76	2036	7	Cu
73.57	2026	f	Mg	73.22	2031	f	Cu
73.70	2024	f	Cu	73.61	2025	6	Cu
73.88	2022	fff					
74.20	2018	f	Cu				
				74.32	2017	f	Cu
				74.44	2016	f	Cu
				74.64	2013	f	Cu
74.78	2011	ff					
				75.86	2000	8	Cu
				76.78	1990	6	Cu
76.88	1986	fff	Cu				
76.90	1987	fff					
77.35	1982	fff					
77.58	1980	fff					
77.70	1979	fff	Cu	77.70	1979	6	Cu
78.05	1975	fff					
				81.04	1944	1	Cu
				81.42	1938	fff	Cu

Table 6

In view of the fact that good spectra of the residue could only be obtained by having very long exposures which tended to produce a fogging of the plate, a larger transformer and suitable condenser and self-induction coil were used to give a more intense spark, so that the time of exposure could be decreased.

The following table shows the spectra on plate 4, the first group with the original 10,000 volt transformer, and the next group with a 20,000 volt transformer. This apparatus was used throughout the remainder of the research and is that described under 'Electrical Apparatus'.

Number	Position	Exposure	Electrodes
1	6	2 secs.	Copper
2	10	5 "	Copper
3	14	60 mins.	Cu. & U.R.
4	18	10 secs.	Copper
5	22	15 "	Copper
6	30	2 secs.	Copper
7	34	2 mins.	Cu. & U.R.
8	38	5 secs.	Copper
9	42	5 mins.	Cu. & U.R.
10	46	10 secs.	Copper
11	50	10 mins.	Cu. & U.R.
12	54	15 secs.	Copper
13	58	15 mins.	Cu. & U.R.
14	62	30 secs.	Copper
15	66	30 mins.	Cu. & U.R.
16	70	60 mins.	Cu. & U.R.

Table 7

A spectrum of the residue in iron rods was examined and compared with the usual copper and residue spectrum to check the unknown lines. In the tables below the lines from Spectrum 9, Plate 3 and Spectrum 13, Plate 4 are given together for ready comparison.

Plate 3, Spectrum 9, Fe $\neq$ U.R.Plate 4, Spectrum 13, Cu $\neq$ U.R.

Position	λ	I	Element	Position	λ	I	Element
23.43	3366	9	H				
23.59	3358	ff	Ca, K				
24.15	3324	ff	K				
24.56	3301	f	Na	24.53	3302	15	Na
25.01	3276	f	Fe	25.03	3274	20	Cu
25.16	3267	f	Fe				
25.49	3250	ff	Cu	25.53	3248	20	Cu
25.86	3230	f	Fe	25.92	3227	f	Cu
			Ca, Na				Ca
26.20	3215	1	(Fe)	26.23	3212	1	Na
26.37	3207	f	Fe, Ca	26.52	3197	3	Fe, Cu
26.79	3184		Ca	26.80	3183	1	Ca
27.10	3168	f	Fe				
27.23	3161	2	Ca	27.20	3162	1	Cu
27.39	3152	f	Fe				
				27.52	3145	2	Cu
27.70	3155	2	Na, Fe				
27.89	3126	1	Fe	27.83	3129	2	Na
28.00	3130	1					
28.14	3113	f					
				28.21	3110	2	Cu
28.36	3102	f	K, Fe				
			Mg				
28.57	3093	1	Na (Fe)	28.52	3093	2	Cu
28.88	3076	fff	Fe				
				28.97	3072	1	Cu, Na
29.11	3067	2	Fe	29.17	3062	3	K, Cu
29.28	3057	f	K, Fe				
29.49	3048	f	Fe				
29.65	3042	ff	Fe				
29.73	3033	ff	Fe	29.78	3036	3	Cu
30.02	3026	f	Fe				
30.10	3024	2	Fe, K				
				30.33	3013	3	Cu, Ca

Plate 3, Spectrum 9, Fe $\neq$ U.R.

Position	λ	I	Element
30.40	3010	ff	Fe
30.55	3004	f	Fe
30.69	2996	ff	Ca, Fe
30.85	2992	f	Fe, K
30.90	2990		
30.95	2988	3	K
31.20	2977	f	Na(Fe)
31.37	2970	f	Fe
31.51	2962	fff	K
31.68	2957	ff	Fe
31.79	2953	f	Fe
31.87	2950	ff	Fe
32.12	2941	ff	Fe
32.42	2927	1	Mg, Fe
32.79	2922	1	Na
33.12	2900	1	Na
33.23	2892	1	Fe
33.53	2883	ff	Fe
33.66	2878	1	Fe
33.89	2869	1	Fe
34.14	2860	1	Na, (Fe)
34.32	2852	1	Mg, Fe(Na)
34.50	2845	1	Fe
34.70	2838	4	(Fe)C
34.83	2832	1	Fe
35.07	2823	f	Fe
35.19	2819	fff	K
35.38	2812	f	Fe
35.64	2802	1	Mg
35.74	2799	f	Fe
35.85	2795	1	Mg, Fe
36.09	2787	ff	Fe
36.16	2785	1	Fe
36.32	2780	1	Fe
36.63	2770	5	Fe
36.80	2764	f	Fe
37.00	2757	8	Fe
37.25	2749	9	(Fe) C
37.36	2746	f	Fe
37.48	2742	5	Fe
37.55	2739	1	Fe
37.79	2731	f	Fe
37.86	2729	2	Fe
38.13	2721	1	Fe
38.26	2717	1	Fe
38.34	2714	1	Fe

Plate 4, Spectrum 13, Cu $\neq$ U.R.

Position	λ	I	Element
30.63	3000	1	Ca, Cu
31.07	2981	f	Na
31.53	2962	10	Cu
32.40	2927	f	Mg
33.46	2885	2	Cu
34.31	2852	10	Na, Mg
35.05	2824	10	Cu
35.66	2802	10	Mg
35.86	2794	10	Mg
36.27	2781	1	Mg
36.63	2770	9	Cu
37.14	2752	1	Cu
38.17	2719	1	Cu
38.34	2713	1	Cu

Plate 3, Spectrum 9, Fe $\neq$ U.R.

Position	λ	I	Element
38.61	2706	1	Fe
38.79	2700	1	Hg, Fe
38.98	2694	2	Fe
39.10	2690	ff	Fe
39.22	2686	1	Fe
39.47	2679	3	Na, Fe
39.64	2673	ff	Na, Hg
39.89	2666	5	Fe
40.11	2659	ff	Fe
40.35	2652	ff	Fe
41.01	2632	8	Fe
41.11	2630	1	Fe
41.22	2627	3	Fe
41.36	2623	ff	Fe
41.49	2620	2	Fe
41.70	2615	8	Fe
41.88	2608	7	Fe
42.20	2600	9	Fe
42.41	2594	1	Na (Fe)
42.57	2589	f	Fe
42.64	2586	5	Fe
42.76	2585	1	Fe
42.96	2578	f	Fe
43.07	2575	f	Fe
43.19	2572	f	Fe
43.35	2568	f	Fe
43.51	2563	5	Fe
43.58	2562	f	Fe
43.79	2556	ff	Fe
44.01	2550	f	Fe
44.41	2541	4	Fe
44.48	2539	1	Fe
44.61	2535	1	Fe
44.78	2530	1	Fe
44.93	2527	1	Fe
45.09	2523	f	Fe
45.23	2520	f	Fe
45.41	2515	f	Fe
45.49	2513	3	Fe
45.74	2507	f	C, Fe
45.84	2505	1	Fe
46.02	2500	3	Fe
46.24	2495	6	Fe
46.39	2492	4	Fe
46.51	2488	fff	Fe

Plate 4, Spectrum 13, Cu $\neq$ U.R.

Position	λ	I	Element
38.72	2703	3	Cu
39.09	2690	2	Cu
39.40	2681	1	Na (Cu)
39.85	2667	1	Cu
40.45	2649	f	Fe
40.93	2635	f	K
41.15	2629	f	Cu
41.46	2621		Cu
41.54	2618	10	Cu
42.17	2600	4	Cu
42.50	2591	f	Cu
42.94	2579	f	Fe
44.23	2545	3	Cu
44.90	2520	2	Cu
45.74	2506	2	C, Cu
46.35	2492	10	Cu
46.43	2490	f	Cu
46.58	2486	1	Cu

Plate 3, Spectrum 9, Fe / U.R.

Plate 4, Spectrum 15, Cu / U.R.

Position	λ	I	Element	Position	λ	I	Element
46.63	2485	4	Fe				
46.80	2481	1	Fe				
46.87	2480	f	Fe	46.88	2479	3	Cu
47.03	2476	f	C (Fe)	47.10	2473	1	Cu
47.10	2474	1	Fe				
47.22	2472	1	Fe				
47.39	2468	2	Fe				
47.59	2464	3	Fe				
47.70	2461	2	Fe				
47.90	2455	f	Fe				
48.08	2452	ff	Fe, Na				
48.20	2450	f	Fe				
48.30	2447	4	Fe				
48.54	2442	2	Fe	48.49	2443	9	Cu
48.75	2437	2					
48.85	2434	2	Fe				
49.02	2431	3	Fe				
49.21	2427	2	Fe	49.24	2425	f	Cu
49.26	2425	f	(Fe)				
49.52	2420	f	Fe				
49.73	2415	2	(Fe)				
49.85	2412	6	Fe				
50.04	2408	5	Fe	50.08	2407	2	Cu
50.12	2406	6	Fe				
				50.21	2404	3	Cu
50.57	2400	4	Fe	50.58	2400	3	Cu
50.56	2396	7	Fe				
				50.71	2392	9	Cu
50.87	2390	5	Fe				
51.21	2382	9	Fe				
51.30	2380	f	Fe				
51.51	2375	f	Fe	51.50	2376	f	Cu
51.57	2374	2	Fe				
51.82	2370	3	Fe	51.73	2370	10	Cu
51.95	2367	f	Fe				
52.02	2365	5	Fe				
52.28	2360	8	Fe				
52.51	2355	2	Fe	52.46	2356	3	Cu
52.59	2352	ff	Fe				
52.84	2349	6	Fe				
53.07	2344	9	Fe				
53.34	2339	3	Fe				
				53.47	2334	f	Cu
53.61	2333	4	Fe				
53.68	2331	3	Fe				
				54.51	2327	f	Fe
54.57	2313	fff	Fe				
54.71	2311	fff	Fe				
54.96	2305	fff	Fe				
55.14	2302	fff	Fe	55.20	2301	9	Fe, Cu

Plate 3, Spectrum 9, Fe γ H.R. Plate 4, Spectrum 13, Cu γ U.R.

Position	λ	I	Element	Position	λ	I	Element
55.40	2295	ff	C	55.64	2294	12	Cu
55.84	2291	fff	Fe	56.05	2286	1	Cu
56.22	2284	ff	Fe				
56.47	2280	ff	Fe				
56.65	2276	fff	Ca, K	56.65	2276	10	Cu
57.27	2265	ff	Fe	57.30	2264	10	Cu
57.57	2260	ff	Fe	57.57	2260	1	Cu
57.79	2256	ff	K(Fe)	57.95	2255	1	Cu
58.05	2251	f	Fe				
58.15	2249	f	K, Fe	58.31	2247	15	Cu
58.57	2245	ff	Fe	58.57	2242	15	Cu
				58.90	2237	3	
59.31	2230	ff	Fe	59.10	2235	3	Cu
59.52	2227	f		59.44	2227	3	Cu
59.87	2220	f	Fe	59.62	2224	3	
60.27	2214	ff	Fe	60.00	2218	15	Cu
60.56	2210	ff		60.30	2215	10	Cu
60.69	2207	fff	Ca	60.50	2210	10	Cu
60.85	2204	ff	K				
61.35	2196	fff	CaIII	61.05	2201	ff	Cu
				61.14	2200	10	Cu
62.70	2174	ff		61.34	2196	3	Cu
63.00	2170	fff		62.27	2181	10	Cu
63.55	2160	ff	Fe	63.07	2169	3	Cu
64.69	2115	fff	Ca	73.67	2025		
				82.35	1930	2	C

Analysis of Blood Serum

After obtaining the data represented by the preceding tables attention was directed to the analysis of blood serums. These were at first evaporated, and the residues examined as in the previous cases. Some attempts were then made with the blood serum itself. Various difficulties were encountered, due to the high viscosity of the fluid, and to rapid evaporation producing a crust over the liquid. However, using electrodes described in the discussion of the apparatus, data was obtained which was substantially in agreement with the results for the residues.

Particulars of two of the spectra of the copper and blood serum residue are given below and the lines are listed in Table 8.

Plate	Number	Position	Exposure	Electrodes
5	12	66	20 secs.	Cu ∇ B.S.
6	7	36	15 secs.	Cu ∇ B.S.

Table 8

Plate 5, Spectrum 12, Cu ∇ B.S.

Plate 6, Spectrum 7, Cu ∇ B.S.

Position	λ	I	Element	Position	λ	I	Element
				16.50	3920	5	C
				16.66	3686	1	Fe, C
				17.12	3640	5	Mg
				17.25	3628	3	Mg
				17.51	3603	3	K
				17.87	3772	4	Cu
				18.13	3750	3	Fe

Plate 5, Spectrum 12, Cu / B.S.

Position	λ	I	Element
19.83	3612	2	Cu
20.00	3603	5	Cu
20.20	3590	f	C
20.57	3563	3	Fe
21.00	3533	4	Cu
21.17	3520	f	Cu
21.81	3477	1	Cu
22.22	3449	1	K, Cu
22.32	3442	5	K
22.77	3413	ff	Cu
23.05	3394	4	Fe
23.28	3377	ff	Cu
23.48	3365	f	Cu
24.02	3332	6	Mg
24.52	3302	5	Na
24.76	3294	f	(Cu), K
25.04	3274	10	Cu
25.36	3255	1	
25.52	3249	10	Cu
25.73	3238	f	Cu, K
26.01	3224	ff	Cu
26.53	3197	1	Cu
26.79	3184	f	Ca
27.00	3173	f	Ca
27.16	3164	f	Cu
27.44	3149	f	Na
27.58	3141	2	Cu
27.83	3129	f	K, Na
28.23	3108	1	Cu
28.52	3094	1	Cu

Plate 6, Spectrum 7, Cu / B.S.

Position	λ	I	Element
18.41	3727	1	Fe
18.56	3714	1	Na,
18.71	3701	8	Cu
18.90	3686	2	Cu
19.27	3656	f	Cu
19.87	3610	10	K
20.01	3602	3	Cu
20.25	3586	f	C
20.51	3568	f	Fe
20.72	3554	ff	Fe
21.05	3524	f	Cu
21.24	3515	3	Cu
21.56	3492	ff	Fe, Ca
21.79	3479	3	Cu
22.15	3453	2	Cu
22.33	3441	6	K
22.60	3424	ff	Cu
22.78	3413	1	Cu
23.07	3392	1	Fe
23.27	3378	1	Cu
23.47	3365	1	Cu
23.67	3352	f	Cu
23.89	3340	2	Cu
24.07	3329	5	Mg
24.23	3320	f	Cu
24.44	3304	4	Na
24.78	3294	3	(Cu), K
25.05	3275	10	Cu
25.32	3257	7	
25.52	3248	10	Cu
25.72	3238	ff	Cu, K
26.02	3224	ff	Cu
26.26	3212	ff	Na, Ca
26.54	3197	f	Cu
26.66	3191	1	Na, K
26.75	3186	5	Ca
26.98	3174	ff	Ca
27.17	3164	3	Cu
27.42	3150	f	Na
27.64	3139	4	Cu
27.86	3127	f	Cu
28.09	3116	ff	Cu
28.21	3109	1	Cu
28.40	3100	ff	Cu
28.64	3088	fff	Mg

Plate 5, Spectrum 12, Cu $\nearrow$ B.S.

Position	λ	I	Element
28.89	3076	f	Na, Cu
29.19	3063	f	Cu
29.32	3056	f	Na, K
29.52	3047	ff	Fe
29.74	3038	ff	Cu
30.02	3027	1	Fe
30.39	3011	2	Cu
30.72	2996	f	Cu
31.00	2985	1	K
31.47	2966	1	Cu
31.72	2955	f	Fe
32.07	2942	ff	Mg
32.56	2923	ff	Na
32.65	2909	ff	Na
33.04	2902	ff	Na
33.30	2892	1	Fe
33.53	2882	1	Cu
33.91	2868	f	
34.22	2856	2	K
34.63	2840	6	Cu
34.99	2826	2	Cu
35.46	2809	1	Na
35.64	2802	8	Mg
35.82	2796	9	Mg
35.92	2793	f	Mg
36.21	2783	f	Mg
36.55	2772	6	Cu
37.24	2749	3	Cu
37.64	2736	f	Cu
38.11	2721	3	Cu
38.23	2716	4	Cu
38.65	2704	7	Cu

Plate 6, Spectrum 7, Cu $\nearrow$ B.S.

Position	λ	I	Element
28.94	3074	fff	Cu
29.19	3062	ff	Cu
29.55	3045	1	Fe
29.77	3037	1	Cu
30.05	3026	1	Fe
30.25	3016	f	Fe
30.41	3010	5	Cu
30.96	2987	3	K
31.12	2980	f	Na
31.51	2964	3	Cu
31.71	2955	ff	
31.92	2948	fff	Na
32.08	2942	ff	Mg
32.56	2929	fff	Mg
33.43	2886	4	Cu
33.69	2860	4	Cu
34.15	2859	ff	Na
34.29	2853	2	Na, Mg
34.68	2838	7	Cu
34.93	2829	f	
35.05	2823	4	Cu
35.54	2806	1	
35.66	2801	10	Mg
35.86	2794	10	Mg
35.98	2791	1	Mg
36.25	2781	ff	Mg
36.47	2776	f	Mg
36.60	2771	7	Cu
37.00	2757	ff	
37.12	2753	ff	Cu
37.32	2746	3	Cu
37.55	2739	f	Cu
38.04	2726	f	Fe
38.14	2720	8	Cu
38.31	2715	7	Cu
38.72	2702	9	Cu

Plate 5, Spectrum 12, Cu $\neq$ B.S.

Position	λ	I	Element
39.02	2692	5	Fe
39.18	2687	1	Fe
39.78	2669	1	Mg
39.94	2664	1	Cu
40.57	2651	ff	Cu
40.62	2644	1	Cu
40.92	2634	1	K, Mg
41.16	2629	2	Mg
41.43	2621	5	Cu
41.72	2612	3	Fe, Na
41.97	2605	1	Mg
42.09	2602	4	Cu
42.43	2592	1	Cu
42.77	2582	3	Fe
42.89	2578	3	Fe
43.11	2573	f	Cu
43.34	2568	f	Cu
43.62	2555	1	
43.97	2552	1	K
44.15	2547	9	Cu
44.40	2541	3	Cu
44.64	2534		Cu
44.76	2531	4	Cu
45.15	2521	2	Cu
45.42	2513	4	Cu
45.67	2509	7	Cu
46.02	2500	f	Cu
46.26	2494	f	Cu
46.36	2491	2	Cu
46.45	2490	3	Cu

Plate 6, Spectrum 7, Cu $\neq$ B.S.

Position	λ	I	Element
38.97	2694	f	Fe
39.10	2690	8	Cu
39.65	2667	5	Mg
39.96	2664	ff	Cu
40.41	2650	ff	Cu
40.50	2648	f	Fe
40.60	2645	2	Cu
40.69	2642	f	
41.06	2631	1	Mg
41.57	2623	f	
41.46	2619	4	Cu
41.70	2613	f	Fe, Na
41.83	2609	3	Cu
42.05	2603	8	Cu
42.19	2600	8	Cu
42.39	2594	f	Na
42.46	2592	5	Cu
42.64	2587	f	Cu
42.90	2579	f	Fe
43.01	2576	f	Fe
43.15	2573	1	Cu
43.26	2570	ff	Cu
43.39	2567	f	Cu
43.52	2563	f	Fe
43.77	2556	f	
43.88	2553	3	
44.08	2549	7	K, Cu
44.25	2544	9	Cu
44.45	2539	f	Cu
44.66	2534	f	Cu
44.82	2530	6	Cu
44.92	2527	f	Cu
45.07	2523	1	Cu
45.23	2520	1	Cu
45.32	2516	f	Cu
45.54	2512	f	Cu
45.77	2506	8	Cu
46.11	2496	1	Cu
46.33	2492	1	Cu
46.44	2490	7	Cu

Plate 5, Spectrum 12, Cu $\neq$ B.S.

Position	λ	I	Element
46.85	2480	10	Cu
47.01	2476	2	Cu $\neq$ C
47.22	2471	2	Fe
47.61	2463	1	Cu
47.88	2457	f	Cu
48.24	2449	5	
48.39	2445	1	Cu
48.65	2439	f	Cu
48.78	2436	1	Cu
48.90	2433	f	Cu
49.19	2426	f	Cu
49.53	2419	ff	Cu
49.72	2414	f	Cu
50.12	2406	9	Cu
50.30	2402	8	Cu
50.68	2394	f	Cu
51.40	2378	f	K, Cu
51.75	2370	15	Cu
52.39	2358	4	Cu
52.86	2348	f	Cu
53.39	2338	1	Fe
54.07	2323	3	Cu
54.40	2317	4	Cu
54.77	2310	f	
55.14	2302	1	Cu

Plate 6, Spectrum 7, Cu $\neq$ B.S.

Position	λ	I	Element
46.53	2488	7	Cu
46.77	2481	f	Cu
46.89	4479	5	Cu
47.10	2474	5	Cu
47.31	2470	5	Cu
47.53	2465	f	Cu
47.73	2460	1	Cu
47.97	2456	1	Cu
48.21	2449	1	
48.31	2446	6	Cu
48.49	2443	f	Cu
48.79	2436	f	Cu
48.99	2432	f	Cu
49.12	2428	f	Cu
49.25	2426	5	Cu
49.60	2415	3	Cu
49.82	2408	ff	Cu
50.23	2404	10	Cu
50.38	2400	9	Cu
50.58	2396	f	Fe, Cu
50.76	2392	f	Cu
51.10	2385	f	
51.20	2382	1	Fe, K
51.47	2377	7	Cu
51.71	2371	7	Cu
51.85	2369	10	Cu
52.45	2356	7	Cu
52.54	2355	f	Cu
52.84	2349	3	Cu
52.95	2347	f	Cu
53.09	2344	f	Fe
53.35	2339	1	Fe
53.47	2336	5	Cu
53.69	2331	ff	Fe
54.12	2322	f	Cu
54.22	2320	f	Cu
54.48	2316	4	Cu
54.86	2307	2	
55.20	2302	2	Cu
55.33	2300	1	Fe

Plate 5, Spectrum 12, Cu $\nearrow$ B.S.Plate 6, Spectrum 7, Cu $\nearrow$ B.S.

Position	λ	I	Element	Position	λ	I	Element
55.43	2298	10	Fe	55.51	2297	9	C
55.62	2294	10	Cu	55.70	2293	9	Cu
55.76	2292	f	Cu	55.85	2291	2	Cu
56.05	2287	5	Cu	56.10	2286	6	Cu
56.61	2276	12	Cu	56.52	2278	7	Cu
57.28	2265	8	Cu	56.70	2275	8	Ca, K
57.77	2256	2	Cu	56.93	2270	ff	
58.00	2252	2	Cu	57.24	2265	8	Cu
58.29	2247	12	Cu	57.40	2263	8	Cu
58.56	2245	12	Cu	57.51	2261	ff	Cu
59.00	2238	f	Cu	57.85	2254	6	Cu
59.39	2236	15	Cu	58.08	2250	4	Cu
59.53	2229	2	Cu	58.39	2246	15	Cu
60.01	2218	12	Cu	58.65	2242	12	Cu
60.15	2216	9	Cu	59.11	2234	f	Cu
60.48	2210	12	Cu	59.47	2228	15	Cu
61.10	2200	10	Cu	59.64	2225	9	Cu
61.34	2196	8	Cu	60.08	2217	15	Cu
61.56	2193	10	Cu	60.26	2214	10	Cu
61.76	2189	10	Cu	60.60	2208	12	Ca, Cu
62.41	2179	12	Cu	61.20	2198	12	Cu
62.66	2175	9	Cu	61.40	2194	10	Cu
63.30	2165	5	Cu	61.66	2191	12	Cu
63.54	2162	8	Cu	61.85	2188	10	Cu
63.78	2158	f		62.16	2182	3	Cu
64.14	2153	4	Cu	62.51	2177	12	Cu
64.40	2149	10	Cu	62.76	2173	10	Cu
64.59	2145	3	Fe	63.42	2164	6	Cu
64.80	2143	ff		63.65	2160	10	Cu
				63.91	2156	3	Cu
				64.22	2152	8	Cu
				64.51	2147	12	Cu
				64.70	2144	6	Fe

Plate 5, Spectrum 12, Cu $\nearrow$ B.S.Plate 6, Spectrum 7, Cu $\nearrow$ B.S.

Position	λ	I	Element	Position	λ	I	Element
64.98	2140	15	Fe	65.06	2139	1	Cu
65.40	2134		Cu	65.38	2135	12	Cu
				65.49	2133	8	Cu
65.64	2131	3	Cu	65.69	2130	1	Cu
65.99	2125	10	Cu	66.02	2125	12	Cu
66.20	2123	10	Cu				
				66.30	2121	12	Cu
66.58	2117	9	Cu	66.57	2117	9	Cu
				66.67	2116	8	Cu
66.98	2112	10	Cu				
				67.09	2110	12	Cu
67.49	2105	10	Cu	67.41	2106	9	Cu
				67.59	2103	8	Ca
67.92	2099	8	Cu				
				68.03	2097	10	Cu
68.29	2094	8	Fe	68.28	2094	3	Fe
				68.36	2093	3	
68.71	2088	6	Cu	68.81	2087	10	Cu
68.90	2086	8	Cu	68.99	2085	7	Cu
69.39	2080	8	Cu				
				69.49	2078	10	Cu
				69.61	2076	f	
70.01	2071	ff					
				70.15	2069	f	
70.36	2067	2	Cu				
70.47	2066	f	Cu	70.46	2065	5	Cu
70.66	2063	3	Fe	70.77	2061	9	Fe
71.28	2055	12	Cu	71.23	2055	8	Cu
				71.38	2053	8	
71.87	2046	f		71.92	2046	f	
72.17	2043	12	Cu	72.27	2042	12	Cu
72.41	2040	15	Fe, Cu				
				72.90	2034	20	Cu
72.81	2035		Cu	73.26	2030	9	Cu
73.17	2031	8	Cu	73.74	2024	10	Cu
73.65	2025	10	Cu	74.00	2021	ff	
74.26	2019	f	Cu	74.31	2017	f	Cu
74.36	2017	2	Cu	74.44	2016	4	Cu
74.49	2015	f	Cu	74.58	2014	3	
				74.75	2012	4	Cu
74.68	2013	2	Cu				

Plate 5, Spectrum 12, Cu γ B.S. Plate 6, Spectrum 7, Cu γ B.S.

Position	λ	I	Element	Position	λ	I	Element
75.89	1999	12		75.96	1998	12	Cu
76.08	1997	3	Cu	76.86	1988	12	Cu
76.78	1989	11	Cu	77.76	1978	12	Cu
77.67	1979	12	Cu	78.61	1969	4	Cu
78.51	1970	2	Cu	79.24	1962	fff	
				79.67	1958	fff	
80.90	1944	1	Cu	80.91	1944	2	Cu
				81.07	1942	4	
				81.51	1938	fff	Cu
82.35	1929	12	C	82.26	1930	3	C
				82.44	1928	4	
				83.16	1922	2	
83.06	1921	2					
84.12	1915	22	Fe	84.15	1915	2	Fe
86.03	1895	22	Fe				
86.98	1886	2	Mg	87.21	1873	2	Ca
90.14	1857	2	Mg	90.15	1857	2	Mg

Table 9

Many of the persistent lines of the elements occur in the near ultra-violet region, but this part of the spectrum had been overexposed in securing good definition for the rest of the spectrum. In order to investigate this region more thoroughly a number of spectra were obtained with short exposures, so as to have this region clear.

The lines from two of these spectra are given in Table 9, the exposure time in both cases being 10 seconds, but in the case of spectrum 8, there was no self-induction in the circuit.

Plate 7, Spectrum 7, Cu $\neq$ B.S.

Plate 7, Spectrum 8, Cu $\neq$ B.S.

Position	λ	I	Element	Position	λ	I	Element
13.15	4260	2	Cu, K				
13.58	4232	6	Ca				
13.64	4204	f	Fe				
13.78	4186	f	K				
13.91	4170	f	Mg				
14.02	4156	f	Fe				
14.64	4086	f	Fe				
14.79	4072	5	Fe				
14.96	4058	1	Cu, K				
15.14	4038	5	Cu	15.12	4038	5	Cu
				15.49	4002	6	K
15.57	3993	2	K				
15.71	3975	7	Ca, K	15.75	3973	5	Ca, K
15.91	3958	2	Cu, Ca	15.97	3950	f	Cu, Ca
16.06	3942	9	K	16.11	3938	7	
				16.29	3920	f	O
16.46	3904	3	Fe				
16.60	3891	10	Fe	16.65	3887	2	Fe
17.02	3850	12	Fe	17.00	3852	10	Fe
17.25	3828	10	Mg	17.23	3830	5	Mg
				17.56	3800	ff	Cu
17.89	3770	ff	Cu				
				18.00	3760	fff	Cu

Plate 7, Spectrum 7, Cu γ B.S.Plate 7, Spectrum 8, Cu γ B.S.

Position	λ	I	Element	Position	λ	I	Element
18.24	3742	ff	Fe	18.14	3750	4	Fe
18.84	3692	f	Cu	18.41	3726	2	
19.29	3656	f	Cu	18.66	3704	fff	Fe, Ca
20.00	3603	2	Cu	18.97	3680	fff	Fe, K
20.18	3592	5	Cu	19.35	3652	fff	Cu
20.97	3536	5	Cu	19.57	3634	4	Cu
21.16	3521	f	Cu	20.00	3603	5	Cu
21.60	3490	f	Ca	20.54	3566	f	Fe
21.71	3483	f	Cu	20.80	3560	fff	
22.10	3456	f	Cu	21.00	3534	ff	Cu
22.66	3420	ff	Cu	21.20	3510	ff	Cu
22.84	3409	ff	K	21.58	3491	f	
23.20	3384	ff	Cu	21.79	3478	1	Cu
23.40	3365	1	Cu	22.17	3451	2	Cu
23.75	3348	f	Cu	22.30	3443	6	Fe, K
23.90	3338	1	Cu	22.62	3422	fff	Cu
24.23	3320	f	Cu	22.80	3411	fff	
24.32	3314	2	K	23.06	3393	1	Fe
24.47	3303	10	Na	23.30	3376	f	K
24.71	3292	2	Cu	23.46	3363	f	Cu, K
24.82	3286	5	Cu	23.73	3349	ff	Cu
25.04	3274	10	Cu	23.88	3340	5	Cu
25.27	3261	7	Cu	24.04	3332	6	Mg
25.53	3248	10	Cu	24.33	3314	ff	K
26.25	3212	ff	Na, (Cu)	24.43	3306	5	Cu
26.47	3201	2	K	24.51	3304	ff	Na
26.76	3185	f	Ca	24.75	3290	2	Cu
26.95	3176	ff		24.88	3282	5	Cu
				25.04	3274	10	Cu
				25.32	3259	7	Cu
				25.53	3248	10	Cu
				25.78	3236	f	Cu
				26.57	3196	1	Cu
				26.77	3185	1	Ca
				26.98	3174	fff	Ca
				27.20	3162	ff	Cu, Ca
				27.44	3150	f	Ca, Cu
				27.62	3140	f	Cu

Plate 7, Spectrum 7, Cu $\neq$ B.S.Plate 7, Spectrum 8, Cu $\neq$ B.S.

Position	λ	I	Element	Position	λ	I	Element
27.73	3131	4	K, Na	27.84	3129	f	Na, K
28.15	3112	4	Cu	28.23	3109	f	Cu
				28.40	3100	f	Cu
28.49	3096	f	Hg	28.56	3093	ff	Cu, Na
28.94	3074	f	Cu, Na				
29.09	3067	5	Cu				
29.60	3044	f					
29.71	3039	5	Cu	29.73	3039	ff	Cu
30.09	3023	ff	Cu	30.10	3024	ff	Cu
30.16	3021	f	Cu				
30.23	3016	5	Fe	30.25	3016	ff	Fe
				30.39	3011	4	Cu
				30.51	3006	fff	Ca
30.60	3002	2	Ca, Cu	30.86	2991	fff	C, K
31.07	2983	ff	Fe, Na	31.10	2982	ff	Fe, Na
31.33	2972	5	Fe	31.37	2970	ff	Fe
31.46	2966	7	C, Cu	31.51	2964	ff	Cu
				31.73	2955	fff	Fe
33.32	2891	f					
33.44	2886	1		33.45	2885	1	
33.57	2882	f	Cu	33.60	2880	1	
34.11	2860	5	Na	34.13	2860	fff	Na
34.25	2855	7	Hg, Na	34.30	2853	fff	Hg, Na
				34.56	2843	ff	Na
				34.69	2839	ff	Cu
34.87	2830	5	Fe	34.92	2829	ff	Fe
35.01	2825	7	Cu	35.05	2824	1	Cu
35.51	2807	f	Fe	35.54	2806	f	Fe
35.64	2802	5	Hg	35.65	2802	5	Hg
35.71	2800	ff	Hg	35.72	2800	ff	Hg
35.83	2796	7	Hg	35.86	2795	8	Hg

Analysis of Liquid SerumTable 10

As described in the discussion of the 'Electrodes' a special type of lower electrode was devised to enable the blood serum to be used in liquid form. Details of Plate 8, on which two spectra of the serum were obtained are given in Table 10.

Number	Position	Exposure	Electrodes
1	20	60 secs.	Copper
2	22	10 mins.	Cu. & Blood Serum
3	26	60 secs.	Copper
4	40	60 secs.	Copper
5	44	6 mins.	Cu. & Blood Serum
6	48	60 secs.	Copper

Table 11

The lines from spectra 2 and 4 of plate 8 are shown in Table 11. For spectrum 2 the exposure was continuous, but for spectrum 4 the spark was passed intermittently for short periods, with a fresh drop of the serum added to the lower electrode between exposures. It will be noticed that the intensities are slightly less in the case of spectrum 4, but otherwise the spectra are very similar.

Plate 3, Spectrum 2, Cu $\frac{1}{2}$ B.S. (liquid) Plate 3, Spectrum 4, Cu $\frac{1}{2}$ B.S. (liquid)

Position	λ	I	Element	Position	λ	I	Element
23.57	3358	14	K	23.45	3365	9	Cu, K
23.94	3336	4	Cu	23.59	3358	8	K
				23.95	3337	1	Cu
				24.35	3312	f	K
24.52	3304	15	Na	24.45	3308	10	Cu
25.05	3274	20	Cu	24.55	3302		Na
25.52	3248	20	Cu	25.06	3274	20	Cu
25.76	3236	ff	Cu	25.57	3248	20	Cu
25.94	3227	f	Cu	25.72	3238	fff	Cu
26.23	3212	1	Na	25.94	3228	f	Cu
26.47	3200	4	K	26.26	3212	f	Na
26.80	3182	fff	Ca	26.53	3198	3	K
27.22	3162	f	Cu	26.85	3181	f	Ca
				27.23	3161	f	Cu
27.85	3123	3	Cu	27.52	3145	ff	Cu
28.23	3109	3	Cu	27.87	3126	1	Cu
				28.24	3108	f	Cu
28.57	3091	3	Cu	28.40	3100	1	Cu
29.02	3069	f	Cu	28.57	3091	1	Cu
29.17	3062	3	Cu	28.95	3074	5	Cu
29.67	3040	1		29.17	3064		Cu
29.78	3036	4	Cu	29.68	3039	ff	
30.23	3017	f		29.79	3036	3	Cu
30.35	3012	4	Cu	30.20	3017	f	
30.66	3000	3	Cu	30.35	3012	3	Cu
31.34	2971	f	Cu	30.68	2999	2	Cu
31.53	2962	9	Cu	31.32	2972	f	Cu
31.73	2955	ff		31.52	2962	9	Cu
32.04	2942	fff	Mg	31.74	2955	ff	
32.39	2928	fff	Mg	32.07	2941	fff	Mg
33.35	2890	f		32.46	2926	ff	Mg
33.48	2884	3	Cu	33.37	2889	f	
33.64	2878	f	Cu	33.49	2884	2	Cu
34.22	2855	f		33.64	2878	f	Cu
34.50	2852	4	Mg, Na	34.20	2856	1	
34.70	2836	ff	Cu	34.30	2852	4	Mg, Na
34.93	2829	5		34.72	2837	fff	Cu
35.08	2823	9	Cu	34.94	2828	1	
35.58	2804	f	Mg	35.07	2824	8	Cu
35.70	2800	5	Mg	35.56	2804	1	Mg
				35.70	2800	6	Mg
35.89	2794	8	Mg	35.77	2798	1	Mg
36.53	2773	f	Fe	35.88	2794	7	Mg
36.62	2770	6	Cu	36.55	2772	f	Fe
36.74	2766	8	Cu	36.63	2770	1	Cu
				36.73	2766	4	Cu

Plate 8, Spectrum 2, Cu $\frac{1}{2}$ B.S.Plate 8, Spectrum 4, Cu $\frac{1}{2}$ B.S.

Position	λ	I	Element	Position	λ	I	Element
37.17	2752	f	Cu	37.19	2757	fff	Cu
37.39	2745	f	Cu	37.30	2745	fff	Cu
37.58	2738	f	Cu	37.57	2737	fff	Cu
38.08	2732	2	Cu	38.10	2722	f	Cu
38.19	2718	4	Cu	38.20	2719	1	Cu
				38.27	2716	ff	Fe
38.36	2713	4	Cu	38.36	2713	1	Cu
38.61	2705	f	Cu	38.66	2704	2	Cu
38.74	2702	5	Cu	38.75	2701	4	Cu
39.05	2692	f	Fe	39.02	2693	f	Fe
39.13	2690	4	Cu	39.15	2690	2	Cu
39.48	2678	fff	Na	39.47	2678	ffff	Na
39.90	2665	f	Cu	39.91	2666	ff	Cu
40.13	2659	fff	Mg	40.13	2659	ffff	Mg
40.35	2652	fff	Cu	40.31	2653	ffff	Cu
40.60	2644	ffff	Cu	40.47	2648	ffff	Cu
40.94	2635	fff	Cu, K	40.59	2636	ffff	Cu, K
41.14	2629	fff	Fe				
41.41	2621	2	Cu	41.45	2620	3	Cu
41.57	2617	10	Cu	41.57	2617	10	Cu
42.09	2603	f	Mg	42.07	2603	ff	Mg
42.21	2600	6	Cu	42.19	2600	4	Cu
42.51	2591	2	Cu	42.50	2591	ff	Cu
				42.56	2589	ffff	
42.71	2585	ffff	Fe				
42.95	2578	ffff	Cu	42.95	2578	ffff	Cu
43.22	2571	f	Cu	43.16	2572	ffff	Cu
43.48	2564	fff	Cu	43.47	2564	ffff	Cu
43.93	2552	fff	Cu	43.93	2552	fff	Cu
44.17	2546	1	Cu	44.17	2546	2	Cu
44.26	2544	7	Cu	44.25	2544	4	Cu
44.64	2538	3	Cu	44.81	2530	1	Cu
44.92	2525	2	Cu	44.95	2525	f	Cu
45.69	2508	9	Cu	45.70	2508	f	Cu
45.76	2507		Cu	45.76	2506		Cu
46.34	2492	12	Cu	46.32	2492	2	Cu
46.44	2490	f	Cu	46.43	2489	2	Cu
46.60	2486	f	Cu	46.60	2486	ff	Cu
46.90	2478	10	Cu	46.80	2481	2	Cu
47.12	2474	1	Cu	47.10	2473	f	Cu
47.33	2469	f	Cu	47.29	2468	ff	Cu
47.73	2460	fff	Cu				
48.16	2450	fff	Cu				
48.41	2444	9	Cu	48.43	2444	8	Cu
48.49	2442			48.52	2442		
48.71	2438	fff	Cu	48.77	2437	fff	Cu
49.04	2431	ffff	Cu	49.03	2430	fff	Cu
49.26	2426	f	Cu	49.25	2425	fff	Cu
49.50	2420	ffff					
				49.63	2417	fff	Cu

Plate 3, Spectrum 2, Cu γ B.S.Plate 3, Spectrum 4, Cu γ B.S.

Position	λ	I	Element	Position	λ	I	Element
49.84	2413	fff	Cu	49.84	2412	fff	Cu
50.00	2410	fff	Cu	50.09	2407	ff	Cu
50.17	2405	2	Cu	50.16	2405	f	Cu
50.22	2404	5	Cu	50.29	2404	f	Cu
50.39	2400	6	Cu	50.38	2400	3	Cu
				50.64	2394	f	Cu
50.74	2393	4	Cu	50.74	2392	3	Cu
50.91	2388	fff		51.02	2386	fff	
51.09	2385	fff	Cu	51.10	2384	fff	Cu
51.50	2376	1	Cu	51.49	2376	ff	Cu
				51.74	2370		Cu
51.84	2369	15	Cu	51.84	2369	15	
52.46	2356	5	Cu	52.44	2356	1	Cu
52.53	2355	f	Cu	52.49	2356	f	Cu
52.86	2343	ff	Cu	52.86	2343	fff	Cu
53.49	2334	f	Cu	53.48	2335	fff	Cu
53.72	2330	fff	Fe				
54.13	2322	fff	Cu	54.16	2321	ffff	Cu
54.37	2317	fff	Cu	54.36	2316	ffff	Cu
54.48	2315	fff	Cu				
54.55	2313	fff	Fe	54.76	2309	ffff	Cu
54.89	2307	fff		54.93	2306	fff	
55.13	2302		Cu	55.14	2303	2	Cu
55.22	2300	6	Cu	55.23	2300	f	Cu
55.52	2295		Cu	55.64	2293		Cu
55.76	2292	12	Cu	55.74	2292	10	Cu
56.08	2286	1	Cu	56.07	2286	fff	Cu
56.35	2281	ffff	Cu	56.31	2281	fff	Cu
56.62	2276	10	Cu	56.70	2275	10	Cu
57.36	2263	9	Cu	57.41	2263	8	Cu
57.54	2260	f	Cu	57.55	2260	2	Cu
57.85	2255	1	Cu	57.85	2255	fff	Cu
58.35	2247	15	Cu	58.40	2246	15	Cu
58.60	2242	15	Cu	58.64	2242	15	Cu
58.81	2239	f	Cu	58.82	2239	ff	Cu
58.95	2236	f	Cu	58.94	2236	ff	Cu
59.44	2227	15	Cu	59.45	2227	20	Cu
59.60	2224	15	Cu	59.56	2225	5	Cu
60.00	2216	12	Cu	60.10	2216	10	Cu
60.23	2214		Cu	60.25	2214	10	Cu
60.28	2213	12	Cu				
60.50	2210	12	Cu	60.55	2209	10	Cu
61.11	2200	12	Cu	61.15	2199	10	Cu
61.37	2196	2	Cu	61.37	2196	2	Cu
61.60	2192	10	Cu	61.66	2192	15	Cu
61.75	2190	10	Cu	61.84	2186	15	Cu
62.23	2180	8	Cu	62.29	2180	5	Cu

Plate 8, Spectrum 2, Cu $\times$ B.S. Plate 8, Spectrum 4, Cu $\times$ B.S.

Position	λ	I	Element	Position	λ	I	Element
62.46	2178	12	Cu	62.51	2177	10	Cu
62.70	2175	6	Cu	62.71	2175	3	Cu
63.08	2169	f	Cu	63.09	2169	ff	Cu
63.36	2165	8	Cu	63.38	2164	4	Cu
63.58	2161	3	Cu	63.58	2161	1	Cu
64.22	2152	3	Cu	64.30	2150	f	Cu
64.47	2148	12	Cu	64.45	2149	10	Cu
64.53	2146	f	Cu	64.51	2146	1	Cu
64.62	2145	ff	Cu				
65.16	2138	f	Cu	65.17	2138	ff	Cu
65.28	2136	10	Cu	65.31	2135	10	Cu
65.38	2134	9	Cu	65.42	2134	10	Cu
65.68	2130	f	Cu	65.69	2130	ff	Cu
65.97	2126	10	Cu	66.02	2125	10	Cu
				66.09	2124	1	Cu
66.20	2123	10	Cu	66.25	2122	10	Cu
66.38	2120	1		66.30	2120	1	
66.60	2117	5	Cu	66.62	2117	f	Cu
67.00	2111	10	Cu	67.01	2111	10	Cu
67.11	2110	f		67.07	2110	f	
67.39	2106	10	Cu	67.51	2105	10	Cu
67.54	2104		Cu				
67.63	2103	f	Cu	67.59	2103	f	Cu
				67.78	2101	fff	
67.96	2099	2	Cu	67.99	2098	ff	Cu
68.27	2094	f	Cu	68.26	2094	fff	Cu
68.75	2088	2	Cu	68.76	2088	1	Cu
68.93	2086	2	Cu	68.90	2086	1	Cu
69.42	2079	1	Cu	67.42	2079	f	Cu
71.24	2055	9	Cu	71.26	2055	6	Cu
71.40	2053	f		71.35	2054	2	
72.13	2044	9	Cu	72.17	2043	6	Cu
72.30	2041	f	Fe	72.26	2042	1	Fe
72.67	2037	6	Cu	72.69	2037	2	Cu
72.76	2036	6	Cu	72.80	2036	2	Cu
72.95	2033	f	Ga	72.89	2034	1	Ga
73.13	2031	ff	Cu				
73.57	2027	5	Hg				
73.69	2025	f	Cu	73.64	2026	1	Cu
				73.75	2024	f	Cu
74.35	2017	fff	Cu				
74.48	2015	fff	Cu	74.46	2015	fff	Cu
74.62	2013	fff	Cu				
				74.72	2012	fff	Cu
75.62	2000	3	Cu	75.60	1999	4	Cu
76.71	1990	1	Cu	76.76	1989	1	Cu
77.61	1979	1	Cu	77.66	1979	1	Cu
				82.33	1930	1	C

Table 12

To check the lines from the copper and blood serum spectra, some of the residue was put into tin electrodes and spectra of tin, and blood serum were obtained. The lines from one of these spectra are given in Table 12, with copper and blood serum lines shown for comparison. The tin used was not spectroscopically pure, but the chemical analysis showed it to contain small amounts of lead and iron. The chemical analysis of the tin and particulars of the two spectra are given below, preceding the actual tabulation of the lines.

Chemical Analysis of Tin

Lead	.010 %		Zinc	None
Iron	.002 %		Copper	None
		Arsenic	None	

Plate 9

Number	Position	Exposure	Electrodes
12	58	10 secs.	Cu / B.S.
14	68	10 secs.	Sn / B.S.

Concerning the tin, it is of interest to note that the lead and iron were definitely detected, and indications of arsenic, zinc, and copper were also found.

Plate 9, Spectrum 12, Cu $\neq$ B.S.Plate 9, Spectrum 14, Sn. $\neq$ B.S.

Position	λ	I	Element	Position	λ	I	Element
13.23	4244	1	Cu				
13.42	4226	f	Fe				
13.73	4192	f	Fe				
14.11	4145	ff	Fe				
14.76	4075	ff	Fe				
14.91	4061	f	Cu				
15.03	4048	f	K				
15.27	4023	f	Cu	15.13	4037	7	As
15.66	3983	1	Mg	15.50	4000	8	K
15.79	3970	7	Ca	15.79	3970	7	Ca
16.01	3948	f	Fe, Ca	16.15	3934	9	Ca
16.14	3934	7	Ca	16.40	3910	f	Sn
16.57	3893	f	Fe				
16.68	3884	f	Fe	16.61	3870	f	Fe
16.83	3868	f	Fe	17.02	3850	5	Fe
17.01	3850	f	Fe	17.13	3840	1	Mg
17.21	3830	ff	Mg				
17.29	3824	ff	Cu				
17.32	3822	fff	Cu	17.44	3810	f	Fe
				17.57	3798	8	Sn
				18.03	3753	f	Fe
				18.20	3743	f	Sn
18.32	3735	ff	Fe, Ca	18.37	3730	f	Fe
18.51	3720	fff	Fe	18.64	3709	2	Fe
18.73	3700	fff		18.95	3683	1	Pb
				19.32	3654	f	Sn
				19.56	3638	f	Pb
19.95	3606	fff	Cu	20.11	3596	f	
20.09	3598	f	Cu	21.63	3488	f	Ca
				21.79	3478	5	Cu
				21.90	3470	f	Ca
				22.20	3450	f	Cu
				22.34	3440	5	Fe
				22.63	3422	f	Fe
				22.76	3413	6	Sn

Plate 9, Spectrum 12, Cu $\nearrow$ B.S. Plate 9, Spectrum 14, Sn. $\nearrow$ B.S.

Position	λ	I	Element	Position	λ	I	Element
23.55	3360	ffff	K, Ca	23.47	3363	12	Sn
23.93	3337	fff	Mg, Cu	23.80	3343	10	Mg
24.36	3312	ff	K	24.09	3339	ff	K
24.47	3306	1	Cu	24.37	3311	ff	K
24.54	3302	7	Na				
24.92	3276	1	Cu	24.66	3294	6	Cu
25.05	3274	10	Cu	24.94	3280	12	Sn
25.39	3256	1	Fe	25.06	3274	2	Cu
25.54	3243	10	Cu	25.29	3260	10	Sn
				25.51	3249	1	Cu
				25.73	3238	f	K
				25.98	3226	3	Fe, Cu
				26.09	3221	f	Sn
				26.72	3187	7	Na
26.60	3161	2	Ca	26.91	3177	9	Sn
27.21	3161	1	Cu	27.16	3153	f	Cu
27.54	3144	fff	Cu	27.42	3150	f	Na
27.84	3129	fff	K, Na	27.54	3144	3	Sn
				27.63	3140	ff	Pb
				27.91	3124	ff	
28.37	3101	fff	Cu	28.11	3114	ff	
28.52	3079	fff	Na, Cu	28.50	3095	3	Na, Mg
29.15	3064	fff	Cu	29.02	3070	3	Zn
29.76	3037	fff	Cu	29.45	3050	ff	K
				29.56	3045	f	Pb
30.12	3023	fff	Cu	29.84	3034	10	Sn
30.32	3011	fff	Cu	30.04	3026	ff	Fe
30.68	2998	fff	Cu	30.24	3016	5	Zn
30.93	2988	ffff	K	30.39	3011	9	Sn
31.42	2968	f	Fe, C	30.95	2987	f	K
31.50	2964	1	Cu				
				32.55	2922	f	Na
				32.64	2918	4	Na
				32.72	2914	f	Sn
				32.99	2904	f	
				33.12	2900	5	As
				33.37	2888	ff	Fe
33.48	2894	fff	Cu				

Plate 9, Spectrum 12, Cu $\frac{1}{2}$ B.S.Plate 9, Spectrum 14, Sn. $\frac{1}{2}$ B.S.

Position	λ	I	Element	Position	λ	I	Element
				33.85	2870	5	Fe
				33.99	2855	9	Sn
34.11	2860	ff					
34.19	2857	f		34.21	2856	f	
34.31	2852	5	Hg, Na	34.31	2852	5	Hg, Na
				34.38	2850	f	Sn
				34.64	2840	10	Sn
34.73	2836	fff	Cu				
35.05	2823	3	Cu				
				35.24	2816	f	
				35.35	2812	5	Sn
35.36	2805	f	Fe	35.55	2806	ff	Fe
35.60	2801	4	Hg	35.64	2802	3	Hg
35.76	2799	f	Hg	35.74	2799	f	Hg
35.80	2794	4	Hg	35.86	2794	6	Hg
				36.15	2785	1	Sn
				36.20	2783	ff	Hg
36.30	2780	fff	Hg	36.32	2780	5	Sn
36.63	2763	fff	Cu	36.66	2769	ff	Cu
				36.89	2761	ff	Fe
				37.03	2756	3	Fe
37.24	2750	ffff	Cu	37.28	2743	4	Fe
				37.53	2739	3	Fe
38.14	2721	ffff	Cu				
				38.53	2707	10	Sn
				39.92	2655	7	Fe
				40.17	2654	10	
				40.66	2643	10	Sn
				41.07	2631	9	Sn
				41.13	2623	f	Fe
41.50	2619	2	Cu				
				41.71	2612	3	Fe
				41.89	2608	2	Fe
				42.08	2603	f	Fe
42.15	2601	fff	Cu	42.14	2601	4	Cu
				42.25	2598	ff	Fe
				42.36	2595	5	Sn
				42.43	2593	f	Sn
				42.66	2586	1	Fe
				43.07	2575	2	Pb
				43.22	2571	8	Sn
				43.38	2569	ff	Zn
				43.50	2567	2	Zn
				43.64	2560	f	Zn
				43.90	2553	ff	
				44.00	2551	f	Fe, K
				44.16	2546	3	Sn

Plate 9, Spectrum 12, Cu γ B.S. Plate 9, Spectrum 14, Sn. γ B.S.

Position	λ	I	Element	Position	λ	I	Element
				44.46	2539	f	Fe
				44.64	2534	ff	Sn
				44.76	2531	ff	Sn
				44.88	2528	f	Sn
				45.05	2524	5	Sn
				45.15	2521	f	Fe
				45.47	2513	ff	C
				45.65	2510	fff	C
				45.81	2505	fff	Cu
				46.05	2500	f	Sn
				46.17	2496	7	Sn
46.34	2492	f	Cu	46.36	2492	fff	Sn
46.50	2488	ff	Cu	46.54	2488	9	Cu, Fe
				46.69	2484	8	Sn
46.88	2479	1	Cu	46.89	2479	7	C
				47.13	2473	fff	Cu
				47.23	2471	fff	
				47.47	2466	fff	
				47.59	2464	fff	Fe
				47.76	2460	ff	Fe
				47.96	2455	5	Sn
				48.13	2451	5	
				48.22	2449	ff	
				48.33	2445	ff	Pb
48.48	2443	fff	Cu	48.58	2441	f	Cu
				48.68	2436	4	Fe, Sn
				49.06	2430	12	Sn
				49.43	2421	12	Sn
				49.49	2420	ff	
				49.79	2413	f	Fe
				49.94	2410	7	Sn
				50.12	2406	7	
				50.45	2399	1	Cu, Pb
				50.55	2397	4	Fe, Ca
				50.79	2391	f	Pb
				50.88	2389	2	Sn
				51.23	2382	8	Fe
				51.26	2381	f	Sn
				51.50	2376	fff	Fe
51.77	2370	fff	Cu	51.72	2371	ff	Cu, As
				51.87	2369	9	Sn
				52.02	2365	ff	Sn
				52.31	2359	1	Sn
				52.42	2356	9	Sn
				52.59	2354	9	
				52.74	2351	ff	Fe

Plate 9, Spectrum 12, Cu / B.S.

Plate 9, Spectrum 14, Sn. / B.S.

Position	λ	I	Element	Position	λ	I	Element
				52.84	2349	f	As
				53.09	2344	3	Fe
				53.19	2342	ff	
				53.55	2334	10	Sn
				53.63	2333	ff	Fe
				53.90	2327	fff	Fe
				54.23	2320	ff	Cu
				54.49	2315	11	Sn
				54.64	2312	ff	Zn
				55.32	2299	ff	Fe
				55.53	2296	5	C
55.66	2294	2	Cu				
56.13	2286	fff	Cu	56.07	2286	6	Sn
				56.30	2282	ff	Sn
56.38	2281	fff	Fe				
56.66	2275	fff	Cu	56.62	2276	fff	Ca, Cu
				56.90	2271	5	Sn
				57.06	2268	10	Sn
				57.24	2265	10	Sn
57.36	2263	f	Cu				
58.27	2247	1	Cu	58.00	2251	ff	Sn
58.53	2243	f	Cu				
				58.39	2246	11	Sn
				58.54	2243	3	Cu
				58.81	2239	fff	Fe, Cu
				59.02	2235	ff	
				59.18	2233	f	Sn
59.29	2231	1	Cu				
59.39	2230	1	Cu	59.36	2230	9	Sn
59.97	2219	ff	Cu	59.92	2220	f	Cu
60.16	2215	f	Cu	60.13	2215	8	Cu
60.45	2210	ff	Cu	60.45	2210	9	Sn
				60.56	2209	9	
				60.68	2207	fff	Ca
				60.85	2204	fff	K, Pb
61.09	2200	f	Cu				
61.15	2199	ff		61.19	2198	8	Sn
				61.49	2194	8	Sn
61.58	2192	f	Cu	61.62	2191	fff	Cu
				61.85	2188	fff	Cu
62.19	2182	ff	Cu	62.25	2181	fff	Cu
62.38	2179	f	Cu	62.44	2178	ff	Cu
				62.75	2174	fff	Pb
				62.90	2172	ff	Sn
				63.03	2170	fff	Pb
63.29	2166	fff	Cu	63.29	2166	fff	As, Cu
64.40	2149	fff	Cu	64.33	2150	15	Sn

Plate 9, Spectrum 12, Cu $\neq$ B.S.Plate 9, Spectrum 14, Sn. $\neq$ B.S.

Position	λ	I	Element	Position	λ	I	Element
				64.48	2148	2	Sn
				65.00	2140	1	Sn
65.26	2136	1	Cu	65.28	2136	3	Cu
65.35	2135	f	Cu				
				65.84	2114	9	Sn
				66.94	2112	ff	Ca, As
67.22	2109	fff		67.21	2109	2	
				67.79	2101	2	Sn, Zn
				68.18	2095	2	Sn
				68.51	2091	6	Sn
				68.82	2086	ff	Pb
				68.97	2085	ff	Fe
				69.15	2083	1	Fe
				69.29	2081	f	Sn
				69.80	2074	f	As, Pb
				70.05	2071	10	Sn
				70.16	2069	10	Sn
				70.27	2068	f	
				70.59	2064	2	Sn, Zn
				70.72	2062	1	Zn
				72.41	2040	3	Sn
				73.09	2032	f	As
				73.69	2025	f	Zn, Cu
				75.69	1999	ff	Cu
				76.34	1994	ff	
				76.67	1990	ff	Cu
				77.33	1985	ff	
				77.92	1979	f	Cu
				77.81	1977	ff	
				78.47	1970	ff	Cu
				79.33	1961	f	
				79.45	1960	ff	
				79.81	1956	f	
				79.94	1955	ff	Fe
				81.12	1941	5	Sn
				81.30	1940	5	Cu
				82.27	1930	3	C
				82.39	1929	3	C
				82.67	1926	ff	
				82.80	1925	fff	
				83.24	1921	fff	
				83.57	1918	fff	Zn
				83.72	1916	ff	
				84.37	1908	fff	Sn
				85.00	1904	fff	
				85.07	1903	ff	
				85.21	1902	f	
				85.33	1901	10	Sn
				85.53	1899	10	Sn
				85.72	1898	8	

Summary of Results

Analysis of Urine

In the following table all the lines due to elements in the Urinal Residue are arranged together according to the spectrum in which they appeared.

Table 13

Urinal Analysis Lines Arranged According to Plate and Spectrum

Plate 3, Sp. 8. Plate 3, Sp. 5. Plate 3, Sp. 9. Plate 4, Sp. 13.

λ	Element	λ	Element	λ	Element	λ	Element
				3356	K		
				3358	Ca, K		
3330	Mg	3330	Mg				
3304	Na	3305	Na	3324	K		
3253	Fe			3301	Na	3302	Na
				3215	Ca, Na	3212	Ca, Na
				3207	Ca		
				3184	Ca	3197	Fe
3161	Ca	3161	Ca	3161	Ca	3183	Ca
3135	Na	3136	Na	3135	Na		
3131	Na, K					3129	Na
3091	Na, Mg	3090	Na, Mg	3102	K		
		3080	Na	3093	Mg, Na		
						3072	Na
3069	Fe						
						3062	K
3053	Fe			3057	K		
				3024	K		
				2998	Ca	3013	Ca
				2992	K	3000	Ca
				2988	K		
2984	Na, K						
2980	Na	2978	Na	2977	Na	2981	Na
2963	Fe, C						
				2962	K		

Plate 3, Sp. 8. Plate 3, Sp. 5. Plate 3, Sp. 9. Plate 4, Sp. 13.

λ	Element	λ	Element	λ	Element	λ	Element
2955	Fe	2955	Fe				
2942	K, Mg			2927	Hg	2927	Hg
2930	Hg			2922	Na		
2900	Na			2700	Na		
2870	Fe						
				2860	Na		
2854	Na, Mg	2852	Na, Mg	2852	Na, Mg	2852	Na, Mg
				2838	C		
				2819	K		
2804	Hg	2801	Hg	2802	Hg	2802	Hg
2800	Hg						
2795	Hg	2794	Hg	2795	Hg	2794	Hg
						2781	Hg
				2749	C		
2727	Fe						
				2700	Hg		
2679	Na	2660	Na	2679	Na	2661	Na
				2673	Hg, Na		
						2649	Fe
						2635	K
		2592	Na	2594	Na		
		2586	Fe				
						2579	Fe
				2507	C	2506	C
				2476	C		
				2452	Na		
2385	Fe						
2371	Ca						
2361	Fe	2361	Fe				
2351	K						
						2327	Fe
						2301	Fe
				2295	C		
				2276	Ca		
				2256	K		
				2249	K		
				2207	Ca		
				2204	K		
						2201	Ca
2199	Ca	2197	Ca	2196	Ca		
2112	Ca			2113	Ca		
2104	Ca						
2092	Fe						
2026	Hg						
						1950	C

Table 14

From Table 13, it is evident that the six elements calcium, magnesium, potassium, sodium, iron, and carbon are present in the samples of the urinal residue examined.

These elements and the corresponding observed lines are arranged below, with the wavelengths and intensities, as given in the wavelength tables.

Calcium		Magnesium		Potassium		Sodium		Carbon		Iron	
λ	A I S	λ	A I S	λ	A I S	λ	A I S	λ	A I S	λ	A I S
3362	4	3330	5 3	3364	6	3303	6 6	2968	1 1	3254	4 1
				3363	8	3302	6 10			3252	4 1
		3093	5 3			3212	5			3197	5 2
3159	4 15	3091	5 2	3360	2	3136	3	2638	2	3196	2
3215	2			3358	2			2657	3	3067	9
3210	1	2942	3	3322	4	3130	6	3059		3059	6
										3057	8
3181	1 8	2929	1 10	3129	2	3093	8	2747	2	2970	6
3179	4 15	2852	10 8	3102	2	3081	2	2509	2	2957	5 2
				3102		3079	4				
				3063	5						
3009	5	2803	8 10	3057	3	3075	5	2479	15	2869	6 1
2999	2 2										
2997	2 2	2798	1 5	3023	2	2984	3	2297	4	2728	4 5
										2727	2
2198	1	2796	8 10	2992	4	2980	3	1931	2	2652	3 1
										2647	3
								1930	8		
2113	2	2781	5 4	2986	2	2975	3				
				2963	1						
2103	1	2698	5	2938	2	2921	3			2586	4
		2673	2	2919	3	2901	2			2382	3 10
		2028	6 6	2636	2	2860	2			2362	8
				2350	2	2853	6 4			2327	2 6
				2258	2	2680	2			2302	1 5
				2248	2	2672	2			2299	5
				2204	2	2594	1			2094	4

Summary of Results

Analysis of Blood Serum

The various lines due to elements in the Blood Serum were arranged as in the case of the urinal residue lines, according to the spectrum in which they were observed, and also in another set of tables according to the respective elements.

Table 15

The Blood Serum lines from Tables 8 and 9, are recorded here, and it will be noticed that many more of the long wavelength lines were observed in the spectrum from Plate 7 which was intended to show the lines in the near ultra-violet.

Blood Serum Lines Arranged According to Plate and Spectrum

Plate 5, Spectrum 12. Plate 6, Sp. 7. Plate 7, Sp. 7. Plate 7, Sp. 8.

λ	Element	λ	Element	λ	Element	λ	Element
		4260	(K)				
		4232	Ca				
		4204	Fe				
		4186	K				
		4170	Mg				
		4156	Fe				
		4086	Fe				
		4072	Fe				
		4058	(K)				
		3993	K	4002	K		
		3975	Ca, K	3973	Ca, K		
		3958	(Ca)	3950	(Ca)		
		3942	K	3920	O		
3920	O						

Plate 5, Sp. 12.

Plate 6, Sp. 7.

Plate 7, Sp. 7.

Plate 7, Sp. 8.

λ	Element	λ	Element	λ	Element	λ	Element
				3004	Fe		
				3091	Fe		
		3086	Fe, C			3087	Fe
		3040	Mg	3050	Fe	3052	Fe
		3028	Mg	3028	Mg	3030	Mg
		3003	K				
		3750	Fe			3750	Fe
		3727	Fe	3742	Fe		
		3714	Na,				
						3704	Fe, Ca
		3610	K			3680	Fe, K
3590	C						
		3586	C				
		3568	Fe			3566	Fe
3562	Fe						
		3554	Fe				
		3492	Fe, Ca	3490	Ca		
3449	(K)						
3442	K	3441	K			3443	Fe, K
				3409	K		
3394	Fe	3392	Fe			3393	Fe
						3376	K
						3362	(K)
3332	Mg					3332	Mg
		3329	Mg				
				3314	K	3314	K
3302	Na	3304	Na	3305	Na	3304	Na
3294	(K)	3294	(K)				
3238	(K)	3238	(K)				
		3212	Na, Ca	3212	(Na)		
				3201	K		
		3191	Na, K				
3184	Ca	3185	Ca	3185	Ca	3185	Ca
3173	Ca	3174	Ca	3176	Ca	3174	Ca
						3162	(Ca)
3149	Na	3150	Na			3150	(Ca)
3129	K, Na			3131	K, Na	3129	K, Na
				3096	Mg		
						3093	(Na)
		3086	Mg				
3076	(Na)			3074	(Na)		
3056	Na, K						
3047	Fe	3045	Fe				
3027	Fe	3025	Fe				

Plate 5, Sp. 12. Plate 6, Sp. 7. Plate 7, Sp. 7. Plate 7, Sp. 8.

λ	Element	λ	Element	λ	Element	λ	Element
		3016	Fe	3016	Fe	3016	Fe
				3002	(Ca)	3006	Ca
2985	K	2987	K			2991	C, K
		2980	Na	2983	Fe, Na	2982	Fe, Na
				2972	Fe	2970	Fe
2955	Fe	2955	Fe	2966	(C)	2955	Fe
		2946	Na				
2942	Mg	2942	Mg				
		2929	Mg				
2923	Na						
2909	Na						
2902	Na						
2892	Fe						
		2859	Na	2860	Na	2860	Na
2856	K						
		2853	Na, Mg	2855	Mg, Na	2853	Mg, Na
						2845	Na
				2830	Fe	2829	Fe
2800	Na						
		2801	Mg	2807	Fe	2806	Fe
2802	Mg			2802	Mg	2802	Mg
				2800	Mg	2800	Mg
2796	Mg	2794	Mg	2796	Mg	2795	Mg
2753	Mg	2791	Mg				
2783	Mg	2781	Mg				
		2775	Mg				
		2728	Fe				
2692	Fe	2694	Fe				
2687	Fe						
2669	Mg	2657	Mg				
		2648	Fe				
2634	K, Mg						
		2631	Mg				
2620	Mg						
2612	Fe, Na	2613	Fe, Na				
2605	Mg						
		2594	Na				
2582	Fe						
2578	Fe	2579	Fe				
		2576	Fe				
		2563	Fe				
2552	K						
		2549	(K)				
2476	(Ca)						
2471	Fe						
		2396	Fe, Ca				

Plate 5, Sp. 12. Plate 6, Sp. 7. Plate 7, Sp. 7. Plate 7, Sp. 8

λ	Element	λ	Element	λ	Element	λ	Element
2378	(K)	2382	Fe, K				
		2344	Fe				
2336	Fe	2339	Fe				
		2331	Fe				
		2300	Fe				
2298	Fe						
		2297	C				
		2275	Ca, K				
		2208	(Ca)				
2145	Fe	2144	Fe				
2140	Fe						
		2103	Ca				
2094	Fe	2094	Fe				
2063	Fe	2061	Fe				
2040	Fe, Ca						
1929	C	1930	C				
1913	Fe	1913	Fe				
1895	Fe						
1886	Mg						
		1873	Ca				
1857	Mg	1857	Mg				

Table 16

The Blood Serum lines from Tables 11 and 12 are placed in this table according to plate and spectrum.

Plate 8, Sp. 2: Plate 8, Sp. 4: Plate 9, Sp. 12: Plate 9, Sp. 14:

λ	Element	λ	Element	λ	Element	λ	Element
				4228	Fe		
				4192	Fe		
				4145	Fe		
				4075	Fe		
				4048	K		
				3983	Mg	4000	K
				3970	Ca	3970	Ca
				3943	Fe, Ca		
				3934	Ca	3934	Ca
				3893	Fe		
				3884	Fe		
				3868	Fe	3870	Fe
				3850	Fe	3850	Fe
						3840	Mg
				3830	Mg		
				3735	Fe, Ca		
				3720	Fe	3730	Fe
						3596	C
						3488	Ca
						3470	K
3358	K	3365	(K)	3360	K, Ca		
		3358	K	3337	(Mg)	3339	Mg
		3312	K	3312	K	3311	K
3304	Na	3302	Na	3302	Na		
				3256	Fe		
3212	Na	3212	Na			3238	K
3200	K	3198	K			3187	Na
3182	Ca	3181	Ca	3181	Ca		
				3129	K, Na	3150	Na
				3079	(Na)	3095	Na, Mg
				2988	K	3050	K
2942	Mg	2941	Mg	2968	Fe, C	2987	K
2928	Mg	2926	Mg			2922	Na
						2918	Na

Plate 8, Sp. 2: Plate 8, Sp. 4: Plate 9, Sp. 12: Plate 9, Sp. 14:

λ	Element	λ	Element	λ	Element	λ	Element
2852	Hg, Na	2852	Hg, Na	2852	Hg, Na	2852	Hg, Na
2804	Hg	2804	Hg	2805	Fe	2806	Fe
2800	Hg	2800	Hg	2801	Hg	2802	Hg
		2796	Hg	2799	Hg	2799	Hg
2794	Hg	2794	Hg	2794	Hg	2794	Hg
						2783	Hg
				2780	Hg		
2773	Fe	2772	Fe				
		2716	Fe				
2692	Fe	2696	Fe				
2678	Na	2678	Na				
2659	Hg	2659	Hg				
2636	(K)	2636	(K)				
2629	Fe					2528	Fe
2603	Hg	2603	Hg				
2585	Fe					2536	Fe
						2551	Fe, K
						2513	C
						2510	C
						2479	C
						2333	Fe
2330	Fe					2327	Fe
2313	Fe						
				2281	Fe	2296	C
						2276	(Ca)
						2259	Fe
						2207	Ca
						2204	(K)
						2112	(Ca)
2103	Ca	2103	Ca				
						2085	Fe
						2085	Fe
2041	Fe	2042	Fe				
2033	Ca	2034	Ca				
2027	Hg					1955	C
		1930	C			1930	C
						1929	C

Table 17

The Blood Serum lines from Tables 15 and 16 are re-arranged according to elements; the corresponding wavelengths and intensities being taken from the tables of Eder and Valenta, or Kayser.

Since a very large number of ion lines were obtained these have been arranged separately in Table 17 (a), following Table 17.

Blood Serum Lines According to Elements

Calcium			Magnesium			Potassium			Sodium			Carbon		
λ	I		λ	I		λ	I		λ	I		λ	I	
	A	S		A	S		A	S		A	S		A	S
4237	50	50	4168	4		4263		6	3711		2	3921		3
3971	1	2	3987	1		4166		10	3503	6	4	3884		30
3969	20	20	3536	10	10	4058		2	3302	6	10	3590		6
3957	1	3	3829	10	8	4048	10	10	3212		5	3586		8
3949	1		3337	6	7	4001		4	3190		4	2993	1	4
3951	30	30	3332	4	5	3995		3	3150		3	2968	1	1
3787	1	15	3330	5	3	3973		3	3130		6	2512		3
3706		15	3097	3	3	3945		2	3093		3	2509		2
3460	2		3093	5	3	3901		2	3081		2	2479		15
3362	4		3091	5	2	3682		3	3079		4	2297		4
3215	2		2942	3		3609		3	3075		3	1951		2
3210	1		2929	1	10	3447	4	2	3056		5	1930		8
3181	1	8	2952	10	8	3446	4	2	2984		3			
3179	4	15	2902	3	10	3440		4	2960		3			
3159	4	15	2793	1	5	3405		2	2952		5			
3151	4		2796	3	10	3374		3	2921		3			
3097	2	4	2791		10	3365		6	2913		4			
3001	2		2783	5	4	3353		8	2905		4			
3000	2	2	2781	5	4	3360		2	2901		2			
2999	2	3	2730	6	6	3358		2	2860		2			
2975	2	2	2778	5	3	3313		3	2853	6	4			
2909		2	2670	2		3291		3	2842		4			
2113		2	2668	2		3241		2	2810		3			
2103		1	2652	1		3202		3	2690		2			
2040	4		2630	1		3190		2	2612		2			
1873		3	2605	1		3188		2	2594	1				
			2028	6	6	3129		2						
			1886	5		3057		2						
			1856	5		3052		3						
						2992		4						
						2966		2						
						2854		2						
						2636		2						
						2550		2						
						2380		2						
						2274		2						
						2204		3						

Table 17 (a)

Iron			Iron			Iron		
λ	I		λ	I		λ	I	
	A	S		A	S		A	S
4228	5	5	5442	4	1	2553	5	4
4204	5	1	5392	4	2	2550	6	
4191	6	3	5357	4	1	2472	5	
4157	4	2	5254	4	2	2396	8	5
4155	4	2	5045	4		2395	5	3
4144	7	5	5026	6	2	2382	3	10
4085	5	1	5019	5	2	2344		9
4075	3	1	2963	4	3	2338	6	
4072	10	8	2975	4	2	2335	2	6
3949	4	2	2970	4	2	2331		7
3948	3	1	2954	4	2	2327	2	6
3904	5	1	2892	3		2315	5	
3892	4	1	2851	3	4	2300		5
3888	7	4	2829	4		2299		5
3885	5	1	2807	7	2	2296	6	
3872	7		2773	4	1	2280	6	
3850	6		2772	6	1	2275	5	
3750	10	10	2728	4	1	2240	5	
3743	10	6	2716	3	3	2144	5	
3735	15	10	2693	3	4	2140	5	
3728	10		2665	3	4	2094	4	
3720	10	7	2647	3		2084	4	1
3705	5	2	2623	6	8	2082		7
3680	7		2613	5		2064	5	
3667	4	1	2612	8	10	2041		3
3565	10	5	2596	7	10	1954		2
3554	4,5	1,2	2582	4	4	1913		5
3491	6	4	2578	4	1	1896	4	6
3444	6	3	2576	4	1	1895		5

Conclusion

From the preceding tables of data it is evident that the six elements, calcium, magnesium, potassium, sodium, carbon and iron were definitely detected in both the residue of urine, and blood serum samples.

If very minute amounts of other elements are present an instrument of much greater dispersion would be necessary to detect them. This is an important result since one of the objects of the research was to find out what could be done in this field with a small laboratory instrument.

However, as a means of detecting the presence of these major constituents the method described in this thesis is apparently fairly satisfactory, and after the technique has been developed the entire process would require only a few hours.

As indicated by Appendix II, it is possible to make a quantitative analysis of the inorganic constituents of urine by chemical means. Consequently in this case, the spectroscopic examination as described in this thesis has no advantage unless it is the small quantity of material necessary, this being about 0.5 gm. of residue or in the case of solutions a few cubic centimetres suffice for several exposures, and these quantities could be decreased if desired.

Although efforts were made to determine the presence or absence of copper, these were unsuccessful since copper is a very common impurity in other metals and no electrodes were obtainable which were definitely without copper.

Regarding the relative advantage of the visible and ultra-violet regions several observations were made. Many more lines are obtained in the ultra-violet and this renders the work more complex but gives correspondingly more possibility of success. Also a large number of the raies ultimes and persistent lines of the elements come below the limit of the transparency of ordinary glass. Since the detection of small amounts of elements frequently depends upon the observation of these lines, the use of a glass prism spectrograph is not always advisable. It was noticed that the various wavelength tables become increasingly incomplete for lines in the shorter wavelength regions and this was found to be a distinct disadvantage in one respect since many quite prominent lines could not be identified. On the other hand, the dispersion of the spectrograph varies inversely as the wavelength so that the wavelengths could be estimated to one Angstrom unit quite readily at the far end of the spectrum. In this connection it may be mentioned that the above factors made for very

definite identification of elements with prominent lines in the extreme ultra-violet.

This research was done in conjunction with Mr. Herman Johnson and as his results showed no indication of iron or carbon lines in the visible region, this would seem to confirm the conclusion reached above, that the ultra-violet spectrograph is more suitable for this type of work.

Finally, the writer wishes to express his appreciation to the Department of Physics, University of Manitoba, for the use of space and apparatus, and to Dr. P. A. Macdonald, of the Manitoba Cancer Relief and Research Institute, who suggested this problem.

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Appendix I

Raies Ultimes and Persistent Lines

The lines listed below are the sensitive, ultimate or persistent lines of the elements, Calcium, Magnesium, Potassium, Sodium, Carbon, and Iron. The first column gives the wavelengths as recorded by De Gramont, and the second, gives the lines noted by Pollok and Leonard.

The ultimate rays are designated by the symbols u_1 , u_2 , u_3 ; u_1 being the last to disappear. The letter 'u' indicates that this is the only ultimate ray, or that the order of disappearance has not been definitely established.

The Greek letter symbols in the case of the Pollok and Leonard lines refer to their order of disappearance, as described in the discussion of the Hartly, Pollok and Leonard method of quantitative analysis.

Carbon was apparently not investigated by Pollok and Leonard, so the De Gramont lines only are given for this element along with those for Iron. Following this the numerous persistent lines for iron are listed.

Appendix I
(Continued)

<u>Calcium</u>				<u>Magnesium</u>			
4226.7	u ₃	4226.9	10	3838.3		3835.4	10
3968.5	u ₂	3968.6	80	3852.3		3832.5	10
3933.7	u ₁	3933.8	100			3829.5	10
		3737.2	15			3336.8	8
		3706.2	10			3332.3	8
		3644.5	2			3330.1	6
		3630.8	1			3097.1	8
3179.3		3179.4	10			3093.1	8
3158.9		3159.1	10			2937.0	10
						2928.7	10
						2915.5	10
				2852.1		2852.2	10
				2802.7	u ₂		
						2798.2	8
				2795.5	u ₃		
						2790.9	10
						2783.1	4
						2781.5	4
						2779.9	6
						2778.4	4
						2776.8	4
<u>Potassium</u>				<u>Sodium</u>			
4047.2	u ₁	4047.4	10	3303.0	u ₂	3303.1	10
4044.2	u	4044.3	10	3302.3	u ₂	3302.5	10
3447.4		3447.5	8	2852.8		2852.9	6
3446.4		3446.5	10				
<u>Carbon</u>				<u>Iron</u>			
4266.9				4045.8			
2478.6	u			3820.4			
2296.9				3737.1			
				3734.9			
				3570.2			
				3565.4			
				2755.7	u		
				2749.3	u		
				2739.6	u		
				2395.6	u ₂		
				2382.0	u ₁		

Appendix II

THE INORGANIC CONSTITUENTS OF URINE ¹

Average normal urines contain about 1.5% of inorganic solids out of a total solid content of 4 or 5%. The constituents present are given in the table. The values given are not average values of a 24 hour specimen, but merely represent approximate values obtained by various analyses of

Constituent	Analysed As	%
1. Chloride	NaCl	1.0
2. Sodium	Na ₂ O	0.3
3. Potassium		0.12
4. Sulphate	SO ₃	0.14
5. Phosphate	P ₂ O ₅	0.13
6. Ammonium	NH ₃	0.04
7. Calcium		0.01
8. Magnesium		0.01
9. Iron		0.0004
10. Silicates	Silicic acid	0.03
11. Carbonates		Traces
12. Fluorides		"
13. Nitrates		"
14. Copper		"
15. Zinc		"
16. Hydrogen Peroxide		"

single specimens.

However the figures are fairly representative.

The first eight of these substances with the exception of ammonium show the same descending order in the blood.

Naturally, the composition of urine will vary with diet and in various diseases.

¹

The writer is indebted to Mr. Sidney Margoless, B.Sc., for the compilation of this analysis.