

## X-RAY STUDY OF COLLOIDAL COLOURED GLASSES

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### GENERAL INTRODUCTION.

Many investigations have been carried out on the coloration in glass and Weyl (1945) has contributed much towards the understanding of that subject. In dealing with the problem of coloured glass, it is necessary to take into account the structural as well as chemical considerations of the glass base and experimental conditions. The problem may be divided into two sections: (a) the colouring element is a metallic atom, and (b) the colouring element is metallic ion.

The study of glass systems with particular reference to the structure of glass is engaging the attention of a number of physicists and chemists. Generally the oxides most suited for the formation of glass are those of the elements which provide small and highly charged ions like  $B^{+3}$  ( $r = 0.20$  Å),  $Si^{+4}$  ( $r = 0.41$  Å),  $P^{+5}$  ( $r = 0.34$  Å), etc. The classical work on the glass-forming ability of oxides with particular reference to the structure has been done by Goldschmidt (1926). Later on Zachariasen (*J. Am. Chem. Soc.*, 54, 3841, 1932) published an interesting paper on the structure of glass wherein he predicted a random network type of structure extended in three dimensions. From that point of view, it will be interesting to study the distribution and the state of existence of the noble metal salts in the glassy matrix.

*Colloidal particle and its stability in different media.*—The stability of the colloidal particle is determined to a great extent by the nature of the dispersion medium. Svedberg (1907) showed that the Colloidal solutions of noble metal in ethyl ether is the least stable while the solution in water is the most stable. In the case of solid dispersoid both disperse phase and the dispersion medium are solid, but both of them need not be crystalline. All the glass systems for the present investigation consist of the dispersion of a crystalline substance in the amorphous medium.

In the preparation of colloidal coloured glass, sometimes it is necessary to add  $SnO$ ,  $PbO$  or  $ZnO$  to develop the colour of ruby glass as well as to stabilize the colloidal solution. It is well known that the presence of a small amount of the above oxide in the melt increases the solubility of the noble metal as well as determines the particle size of the metal. Numerous parallel examples are known in liquid systems where the presence of a small amount of a third substance increases the solubility of a substance in another substance to a considerable extent. The classical example is the addition of sodium salt of benzol sulphonic acid in benzoic acid-water system.

### PRESENT WORK.

The nature of colloidal particles of Au, and Pt, in glass systems and their influence on the structure of glass have been investigated. Zsigmondy (1909) first demonstrated the existence of colloidal gold in Ruby glass by the Ultramicroscope. Further it is known that elemental carbon, sulphur, selenium, solid solution

like CdS and CdSe, etc., can exist in the glassy matrix. It is also known that in a glass phase, the existence of colloidal and crystalline phase has been found to be possible.

There is a controversy regarding the mechanism of the growth of ruby colour in glass. One school of scientists believes that Au dissolves as  $Au^+$  or  $Au^{+3}$  ions in molten glass and that the formation of ruby colour on low temperature heat treatment results from reduction of the ions to metallic gold by reducing agent present in glass. The other school believes that Au dissolves initially as colourless atoms, and glass forms a supersaturated solution of metallic Au on cooling but at the same time containing larger gold particles as nuclei and finally reheating causes growth of these nuclei to produce colour. On the basis of above observations, it would be fruitful to extend the investigation to study the course of formation and the state of existence of Au and Pt, in different glass bases. Practically a very small amount of work has been done on the above problem. Because the complete investigation of glass at the ordinary temperature is limited by the rigidity of the dispersion medium whereby electrokinetic phenomena, etc. cannot be studied. However, we have studied the following different aspects of the problem and for the present, the investigation is confined to Boric oxide glass base containing different network modifying cations.

1. Vitreous limit of each type of glass composition.
2. Colour of the glass specimen.
3. X-ray analysis of glass samples.
4. Lattice constant of the dispersoid.
5. Absorption.
6. X-ray analysis of the dispersoid isolated from the glassy matrix by chemical process.

#### VITREOUS LIMIT.

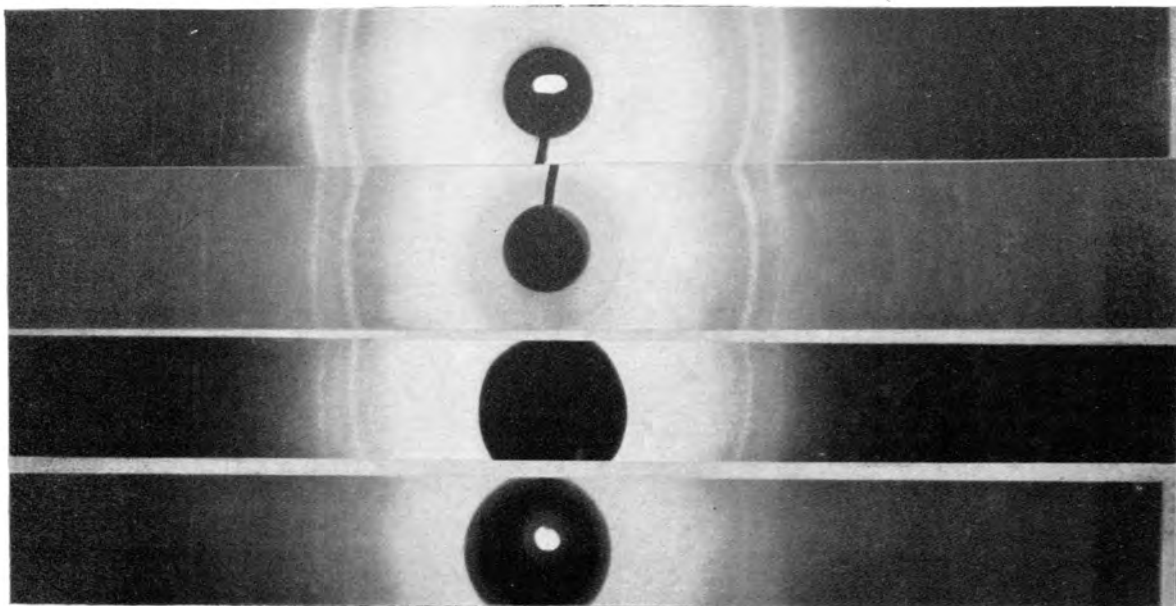
In the preparation of colloidal coloured glass specimen, utmost care is taken in selecting the composition, purity of the ingredients as well as the furnace temperature. All samples have been prepared in a Platinum crucible under identical condition at  $1000^{\circ}C$ . and consequently we can get a comparative idea about the vitreous limit of each glass series. All samples are kept in a vacuum desiccator. The gold content is determined idometrically and Platinum content colorimetrically by  $SnCl_2$  method. The following results have been obtained.

| Glass Composition.     | Maximum concentration of dispersoid in wt. per cent. |
|------------------------|--|
| Pt-Borax .. ..         | 2.8  |
| Au-Borax .. ..         | 2.45   |
| Pt- $B_2O_3$ .. ..     | 2.39   |
| Au- $B_2O_3$ .. ..     | 2.12   |
| Pt-Lindemann glass* .. | 2.05   |

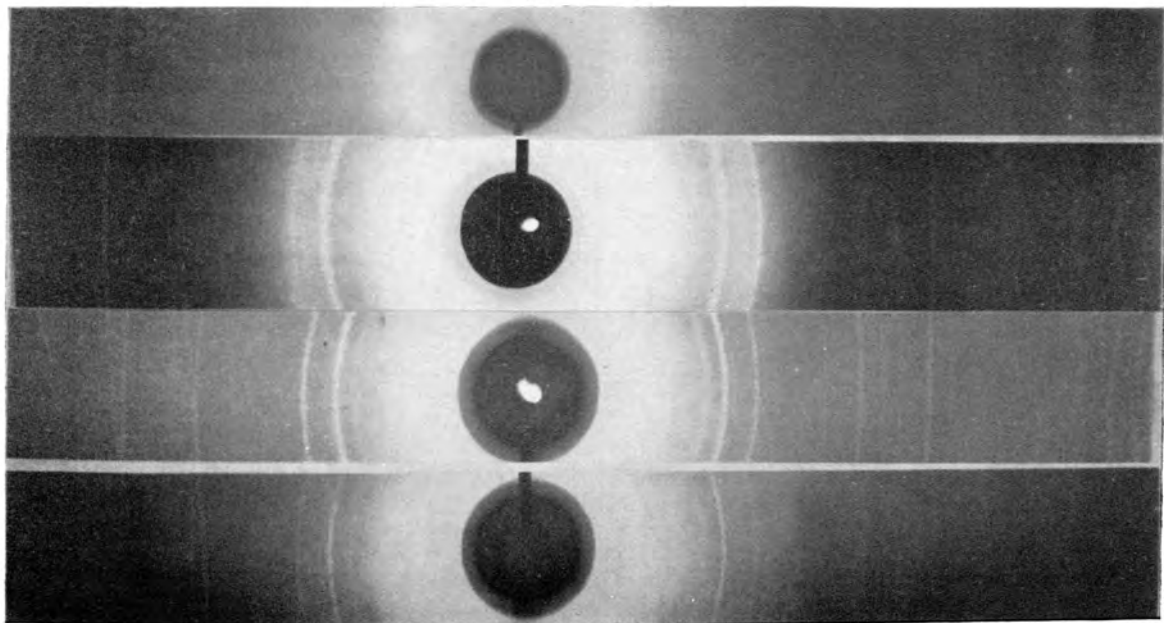
\* Lindemann glass is formed by fusing together 17.8 parts by weight of  $Li_2CO_3$  with 5.8 parts of  $BeCO_3$  and 76.4 parts of Boric acid.

However, in each system the vitreous limit can be extended by the addition of oxide of Pb, Zn, Sn, etc., to the glass composition as well as by raising the furnace temperature. The addition of alkali oxide also extends the vitreous limit to a certain extent. It is also observed that the behaviours of the same solute

A



B



Pt Planes

↑ [111] ↑ [200]  
↑ [220] ↑ [311] ↑ [222]  
↑ [400] ↑ [331] ↑ [420]

in different glass bases is not similar. In the present case it is found that the solubility of each dispersoid is greatest in the borax base.

#### COLOUR.

The Colour of gold specimen is pink and that of Pt is grey. Besides the oxide of Pb, Sn, Zn, etc., alkali oxide also increases the intensity of the colour to a considerable extent. Ordinarily the colour of the above glass specimens remains unaffected.

The colour of Au and Pt samples is very susceptible to the presence of some polar salts like alkali halide. It has been found that the glass batch containing a very small amount of KCl or NaCl in  $B_2O_3$  glass fails to develop ruby colour. Again, it has been found that X-rays have no special action on the above glass specimens. Only the portion which has been exposed to X-rays for about 50 hours, shows a slight variation in colour from the rest of the portion. It will be interesting to mention the work of Galecki (1912) on the action of X-rays on gold solution where he found that the red colour of the solution was slightly altered, doubtless because the larger number of the fine particles remained unchanged.

#### X-RAY ANALYSIS OF GLASS SAMPLES.

X-ray was obtained from a Hadding-Seigbahn type of X-ray tube with Cu anti-cathode run at a voltage of the order of 60 Kv. with tube current of 10 milli-amperes and the diffraction photographs were taken in a cylindrical camera of 3.90 cm. radius.

The X-ray diffraction pattern of some samples consists of some lines in addition to the diffuse band from the glass and the presence of lines in the X-ray picture indicates one or more crystalline phases in the glassy matrix. That observation gives a sharp contrast to the usual diffraction pattern of oxide glass.

It is well known that each crystalline substance has its characteristic set of plane spacings and the relative intensities of various reflections are also characteristic. The data thus obtained from the experimental specimen were compared with those of the likely substances. The lines on the X-ray picture can also be identified by finding by trial a unit cell such that the reflexion in the planes ( $hkl$ ) will give the same value of  $\sin^2\theta$  where  $\theta$  is the Bragg angle as is found by the measurement of the film. As for example in the cubic crystal

$$\alpha^2 = \left(\frac{\lambda}{2}\right)^2 \frac{h^2 + k^2 + l^2}{\sin^2\theta}$$

where  $\alpha$  = lattice constant,  
 $\lambda$  = wave-length of X-ray,  
 $h, k$  and  $l$  = indices of the plane

But in the case of a crystal of lower symmetry, the powder picture becomes very complicated. However, in the present case the crystal structure of dispersoid is cubic. Consequently, it is expected that the diffraction of each specimen will not be very much complex. Moreover the absorption coefficient of the  $B_2O_3$ , Borax and Lindemann glass is low, so the nature and the state of existence of each dispersoid can be studied in detail. For the sake of convenience, colloidal coloured glass of each dispersoid has been studied one after another.

#### PLATINUM GLASS.

Pt has been dispersed in three glass bases such as Borax,  $B_2O_3$  and Lindemann glass. Each set consists of many samples with concentration variation of noble metal. The composition of each sample is given in the following table.

In the case of Sp. 1 and Sp. 2 of each series, bands are quite prominent. The diffraction angles of those bands along with the data of the other samples of each series are given in the following table:—

TABLE I.

| Glass Composition.                     | Sp. No. | Concentration of Pt in wt. per cent. | $\theta$ | Int.   | $\theta$ | Int.  |
|--|---------|--------------------------------------|----------|--------|----------|-------|
| Pt-Borax .. ..                         | 1       | 0.75                                 | 9° 21'   | S      | 22° 30'  | w(d)  |
|  | 2       | 0.975                                | 9° 21'   | S      | 22° 30'  | w(vd) |
|  | 3       | 1.25                                 | 9° 21'   | S(d)   |          |       |
|  | 4       | 1.63                                 | 9° 21'   | M(vvd) |          |       |
| Pt-B <sub>2</sub> O <sub>3</sub> .. .. | 5       | 0.07                                 | 10° 55'  | S      | 21° 35'  | w(d)  |
|  | 6       | 0.80                                 | 10° 55'  | S      | 21° 35'  | w(d)  |
|  | 7       | 1.097                                | 10° 45'  | M(d)   |          |       |
|  | 8       | 1.62                                 | 10° 45'  | M(d)   |          |       |
| Pt-Lindemann ..                        | 9       | 0.75                                 | 10° 39'  | S      | 22° 20'  | w     |
|  | 10      | 1.02                                 | 10° 39'  | S      | 22° 30'  | w(d)  |
|  | 11      | 1.75                                 | 10° 46'  | S(d)   |          | vw(d) |
|  | 12      | 1.825                                | 10° 39'  | MS(d)  |          | vw(d) |

TABLE II.

## Pt-Borax Systems.

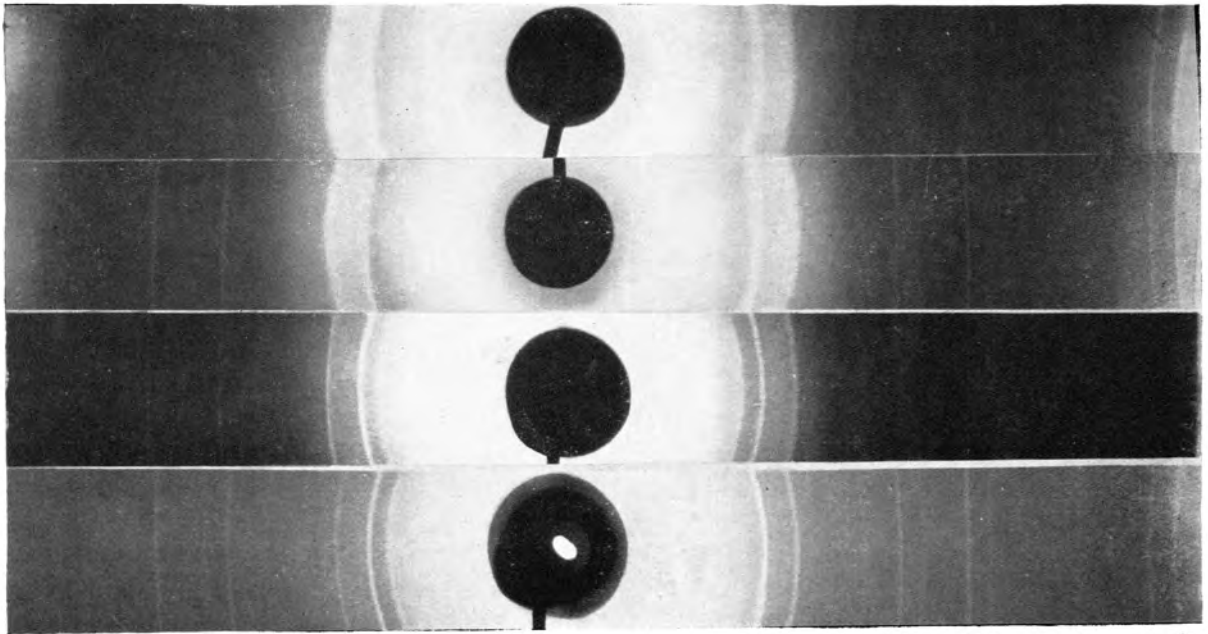
| Pure platinum. |          |                 | Sample 1 |      | Sample 2 |      | Sample 3 |      | Sample 4 |      |
|----------------|----------|-----------------|----------|------|----------|------|----------|------|----------|------|
| Plane.         | $\theta$ | Inten-<br>sity. | $\theta$ | Int. | $\theta$ | Int. | $\theta$ | Int. | $\theta$ | Int. |
| (111)          | 20° 1'   | 1.00            | 20° 6'   | s.   | 20° 6'   | s.   | 20° 6'   | s.   | 20° 6'   | s.   |
| (200)          | 23° 16'  | 0.30            | 23° 25'  | m.   | 23° 19'  | m.   | 23° 19'  | m.   | 23° 19'  | m.s. |
| (220)          | 33° 52'  | 0.16            | 33° 58'  | w.   | 33° 58'  | w.   | 33° 51'  | m.w. | 33° 58'  | m.   |
| (311)          | 40° 49'  | 0.16            | 40° 59'  | w.   | 40° 52'  | w.   | 40° 52'  | m.w. | 40° 45'  | m.   |
| (222)          | 43° 4'   | 0.03            | 43° 3'   | v.w. | 43° 15'  | v.w. | 43° 8'   | w.   | 43° 8'   | m.w. |
| (400)          | 51° 58'  | 0.03            | 52° 9'   | v.w. | 52° 9'   | v.w. | 52° 2'   | w.   | 51° 55'  | m.w. |
| (331)          | 59° 8'   | 0.03            |          |      |          |      |          |      | 59° 2'   | w.   |
| (420)          | 61° 46'  | 0.02            |          |      |          |      |          |      | 61° 45'  | w.   |

TABLE III.

Pt-B<sub>2</sub>O<sub>3</sub> Systems.

| Pure platinum. |          |                 | Sample 5 |      | Sample 6 |      | Sample 7 |      | Sample 8 |      |
|----------------|----------|-----------------|----------|------|----------|------|----------|------|----------|------|
| Plane.         | $\theta$ | Inten-<br>sity. | $\theta$ | Int. | $\theta$ | Int. | $\theta$ | Int. | $\theta$ | Int. |
| (111)          | 20° 1'   | 1.00            | 20° 6'   | m.w. | 19° 57'  | s.   | 20° 6'   | s.   | 19° 57'  | s.   |
| (200)          | 23° 16'  | 0.30            | 23° 25'  | v.w. | 23° 8'   | m.   | 23° 25'  | m.   | 23° 8'   | m.s. |
| (220)          | 33° 52'  | 0.16            |          |      | 33° 43'  | m.w. | 33° 51'  | m.w. | 33° 50'  | m.   |
| (311)          | 40° 49'  | 0.16            |          |      | 40° 46'  | m.w. | 40° 46'  | m.w. | 40° 46'  | m.   |
| (222)          | 43° 4'   | 0.03            |          |      | 42° 59'  | w.   | 43° 3'   | w.   | 42° 59'  | m.w. |
| (400)          | 51° 58'  | 0.03            |          |      | 51° 53'  | w.   | 51° 51'  | w.   | 52° 9'   | m.w. |
| (331)          | 59° 8'   | 0.03            |          |      |          |      |          |      | 59° 9'   | m.w. |
| (420)          | 61° 46'  | 0.02            |          |      |          |      |          |      | 61° 52'  | w.   |

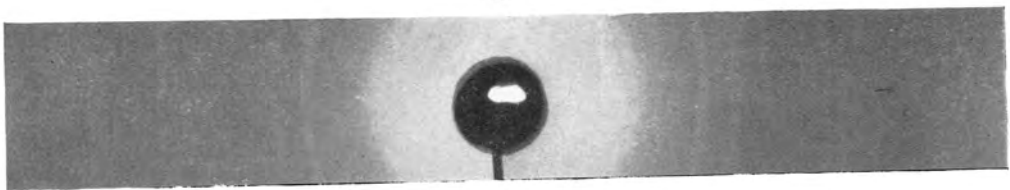
C



Pt Planes

$\uparrow$   $\uparrow$   $\uparrow$   $\uparrow$   $\uparrow$   $\uparrow$   
[111] [002] [220] [311] [222] [400] [331] [420]

D



E



Pt Planes

$\uparrow$   $\uparrow$   $\uparrow$   $\uparrow$   
[111] [002] [220] [311]

It is quite evident from Table I that the nature of the band in each glass specimen alters appreciably with the increase of Pt content in the glass base. The X-ray picture of the last sample of each series differs considerably from that of the first sample of the respective series.

The X-ray pictures of all samples are given in Plates VIII and IX. The diffraction angle with relative intensity of each line is given in Table II.

TABLE IV.  
*Pt-Lindemann Systems.*

| Pure platinum. |          |                 | Sample 9 |      | Sample 10 |      | Sample 11 |      | Sample 12 |      |
|----------------|----------|-----------------|----------|------|-----------|------|-----------|------|-----------|------|
| Plane.         | $\theta$ | Inten-<br>sity. | $\theta$ | Int. | $\theta$  | Int. | $\theta$  | Int. | $\theta$  | Int. |
| (111)          | 20° 1'   | 1.00            | 20° 6'   | s.   | 19° 50'   | s.   | 20° 6'    | s.   | 19° 50'   | s.   |
| (200)          | 23° 16'  | 0.30            | 23° 25'  | m.s. | 22° 51'   | m.s. | 23° 13'   | m.s. | 23° 4'    | m.s. |
| (220)          | 33° 52'  | 0.16            | 33° 58'  | m.w. | 33° 51'   | m.w. | 33° 53'   | m.w. | 33° 43'   | m.w. |
| (311)          | 40° 49'  | 0.16            | 40° 59'  | m.w. | 40° 45'   | m.w. | 40° 52'   | m.w. | 40° 38'   | m.w. |
| (222)          | 43° 4'   | 0.03            | 42° 59'  | w.   | 42° 59'   | w.   | 43° 9'    | w.   | 42° 52'   | w.   |
| (400)          | 51° 58'  | 0.03            | 51° 53'  | w.   | 52° 9'    | w.   | 51° 55'   | w.   | 51° 55'   | w.   |
| (331)          | 59° 8'   | 0.03            |          |      |           |      | 59° 13'   | w.   | 59° 2'    | w.   |
| (420)          | 61° 46'  | 0.02            |          |      |           |      |           |      | 61° 45'   | w.   |

From the preceding tables it is quite evident that the broad lines present in the X-ray picture are due to the crystallites of Pt. As is quite natural the intensity of the lines increases with the rise of concentration of Pt content in the glass specimen, but along with it the nature of the band undergoes a distinct change—they become more and more diffuse with concentration. In the case of B<sub>2</sub>O<sub>3</sub> series, there are some weak new lines which are due to the crystalline B<sub>2</sub>O<sub>3</sub>.

GOLD RUBY GLASS.

Both Borax and B<sub>2</sub>O<sub>3</sub> glass systems containing gold have been studied. Each set consists of a number of samples with the percentage variation of gold.

As in the case of Pt series, here too, the diffraction picture given in Plate X consists of both lines and bands. The diffraction angle of each band along with the relative intensity is shown below.

TABLE V.

| Glass composition.                  | Sp. No. | Concentration in wt. per cent. | $\theta$ | Int. | $\theta$ | Int.     | $\theta$ | Int. |
|-------------------------------------|---------|--------------------------------|----------|------|----------|----------|----------|------|
| Au-Borax ..                         | 13      | 1.28                           | 9° 21'   | s.   | 14° 20'  | w(d)     | 22° 24'  | w.   |
|                                     | 14      | 1.87                           | 9° 21'   | s.   | 14° 20'  | w(d)     | 22° 24'  | w.   |
|                                     | 15      | 2.01                           | 9° 21'   | s.   | 14° 15'  | v.v.w(d) | 22° 35'  | w.   |
| Au-B <sub>2</sub> O <sub>3</sub> .. | 16      | 0.05                           | 10° 48'  | s.   | 21° 25'  | w.       |          |      |
|                                     | 17      | 0.40                           | 10° 39'  | s.   | 21° 30'  | w.       |          |      |
|                                     | 18      | 1.56                           | 10° 39'  | s.   | 21° 45'  | w(v.d.)  |          |      |

It is quite evident from the preceding tables that the nature of the band is affected much by the presence of Au in the glass base and that is quite remarkable in the case of borax series.

The lines in the X-ray picture of Au series are weak in comparison with the Pt series and there is a much background scattering in each photograph. Nevertheless, the diffraction angle of each line (in  $\text{CuK}\alpha$  radiation) has been compared with those of pure Au in the following table.

TABLE VI.  
*Au-Borax series.*

| Plane. | Pure Au  |      | Au-Borax Sp. 13 |      | Sp. 14   |      | Sp. 15   |      |
|--------|----------|------|-----------------|------|----------|------|----------|------|
|        | $\theta$ | Int. | $\theta$        | Int. | $\theta$ | Int. | $\theta$ | Int. |
| (111)  | 19° 7'   | 1.00 | 19° 5'          | m.w. | 19° 0'   | m.   | 19° 10'  | m.   |
| (200)  | 22° 127' | 0.53 | 22° 24'         | w.   | 22° 24'  | m.w. | 22° 24'  | m.w. |
| (220)  | 32° 21'  | 0.33 |                 |      |          |      | 32° 39'  | w.   |
| (311)  | 38° 53'  | 0.40 |                 |      |          |      | 39° 5'   | w.   |
| (222)  | 41° 2'   | 0.09 |                 |      |          |      | 41° 9'   | v.w. |
| (400)  | 49° 7'   | 0.03 |                 |      |          |      |          |      |
| (331)  | 55° 27'  | 0.09 |                 |      |          |      |          |      |
| (420)  | 57° 48'  | 0.07 |                 |      |          |      |          |      |

TABLE VII.  
*Au-B<sub>2</sub>O<sub>3</sub> series.*

| Plane. | Pure Au  |      | Sp. 16   |      | Sp. 17   |      | Sp. 18   |      |
|--------|----------|------|----------|------|----------|------|----------|------|
|        | $\theta$ | Int. | $\theta$ | Int. | $\theta$ | Int. | $\theta$ | Int. |
| (111)  | 19° 7'   | 1.00 | 19° 5'   | v.w. | 19° 5'   | m.w. | 19° 5'   | s.   |
| (200)  | 22° 17'  | 0.53 |          |      | 22° 9'   | w.   | 22° 17'  | m.s. |
| (220)  | 32° 21'  | 0.33 |          |      | 32° 17'  | v.w. | 32° 9'   | m.   |
| (311)  | 38° 53'  | 0.40 |          |      |          |      | 38° 47'  | m.   |
| (222)  | 41° 2'   | 0.09 |          |      |          |      | 41° 2'   | m.w. |
| (400)  | 49° 7'   | 0.03 |          |      |          |      | 49° 13'  | w.   |
| (331)  | 55° 27'  | 0.09 |          |      |          |      |          |      |
| (420)  | 57° 48'  | 0.07 |          |      |          |      |          |      |

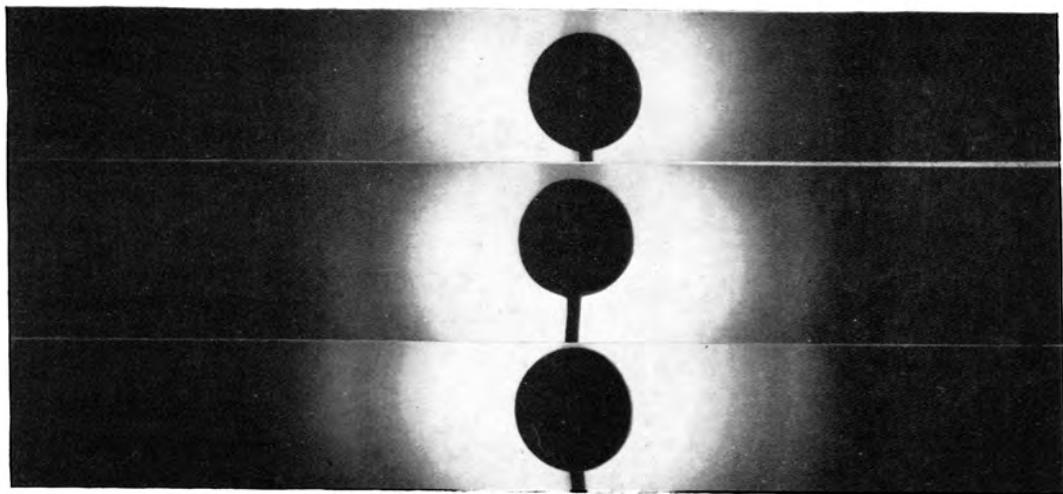
From the preceding tables, it is quite evident that the lines present in the diffraction photograph of the above series are due to gold. Lines are usually weak. In the case of  $\text{B}_2\text{O}_3$  series, there are some weak lines due to  $\text{B}_2\text{O}_3$ .

#### LATTICE CONSTANT OF THE DISPERSOID.

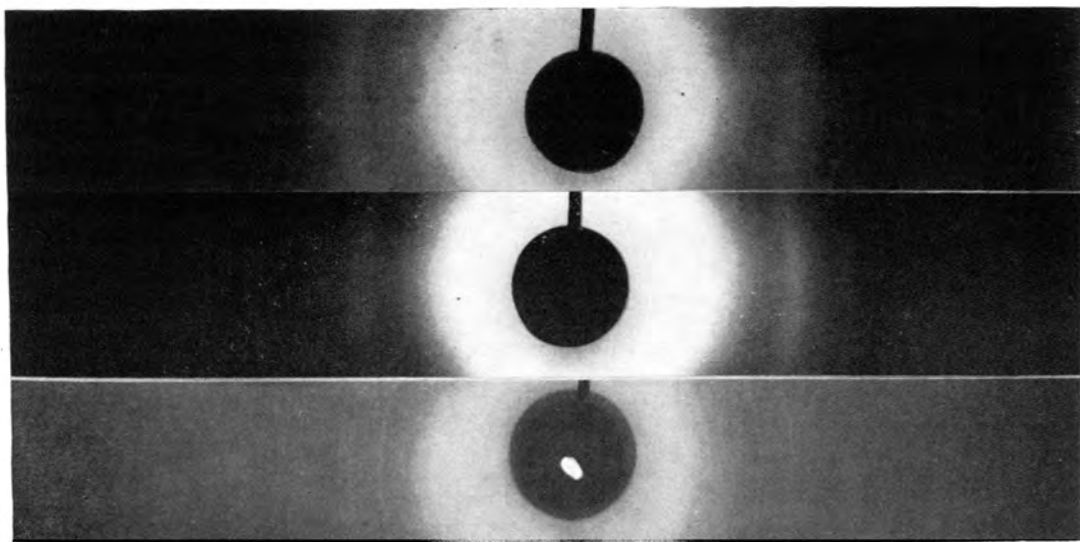
The systematic errors involved in measuring the 'd' values by the X-ray diffraction method have been studied by various workers. The errors listed are mainly due to (i) Film shrinkage, (ii) Eccentricity of the sample, and (iii) Absorption. In the present case, the 'd' value of the dispersoid in the glass system has been determined by the Internal Mixture method. As for example, Sp. 1 of Pt-Borax series is mixed with Al powder in the weight ratio 1 : 1 where Al served as a



F



G



Au Planes

$\uparrow$  [111]  $\uparrow$  [200]  
 $\uparrow$  [220]  $\uparrow$  [311]  $\uparrow$  [222]

standard substance. The X-ray picture of the cylindrical form of the above mixture is taken in a cylindrical camera of 5.0 cm. radius. The 'd' value of each line of Pt is calculated with reference to the 'd' value of Al which serves as a check in the value of radius of the camera in the equation where  $x$  = distance between a pair of lines.

$$\theta^\circ = \frac{x}{4r} \times 57.3 \quad r = \text{radius of the camera.}$$

The diffraction angle of each line of Pt is in good agreement with the diffraction angle of Pt calculated from the lattice constant of Pt.

TABLE VIII.

| Experimental. |        |                                   |        |
|---------------|--------|-----------------------------------|--------|
| $\theta$      | Int.   | Diffraction angle of the element. | Plane. |
| 19° 18'       | v.s.   | Al                                | (111)  |
| 20° 1'        | m.     | Pt                                | (111)  |
| 22° 24'       | s.     | Al                                | (200)  |
| 23° 16'       | m.w.   | Pt                                | (200)  |
| 32° 33'       | m.s.   | Al                                | (220)  |
| 33° 52'       | w.     | Pt                                | (220)  |
| 39° 12'       | m.s.   | Al                                | (311)  |
| 40° 49'       | w.     | Pt                                | (311)  |
| 41° 14'       | m.w.   | Al                                | (222)  |
| 43° 4'        | v.w.   | Pt                                | (222)  |
| 49° 37'       | w.     | Al                                | (400)  |
| 51° 58'       | v.v.w. | Pt                                | (400)  |

ABSORPTION.

So far we have discussed about the nature of the crystalline phase in the glassy matrix. It is also pointed out that in many of the photographs one or more bands appear. Moreover, pure glass base such as B<sub>2</sub>O<sub>3</sub>, Borax, Lindemann glass, etc. gives rise only to bands in the diffraction pattern and the values with intensity relation are given in the following table:—

TABLE IX.

| Glass.                           | $\theta$ | Character. | $\theta$ | Character.             | $\theta$ | Character. |
|----------------------------------|----------|------------|----------|------------------------|----------|------------|
| Borax ..                         | 9° 18'   | Sharp ..   | 14° 10'  | Fairly sharp ..        | 22° 27'  | Sharp.     |
| B <sub>2</sub> O <sub>3</sub> .. | 10° 48'  | Sharp ..   | 21° 25'  | Weak but well-defined. |          |            |
| Lindemann                        | 10° 33'  | Sharp ..   | 21° 24'  | Weak but well-defined. |          |            |

Although in no case of the glass specimens, the content of the dispersed phase hardly exceeds about 2.5 per cent but from the pictures of the plate it can be readily seen that the bands fade out with the rise of Pt content. Similar observation is also made in other series such as Au specimens.

All the X-ray pictures have been taken in the same camera with the same radius of the sample stick, consequently with the same volume of the substance irradiated. The fading of the bands for stronger concentrations show that absorption plays a leading rôle in quenching the intensity of the bands in the X-ray pictures of the glass specimens containing Au or Pt as a dispersoid. Thus at an appreciable concentration of the dispersoid its high mass absorption overrides the low absorption coefficient of glass base, which contains very large percentage of weightage.

#### X-RAY ANALYSIS OF THE DISPERSOID ISOLATED FROM GLASSY MATRIX.

The crystalline phase was separated from the glassy matrix with the help of HF. The effect of HF was to dissolve the glass, setting free the gold particles which were not attacked by HF. A typical sample of Pt—B<sub>2</sub>O<sub>3</sub> series—sp. 6 was taken and about 5 gms. of that sample was treated in a Pt basin over water-bath. In this way Platinum was isolated in an unaffected state from the glassy matrix with distilled water. The X-ray picture of the isolated Platinum from the same specimen is given in Plate No. IX. The X-ray data are given in the following table:—

TABLE X.

| Int. | $\theta$ | $\theta$ | Int.  |
|------|----------|----------|-------|
| 1-00 | 20° 1'   | 19° 55'  | s.    |
| 0-3  | 23° 16'  | 23° 2'   | m.s.† |
| 0-16 | 33° 52'  | 33° 52'  | m.    |
| 0-16 | 40° 49'  | 40° 52'  | m.    |
| 0-03 | 43° 4'   | 42° 58'  | m.w.  |
| 0-03 | 51° 58'  | 52° 0'   | m.w.  |
| 0-03 | 59° 8'   | 59° 15'  | w.    |
| 0-02 | 61° 46'  | 61° 50'  | w.    |

From the width of the line of the isolated crystallite, it is quite evident that the particle is of colloidal size. Further it is found that besides the lines of Pt, there are some weak lines in the X-ray picture of the isolated specimen.

The observations detailed above show that in the X-ray diffraction photographs due to coloured glasses produced by the solution of Au and Pt in boric oxide, borax or Lindemann glasses consist of bands accompanied by fairly sharp lines. The lines have the same spacings as those present in the powder photographs of the dispersoid materials. For very weak concentrations of the dispersoid the lines are usually absent apparently due to too weak intensity. For much stronger concentrations sometimes only lines are found in the X-ray picture. This is evidently due to strong absorption by the dispersoid. All these glass samples showed no sign of devitrification when examined under a polarizing microscope and a glass slab of appreciable thickness showed no sign of milkiness. So it is evident that the lines are due to the dispersoid and their sharpness indicate that they are of colloidal dimensions. Half-intensity widths of these lines are being determined in order to find out the average sizes of these colloids.

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## SUMMARY.

The nature of the colloidal particles of Au and Pt in glass samples of  $B_2O_3$ , borax and Lindemann glass and their influence on the structure of the glass have been investigated. The method of formation, vitreous limit, colour and the other interesting properties of the above glass systems have been also discussed. X-ray photographs of the samples reveal the presence of broad lines of the noble metals besides the diffuse haloes of glass.

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