

*The Theory of Photographic Processes, Part III: The Latent Image and its Destruction. (Abridged Account.)*

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The following abridged account summarises the results of an investigation to be published in a more extended form subsequently. It deals with the formation of so-called "latent images" on photo-films, their destruction by chemical agents, and the bearing of these results upon the nature of the light-product in silver halides and its function in promoting reduction.

PART I.—*The Developable Condition in Halide Emulsions.*

The essential chemical reaction in development may be typified by the equation  $\text{Ag} + \text{R}' \rightleftharpoons \text{Ag (met.)} + \text{R}'$ . It is somewhat difficult to give a comprehensive and characteristic definition of development which shall distinguish it from normal reduction of silver ions to the metallic state, the more so that the word develop is used in such varied senses. For present purposes the following is probably sufficient. Developability is brought about when a preliminary treatment accelerates a subsequent reduction with reducing agents. It is, perhaps, impossible to draw a line of strict demarcation, but the inner mechanism will be clearer in the sequel. An investigation by one of the authors\* has shown that the aforementioned reaction in development is reversible. Independently, then, of "developability" the reaction  $\text{Ag} + \text{R}' \rightleftharpoons \text{Ag} + \text{R}'$  proceeds to a state of equilibrium. But it does not follow that metallic silver is precipitated. Unless the potential of the reducing ion is very high, the metallic silver may remain in solution. Two further eventualities are possible. A *colloidal* silver solution may be formed, stable under certain conditions, but liable to coagulation by electrolytes. Or there may be some cause lowering the meta-stable limit, so that metallic silver is precipitated. In the presence of solid silver with normal reducing agents complete reduction of the gelatino-halide grain is ensured,† in agreement with the "silver-germ" theory of development.‡ *Any cause tending to lower the meta-stable limit of the silver solution makes the halide developable.* The aforementioned investigation showed that the reduction in

\* 'Chem. Soc. Trans.,' 1905, vol. 87, p. 1317.

† 'Roy. Soc. Proc.,' A, 1905, vol. 76, p. 217: "Theory of Photographic Processes, Part II.

‡ 'Chem. Soc. Trans.,' *loc. cit.*

development could be divided into two periods, an initial induction, the length of which depended chiefly on chemical processes, and a second period, in which the velocity depends chiefly on the supply of reducing ions to the affected grains.

A number of substances, if introduced into the grain in very intimate mixture—probably as a solid solution\*—can greatly shorten the induction period and bring about developability. We found that the following could act as “germs” for a dry-plate:—

- (a) *Silver*, introduced as colloidal silver by treatment with silver nitrate solution and then Carey Lea's ferrous citrate solution. Dilute HCl was then applied, converting the colloidal silver to metallic, and in a developer reduction proceeded forthwith.
- (b) *Gold*, by the action of gold chloride on the gelatin film.
- (c) *Platinum*, to some extent as with gold, and better by the action of ferrous oxalate.
- (d) *Silver sulphide*, by the action of polysulphides and of acid thiosulphate with ferrous oxalate.
- (e) *Gas ions* from flame gases with a plate soaked in developer.

That the shortening of a chemical induction period by lowering the meta-stable limit is the essential factor in developability appears to be confirmed by the following. Gelatino-silver nitrate, jellified with 10-per-cent. gelatin, gave, with certain precautions, on treatment with ammoniacal pyrogallol, or better, ferrous fluoride, rings of metallic silver deposited at regular intervals, in addition to a general coloured deposit. The former are the well-known Liesegang's rings,† considered by Ostwald as a confirmation of his theory of a meta-stable limit, and quantitatively investigated for silver chromate by Morse and Pierce.‡

*Non-emulsified Silver Halide and the Function of Gelatin.*—An investigation of the action of light and reducing agents on pure precipitated silver bromide layers confirmed the statements of Abney and Schaum,§ that gelatin mechanically or chemically retards reduction by developers. Now, Jaffé,|| in some studies on supersaturation, found that the “life” of a solution was always prolonged by repeated preliminary filtration. The removal of “germs” mechanically raised the meta-stable limit. Our experiments point to the gelatin functioning as a protective sheath against “germ infection,” thus

\* Cf. H. Weisz, 'Zeit. phys. Chem.,' 1906, vol. 54, p. 305.

† 'Chemische Reaktionen in Gallerten' (Düsseldorf).

‡ 'Zeit. phys. Chem.,' 1904, vol. 45, p. 600.

§ 'Zeit. wiss. Phot.,' 1904, vol. 1, p. 377.

|| 'Zeit. phys. Chem.,' 1903, vol. 43, p. 565.

mechanically retarding reduction. In part, also, it forms solid solutions with the halide, and complex ions with the silver ion, both additional helps to the stability of the halide.

On the whole, the evidence tends to the conclusion that a necessary and sufficient condition for "developability" is the production in the silver halide grain of a *new* substance. Now, the developable condition may be induced by the action of various energies, which we may group as follows\* :—

- (a) Ether vibrations, from infra-red to ultra-violet.
- (b) Röntgen rays, kathode rays, and the  $\beta$ - and  $\gamma$ -radiation of radio-active bodies.
- (c) Mechanical stress or pressure.
- (d) Heat.
- (e) Chemical action.

At present we will only consider the first, resulting in the ordinary photographic image. To deal critically with the various theories, physical and chemical, as to its nature, would take too much space. But it is almost impossible to account for the way in which the "latent" image interferes with certain definite chemical reactions on any physical theory. Such are the aforementioned abbreviation of an induction in reduction, the existence of an image capable of development after fixation, and, in particular, the destruction of the "latent" image by halogenising and oxidising agents. We have made a somewhat extended investigation of the action of the latter and may collect our conclusions as follows.

## PART II.—*The Destruction of the "Latent" Image.*

### Section A. *The Action of Oxidisers Subsequent to Exposure.*

It has frequently been maintained that halogenising and oxidising agents do not actually destroy the latent image, but only retard development. Sterry,† for example, considered that their effect was to delay what he termed "secondary development," *i.e.*, an assumed intensification of a primarily formed image by silver from neighbouring granules. Our experiments with chromic acid subsequent to exposure led to the following conclusions:—

Plates were dipped by rotation in  $\text{CrO}_3$  solution for a given time, then rinsed by rotation, and developed.‡ The plate-curve was distorted at the top, but

\* See also C. Lea, 'Phil. Mag.,' 1891, p. 320.

† J. Sterry, 'Phot. Journ.,' 1904, vol. 54, p. 50.

‡ For the authors' experimental methods, and for the meaning of the symbols  $\log i$  and  $\gamma_\infty$ , etc., see the previous papers, 'Roy. Soc. Proc.,' 1904, vol. 74, p. 447, and A, 1905, vol. 76, p. 217.

$\log i$  and  $\gamma_{\infty}$  were unchanged. The velocity-constant  $K$  of development was diminished, approximately in proportion to the *logarithm* of the strength of the preliminary  $\text{CrO}_3$  bath. Prolonged washing never entirely annulled the effect, but it was diminished. The values of  $K$  (the velocity of development) decreased with the time of immersion in  $\text{CrO}_3$ , ultimately reaching a minimum for each concentration, the function of the effect on  $K$  being independent of the concentration.

From these facts we conclude that the  $\text{CrO}_3$  is irreversibly absorbed in the film, probably both to the film and to the silver halide, forming with the latter something of the nature of a solid solution. Freshly precipitated  $\text{AgBr}$  is coloured yellow by chromic acid, and the colour is not removed by long washing. The retained oxidiser then slows development by oxidising the developer in the film. This view was further confirmed as follows. Plates were treated, after "chromating," with a solution of sodium sulphide, which restored  $K$  to its normal value by reducing the chromic acid.

This "sulphite reaction" enabled us to decide without doubt that the prolonged action of  $\text{CrO}_3$  destroyed the latent image, *i.e.*, both  $\log i$  and  $\gamma_{\infty}$  were altered. *After* sulphiting, since  $K$  is now restored to its normal value, any change in  $\gamma$  is due to a lessening of the mass of the latent image. The following table exemplifies the results for N/50  $\text{CrO}_3$ , with a subsequent bath of N/10  $\text{Na}_2\text{SO}_3$ , all developed in M/20 quinol for five minutes:—

	$t = \text{time of immersion in } \text{CrO}_3 \text{ in minutes.}$				
	$t = 0.$	2.	20.	40.	120.
$\gamma$ .....	1.65	1.65	0.77	0.48	0.34
$\log i$ .....	1.25	1.25	1.30	1.50	1.80

The rate of attack on the latent image was found to increase very rapidly with the concentration of the  $\text{CrO}_3$ . The phenomena point to a re-oxidation (possibly involving the release of halogen from a combination with gelatin) of a reduction product, the latter being in solid solution in the normal halide.

#### Section B. *Desensitisers.*

Plates bathed before exposure in certain metallic salt solutions show a diminished sensitiveness to light, even after prolonged washing.\* We find that salts of the following cations are effective, the anion being unimportant:— $\text{Cu}^+$ ,  $\text{Hg}^+$ ,  $\text{Fe}^{++}$ , and  $(\text{UO}_2)^{++}$ , whilst the following have no action:— $\text{H}^+$ ,  $\text{K}^+$ ,  $\text{Ba}^+$ ,  $\text{Mg}^+$ ,  $\text{Mn}^+$ ,  $\text{Co}^+$ ,  $\text{Ni}^+$ ,  $\text{Fe}^-$ ,  $\text{Zn}^-$ ,  $\text{Mo}^-$ ,  $\text{Cr}^-$  (?),  $\text{Ag}^-$ ,  $\text{Pb}^-$ ,  $\text{Th}^-$ . If plates are dipped in  $\text{CuSO}_4$  immediately prior to development with  $\text{FeC}_2\text{O}_4$ , there is no action. If left standing,  $\gamma_{\infty}$  is lowered, the latent image being destroyed in a

\* Lüppo-Kramer, 'Wiss. Arb. auf d. Geb. d. Phot.' (Knapp, Halle).

manner similar to the action of chromic acid. But if dipped before exposure, the value of  $\log i$  is greatly increased, *i.e.*, the sensitiveness diminished, but  $\gamma_{\infty}$  and  $K$  remain unchanged.

The peculiar behaviour of desensitisers might be referred to two categories: either (a) it alters the sensitive salt prior to exposure; or (b) it occurs during exposure by reversal of the photo-chemical reaction. The first would agree with that theory of "ripening" which supposes this process produces a minute quantity of the photo-reduction product. The second requires that some of the desensitising salt be retained in spite of prolonged washing, a view confirmed by some experiments with metol development. The following experimental results, with ferrous oxalate development, fully bear out the theory that *desensitisers act during exposure by reversal of the photo-chemical action*, and not by any modification of the sensitive substance:—

- (i) *Moist and Dry Films.*—We have confirmed Sterry's result: that moist films are less sensitive than dry ones, but have a higher  $\gamma_{\infty}$ .
- (ii) *Time of Immersion and Concentration.*—The effect, as measured by  $\Delta \log i$ , increases with the time of immersion, and on prolonged immersion weak solutions give the same effect as strong ones. Conversely, different solutions, acting for the same time but with long washing out, give the same effect. Otherwise this depends on the concentration and time.
- (iii) *Re-sensitising.*—By the action of a solution which combines with or reduces the desensitising ion, partial or complete resensitising may be obtained. With copper salts, quinine and benzaldehyde act in this manner; with ferric ions, oxalate solution, the ferric complex not being so effective.

Hence it appears probable that the desensitiser forms a solid solution or some combination with the silver salt, the maximum effect being for the limiting quantity absorbed. For the relative effect the following results were obtained:—

Plates bathed in.....	Water.	CuSO <sub>4</sub> .	(UO <sub>2</sub> )(NO <sub>3</sub> ) <sub>2</sub> .	FeCl <sub>3</sub> .	HgCl <sub>2</sub> .
Log $i$ .....	1.95	0.50	0.59	1.79	not > 2

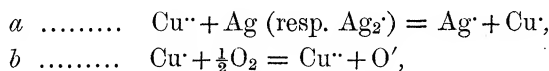
Hence extent to which plate is made insensitive—

—	3.6	4.4	69	> 100
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*The Mechanism of Desensitising.*—It is noteworthy that an effect may be obtained with very slight concentrations. Thus with M/100,000 CuSO<sub>4</sub>, with two hours' immersion before exposure, we obtained  $\log i$  (unbathed) 1.60,  $\log i$  (bathed) 2.25.

Hence, the desensitising effect of water is probably to be attributed to small quantities of impurities, and the action may give the clue to some of the troubles met with in emulsion-making, where the sensitiveness is sometimes found to drop for unknown reasons.

Further, if a plate containing  $\text{CuSO}_4$  be exposed long enough to overcome the resistance introduced by the  $\text{CuSO}_4$  and so give a full density, after a time the image again disappears. A very small quantity of the desensitiser can thus continually destroy the latent image. The action may be described as catalytic. The metallic ions effective are all known to act as catalysts in oxidising and halogenising processes.\* Substances such as stannous salts, quinine, mannite, etc.,† inhibit the positive catalysis by reacting with the catalytic ion, and hence acting as negative catalysts. The catalysis is to be referred probably to pseudo-catalysis or "Uebertragungscatalyse" (Wagner, Ostwald), since the copper probably takes a definite part in the reaction according to some scheme of the form—



the reformed  $\text{Cu}^{\cdot\cdot}$  again taking part in the destruction of the image.

*During exposure*, this reversing action prevents the formation of the reduction product. The effect would be different after exposure, owing to the reduction product forming a solid solution in normal halide. This view of a catalysis of a reverse action was confirmed by an increase in the *intermittency failure* in presence of a desensitiser.

#### Section C. *The Spontaneous Decay of the Latent Image.*

Much evidence has been brought forward pointing to a spontaneous decay of the latent image,‡ with which we may associate the phenomena of "reversal," and the failure of the Bunsen-Roscoe reciprocity relation, which states that the photo-chemical effect of an exposure  $\text{E}$  is the same whether the intensity or the time be altered, provided  $\text{It} = \text{E}$  be constant.

Abney§ and others have shown that this law does not hold absolutely for photographic plates, but that there is a range giving the maximum available energy. Repeating the work in a different manner, we used a very wide range of intensities. A typical table is as follows :—

\* Bredig, 'Zeit. phys. Chem.,' 1903, vol. 46, p. 502; Titoff, *ibid.*, 1903, vol. 45, p. 641.

† Bigelow, 'Zeit. phys. Chem.,' 1898, vol. 27, p. 585; and Titoff, *loc. cit.*

‡ Cf. Backeland, 'Zeit. wiss. Phot.,' 1905, vol. 3, p. 58.

§ 'Phot. Journ.,' 1893.

I.	$t$ (to give $D = 1$ ) in secs.	$I.t.$	$\log (I \times 1000).$
84.5	0.204	17.2	4.927
6.0	2.59	15.5	3.720
1.71	9.61	16.4	3.232
0.452	34.4	15.5	2.655
0.130	120	15.5	2.114
0.198	931	18.4	1.296
0.0074	4760	35.1	0.869
0.0056	6400	36.2	0.750

The deviations are best shown as follows: if the values of  $I.t.$ , which gave an equal effect (density) be plotted against those of  $I$ , or, for convenience,  $\log I$ , then the resultant curve will, if there be no deviation, be a straight line parallel to the  $x$  axis, but otherwise a curve showing the nature of the deviations. (Compare Amagat's  $pv-p$  curves.) It was found that:—

- (a) The failure is not a steady function of  $t$ .
- (b) Is independent of the total value of  $I.t.$
- (c) Is relatively independent of the sensitiveness of the plate, *i.e.*, starts at the same point relatively to the inertia point.\*

*The Intermittency Failure.*—Another form of reciprocity failure is with intermittent exposure, and this has been investigated by Abney and Englisch.† Our results are in good qualitative agreement with these observers', whilst practically they show that in sensitometry sector-wheels should not be driven at more than 100 revolutions per minute, the error below this being negligible. The general conclusions are:—

- (i) The failure increases with the pause between each illumination, increasing as the sector-angles diminish.
- (ii) It increases with the *rate* of intermittency.
- (iii) It is greater with small intensities.

Englich attributes the failure to an initial induction and also to a "fading-loss" or deduction. This latter merits chief consideration. Various "molecular" and "strain" hypotheses have been suggested, but the peculiar nature of photo-chemical equilibria appears to give sufficient explanation. Abegg‡ has correlated these phenomena with the lessened photo-effect obtained when plates are exposed through the glass side. From the

\* This is opposed to Abney's results, and possibly requires further confirmation; our results are for plates of 20 and 200 H. and D. Experiments with "gas-light" emulsion are desirable, but difficult, owing to the great exposures required.

† 'Schwarzungs-Gesetz phot. Platten.' W. Knapp, Halle.

‡ 'Sitz.-Ber. Wien Akad.,' 1900, vol. 109, p. 1.

investigations of Luther\* it appears that the continuous exposure of silver halides to light results in a state of equilibrium in which every light-intensity is balanced by a definite halogen potential (whether expressed as gas pressure, solution pressure, or electric potential). Equilibrium is not usually reached in ordinary exposures because these are too short, whilst the halogen is removed by diffusion and combination with the gelatin. Diffusion is easier from the film-air side; to this Abegg attributes the lessened effect through glass.† When the incident light is cut off, the reverse reaction is no longer opposed by the photo-dissociation, and the theory agrees well with the facts brought forward on the intermittency failure. The failure with small intensities is less easily accounted for, and is perhaps involved in processes antecedent to the dissociation of halogen, which will be mentioned later.

*Reversal.*—The peculiar phenomenon of reversal by very prolonged or intense exposure has not yet received a satisfactory explanation. Experiments with “retarded” development‡ show that the characteristic plate curve does not give a complete epitome of the photo-chemical reaction. In the diffusion period of development§ it is evident that an increase per grain of the photo-reduction product would not accelerate development, whilst if the bromine released were mechanically retained in the film it would oxidise the developer, as was found with chromic acid (see p. 464), hence leading to apparent reversal. The results of Precht|| with plates containing a developer (edinal sulphite) favour this view, since reversal is then much retarded. Weisz,¶ in a comprehensive study of this phenomenon, has shown that “tanning” theories must be abandoned, and apparently considers that a modification of the physical state of the reduction-germ or nucleus is brought about.

*The Nature of the Reduction Product.*—So far the evidence only shows, if with some degree of conclusiveness, that the latent image consists of a substance containing less halogen. The “free silver” theory is negatived by the general behaviour of oxidising agents, and especially by that of nitric acid.\*\* By the researches of Luther†† on the halogenisation of silver, the existence of the half-halides  $\text{Ag}_2\text{X}$  is made very probable, as well as their

\* ‘Zeit. phys. Chem.,’ 1899, vol. 30, p. 628.

† *Loc. cit.*

‡ ‘Chem. Soc. Trans.,’ 1905, vol. 87, p. 1317.

§ *Ibid.*, p. 1316.

|| ‘Zeit. wiss. Phot.,’ 1905, vol. 3, p. 79.

¶ ‘Zeit. phys. Chem.’

\*\* ‘Zeit. wiss. Phot.,’ 1905, vol. 3, p. 329.

†† *Loc. cit.*



identity with the visible and latent images, but later investigations by Günter and Baur\* show that the half-halide must form solid solutions in all proportions with normal halide. The varying behaviour of different exposures to oxidisers may then be explained as follows: In consequence of the thickness of the film and the absorption of light by this, there exist layers of halide grains with varying amounts per grain of reduction-product. If  $n$  grains must be reduced to the metallic state to give a visible image (Schwellenwert), the corresponding exposure will be shifted by reoxidation, progressively with time and concentration, but as the amount of subhalide falls, and its concentration in the grain is lessened, the potential of the oxidiser must be raised, or in the more exposed portions there will still be left sufficient grains with a sufficient minimum of half-halide to ensure developability.

PART III.—“*Ripening*” and the Photo-electric Effect.

Before summarising our conclusions on the photographic process we may interpolate a brief note on the process of ripening and on a probable action preliminary to any chemical action in exposure.

Ripening or the raising of sensitiveness by “cooking” aggregates the particles in a well-known manner,† and increases the opacity to light. A possible explanation of the change involved is the following: The vibrations of light are considered to be of an electro-magnetic nature, and their absorption as conditioned by resonance. Previously mentioned researches by Quincke show that in a gelatino-halide emulsion the admixture is of the most intimate kind. Every electro-magnetic resonance is conditioned not only by the electric and magnetic properties of the resonators and of *their surrounding medium*, but also necessarily by their spatial distribution. In fact, the vibration period increases with the spatial extension of the resonators, with the closeness of their packing and with the dielectric constant of the medium.‡ Zsgimondy, by the ultra-microscopic method,§ has shown that gelatin consists of a homogeneous basis containing aggregates or “clumps,” the proportion being variable and influenced by the state of the gelatin. In an emulsion these clumps would give their form and distribution to the associated halide. They may be considered as forming the resonators or groups of systems of resonators postulated above, and their formation as one end in ripening. To this is also probably due the slow alteration in the viscosity of gelatin on cooking, noted by Schröder.

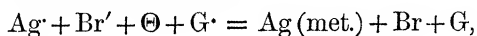
\* ‘Zeit. phys. Chem.’ vol. 45, p. 618.

† Cf. Ostwald, ‘Zeit. phys. Chem.’ 1900, vol. 34, p. 495.

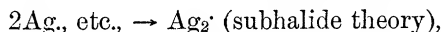
‡ Cf. Luther, ‘Zeit. wiss. Phot.’ 1905, vol. 3, p. 264.

§ ‘Zeit. Elektrochem.’ 1902, vol. 8, p. 686.

*The Photo-electric Effect.*—As is well known, certain metals and other substances, under the influence of ultra-violet light, lose a negative charge. The sensitiveness of the effect runs parallel with the absorption and is greatest for the region chiefly absorbed. The silver halides and many dye-stuffs used as sensitisers are highly photo-electric. It is assumed that the incident light sets free electrons or negative corpuscles, which at a bounding surface ionise the gas and are removed by diffusion and convection, or, if in an electric field, move in accordance. There is, however, another photo-electric effect. Many substances, and especially silver and the silver halides, give a difference of potential when immersed in an electrolyte and one pole exposed to light. M. Wilderman,\* from a quantitative study of the phenomenon, concludes that the solution pressure of the exposed plate is increased. H. Scholl† finds that silver iodide in light undergoes a species of dissociation which produces the ions of AgI and negative electrons. The latter are much more mobile than the electrolytic ions in solid silver iodide and impart metallic conductivity to this. Hence we must agree that in the photo-film the electron is set free, not only at the bounding surface, but as far through the substance as the intensity of the light is sufficient. This may be regarded as the primary photo-chemical change. Joly‡ has ably resumed the bearing of the photo-electric effect. He considers that the latent image is built up of ionised atoms or molecules and upon these the chemical effects of development are subsequently imposed. But the assumed stability of the free electric charges remains unexplained,§ as also the destruction of the latent image by oxidising agents. Rather does it seem that the liberated electron brings about a chemical change (if temperature and other conditions are favourable) and that the product, when below the threshold of perception, forms the latent image. The process may be typified as follows:—



or



where G is a molecule which becomes positively charged to G' (molion) by the photo-electric process.

Probably many of the phenomena of photographic induction may be susceptible of an explanation by this theory. In addition it accounts for the action of dyes as sensitisers for their own region of absorption, since the electrons liberated from the dye would act as before.

\* 'Roy. Soc. Proc.,' 1904, vol. 74, p. 369.

+ 'Ann. Phys.,' 1903 [4], vol. 16, pp. 193 and 417.

‡ Address to Photographic Convention, 1905. 'Brit. Journ. of Phot.,' 1905, vol. 52, p. 551.

§ Cf. also Scholl, "On the Evanescence of Photo-electric Effect," *loc. cit.*

*Summary.*

The photographic process, in brief, consists in the passage of ionised silver to the metallic state, with a sub-oxidation stage as probably intermediate. We may summarise our conclusions at the present stage as follows:—

1. *Ripening* due to—

(a) Formation of resonating systems.

(b) Formation of (intermediate) reduction-product.

Function of gelatin: forms resonators and assists reduction.

2. *Exposure*, light absorbed and electrons set free which ionise the halide and surrounding gas.

Function of gelatin: high dielectric constant, photo-electric, conserves electrons.

Function of gas: according as it removes electrons or not, may diminish sensitiveness. Electrons may be emitted either from halide or from sensitisers.

3. *Ionisation* leads to chemical reduction: electrolytically dissociated halide becomes discharged by interaction with electrons and positive atom or molions.

Function of gelatin: combines with free halogen.

The reduction probably results in a half-halide,  $\text{Ag}_2\text{X}$ , in solid solution. The action is reversible, a definite halogen pressure corresponding to each intensity of light.

## Destruction of latent image—

(a) Free halogen during and after exposure.

(b) Desensitisers during exposure; cyclic action with oxygen involved.

(c) Oxidisers after exposure; possibly halogen released from gelatin.

(d) Reversal (1) halogen reconverts subhalide; (2) halogen (absorbed) oxidises developer.

4. *Development*: subhalide reduced to metallic silver, silver germ formed and complete reduction consequent on—

(a) Formation of silver germs: velocity chiefly dependent on chemical processes; *induction period*.

(b) Deposition on silver germ: velocity dependent on diffusion processes *steady state*.

Very possibly subhalide occurs as an intermediate product in development also.

Function of gelatin: filter against germs, so preventing fogging.

5. *Fixation* or removal of remaining halide.\*

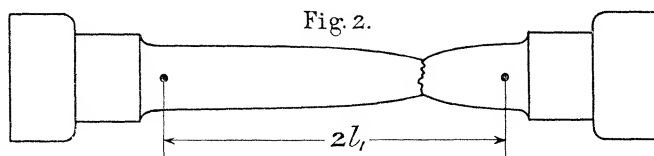
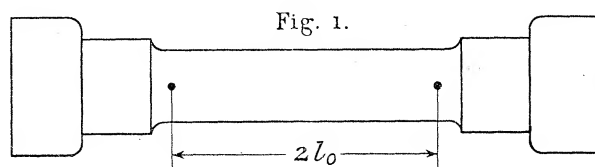
In conclusion, the authors desire to express their great thanks to Sir William Ramsay, K.C.B., F.R.S., for his constant advice and interest in the investigation.

*The Relation between Breaking Stress and Extension in Tensile Tests of Steel.*

By A. MALLOCK, F.R.S.

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A large number of the tensile tests of steel are now made with test-pieces, which are only a few diameters long (fig. 1).



When such a test-piece is broken by tension, it has a profile, as shown in fig. 2. The usual records, made when the tests are carried out, include, among other things, “breaking stress” and “extension per cent.”

“Breaking stress” here means the maximum tension applied divided by the original area of the test-piece; and extension per cent. is taken as the percentage increase due to the strain, in the distance between two marks, one at either end of the test-piece, whose unstrained distance is known. The use of the term “breaking stress” in the above sense is convenient, from an engineer’s point of view, as showing what force a bar, etc., of given sectional area will stand before giving way. The true breaking stress of a material, however, is the actual intensity of the stress at

\* ‘Phot. Journ.’ (Trans. Roy. Phot. Soc.), 1906, vol. 46, p. 235: “On the Theory of Fixation.”