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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
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Letter
Circular
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FLUORESCENCE AND PHOSPHORESCENCE

The National Bureau of Standards often receives requests for information on work it has done in the field of fluorescence and phosphorescence, or for information on fluorescent and phosphorescent materials or on equipment for demonstrating fluorescence and phosphorescence. This letter circular has been prepared in answer to such requests. It contains information which has been accumulated in answering these letters, but it does not represent an exhaustive study of fluorescence (1) nor an attempt to make the information complete in any case. The references given will, however, serve as a basis for those wishing to pursue the subject further.

(1) The term, fluorescence, will from here on be used to designate both fluorescence and phosphorescence. In common usage the distinction is mainly one of time. Phosphorescent materials continue to emit light after the exciting radiant energy is turned off, the intensity of this emitted light decreasing continuously with time. In the case of fluorescent materials, the decay is too rapid to be perceptible; hence no light is emitted after the exciting energy ceases. Furthermore, it should be noted that this letter circular considers primarily only that type of luminescence excited by ultraviolet radiant energy, although some of the references given in sections 1 and 6, below, treat also of other types of luminescence.

1. Work of the National Bureau of Standards in Fluorescence.

No systematic study of the theory or application of fluorescence has been made at this Bureau, although the following publications relating to the subject have been issued:

H. E. Ives and W. W. Coblentz, Luminous efficiency of the firefly, Bul. BS 6, 321 (1909-10) S132,

W. W. Coblentz and C. W. Hughes, Spectral energy distribution of light emitted by plants and animals, BS Sci. Pap. 21, 521 (1926) S538,

Fluorescence as a means of detecting the admixture of refined in unrefined edible olive oil, BS Tech. News Bul. No. 27, Nov. 1927,

Luminous paints, BS Letter Circular, LC-336, July 1932,

L. F. Curtiss, Brightness meter for self-luminous dials, J. Research NBS 15, 1 (1935) RP804,

K. S. Gibson and H. J. Keegan, On the magnitude of the error resulting from fluorescence in spectrophotometric measurements, J. Opt. Soc. Am. 28, 180 (1938).

A collection of fluorescent and phosphorescent substances is on display in the Colorimetry and Spectrophotometry Section of the Bureau. In the same section are three sources of ultraviolet energy (mercury lamps with glass filters) suitable for examination of materials for fluorescence. Visitors are permitted to examine objects (including themselves) by means of these sources for analytical or educational purposes. Equipment for fluorescent microscopy has been assembled and used in the Organic and Fibrous Materials Division of the Bureau and will be demonstrated to those interested in this technical field.

2. Equipment for Exciting or Demonstrating Fluorescence.

Sources of ultraviolet energy commonly employed in fluorescence excitation are the mercury arc, the iron arc and spark, the carbon arc, the argon glow lamp, and sunlight. The argon glow lamp and iron spark may be used without any filter. The argon glow lamp, rated at 2 watts, 110 volts, is especially useful for home demonstrations of fluorescence, although it must be placed close to the fluorescent object because of its low radiant intensity. It is manufactured by the General Electric Company and the Westinghouse Lamp Division, and is obtainable from dealers of electrical supplies. The iron spark is operated with transformer and condenser yielding a disruptive discharge at about 4000 volts. This source is especially rich in ultraviolet energy in the spectral region from 200 to 300mμ (2) and has been found particularly

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(2) This region of the spectrum is, however, very dangerous to the eyes. Due care should be taken to protect the eyes when one is working with sources which are not enclosed in ordinary glass. Ordinary spectacles are sufficient protection, unless perhaps, in the case of high-intensity quartz-mercury or other arcs.

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suitable for demonstrating the fluorescence of minerals. Complete units may be obtained from H. T. Strong, 234 West 56th Street, New York, N. Y.

All of the other sources listed require special filters which will transmit the desired ultraviolet region of the spectrum freely but absorb most or all of the visible energy, which will otherwise largely or entirely prevent the perception of the fluorescent light. Such filter glasses are sold by Corning Glass Works, Corning, New York, and by The Fish-Schurmann Corporation, 250 East 43rd Street, New York, N. Y. These glasses are listed in the advertising circulars of these companies. They vary in their spectral characteristics from Corning No. 586 (5mm), which transmits from approximately 330 to 390 mμ, with a maximum transmission of about 30 per cent and with practically no transmission in the visible spectrum,

to Corning No. 986 (3 mm) and Jena UG5 (2 mm), which transmit from approximately 240 mμ [3] to about 430 mμ, with a maximum transmis-

(3) These two glasses will, therefore, not protect the eyes from the dangerous ultraviolet energy.

sion of 80 to 90 per cent and with some violet and red transmission. Corning No. 587 is a heat-resisting glass with spectral characteristics intermediate between the extremes noted above.

The violet and red light transmitted by most of these glasses sometimes alters or conceals the color of the fluorescent light. The importance of this effect depends on the source. With a mercury-arc the transmission of these glasses in the red is of little importance, since this source emits relatively little red light. If used with a carbon or iron arc or with sunlight, however, it may prove desirable to combine these glasses with a strong copper sulfate solution, or a glass such as Corning No. 428, to absorb the relatively large amount of red light present, which may otherwise interfere with the perception of the fluorescent light. Such an additional filter will transmit the near ultraviolet freely but will absorb the far ultraviolet completely.

If the faint violet light transmitted by these filters is also objectionable, the denser ones should be used. It should be noted, however, that it is impossible to eliminate the bluish haze which is apparent if one looks directly at, for example, a mercury arc through such a filter. This haze is caused by fluorescence in the eye itself and cannot be eliminated except by the use of special goggles which will absorb the ultraviolet.

Equipment for demonstrating fluorescence, using the mercury arc, iron arc, carbon arc, or sunlight as source, with the above or similar filters, may be obtained from:

Bausch and Lomb Optical Company, Rochester, New York (iron arc [4]),
Central Scientific Co., Chicago, or New York, N.Y. (sunlight),
Fisher Scientific Co., Pittsburgh, Pa. (sunlight, mercury arc),
General Electric Vapor Lamp Co., Hoboken, N.J. (mercury arc),
Hanovia Chemical and Mfg. Co., Newark, N. J. (mercury arc),
Mico Instrument Co., Cambridge, Mass. (mercury arc),
National Carbon Co., Inc., Cleveland, Ohio (carbon arc),
Pfaltz and Bauer, Empire State Bldg., New York, N.Y. (mercury arc, iron arc [4]),
Stroblite Co., 35 West 52nd Street, New York, N.Y. (mercury arc, argon lamp).

(4) Designed especially for fluorescent microscopy.

Information on sources and filters for use in demonstrating fluorescence is given in some of the publications listed elsewhere in this letter circular, particularly the references by Radley and Grant and by Danckwortt, section 4 below, by Buttolph and Johnson, section 5 below, and by Lamplough, section 6 below; also

in the following paper:

Richard L. Barrett, A comparison of ultraviolet sources for producing fluorescence in minerals, The American Mineralogist 19, 578 (1934).

3. Fluorescent Materials.

This Bureau has no publication listing fluorescent materials. Such information may be found in the following references:

M. Luckiesh, Color and its applications, pp. 41-53, D. Van Nostrand Co., New York, N. Y., 1915; Ultraviolet radiation, its properties, production, measurement, and applications, pp. 186-194, D. Van Nostrand Co., New York, N. Y., 1922,

A. E. Sampson, Various applications of fluorescence analysis, Am. Dyestuff Reporter 24, 8 (1935),

R. Jenkins, Microscopy with fluorescent light, Stain Technology 12, 167 (1937),

Fluorescent intermediates and synthetic organic colors (a paper delivered before the French Society of Electricians June 25, 1935 by M. P. Mougeot, Chemist, Kohlmann Co.), translated by P. J. Wood, Am. Dyestuff Reporter, 26, 291 (1937),

B. Bugyi, Farbe und Fluoreszenz der Farbstoffe im kapillaranalytischen Bilde, Kolloid-Zeitschrift 84, 74 (1938).

See also other references below, particularly the books by Radley and Grant and by Danckwortt, section 4, and the papers by Buttolph and Johnson, section 5, and by Gissolf and de Groot, section 6.

This bureau does not distribute fluorescent materials. Such materials are advertised for sale by the following firms:

Continental Lithograph Corp., 952 East 72nd Street, Cleveland, Ohio,
Patterson Screen Co., Towanda, Pa.,
Pfaltz and Bauer, Inc., Empire State Bldg., New York, N. Y.,
Stroblite Company, 35 West 52nd Street, New York, N. Y.,
Ward Mineral Co., Rochester, New York.

4. Analytical Applications of Fluorescence.

Fluorescence is proving of great assistance in various kinds of analytical work. Those interested in such applications should consult the following references:

P. W. Danckwortt, Lumineszenzanalyse, 3d ed., Akademische Verlagsgesellschaft m.b.Z. Leipzig, 1934. Approximately 1000 references,

J. A. Radley and J. Grant, Fluorescence analysis in ultraviolet light, 2d edition, D. Van Nostrand Co., New York, N. Y., 1935. Approximately 800 references.

See also papers by Sampson, section 3 above, and Lamplough, section 6 below.

Fluorescence has also been found of value in microscopic analysis. According to E. M. Chamot and C. W. Mason (Handbook of chemical microscopy, John Wiley and Sons, Inc., New York, N. Y., 1938, pp. 93-95) the best discussion of fluorescence as applied to microscopy is given in the following book:

M. Hartinger, Die Fluoreszenzanalyse in der Mikrochemie, E. Haim and Co., Leipzig, 1937. This work contains 833 references.

This application of fluorescence is also treated in the following reference:

S. H. Gage, The microscope, ultraviolet edition, chapter VI entitled, The ultraviolet microscope and physical analysis, The Comstock Publishing Co., Ithaca, New York, 1932.

5. Fluorescent Lamps for Illumination Purposes.

During the last year or two fluorescent lamps have become commercially available for illumination purposes. (These should not be confused with the lamps described in section 2, above, for demonstrating the fluorescence of objects.) Information on this recent development will be found in the following references:

L. J. Buttolph and L. B. Johnson, Ultraviolet radiation and fluorescence, Trans. Ill. Eng. Soc. 31, 21 (1936),

S. Dushman, The search for high-efficiency light sources, J. Opt. Soc. Am. 27, 1 (1937),

G.E. Inman and R. N. Thayer, Low-voltage fluorescent lamps, Elec. Eng. 57, 245 (1938),

J. A. McDermott, High-voltage gaseous and fluorescent tubes for advertising and architectural lighting, Elec. Eng. 57, 286 (1938

H. G. Jenkins and C. D. Brown, Fluorescent tube lighting, G.E.C. Journal 9, 163 (1938),

J. W. Marden, N. C. Beese, and G. Meister, Effect of temperature on fluorescent lamps, Trans. Ill. Eng. Soc. 34, 55 (1939),

G. E. Inman, Characteristics of fluorescent lamps, Trans. Ill. Eng. Soc. 34, 65 (1939),

R. N. Thayer and B. T. Barnes, The basis for high efficiency in fluorescent lamps, J. Opt. Soc. Am. 29, 131 (1939).

6. Miscellaneous Literature on Fluorescence.

H. Kayser, Handbuch der spectroscopie 4, (1908); chapter 5, Phosphorescenz, chapter 6, Fluorescenz; contains bibliography to 1906,

E. Merritt, E. L. Nichols, and C.D. Child, Selected topics in the field of luminescence, Report of the National Research Council Committee on Luminescence, Bul. National Research Council, 5, Part 5, No. 30 (1923); contains a bibliography of 1329 references, 1906-1922.

E. C. C. Baly, Spectroscopy, vol. 2, Longmans, Green & Co., New York, N. Y., 1924; chapter IV, Fluorescence and phosphorescence,

E.L. Nichols, H.L. Howes, and D.T. Wilbur, Cathodo-luminescence and luminescence of incandescent solids, Carnegie Institution of Washington, Publication No. 384, 1928,

P. Lenard, F. Schmidt, and R. Tomaschek, Phosphoreszenz und Fluoreszenz, Handbuch der experimentel Physik 23 (parts 1 and 2), Akademische Verlagsgesellschaft m.b.Z., Leipzig, 1928,

P. Pringsheim, Fluorescenz und Phosphorescenz im Lichte der neuen Atomtheorie, J. Springer, Berlin, 1928,

E.L. Nichols and E. Merritt, Low-temperature luminescence, International Critical Tables 5, 386 (1929),

A.C.C. Mitchell, Resonance radiation and excited atoms, The MacMillan Co., New York, 1934,

R. W. Wood, Physical optics, 3d edition, The MacMillan Co., New York, N. Y. 1935; chapter XVIII, Resonance radiation and fluorescence of atoms, chapter XIX, The resonance and fluorescence spectra of molecules, chapter XX, The fluorescence and phosphorescence of solids and liquids,

M. Curie, Luminescence des corps solides, Les Presses Universitaires de France, Paris, 1934; bibliography of 168 references,

F.E. Lamplough, Applications of ultraviolet light and some aspects of fluorescence and phosphorescence, Trans. Ill. Eng. Soc. (London) 1, 69 (1936),

J. H. Gisolf and W. de Groot, Fluorescence and phosphorescence Philips Tech. Rev. 3, 241 (1936),

E. Hirschlaff, Fluorescence and phosphorescence, Chemical Publishing Company of New York, Inc., New York, 1938,

J. Ewles. Recent views on the luminescence of solids, Science Progress 33, 563 (1939),

See also the references given by Dushman and by Buttolph and