Infrared Luminescence of Minerals

GEOLOGICAL SURVEY BULLETIN 1052-C

Infrared Luminescence of Minerals

By DAVID F. BARNES

EXPERIMENTAL AND THEORETICAL GEOPHYSICS

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A study of the abundance and causes of infrared luminescence of minerals

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INFRARED LUMINESCENCE OF MINERALS

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ABSTRACT

Infrared luminescence is a phenomenon similar to fluorescence under ultraviolet light except that the emission occurs in the infrared rather than the visible part of the spectrum. This infrared luminescence is generally most efficiently excited by visible light from high-energy incandescent lamps, but violet and ultraviolet excitation are effective for a few minerals.

Infrared luminescence can be viewed through an infrared image tube of the type used in the "snooperscope." The entire study collection of the U. S. National Museum has been examined with an image tube and optical system of a snooperscope to detect the infrared luminescence of minerals. Infrared luminescence was found in about 1,500 specimens representing some 75 distinct mineral species. Filters were used to determine the approximate wavelengths of emission and excitation.

Chromium-activated minerals like corundum, beryl, spinel, jadeite, and kyanite show very strong infrared luminescence. Cadmium causes the universal luminescence of its sulfide, greenockite. The rare earths are responsible for the long-wavelength emissions of many minerals including scheelite, fluorite, apatite, feldspar, and amphibole.

INTRODUCTION

When some mineral specimens are illuminated by an ultraviolet lamp in an otherwise dark room, they glow with colors that are often far more brilliant than those of the same specimens in bright sunlight. This well-known mineral fluorescence involves the absorption of invisible light at the short-wavelength or ultraviolet end of the spectrum and the simultaneous emission of this energy as visible light of longer wavelength. Infrared luminescence is a similar phenomenon in which a mineral absorbs visible light and emits the energy as invisible light at the long-wavelength or infrared end of the spectrum. Stokes formulated the fundamental law of luminescence which states that the wavelength of the fluorescent light is longer than the wavelength of the exciting radiation. Infrared luminescence might thus result from either visible or ultraviolet excitation, but experiments show that in most cases the strongest emissions result from visible light.

The term "luminescence" includes the emission of light resulting from all processes except incandescence. "Fluorescence" is the emission of light at the same time as excitation, and "phosphorescence" is the emission of light following excitation. The term "fluorescence" is, however, frequently associated with emissions excited only by ultraviolet light; therefore the use of the general term "luminescence" seems preferable for infrared emission that is most effectively excited by visible light.

Infrared luminescence has already been observed photographically by Pauli (1911), Servigne (1938 and 1939), Weyl (1942), Lashkarev and Kossonogova (1946), Dhéré and Biermacher (1936), and others, but the lack of a simple method of observation made a survey of many minerals impractical. However, the invention of the infrared image tube (Holst and others, 1934) and its further development during the last war made possible the rapid observation of infrared phenomena with wavelength shorter than 12,000 angstroms. Bailly and Holke (1944) following an idea of Malmquist (1945) used infrared radiation in studying the optical properties of minerals opaque to visible light, and adapted the infrared image tube to serve as an ocular for the petrographic microscope in the manner suggested by Zworykin and Morton (1936).

PURPOSE AND SCOPE OF INVESTIGATION

This report describes the use of the infrared image tube in an examination of the long-wavelength luminescence of minerals. Nearly 200,000 specimens comprising the study collection of the U. S. National Museum have been observed, and infrared luminescence was found in approximately 1,500 specimens representing some 75 distinct mineral species. The investigation determined which minerals show infrared luminescence, where these luminescent specimens are found, and the approximate wavelengths of emission and excitation. The work was divided into two main parts: first, a thorough, piece-by-piece examination of minerals for which luminescence had been previously reported—the group in which almost all infrared luminescence was found; and second, a scanning of all other specimens in the collection with subsequent piece-by-piece examination of those specimens that showed infrared luminescence.

ACKNOWLEDGMENTS

The author is indebted to many who have helped in the work. The project resulted from an idea of H. C. Spicer, of the U. S.

Geological Survey, who supervised the work. Members of the staff of the National Museum, W. F. Foshag, George Switzer, E. P. Henderson, and J. H. Benn, kindly made the Museum facilities available and gave frequent assistance in the identification of minerals. D. J. Looft and Jerome Laufler, of the Engineer Laboratory at Fort Belvoir, Va., assisted with the instruments. K. J. Murata and Michael Fleischer of the Geological Survey gave frequent and valuable advice and Elizabeth King helped in the preparation of the tables.

EQUIPMENT AND METHODS OF OBSERVATION

THE SNOOPERSCOPE

The telescope of a U. S. Army Modol M–1 snooperscope was used for all infrared observations. Similar equipment is now manufactured for scientific research or is available on the surplus market. The snooperscope has an objective lens that focuses the primary image on the cathode of a 1P25 tube (Morton and Flory, 1946). The cathode is a silver-cesium oxide-cesium film, which, under infrared excitation, emits electrons which are then focused by a series of high-voltage electric fields on a zinc silicate phosphor screen showing a green luminescence under electron bombardment. The resulting green image is viewed through an eyepiece.

The lenses in the snooperscope telescope are designed to focus on an object between 4 feet and infinity, but for mineral observations this range was reduced to approximately 9 inches with a 3 diopter portrait attachment. The objective lens was also covered with a filter to limit the sensitivity to the infrared band, because the spectral range of the 1P25 tube extends into the visible part of the spectrum.

For nighttime military operations the snooperscope has an infrared spotlight that illuminates the object, but for studying mineral luminescence a broad range of exciting light from ultraviolet to infrared is required. Accordingly the infrared spotlight was discarded, and the specimens were either scanned with a unit having one high-intensity, broad-spectral-range exciting lamp, or they were examined in a viewing box in which a variety of wide- and narrow-band excitation lamps were used.

The viewing box was built first and was used for the examination of all mineral varieties that were mentioned in the literature as luminescent. The viewing box enabled the observer to estimate the approximate wavelength of infrared emission and to evaluate the relative effectiveness of various types of excitation. This detailed examination of each specimen was, however, very slow—

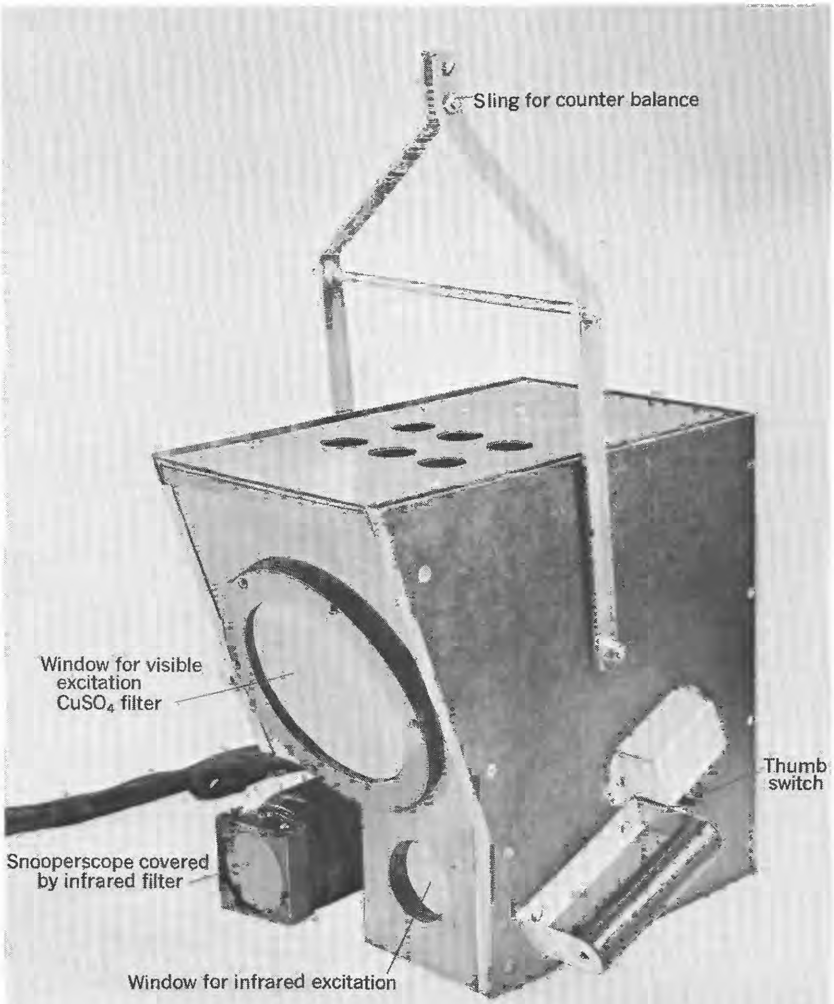
several months were required for the examination of the luminescent minerals alone, a mere quarter of the entire collection. To complete the project in a reasonable time a scanning instrument had to be built for the observation of the remaining three-fourths of the collection. As this scanning instrument was both simpler and more efficient it will be discussed first.

INFRARED LUMINESCENCE SCANNER

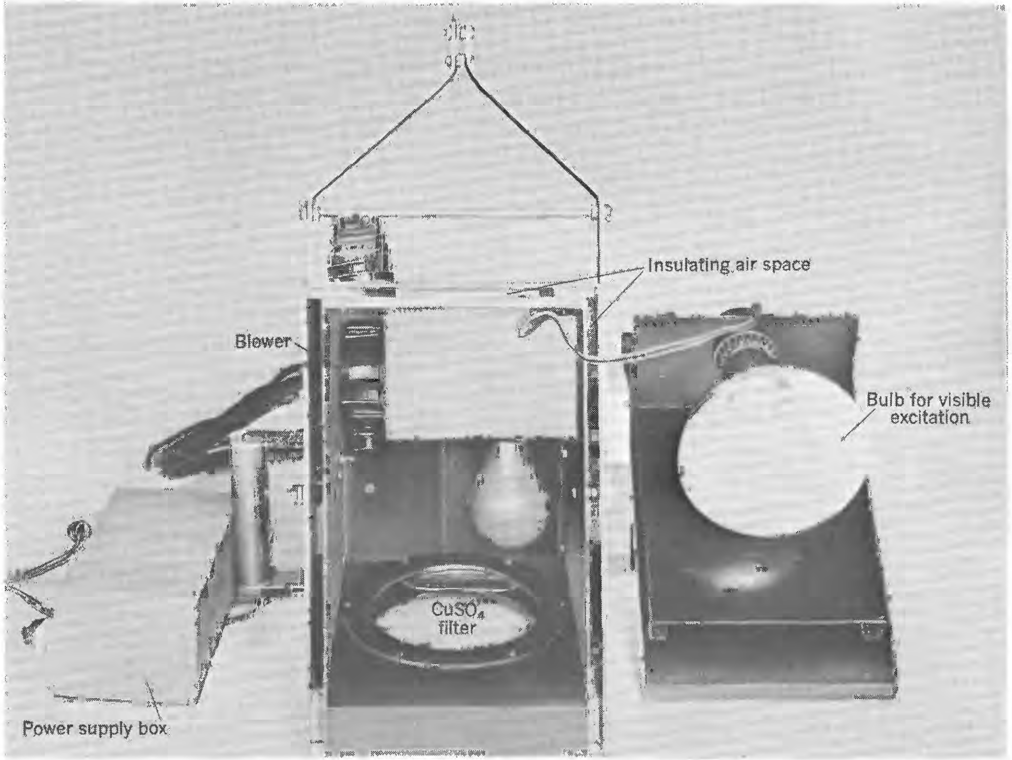
The preliminary examination of luminescent minerals showed that visible light would excite all types of infrared luminescence, and that a broad range of visible light was by far the most effective exciting source. Thus an instrument could be built capable of detecting any type of infrared luminescence in a single observation, provided a sufficiently powerful incandescent lamp was used.

The instrument built by the Geological Survey is shown on plates 4 and 5. A 500-watt photospot was used as the exciting source, but like all incandescent lamps this bulb actually emitted more energy in the infrared than in the visible region. The reflection of this infrared light by the mineral specimen would be strong enough to mask even the strongest infrared luminescence. Accordingly it was necessary to cover the photospot with a filter that would pass only visible light. This enabled the observer to examine infrared luminescence under conditions essentially similar to those used for the study of ordinary mineral fluorescence, when visible light is eliminated by keeping the room dark and by filtering out all but ultraviolet exciting radiation. The filter found most effective for the study of infrared luminescence was a 5-percent $CuSO_4$ solution in a glass or lucite chamber three-quarters of an inch thick; such a filter transmits visible light very well and has a sharp cutoff between 5,500 and 6,500 angstroms. In the infrared scanner this filtering solution was contained in a 6-inch diameter chamber built into the front wall of the instrument.

However, no filter is perfect; the copper sulfate solution passed a little infrared light, and the infrared-transmitting filter in front of the snooperscope telescope did not eliminate all the visible light from the exciting source. Accordingly, nonluminescent minerals that were good reflectors appeared brighter than those which were poor reflectors, and it was difficult to distinguish strong reflection from weak luminescence. Therefore the scanner was provided with a much weaker second lamp covered with an infrared transmitting filter similar to that in front of the snooperscope telescope. A pushbutton switch turned on this infrared



INFRARED LUMINESCENCE SCANNER



INFRARED LUMINESCENCE SCANNER OPENED

light source and at the same time, turned off the photospot. It was thus possible for the observer to quickly estimate the long-wavelength-reflecting properties of the mineral specimen and to judge whether the brightness seen under the visible excitation resulted from reflection of the small amount of light "leaked" by the filters or from actual luminescence.

The two lamps generated considerable heat, so that the inside of the instrument had to be cooled by a small blower. Even with this blower operating, the case of the instrument became so hot that the observer's face and hands had to be protected by a second, outside wall of laminated plastic separated from the inner, aluminum walls by a ¼-inch air space. The instrument was designed primarily for easy construction, and little emphasis was placed on lightness of weight. When completed it weighed about 15 pounds, light enough to be held in the hands for a short period but too heavy to be carried for a whole day. When used to examine the specimens in the high stacks of drawers that hold the study collection of the National Museum, the instrument was supported by a rope running through a pulley system to a counterweight. The observer could thus aim and focus the instrument with very little effort.

VIEWING BOX

With the scanner the observer could detect infrared luminescence and estimate its intensity, but with the viewing box he could learn many additional characteristics of this luminescence. Filters could be used to eliminate all but a narrow spectral band of excitation energy or to restrict the detection range to narrow bands. Thus the relative importance of various wavelengths of excitation and emission could be estimated.

The arrangement of apparatus in the viewing box is shown in figure 25. The box was constructed so that the specimen could be held in the observer's left hand, while his right hand was used to change filters and to turn on and off the excitation lamps, which were operated by pushbutton switches on the outside of the box.

The first excitation lamp was a 25-watt bulb with an infrared-transmitting filter that showed the degree of infrared reflection exhibited by the mineral. Like the similar bulb in the scanner this was used primarily to distinguish infrared luminescence from reflected light "leaked" by the filters.

The second excitation lamp was a 300-watt bulb in a 35-mm slide projector ventilated by a small fan. As the condensing-lens system alone provided adequate focusing of the light beam, the projection lenses were not used. A ¾-inch-thick lucite cell con-

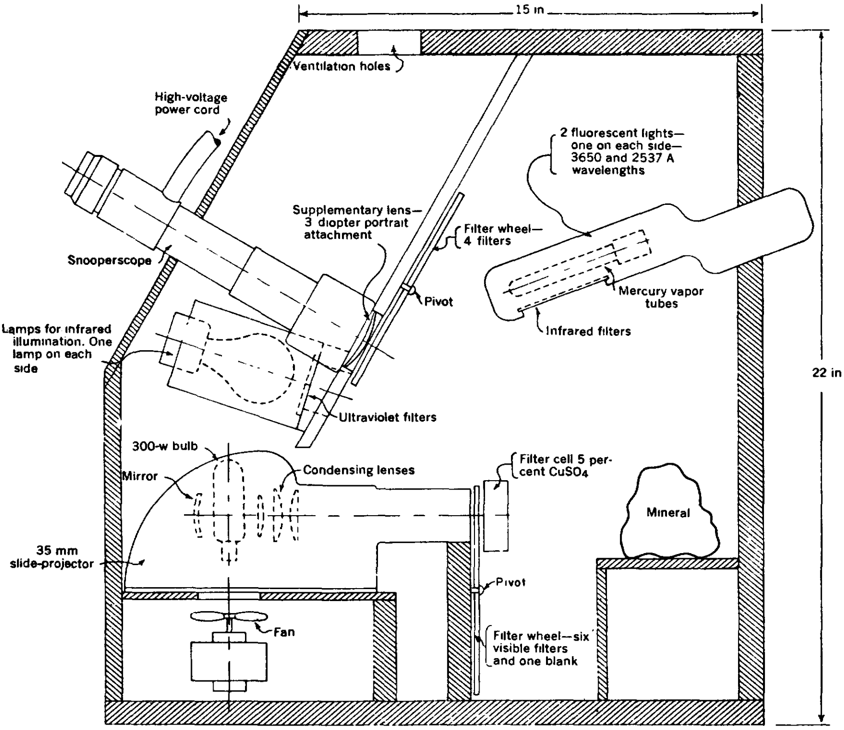


FIGURE 25.—Schematic diagram of infrared viewing box.

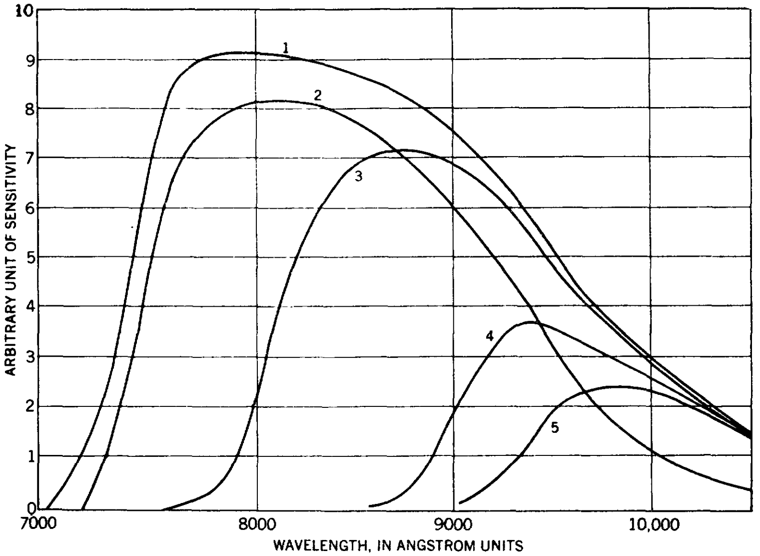
taining a 5-percent solution of $CuSO_4$ was placed in front of the projector to eliminate the infrared radiation generated by the bulb. This projector and its filter thus provided the same type of broad range visible excitation that was furnished by the photospot bulb in the infrared scanner. In the viewing box, however, this visible excitation could be separated into five narrower spectral bands by gelatine filters placed in front of the projector. Each filter passed a spectral band about 800 angstroms wide, and was mounted on a wheel, so that it could be rapidly shifted into position in front of the projector. Table 1 shows the color of light transmitted by each filter.

The third and fourth excitation lamps were two ultraviolet lamps with wavelengths of 3,650 A and 2,537 A. Unfortunately, both these lamps produced a moderate amount of infrared radiation, the reflection of which by the specimen tended to mask any actual infrared luminescence. Accordingly a lucite cell ½-inch thick and containing a 5-percent $CuSO_4$ solution was interposed during most of the experiments to absorb the infrared radiation transmitted by the filter of the SL 3650 lamp. However, such solutions of copper sulfate, even in a quartz cell, absorb about 25 percent of the ultraviolet at 3,600 A and nearly 100 percent at 2,500 A. Consequently a liquid filter could not be used to eliminate the large amount of infrared emitted by the 2,537 A source.

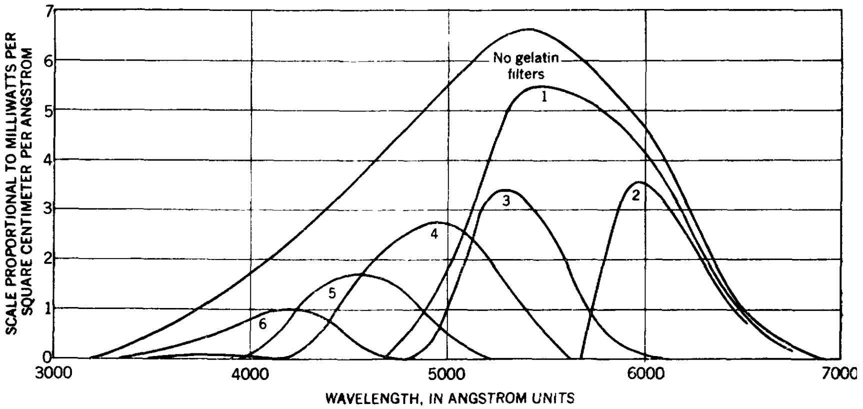
The observer estimated the intensity of the infrared luminescence excited through each of the six filters in front of the projector and by the two ultraviolet lamps. To use these observations to evaluate the relative effectiveness of various wavelengths of excitation it was essential to know at least approximately the amount of energy provided by each source. Unfortunately none of the available methods of illumination measurement is reliable over such a broad spectral range, and the excitation energies had to be calculated from the data available from manufacturers of the components of the illumination system. The methods used for these calculations are given in Moon (1936) and Skogland (1929). The results are given in figure 26*B*, which shows the spectral distribution of energy transmitted by each filter. The total energy transmitted, or the integral beneath each of the curves in figure 26*B* is shown in table 1. The energy produced by the two ultraviolet lamps is so small that it would not show on the graph, but it is given in the table. One can perhaps question the accuracy of some of the assumptions made in computing the energies recorded in table 1, but the relative values are probably at least as accurate as the visually judged measurements the table is intended to explain. Furthermore, the questionable assumptions affect only the relationship between the incandescent and the ultraviolet lamps; the relationships between the energies passed by each filter in front of the projector depend only on the color temperature of that bulb and on the individual filter characteristics, both of which are well known. The decrease in energy transmitted by the filters at the violet or short-wavelength end of the spectrum and the weakness of the ultraviolet lamps compared to even filtered parts of the projector's energy are clearly shown.

To obtain the approximate wavelength of the infrared emission, the spectral range of the viewing system could be varied by rotating a filter wheel mounted in front of the objective lens. This wheel held four filters, whose low wavelength cutoffs ranged from 7,000 to 9,300 A. The spectral transmission curves of these filters were obtained from the manufacturers and were then applied to the spectral sensitivity curve for the 1P25 tube. The resulting sensitivity curves for the receiving unit are shown in figure 26*A*. These curves show that any luminescence with wavelength longer than approximately 9,500 A will give a very weak image regardless of its actual intensity.

Actually some evidence suggests that curve 1 in figure 26*A* should extend further into the visible part of the spectrum. First, many minerals give very different brightness values with filters 1 and 4, which contradicts the apparent closeness of their curves.



A. SPECTRAL CHARACTERISTICS OF THE INFRARED DETECTING UNIT WHEN COVERED WITH VARIOUS FILTERS



B. SPECTRAL CHARACTERISTICS OF THE 300-WATT INCANDESCENT LAMP WHEN COVERED BY COPPER SULFATE FILTER PLUS VARIOUS GELATIN FILTERS

FIGURE 26.—Spectral sensitivity of filters used in the viewing box. Data obtained from manufacturers.

TABLE 1.—*Characteristics of filters used in excitation measurements*

[Curves showing characteristics of filters 1-6 are shown on figure 26*B*]

Filter no.	Excitation bulb	Color	Wavelength range (angstroms)	Integrated energy milliwatts (per cm²)	Energy × wavelength
None	300-watt incandescent	Visible	3,500–6,600	117	62
1	do	Red-green	4,800–6,600	63	35
2	do	Red	5,700–6,600	20	12
3	do	Green	5,000–5,800	20	11
4	do	Blue	4,400–5,500	22	11
5	do	Blue-violet	4,200–5,000	12	6
6	do	Violet	3,800–4,500	7	3
8	Fluorescent tube	Ultraviolet	3,600	.2	.1
9	Hg-vapor tube	do	2,500	.3	.1

Second, many minerals known to give a strong emission just below 7,000 A show brilliant images through filter 1, figure 26*A*. Third, the detection unit picks up a considerable amount of infrared radiation transmitted from the projection bulb even with the $CuSO_4$ filter in place, but according to figure 26*A* these curves do not overlap. Part of this infrared transmission is probably explained by the 0.5 percent transmission of the $CuSO_4$ filter at approximately 10,000 A, but the fact that filters 2, 3, 4 greatly reduce the observed "leakage" suggests that most of it occurs at shorter wavelengths. Thus, although the exact position of curve 1 is unknown, it probably extends into the visible region, the border of which is generally placed between 7,000 and 7,500 A. The actual limit of perception varies with the individual; many people have an extremely slight perception up to 10,000 A or nearly to the point where the heat absorption of the skin becomes important (Griffin, Hubbard, and Wald, 1947).

INFRARED LUMINESCENCE OF MINERALS

CHARACTERISTICS OF INFRARED LUMINESCENCE

According to the quantum theory of matter, luminescence results from the transfer of electrons between the energy levels of an excited atom. The atom is excited when an electron is raised to a higher energy level by the absorption of light; one photon, or quantum light energy, can excite only one electron. The luminescent emission occurs when the excited electron returns to a lower energy level with the release of another photon of light energy. The frequency of the light absorbed or emitted is directly proportional to the energy of the photon; therefore the wavelength of the light is inversely proportional to the energy of the transfer. Thus ultraviolet light, which has a short wavelength and therefore a high energy, can, by Stokes law, excite either visible or infrared luminescence, which have lower energy because of their longer wavelength. Many factors affect the probabilities of the absorption and emission of energy and therefore affect the efficiency of the luminescence. The surroundings of the luminescent atom within the crystal structure are especially important. In many minerals the excitation energy is absorbed by one, perhaps nonluminescent, atom, and is then transferred to the luminescent atom, or in other minerals the light emitted from one atom is reabsorbed by another.

Luminescent minerals can be classified into three groups according to the relationship between the luminescent atom and the host mineral.

The first group contains minerals in which the fluorescent atom is an essential chemical component and in which the fluorescent element is included in the chemical formula. This group includes the fluorescent uranium and tungsten minerals, whose visible emission is caused by the uranyl (UO_2^{+2}) and tungstate (WO_4^{-2}) ions. Greenockite is the only infrared luminescent mineral that can definitely be assigned to this group. In the second group of minerals the luminescent atom is not an essential chemical component but does form a part of the crystal lattice. Such atoms are known as activators and are commonly present in extremely small quantities (of the order of one part in a million). Nevertheless these activators have a considerable affect on the properties of many minerals, and they often determine the characteristic colors of subvarieties. Thus, alexandrite and ruby are chrysoberyl and corundum with distinctive coloring caused by the chromium ion. Very strong and nearly universal infrared luminescence is found in some minerals of this type.

In minerals belonging to the second group, the activator is present in only a few specimens and does not affect the physical properties of the mineral. As the inclusion of the activator in many minerals is accidental, the luminescence of some of them is found only in a very small percentage of specimens. The luminescence of such minerals is subject to wide variations in emission wavelength, excitation spectrum, and place of occurrence. This type of luminescence is, however, exhibited by many varieties of minerals. Typical examples are the brilliant red luminescence of calcite from Franklin, N. J., and the important infrared luminescence caused in many minerals by rare-earth activators.

The third group includes minerals in which the fluorescent atom is not represented in the chemical formula and does not form a part of the crystal lattice. Such luminescence is totally unrelated to the nature of the mineral, although it is commonly associated with specimens found in specific localities. The cause of the luminescence is an impurity which can sometimes be distinguished by eye or microscope, or which at other times is difficult to distinguish in any way from activators forming a part of the crystal lattice. Sulfur from Italy, fluorite from Clay Center, Ohio, and halite from Stazunia, Poland, owe both their visible and infrared luminescence to included organic matter and are thus examples of this third group of luminescent minerals.

It is often difficult to assign a luminescent mineral to any one of these three groups; the groups are thus difficult to use as an actual basis of classification, but they do show the large variety of possible luminescent systems. Almost all luminescence depends on the presence of a minute quantity of elements that are not essential chemical constituents of the mineral. Even the amount of these activators is critical, and overconcentration can by reabsorption quench the luminescence, as effectively as underconcentration can make it impossible. Furthermore, additional elements can either aid or quench the luminescence. For example, Schulman, Evans, Ginther, and Murata (1947) have shown that the brilliant red fluorescence of calcite under ultraviolet light requires a sensitizing impurity such as lead, but this sensitizing impurity may not be necessary for the rarer and less intense infrared luminescence of calcite. One specimen of agate in the National Museum collection showed the importance of impurities and previous history on mineral luminescence. The original agate specimen had been cut into six pieces, each of which was treated in a different way to show the color produced; only one piece showed infrared luminescence—that quenched in sulfuric acid and honey.

The transparency of a mineral specimen has a considerable influence on its luminescence because the activating atom is seldom on the exact surface of the specimen, and both the exciting and emitted light have to pass through at least a small thickness of the crystal. Many examples of the importance of transparency were found in the study of infrared luminescence. Fluorescent cuprite has never been recorded, but Lashkarev and Kossonogova (1946) reported an infrared luminescence from cuprous oxide synthesized in a blast furnace. Almost every cuprite specimen is dull and opaque and shows no luminescence. However, a very small, deep-red, and very clear crystal from Cornwall, England, showed a distinct, long-wavelength infrared emission—a discovery that confirms Lashkarev's work and demonstrates the importance of translucence in mineral luminescence. Likewise, sphalerite and wurtzite, which are the mineral forms of the often-studied phosphor, zinc sulfide, show infrared luminescence only in specimens that are not completely opaque. In many other minerals the infrared luminescence was limited to at least slightly transparent specimens.

All luminescent mineral specimens were tested for infrared phosphorescence, and none was detected. Many minerals, however, show prolonged visible phosphorescence after ultraviolet excitation. This failure to detect infrared phosphorescence can probably be ascribed to insufficient sensitivity of the snooperscope, but the observed absence may be real and not instrumental.

The results of the investigation of the infrared luminescence of minerals are presented largely in tabular form because of the many infrared luminescent specimens discovered and because of the great variation in the properties of this luminescence. All the infrared-luminescent mineral varieties are listed below according to their chemical composition and crystal structure. Minerals without silica are arranged according to Palache, Berman, and Frondel (1944 and 1951) and the silica minerals according to Strunz (1941). This system of classifying minerals is similar in its main categories to Garlick's system (1949, p. 48) for the classification of phosphors.

In tables 2-4, the minerals are arranged in alphabetical order (p. 100–155). Table 2 lists all the localities where infrared-luminescent mineral specimens were found. Table 3 indicates the prevalence of infrared luminescence for each mineral; it gives the percentages of specimens and localities in which infrared luminescence was found. Table 4 shows the characteristics of infrared luminescence found in some of the individual specimens examined. These have been selected as representative samples of the different types of luminescence shown by each mineral.

Infrared-luminescent minerals

MINERALS WITHOUT SILICA

- Native elements
  - Diamond
  - Sulfur
    - Selensulfur
- Sulfides
  - Sphalerite
  - Greenockite
  - Wurtzite
- Oxides
  - Cuprite
  - Montroydite
- Oxides—Continued
  - Senarmontite
  - Corundum (ruby, sapphire)
  - Valentinite
  - Cervantite
  - Stibiconite
    - Stibianite
  - Brucite
  - Hydrotalcite
  - Bauxite
  - Diaspore

Infrared-luminescent minerals—Continued

MINERALS WITHOUT SILICA—Continued

- Oxides—Continued
    - Spinel
    - Chrysoberyl
        - Alexandrite
- Halides
    - Halite
    - Marshite
    - Fluorite
    - Terlinguaite
    - Matlockite
    - Cryolithionite
    - Cryolite
    - Gearksutite
    - Chiolite
    - Creedite
- Carbonates
    - Calcite (reichite, oolite, pisolite)
        - Manganocalcite
        - Cuprocalcite
        - Plumbocalcite
    - Magnesite (baudisserite)
    - Rhodochrosite
    - Smithsonite
    - Aragonite
    - Strontianite
    - Cerussite
    - Dolomite (gurhofite)
        - Tautoklin
    - Pirssonite
    - Gaylussite
    - Phosgenite
    - Hydrocerussite
    - Leadhillite
- Borates
    - Borax
    - Probertite
    - Ulexite
- Borates—Continued
    - Colemanite
    - Meyerhofferite
    - Howlite
    - Hambergite
    - Sussexite
- Sulfates
    - Barite
    - Celestite
    - Anglesite
    - Anhydrite
    - Gypsum
    - Alunogen (solfaterite)
    - Lanarkite
    - Alunite
    - Botryogen (idrizite)
    - Hanksite
    - Crocoite
- Phosphates
    - Anapaite (messelite)
    - Parahopeite
    - Amblygonite
    - Apatite (phosphorite, fluorapatite, dahllite)
        - Rhodophosphite
        - Manganapatite
    - Pyromorphite
    - Mimetite
    - Vanadinite
    - Hedyphane
    - Wavellite
        - Fischerite
- Tungstates
    - Scheelite
    - Stolzite (scheelitine)
    - Wulfenite
    - Cuprotungstite (cuproscheelite)

MINERALS WITH SILICA

- Silica
    - Quartz
        - Agate
        - Chalcedony
        - Jasper
    - Tridymite
    - Cristobalite
        - Melanophlogite
- Silica—Continued
    - Opal (cacholong, hydrophane)
        - Hyalite
        - Silicified wood
        - Geyserite
        - Tabasheer
- Nesosilicates
    - Willemite

Infrared-luminescent minerals—Continued

MINERALS WITH SILICA—Continued

- Nesosilicates—Continued
    - Calcium larsenite
    - Norbergite
    - Leucophoenicite
    - Andalusite
      - Chiastolite
    - Kyanite (raetizite)
    - Topaz
  - Garnets
    - Grossularite
    - Andradite
      - Demantoid

    - Zoisite (thulite, saussurite)
    - Epidote
      - Tawmawite
    - Zircon
      - Cyrtolite
      - Alvite
    - Sphene
    - Axinite
    - Howlite
    - Tourmaline
- Sorosilicates
    - Hemimorphite
      - Vanuxemite
    - Clinohedrite
    - Wollastonite
    - Pectolite
    - Beryl (emerald, aquamarine)
      - Pseudosmaragd
    - Idocrase
      - Californite
- Inosilicates
    - Sillimanite
      - Fibrolite
    - Spodumene
      - Kunzite
      - Hiddenite
  - Pyroxenes
    - Diopside
    - Jadeite
    - Diallage
    - Enstatite
    - Bronzite
  - Amphiboles
    - Tremolite (hexagonite, calamite, chromtremolite)
      - Byssolite
- Inosilicates—Continued
  - Amphiboles—Continued
    - Actinolite
    - Arfvedsonite
      - Szechenyiite
    - Anthophyllite

    - Serpentine (metaxoite)
      - Chrysotile
    - Saponite
    - Cerolite
    - Deweylite (gymnite)
    - Jurupaite
    - Crestmoreite
    - Sepiolite
      - Quincite
    - Iddingsite
- Phyllosilicates
    - Euclase
    - Leucophane
    - Apophyllite
    - Talc (steatite)
      - Lucianite
  - Micas
    - Muscovite (agalmatolite)
      - Fuchsite
    - Lepidolite
    - Taeniolite
  - Chlorites
    - Xanthophyllite
    - Cookeite
    - Colerainite

    - Kaolinite
      - Confolensite
    - Montmorillonite
      - Steargilite
      - Stevensite
    - Allophane
      - Razoumovskyn
      - Collyrite
      - Malthacite
    - Halloysite
    - Gyrolite
    - Okenite
- Tektosilicates
    - Nepheline
    - Trimerite

Infrared-luminescent minerals—Continued

MINERALS WITH SILICA—Continued

- Tektosilicates—Continued
    - Petalite
    - Analcime
    - Pollucite
  - Feldspars
    - Orthoclase (leelite, lennilite, delawarite)
    - Adularia
    - Microcline (amazonstone)
    - Hyalophane
    - Albite
    - Oligoclase
    - Andesine
    - Anorthite

    - Danburite
    - Sodalite (molybdosodalite)
      - Hackmanite
    - Hauynite

- Teklosilicates—Continued
  - Feldspars—Continued
    - Scapolite
    - Meionite (ersbyite)
      - Stroganovite
    - Datolite
  - Zeolites
    - Natrolite
      - Hydronephelite
      - Laubanite
      - Mesolite
      - Thomsonite
        - Harringtonite
      - Laumontite
      - Heulandite
        - Castorite (hydrocastorite)
      - Chabazite
        - Phacolite

All observations of the intensity of infrared luminescence were originally recorded on a numerical scale of 0 to 5 including plus and minus signs and were based entirely on the observer's visual judgment. These original numerical values have all been converted to verbal scales for presentation in this report.

Many specimens in the National Museum are labeled with names now regarded as synonyms for, or subvarieties of, an accepted specie name. These minerals are placed in the tables according to the accepted species name, and cross references are given under the names shown on the specimen label. For some minerals infrared luminescence was found in both the subvariety and the main variety; for others only the subvariety produced luminescence. When the data in the tables apply only to those specimens labeled with the name of a subvariety, this name is indented and placed on a separate line. When, however, the data apply to both the main mineral and its synonyms and subvarieties, these latter names are placed in parenthesis and on the same line as that of the main mineral.

OCCURRENCE OF INFRARED-LUMINESCENT MINERALS

Because the chemical environment of a mineral specimen has a considerable influence on its composition and hence on its luminescence, the locality where the specimen was found is very important.

In many places the activators which cause the luminescence of one species of mineral also cause luminescence in other species found nearby. Table 2 lists the main regions where specimens showing infrared luminescence were found. For each mineral the localities are arranged in three groups—weak, medium, or strong—according to the intensity of infrared luminescence of the minerals found there. Table 3 gives the number of regions represented in the collection and the percentage of these that yielded infrared luminescent specimens.

To keep the locality list moderately short while maintaining a certain amount of precision, areas containing a number of places yielding infrared luminescent specimens are represented either by a regional name (as a county) that does not cover too wide an area, or by the name of a centrally located town supplying most of the minerals showing typical infrared luminescence. Thus, the report of infrared luminescence from one locality may indicate similar occurrences nearby. Indeed, localities are generally regarded as broad areas having a number of mines and sometimes including several counties. For example, each of the following are regarded as one locality: the saline-lake area of Inyo, Kern, and San Bernardino Counties in California; the northern New Jersey mineral district in Sussex and Passaic Counties, N. J., and Orange County, N. Y.; Cumberland, Durham, Westmoreland, Northumberland, and parts of York and Lancaster Counties in England; and the Ural Mountains of Russia.

In the National Museum collection many places are identified by names that could not be found in an atlas, and many others have only general labels. These specimens are usually regarded as the same as another better labeled one from the same area. Thus, if one specimen was labeled merely India, another Chandribahara, India (guaranteed not to be in any atlas), and a third Western Ghats, Bombay, India, the first two are deprived of their possible individuality, and all three are lumped as a single locality, labeled as Bombay, India. A fourth specimen labeled Calcutta would, however, be considered another locality. Accordingly the number of localities given in table 3 may be somewhat smaller than the actual number of localities covered by the survey, but the deviation is probably small. Unfortunately, the identity of the localities is only as good as the labels on the specimens, and many of the specimens were presented to the National Museum a long time ago by people who had only a vague idea where they found the mineral. This explains why many localities are identified by only such vague and inclusive names as Africa, India, and Canada. Also many specimens were found when different geographic names were in use. Japan was once divided into provinces instead of prefectures; Germany and the Balkan States were subdivided into provinces that are no longer compatible with present political boundaries. No attempt has been made to convert the locality names to their modern equivalents. Also, although I have tried to follow modern systems of spelling geographic names, many of the places could not be verified and are presented as they are recorded in the museum catalog. People working with only a few minerals or localities will probably be familiar enough with the areas mentioned to recognize even obsolete spellings.

The lack of a positive report of infrared luminescence in a region does not mean that such specimens cannot be found there. Even if the area is represented by specimens in the National Museum collection, these specimens may have been chosen for some special characteristic such as crystallization, whereas almost all other specimens found in the area have different characteristics and are infrared luminescent. An excellent example is given by the three drawers of calcite specimens from northern New Jersey, many of them from Franklin, which is famous for the brilliant red fluorescence of the calcite found there. However, none of the specimens in those three drawers showed this red fluorescence; these specimens had been chosen for their crystal perfection, and the Franklin calcite crystals were not formed from solutions containing the proper amounts of manganese and lead to show strong fluorescence. However, most of the Franklin willemite and zincite specimens in the National Museum are in a massive calcite gangue that shows extremely brilliant red fluorescence.

Although Franklin, N. J., has long been famous for its large number of fluorescent minerals and for the brilliance of their emission, the infrared luminescence of these minerals is either nonexistent or weak. Indeed no mineral region has been found which produces many varieties of minerals showing intense infrared luminescence. However, weak or medium infrared luminescence is shown by a number of mineral varieties found in some localities. Many of the Franklin, N. J., minerals show such a weak infrared luminescence. Many minerals found near Pikes Peak, Colo., show a weak, but frequently long-wavelength, infrared emission that is believed to result from rare-earth activators. The saline-lake areas of southern California produce many borate and halide minerals that show a weak infrared luminescence, and Melhase (1935) in reporting the accompanying pale-yellow fluorescence of the minerals says that the brine of the lakes also is fluorescent.

ABUNDANCE OF INFRARED LUMINESCENCE

Table 3 is intended to indicate the prevalence of infrared luminescence in minerals. Columns 2 and 3 give the size of the sampling—the number of specimens of the mineral and the number of localities represented. Columns 4, 5, 6, and 7 give the percentages of these specimens and localities that show infrared and visible luminescence. These percentages are given to the nearest 10 percent except that they are given to the nearest unit when less than 10 percent. Percentages are given for both specimens and localities, because either one alone may give biased results for minerals represented by only one or two localities or by a majority of specimens from one locality. Any pieces bearing the same museum number are counted as one specimen, so that the number of samples examined often considerably exceeds the recorded number of specimens. Also, as mentioned above, one locality may cover a broad area and include many mines.

The dependence of most mineral luminescence upon accidental impurities makes statements regarding its occurrence and especially the frequency of the occurrence extremely risky. For example, some 20,000 specimens of about 300 minerals were examined in a preliminary survey; and, although earlier investigators had reported finding fluorescent specimens of every one of these minerals, we did not find a single visible or infrared luminescent specimen for 25 percent of these minerals. Perhaps some of these negative reactions can be explained by a lack of thoroughness in observing visible fluorescence; only a 2,500-A ultraviolet lamp was used in much of the examination for visible fluorescence. A great many minerals, however, did not show luminescence because the National Museum collection lacks specimens containing the right kind and amount of activators. Even if the right region is represented, suitably activated specimens may be absent; all specimens from one locality seldom show the same luminescence. Only parts of some mineral specimens show luminescence. A few specimens showed a zoned infrared luminescence limited to the base, core, or tips of crystals, and in many sphalerite specimens from Colorado the infrared luminescence is limited to the extreme edges of the crystal surfaces.

FACTORS INFLUENCING THE DETECTION OF WEAK LUMINESCENCE

Perusal of tables 2 and 4 shows that a large proportion of the infrared luminescence was judged by the observer to be weak in intensity. Another large group of minerals showed even weaker infrared luminescence, but because of the uncertainty of the observation these are not reported.

When the infrared is weak and luminescence occurs in small spots, it is sometimes difficult to be certain, without careful mineralogic examination, whether the mineral being observed is the one that has been identified. Thus, it is possible that much of the infrared luminescence reported for sphalerite is actually caused by greenockite, which always shows infrared luminescence, and which is present in many sphalerite specimens either as a thin surface coating or in solid solution. Similarly much of the weak and spotty infrared luminescence of cryolite and cryolithionite might be caused by small amounts of chiolite which frequently accompanies these minerals, and which much more commonly shows infrared luminescence. Many other minerals show a weak luminescence that seems to result from coating and cavity fillings of impure clay and carbonate alteration products that are commonly slightly luminescent.

Another factor that makes the detection of weak infrared luminescence uncertain is the difficulty of distinguishing it from reflected light "leaked" by the filters (p. 78). Both the viewing box and the scanner contained a weak infrared light source so that the observer could estimate the importance of this infrared reflection; table 4 includes his evaluation of the specimens' reflectivity. The value recorded is that of diffuse reflection; specular reflection for minerals with good cleavage or with metallic luster is much higher. The reflection is recorded as either "very faint," "faint," "average," or "bright." These observations of infrared reflection seldom show any results that cannot be expected from visual examination. Good cleavage surfaces generally show a high degree of specular reflection, and bright matte surfaces a high degree of diffuse reflection. Specimens with a light-brown or reddish color as from a thin ferrous coating are also frequently bright. A few red minerals such as zincite show strong reflection. Dull-black opaque minerals and clear, almost transparent, minerals reflect very little infrared because of complete absorption and complete transmission, respectively.

COMPARISON OF INFRARED AND VISIBLE LUMINESCENCE

Most infrared luminescent minerals have also been reported as visibly fluorescent, but many infrared luminescent specimens do not show visible fluorescence; and, vice versa, many visibly fluorescent specimens do not show infrared luminescence. The preliminary examination of the National Museum mineral collection was restricted to about 20,000 specimens of 300 minerals for which luminescent phenomena had been reported in at least one of the lists of Engelhardt (1912), Kunz and Baskerville (1903), Krejci-Graf and Krejci-Graf (1934), Walther (1936), Zodac (1936), Deribere (1943, p. 31–46), Dake and DeMent 1941), Warren (1944), DeMent (1945), and in a list of fluorescent minerals in the U. S. National Museum compiled by J. H. Benn (written communication). This preliminary examination disclosed more than 90 percent of all the infrared luminescent specimens found, even though later examinations covered more than 180,000 additional specimens.

There is, thus, an obvious relationship between the two types of luminescence, but the relationship does not imply that the causes of both infrared and visible luminescence are the same. There is ample evidence that some of the activators which cause the strongest and most prevalent visible fluorescence under ultraviolet do not cause any infrared emission. The uranyl-activated silica and uranium minerals, which give a brilliant yellow or green fluorescence under ultraviolet light, show no infrared luminescence. The manganese-activated calcites and willemites from Franklin, N. J., which show spectacular red and yellow-green fluorescence, give little or no infrared emission. Many scheelite and powellite specimens, which always show visible luminescence, do not show infrared emission. However, there are also a number of minerals in which infrared emission is much more common than visible emission. Thus, all specimens of greenockite show a strong infrared emission, but only about half of them give a visible emission with ultraviolet light. Infrared luminescence is also far more common than visible fluorescence in such abundant minerals as feldspars, amphiboles, and pyroxenes. In many other minerals, such as chromium-activated corundum, beryl, jadeite, and kyanite, the infrared luminescence appears much stronger than the visible emission.

We can conclude that, although the activators that cause visible and infrared luminescence are often, if not usually different, the suitability of the host mineral for one activator also often applies to other activators. Thus, scheelite, which owes most of its visible luminescence to the tungstate ion, also can contain rare-earth activators that cause strong infrared luminescence. The suitability of a host mineral for luminescence activators probably involves both the ability of the crystal lattice to hold foreign ions and the transparency of the mineral to both exciting and emitted radiation.

IMPORTANT ACTIVATORS FOR INFRARED LUMINESCENCE

Determination of the cause of luminescence is impossible unless a considerable amount of expensive laboratory equipment is available; precise spectrographic analysis of mineral composition and luminescent emission is essential for the correct identification of activators. Previous investigators have, however, identified the activators responsible for the visible fluorescence of many minerals, and some of these activators are known also to cause infrared luminescence. With such information the cause of the infrared luminescence of some minerals may be assumed, but the assumption is not really justified, because other activators may in some specimens cause at least part of the luminescence. Nevertheless a summary of the activators reported to cause infrared luminescence and of the minerals in which these activators have been found probably provides the best explanation of infrared luminescence that can be made without performing much additional laboratory work. Undoubtedly the list of these activators is not complete, but it includes enough to explain the more brilliant and common infrared emission. The list is primarily based on Kröger's (1948) classification of luminescent minerals according to type of activators.

Cadmium is responsible for the infrared emission of the cadmium sulfide greenockite, apparently the only mineral observed in which luminescence was produced by a major chemical constituent. Gisolf (according to Pringsheim, 1949, p. 607) has shown that the peak of the luminescent emission band of a solid solution of zinc and cadmium sulfides shifts linearly with increasing cadmium content from 4,600 A in the blue to 7,600 A in the infrared. Most specimens also show a weak yellow fluorescence, which results from cadmium ions if they are suitably isolated in the lattice (Weyl, 1942, p. 1037, and Inman, Mroz, and Weyl, 1948). Cadmium may also cause some or all of the less common infrared luminescence of the zinc sulfides sphalerite and wurtzite.

The rare earths cause much of the infrared luminescence emitted by minerals. Generally the rare-earth ions are in a trivalent state, so that their outer electron shell is filled, thus forming a shield for the inner unfilled orbits. The electronic transitions corresponding to the lines of the fluorescence spectra take place within these inner orbits where they are protected from the effects of the surrounding atoms. The lines of the luminescence spectra are thus sharp and practically independent of the type of host mineral. The rare-earth emission spectra cover a broad range and extend beyond 8,000 A, or well into the infrared region; they probably cause most of the longest wavelength infrared luminescence. Samarium and europium are the most important members of the group but Kröger's (1948) table also mentions infrared luminescence resulting from dysprosium, neodymium, praseodymium, terbium, thulium, and ytterbium.

These rare earths probably cause the infrared luminescence of many of the minerals whose visible fluorescence is found in a great many specimens. For example, Tanaka's spectrographic examination (1924a) of the fluorescence of calcite has shown that manganese is the main activator, although dysprosium, ytterbium, thulium, and samarium may be contributing activators. Most of the infrared emission of calcite can probably be attributed to members of this group of rare-earth elements. The luminescence of fluorite, the mineral in which fluorescence was first recognized, is still the subject of much discussion, but most of its luminescence is now attributed to rare-earth activators. Although rare-earth activators are usually in a trivalent state, the europium, samarium, and ytterbium activators in many fluorites have been reduced by radioactivity to a divalent state with resultant changes in the emission band frequencies (Przibram, 1937). The important luminescence of scheelite and powellite results from the tungstate and molybdate ions (Cannon and Murata, 1944), but Servigne (1938, 1939, and 1940) has shown that in addition to this tungstate luminescence the emission spectra of most scheelites show rare-earth lines which extend into the infrared region. More than three-quarters of the scheelite specimens examined showed this infrared luminescence caused by rare earths, but powellite specimens, for some still unexplained reason, did not show it.

Rare earths also cause the infrared luminescence of other minerals, for which visibly fluorescent specimens are no more common than infrared luminescent specimens. Köhler and Haberlandt (1934, p. 90) have found rare-earth lines in the fluorence spectrum of apatite, which may show both visible and infrared luminescence, although the two types of emission do not always occur in the same specimen. Haberlandt and Köhler (1939) also attribute the visible fluorescence of feldspars to the divalent europium ion, and the more common infrared luminescence is probably caused by rare earths in either a divalent or trivalent state. For example, amazonstone from Pikes Peak, Colo., commonly shows infrared emission. Tanaka (1924b) has spectrographically identified samarium and ytterbium in the emission spectra of kunzite; but the investigation of infrared luminescence did not find any luminescent specimens of kunzite, perhaps because localities noted for luminescence are not represented in the National Museum collection. Some borates, especially those from the saline-lake area of California, are infrared luminescent; and the possibility that this luminescence is caused by rare earths is demonstrated by experiments conducted by Nichols and Howes (1926), who found that rare earths produce luminescence in beads of borax flux. Perhaps rare earths may also be the cause of infrared luminescence in minerals commonly associated with other minerals whose luminescence is known to be caused by rare earths. Thus the infrared luminescence of minerals in the cryolite-chiolite group may be caused by rare earths, as many of the infrared luminescent specimens are from Colorado, where they are associated with luminescent fluorite.

By far the most brilliant infrared luminescence results from the chromium ion which gives a series of strong emission bands centered near the border between the visible and infrared. In synthetic ruby, chromium causes a bright red fluorescence; but in kyanite, the emission is almost entirely in the infrared region. This shift in emission wavelength for different minerals can be explained by the fact that the electronic transitions responsible for the fluorescence of chromium take place in the outermost, unfilled shell of the atom and are thus relatively unprotected from the effects of surrounding atoms in the host lattice. Deutschbein (1932) made a thorough study of chromium-activated luminescence and along with Pringsheim (1949) lists the minerals in which such luminescence is found.

The luminescence activator for corundum, the most intensely infrared luminescent mineral found in this investigation, is the chromium ion, which substitutes isomorphously for aluminum in the crystal lattice. Ultraviolet light sometimes excites a red emission, especially in synthetic ruby, which has a very high chromium content, but the infrared emission excited by visible light is far more common. Most of this emission is, however, very close to the visible spectrum. Pale sapphires and light-blue corundum show a weaker infrared luminescence, but emery and dark-blue specimens are sufficiently opaque to quench all luminescence. Some specimens of two other aluminum oxides, spinel and chrysoberyl, show infrared luminescence caused by the chromium ion; and alexandrite, the deep-blue or green chrysoberyl, shows a strong infrared emission.

A number of silicate minerals also show infrared luminescence caused by the chromium ion. Many kyanite specimens show a very strong infrared luminescence, but none show much visible fluorescence under ultraviolet light. Although Pringsheim (1949) reports that its strong doublet emission line has a slightly lower wavelength than that of ruby, the greater part of its emission seems to have a longer wavelength. Topaz, especially when slightly brownish or sherry colored, shows a strong chromium-activated infrared luminescence that is sometimes accompanied by a very slight and perhaps questionable visible emission under ultraviolet light. Beryl in cloudy or opaque specimens generally gives no luminescence, but relatively clear pieces of most emerald and some aquamarine show a strong infrared luminescence. Except possibly for one specimen of synthetic emerald, the emeralds examined did not show any visible luminescence, but luminescence has been previously detected and definitely attributed to chromium by Deutschbein (1932) and Venkateswaran (1935). Jadeite owes its green color to chromium and also gives a very intense infrared luminescence. However, one difference between jadeite and other chromium-activated minerals should be noted — in jadeite the infrared emission occurs at considerably longer wavelengths. All oriental and some Mexican jades show this infrared luminescence; but nephrite, which is colored by iron, does not show any luminescence. Deutschbein (1932, p. 740) reports that uvarovite is another mineral showing chromium-activated luminescence, but none of the specimens examined produced any infrared luminescence. However, some grossularite and demantoid specimens showed an infrared luminescence that resembles that of the chromium-activated minerals. The infrared luminescence of hiddenite also resembles that of the chromium ion in emerald, and Claffy (1953) has shown that the green color of some hiddenites which do not show visible luminescence is caused by the chromium ion. The green color of other luminescent hiddenites can, however, be caused by the radium irradiation of kunzite specimens (Pringsheim, 1949, p. 659); therefore some of its luminescence has a different cause.

EMISSION

The last column of table 4 indicates the wavelength of the infrared emission, as determined by changing the cutoff filter in front of the snooperscope. "Very short" is used for emission which can be seen only through filter 1 and possibly filter 2, the latter passing less than one-third as much energy as 1. Most of the emission described as very short probably has a wavelength of 7,000 to 7,500 A. "Short" emission is visible through filters 1 and 2 and usually through filter 3 which passes less than one-quarter of the emission passed by 1. This type of emission probably has a wavelength between 7,500 and 8,000 A. "Medium" is applied to all emission that is passed by filters 1, 2, and 3 and in some cases by 4 which cuts the strength to less than one-fifth of that passed by 1. Medium emission probably has a wavelength between 8,000 and 9,300 A. "Long" emission is passed by all filters, and filter 4 passes more than three-fifths as much energy as filter 1. Most of the emission described as long probably has a wavelength between 9,300 and 9,700 A. "Very long" is applied to the emission of a few minerals which produce nearly as bright an image through filter 5 as through filter 1. Very long emission has an average wavelength greater than 9,700 A. (See fig. 26*A*.)

Any one of these categories can, however, apply to a number of different types of emission spectra. Thus an emission classed as short might consist of a broad band or series of bands extending from 7,000 to 8,300 A; a single sharp peak at approximately 7,800 A; or a group of bright bands between 7,000 and 7,500 A combined with some low intensity bands between 8,500 and 9,000 A. Furthermore, when the infrared luminescence is weak or very weak it is often difficult for the observer to detect any differences when varying the excitation and emission filters. Indeed, for a few minerals the spectral characteristics of very weak emission have to be recorded as "indeterminable." In general, however, weak luminescence would tend to be recorded as having too short an emission wavelength.

The table shows that infrared luminescence with a short wavelength is more common than luminescence with a longer wavelength. The greater sensitivity of the infrared image tube to short wavelengths might be an explanation of this conclusion, but this sensitivity difference was considered in describing the emission wavelength. A better explanation is provided by the greater efficiency of luminescence processes in which the excitation and emission wavelengths are close together. In the limiting case of resonance luminescence the absorbed radiation has the same frequency as the emitted light, and the efficiency of the process is a maximum. Thus the most efficient infrared luminescence would occur at short wavelengths near to those of the visible excitation.

The wavelength of the luminescence of minerals varies considerably and is seldom the same for all specimens of one mineral or even for all specimens of one mineral activated by the same element. As mentioned on page 91, the wavelength of the luminescent emission caused by the trivalent rare earths is nearly independent of the type of host lattice, but variations in the relative concentrations of the activator elements can change the emission wavelength. Luminescence resulting from the divalent rare earths and most other activators is, however, considerably affected by the nature of the host lattice.

The brilliant infrared luminescence of chromium-activated minerals provides an excellent example of the importance of the host lattice in influencing emission wavelength. Thus, the luminescence wavelength of ruby is classed as "very short" for most specimens, but the wavelength for the much denser minerals kyanite and jadeite is "medium". Deutschbein (1932) has found that the position of one of the brightest lines of the chromium spectrum (6,927 A in ruby) varies as much as 250 A among 8 different minerals, and other lines may show an even greater variation. The electronic transitions responsible for the fluorescence of chromium take place in the outermost, unfilled shell of the ion and are thus relatively unprotected from the effects of surrounding atoms in the host lattice. As the transitions are normally forbidden and can occur only because of the electric fields of the surrounding atoms, the probability of any transition and thus the relative strength of the resulting spectral lines depends on the host crystal. Additional subordinate lines can result in the spectra from the vibrational levels of the host lattice and from intermolecular Stark effects. Furthermore, even if the emission spectrum of an ion is independent of the effect of the host lattice, changes in emission spectra may be caused by self-reversal due to changes in concentration of the activator (Pringsheim, 1949, p. 664).

EXCITATION

Columns 6 and 7 of table 4 give the range and most effective color of exciting radiation for various mineral specimens. The tabulations are based on the observations of relative brightnesses of luminescence produced by excitation through the five filters that could be placed in front of the projector in the viewing box. For the convenience of the reader, the filters are described by the color of the light transmitted. These colors and the approximate wavelengths covered by each are listed in table 1 on page 79. In table 4 the "Range of excitation" column lists all filters whose transmitted light produced a detectable luminescence but the "Maximum of excitation" column gives only those filters that were most effective in producing this luminescence. The recording of more than one filter in the "Maximum of excitation" column means that the same brightness was recorded when the specimen was excited through more than one filter.

All the data suggest that the intensity of the infrared luminescence of most minerals decreases rapidly with a decrease in the wavelength of excitation. However, most of this decrease results from relative weakness of the ultraviolet excitation compared to the red and green excitation (see discussion on p. 75 and data in column 5 of table 1). Even a weaker emission caused by excitation in the violet end of the spectrum can mean that the mineral is actually more sensitive to violet excitation than to red. Accordingly, if the emission caused by short wavelength excitation was equal to that excited by longer wavelengths, the violet or ultraviolet is recorded in the "Maximum of excitation" column. Also the violet or ultraviolet is placed in parentheses as an additional "Maximum of excitation" for specimens in which the emission excited by these wavelengths was large enough to be more than that excited by longer wavelengths if both emission strengths were multiplied by the reciprocal of their excitation energies. Unfortunately, the luminescence under ultraviolet, violet, and blue-violet excitation was recorded as zero intensity for most minerals that showed only weak or very weak infrared luminescence, and such a value cannot be corrected.

Although the data generally show a preponderance of excitation in the red and green end of the spectrum, violet and ultraviolet light are always the most effective form of excitation for marshite, matlockite, mimetite, and phosgenite, and possibly for some specimens of scapolite, hackmanite, sussexite, and xanthophyllite, as well as some carbonates and chromium-activated minerals. Ultraviolet is probably an effective form of excitation for many other minerals, especially for many of those which showed such weak infrared luminescence that the low-energy, short-wavelength sources employed produced no detectable luminescence. Nevertheless, the availablitity of high-energy red and green light from incandescent sources makes this region the most practical for excitation of infrared luminescence.

Before any luminescence can be emitted from a crystal an electron has to be raised to an excited state by the absorption of energy. Such absorption can take place only if there is an electron transition corresponding to the impinging energy, although, fortunately, owing to the effects of thermal vibration the correspondence does not have to be exact. In resonance luminescence, energy is absorbed by the same transition that causes the luminescence, and the exciting radiation has the same wavelength as the luminescence; the efficiency of the process, therefore, is very high. The luminescence described in this report, however, results from excitation of considerably shorter wavelengths. Accordingly, higher energy levels, either in the same ion or in another part of the crystal, lattice are involved, and the energy is transferred with consequent loss to the level from which the emission takes place. Such a transfer of energy may occur in a number of ways, and the probabilities of the transitions may depend on many factors involving not only the activators, but all other components of the luminescent system. In many minerals additional activators are required; thus the ultraviolet excitation of calcite fluorescence generally requires the presence of a sensitizing impurity such as lead (Pringsheim, 1949, p. 647; Schulman, Evans, Ginther, and Murata, 1947). In other minerals, however, the absorption can take place directly in the activating atom. Thus, greenockite specimens from Llallagua and most other localities show a maximum excitation efficiency in the green near 5,000 A, which is, according to Gisolf (*in* Pringsheim, 1949, p. 607), near the fundamental absorption band of cadmium sulfide. The efficiency of excitation of any wavelength will depend, first, on the number of suitable absorption levels, and second, on the probability of energy transfer from these levels to the emission level.

Consideration of the quantum theory of luminescence leads to an additional reason for the decrease of infrared luminescence efficiency at short excitation wavelengths. The luminescence emitted is proportional to the number of excited luminescent centers, and one quantum of light is required to excite each center. The energy of a quantum is proportional to the frequency of the light or inversely proportional to its wavelength. Thus the number of luminescent centers that can be activated by light from each lamp is proportional to the energy times the mean wavelength, which represents the quanta or energy flux per unit area per unit of time. These values are given in column 6 of table 1, and they show an even more rapid decrease with decreasing wavelength than does the energy emitted by the light sources.

An interesting interpretation of the excitation mechanism may partly explain the lack of visible emission from some of the brilliant infrared luminescent chromium-activated minerals. The introduction of chromium adds a broad absorption band in the green at about 5,600 A (Pringsheim, 1949, p. 644). Excitation close to this band (filters 2, 3, and 4) produces a strong infrared luminescence in all chromium-activated minerals, but ultraviolet excitation causes infrared luminescence in only ruby and a few other minerals. The ultraviolet excitation of ruby also produces a strong red luminescence, and Kröger (1948, p. 84) has shown that the absorption of pure aluminum oxide is very small throughout the visible spectrum but increases rapidly for wavelengths below 3,000 A. It would thus appear that irradiation with green light results in direct excitation of the chromium ion and is effective for all chromium-activated minerals. Ultraviolet excitation, however, involves the absorption of light by the host lattice and subsequent transfer to the chromium ion; ultraviolet excitation will thus be effective in only the few chromium-activated minerals that can absorb and then transfer this energy efficiently. As the luminescence of chromium minerals seems to involve the emission of both visible and infrared light, the advantage of the snooperscope for detecting chromium luminescence may result not from its ability to detect infrared radiation, but rather from its use of visible excitation.

POSSIBILITIES FOR PRACTICAL USE

One of the reasons for undertaking this program of investigations was the possibility that the infrared luminescence of minerals might prove a useful prospecting tool. If it is to serve such a purpose a mineral has to be found that will meet the following requisites: The mineral must be of economic importance—either an ore or an associate of ore. It must always show luminescence, which probably means that one of its chemical constituents will be an activator. Thus under ultraviolet light scheelite shows a blue luminescence caused by the tungstate ion, and some uranium minerals show a green luminescence caused by the uranyl ion. In some instances a mineral that always shows infrared luminescence in one locality might be worth considering. Thus ultraviolet light is very useful for detecting manganese-activated zinc minerals at Franklin, N. J. The mineral must be difficult to identify by simpler methods; no one would consider prowling around in the dark with a snooperscope looking for a copper carbonate. The infrared luminescence should be easily distinguished from that produced by less valuable materials. Considering the frequency of weak reactions from clay minerals and the lack of methods for distinguishing wavelength, this might be a serious limitation.

The only mineral that is always luminescent in the infrared region, and thus able to satisfy the second requirement, is greenockite, which is also the only important cadmium mineral. Greenockite occurs as a very thin coating on sphalerite and similar minerals, and is usually extracted as a byproduct of zinc mining.

The brighter infrared luminescence of many chromium-activated gems might be useful. For example, infrared luminescence provides a simple tool for distinguishing most pyroxene jades from their amphibole relatives.

The greatest opportunities for the infrared detection of minerals may result from the possibility of detecting small quantities of rare earths in relatively common minerals like feldspars. As the wavelength of rare-earth luminescence lies in the relatively long infrared, filters could perhaps be used to eliminate the effects of other activators. The usefulness would depend on the intensity of of the infrared luminescence from the common gangue minerals as a guide to concentrations of the rare-earth ore minerals monazite, xenotime, and bastnaesite, which are too opaque to be luminescent. Tests of this relationship would have to be made in individual field localities.

TABLE 2.—*Sources of minerals showing infrared luminescence*

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Actinolite	Franklin, N. J.		
Adularia	Grisons, Switzerland		
Agalmatolite. (See pyrophyllite.)			
Agate. (See quartz.)			
Albite (peristerite.)	Narsarsuk, Greenland		
Alexandrite. (See chrysoberyl.)			
Allophane		Resin Hollow, Ky.	
Collyrite	Schemnitz, Hungary		
Malthacite	Steindorfel, Bohemia		
Razoumovskyn.	Kossmutz, Siberia		
Alunite	Allumiere, France	Oruro, Bolivia	
	Wurzen, Saxony		
Alunogen:			
Solfaterite	Solfaterra, Italy		
Amazonstone. (See microcline.)			
Amblygonite	Pala, Calif.	Harding, N. Mex.	
Amphibole. (See actinolite, anthophyllite, arfvedsonite, tremolite.)			
Anapaite:			
Messelite	Wessel, Germany		
Analcime	Golden, Colo.		
Andalusite	Fresno City, Calif.	Lisens Alp, Tyrol	
	Swarthmore, Pa.		
Chiastolite	Lancaster, Mass.		
	Cumberland, England		
	Baregas, France		
Andesine	Esterel Mountains, France.		
Sacchurite		Glasendorf, Silesia	
Andradite:			
Demantoid			Siberia.
Anglesite	Monte Poni, Sardinia	Cramford, England.	
Anhydrite	Celle, Hanover, Germany.		
	Stassfurt, Germany		
Anorthite		Pala, Calif.	
Anthophyllite	Pylesville, Md.		
	Minneapolis, N. C.		

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Apatite	Renfrew County, Ontario.	Llallagua, Bolivia.	Mesa Grande, Calif.
	Bovey Tracey, England.	Haddam, Conn.	Durango, Mexico.
	Blagodat, India	Furuholmen, Norway.	
	Toghigi Prefecture, Japan.	Amelia, Va	
	Greenwood, Maine		
	St. Lawrence County, N. Y.		
	Odegaard, Norway		
	Kola Peninsula, Russia.		
	Gelivara, Sweden		
	Grisons, Switzerland		
	Twin Peaks, Utah		
Fluorapatite	Dundarragon, Western Australia.		
Dahllite	Manhattan, Nev.		
Rhodophoshite.	Horrsjoberg, Sweden		
Manganapatite.	Westana, Sweden		
Apophyllite	New Almaden, Calif		
	French Creek, Pa		
Aquamarine. (See beryl.)			
Aragonite	Bahama Islands	Bisbee, Ariz	
	Collingwood, Australia.	Sonoma County, Calif.	
	Girgenti, Sicily	Andover, N. J	
	Mount Vesuvius, Italy	Tintic, Utah	
	Shinano Province, Japan.		
	Eureka district, Nev		
	Badlands, Wyo		
	Organ Mountains, N. Mex.		
	Couliege, France		
	Grape Vine Mountains, Nev.		
	Leadville, Colo		
Arfvedsonite:			
Szechenyiite			Burma.
Augite:			
Omphacite		Fichtelgebirge, Germany.	
Axinite	Franklin, N. J		
Barite	Pribram, Bohemia		
	Ashe County, N. C		
	Black Hills, S. Dak		
	Canyon County, Colo.		
	Smoky Hill, Kans		
	Langban, Sweden		
Baudisserite. (See magnesite.)			
Bauxite	Floyd County, Ga		
Bentonite. (See montmorillonite.)			

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Beryl (emerald, aquamarine).			Poona, Western Australia. Emmaville, New South Wales. Heubachthal, Austria. Salzburg, Austria. Bahia, Brazil. Muzo, Colombia. Kongsberg, Norway. Peru. Mitchell County, N. C. Alexander County, N. C. Ural Mountains, Siberia.
Pseudo-smaragd.		Fahlun, Sweden	
Botryogen:			
Idrizite	Idria, Austria		
Brucite	Texas, Pa.		
Bustamite	Franklin, N. J.		
Byssolite. (See tremolite.)			
Cacholong. (See opal.)			
Calamite. (See tremolite.)			
Calcite (manganocalcite, cuprocalcite, reichite, oolite, pisolite, plumbocalcite).	Richmond, Australia Melbourne, Australia Nome, Alaska Pribram, Bohemia Telluride, Colo. Cumberland, England Cornwall, England Andreasberg, Germany. Freiberg, Germany Silesia, Germany Aikawa, Japan Tuscany, Italy Girgenti, Sicily Guanajuato, Mexico Grand Rapids, Mich. Lake Superior, Mich. Bergen Hill, N. J. Joplin, Mo. Hancock, Md. Rockland, Maine Kongsberg, Norway Picher, Okla. Crum Lynne, Pa. Badlands, S. Dak. Cheyenne, Wyo. Langban, Sweden	Badlands, S. Dak. Franklin, N. J. Union County, Ark. Warfield, Ontario Key West, Fla. San Luis Potosi, Mexico. Pyramid Lake, Nev. Sedgewickville, Mo.	

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Calcite—Con.	Trinity, Calif		
	Warren, Ariz		
	Suisun City, Calif		
	Bleiberg, Carinthia		
Calcium larsenite	Franklin, N. J		
Californite. (See idocrase.)			
Cassinite. (See hyallophane.)			
Castorite. (See petalite.)			
Celestite	Warrior, Ala		
	Borate, Calif		
	Girgenti, Sicily		
	Strontian Island, Lake Erie.		
Cerolite. (See saponite.)			
Cerussite	Tsumeb, South-west Africa.		
	Matlock, Derbyshire, England.		
	Joplin, Mo		
	Davidson's mine, N. C		
Cervantite	Silver Hill, Sevier County, Ark.	Humbolt County, Nev.	Charcas, San Luis Potosi, Mexico.
		Zamora, Spain	
	Gulzora, New South Wales.	Camp Floyd, Utah	Toliman, Queretaro Mexico.
Chalcedony. (See quartz.)			
Chiastolite. (See andalusite.)			
Chiolite	Miask, Ural Mountains, Russia.	Ivigtut, Greenland	
Chlorite. (See cookeite, colerainite.)			
Chromtremolite. (See tremolite.)			
Chrysoberyl	Ceylon		
Alexandrite			Katherinenburg, Ural Mountains, Russia.
Chrysotile. (See serpentine.)			
Colemanite (neocolemanite).	Lang, Calif		
Colerainite	Nottingham, Pa		
Collyrite. (See allophane.			
Confolensite. (See kaolinite.)			
Cookeite	Buckfield, Maine		
	Pala, Calif		
Corundum (ruby sapphire).	Ceylon (sapphire)	Zoutspanberg, Transvaal.	Ceylon (ruby).
	Bengal, India	Seluang, Malay	Amity, N. Y.
	Hyderabad, India	NiagaraFalls, N.Y.	Macon County, N. C.

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Corundum (ruby, sapphire) Con.	Bozeman, Mont.	White Mountains, Calif.	Powder Springs, Ga.
	Laurel Creek, Ga.	Ural Mountains, Siberia.	Rabun County, Ga.
	Shimerville, Pa.	------	Mysore, India.
			Piedmont, Italy.
			Lander, Wyo.
			Franklin, N. J.
Creedite	Wagon Wheel Gap, Colo.	------	
Crestmoreite	Crestmore, Calif.	------	
Cristobalite	------	Saplores, Durango, Mexico.	
		Girgenti, Sicily	
Cryolite	Ivigtut, Greenland	Pikes Peak, Colo.	
		Miask, Ural Mountains.	
Cryolithionite	do	------	
Cuprite	Wheal Phoenix, Cornwall, England.	------	
Cuprocalcite. (See calcite.)			
Cuproscheelite. (See cuprotungstite.)			
Cuprotungstite (cuproscheelite).	Huepac, Mexico	Tonechi, Mexico	
	La Paz, Lower California.	Fuerte, Mexico	
Danburite	Danbury, Conn.	------	
Datolite	------	Tadjik, Russia	
Delawarite. (See orthoclase.)			
Demantoid. (See andradite.)			
Deweylite (gymnite).	------	Newcastle County, Del.	
		Baltimore, Md.	
		Texas, Pa.	
		Gulsen, Styria	
		Fleims, Tyrol	
Diallage	Orange County, N. Y.	Franklin, N. J.	
Diamond	South Africa	Brazil	
Diaspore	Gumuchdagh, Asia Minor.	Schemnitz, Czechoslovakia.	
	Laurel Creek, Ga.	------	
	Gillis Range, Nev.	------	
	Horrsjoberg, Sweden	------	
Diopside (lavrovite, melacolite).	St. Lawrence County, N. Y.	Franklin, N. J.	Baikal Lake, Siberia.
	Sing Sing, N. Y.	------	
Dolomite (gurhofite).	Cold Spring, N. Y.	Searcy County, Ark.	
	St. Louis, Mo.	------	
	Traversella, Italy	------	
Tautoklin	------	Freiberg, Saxony	
Emerald. (See beryl.)			
Enstatite	Talcville, N. Y.	------	
Epidote:			
Tawmawite	------	Myitkyina, Burma	

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Ersbyite. (See meionite.)			
Euclase			Villa Rica, Brazil.
Feldspars. (See adularia, albite, andesine, anorthclase, hyallophane, microcline, oligoclase, orthoclase.)			
Fibrolite. (See sillimanite.)			
Fischerite. (See wavellite.)			
Fluorapatite. (See apatite.)			
Fluorite	Monroe, Conn	Ouray County, Colo.	Corocoro, Bolivia.
	Middletown, Conn	Alma, Colo	Clay Center, Ohio.
	San Juan County, Colo.	Pikes Peak, Colo	
	Salgadinho Mine, Brazil.	Haliburton, Ontario.	
	Sweetwater Mountains, Calif.	The Gulf, New South Wales.	
	Swakopmund, Southwest Africa.	Cornwall, England	
	Cumberland, England	Devon, England	
	Durham, England	Keokuk, Iowa	
	Auvergne, France	Ivigtut, Greenland	
	Freiburg, Germany	Westmoreland, N. H.	
	Barnthal, Italy	St. Louis, Mo	
	Shawneetown, Ill	Omodani, Japan	
	Stoneham, Maine	Chatham, N. H	
	Marion County, Ky	Franklin, N. J	
	Oita, Japan	Nertschinsk, Siberia.	
	Essex County, N. Y	Banat, Rumania	
	Amelia Court House, Va.	Shenandoah, Va	
	Switzerland	Renfrewshire, Scotland.	
Yttrofluorite	----------	Hundholmen, Norway.	
Fuchsite. (See muscovite.)			
Garnet. (See andradite, grossularite.)			
Gaylussite	Ragtown Lake, Nev	----------	
Gearksutite	----------	St. Peter's Dome, Colo.	
		Wagon Wheel Gap, Colo.	
Geyserite. (See opal.)			
Glagerite. (See halloysite.)			

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Greenockite	Llallagua, Bolivia	Granby, Mo	Llallagua, Bolivia.
	Marion County, Ark	Modoc County, Calif.	Bishoptown, Scotland.
	Topaz, Calif.	Franklin, N. J	
	Friedensville, Pa	--------	
	Pribram, Bohemia	--------	
Grossularite	Big Bar, Butte County, Calif.	North Thompson River, British Columbia.	South Africa.
	Hull, Quebec	Buffelsfontein, Transvaal.	
	Thetford, Vt	--------	
	Morelos, Mexico	--------	
Gurhofite. (See dolomite.)			
Gymnite. (See deweylite.)			
Gypsum (selenite)	Montmarte, France	Galapagos Islands	
	Borate, Calif	--------	
	Mammoth Cave, Ky	--------	
	Lockport, N. Y	--------	
	Ihlafeld, Germany	--------	
Gyrolite	New Almaden, Calif	--------	
Hackmanite. (See sodalite.)			
Halite	Borax Lake, Calif	Stazunia, Poland	
Halloysite (indianaite, glagerite).	Garland County, Ark	Pala, Calif	
	Baumgarten, Germany.	Bergnersreuth, Bavaria.	
	Bedford, Ind	--------	
	Leoben, Styria	--------	
Hambergite	Helgaraen, Norway	--------	
Hanksite	Searles Lake, Calif	--------	
Harringtonite. (See thomsonite.)			
Hauynite	Laacher See, Germany	--------	
Hedyphane	Franklin, N. J	--------	
Hemimorphite:			
Vanuzenite	--------	Stirling Hill, N. J	
Hexagonite. (See tremolite.)			
Hiddenite. (See spodumene.)			
Hornblende	--------	--------	
Pargasite	--------	Edenville, N. Y	Rossie, N. Y.
Howlite	Lang, Calif	Wentworth, Nova Scotia.	
Hyalophane:			
Cassinite	--------	Media, Pa	
Hydrocerussite	Wanlockhead, Scotland.	--------	
Hydronephelite. (See natrolite.)			
Hydrophane. (See opal.)			
Hydrotalcite	Somerville, N. Y	--------	
Iddingsite. (See serpentine.)			
Idrizite. (See botryogen.)			

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Idocrase:			
Californite		North Thompson River, British Columbia.	Lindsay, Calif.
Indianaite. (See halloysite.)			
Jadeite	Tenochutlan, Mexico		Magoung, Burma. Niigata Prefecture, Japan. Yunnan, China. Buena Vista de Cueller, Guerrero, Mexico.
Jasper. (See quartz.)			
Jurupaite			Crestmore, Calif.
Kaolinite:			
Lithomarge		Banat, Hungary	
Confolensite		Confolens, France	
Kyanite	Schomberg, Moravia	Belgian Congo	Zillerthal, Tyrol.
	Hillswick, Scotland	Brazil	Litchfield County, Conn.
	Lancaster County, S. C.	Langesund, Norway	Thomaston, Ga.
		Cumberland, R. I.	Windham, Maine.
		Yakul, U. S. S. R.	Yancey and Mitchel Counties, N. C.
		Wermland, Sweden.	
		Galax, Va.	Roraas, Norway.
		St. Gotthard, Switzerland.	Delaware County, Pa.
		Pfitsch, Tyrol	Troitzu, Siberia.
			Guadalajara, Spain.
			Charlotte Court House, Va.
Lanarkite	Leadhills, Scotland		
Laubanite. (See natrolite.)			
Laumontite:			
Leonhardite	Zillerthal, Tyrol		
Retzite		Vivero, Lugo, Spain.	
Lavrovite. (See diopside.)			
Lazulite		Horrsjoberg, Sweden.	
Leadhillite	Leadhills, Scotland		
Leelite. (See orthoclase.)			
Lennilite. (See orthoclase.)			
Leonhardite. (See laumontite.)			
Lepidolite		Grotto Ducci, Elba	
Leucophanite		Laven, Norway	
Leucophoenicite	Franklin, N. J		
Lithomarge. (See kaolinite.)			
Lucianite. (See talc.)			

Table 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Magnesite (baudisserite).	Hoboken, N. J	Delight, Md	
	Baumgarten, Germany.	Rising Sun, Md	
	Baudissero, Italy		
Malthacite. (See allophane.)			
Manganapatite. (See apatite.)			
Manganocalcite. (See calcite.)			
Marshite	Chuquicamata, Chile		
	Broken Hill, New South Wales.		
Matlockite		Cromford, Derby, England.	
Meionite:			
Ersbyite	Pargas, Finland		
Stroganovite	Baikal Lake, Siberia		
Melacolite. (See diopside.)			
Melanophlogite. (See cristobalite.)			
Mellite	Antern, Germany	Tula, Russia	
Mesolite	Golden, Colo		
	Antrim, Ireland		
Messelite. (See anapaite.)			
Metaxoite. (See serpentine.)			
Micas. (See muscovite, lepidolite, taeniolite.)			
Microcline (amazonstone).	Pikes Peak, Colo	Fianarantsoa, Madagascar.	
	Urals, Russia		
Mimetite	Tsumeb, South-west Africa.		
Molybdosodalite. (See sodalite.)			
Montmorillonite (steargilite, bentonite).	West Side, Oreg	Montmorillon, France.	
	Glen Riddle, Pa	Paris, Maine	
		Yamagata Prefecture, Japan.	
Stevensite		Paterson, N. J	
Montroydite		Terlingua, Tex	
Moonstone. (See orthoclase.)			
Mooreite		Stirling Hill, N. J	
Muscovite:			
Fuchsite			Brevard, N. C.
Natrolite:			
Laudanite		Steinbruch, Silesia	
Hydronephelite	Brevig, Norway		
Neocolemanite. (See colemanite.)			

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Nepheline	Val di Noto, Sicily		
	Kirovsk, Russia		
"Nitrate salts"	Clark's Cove, Va.		
Okenite	Riverside, Calif.		
	Godhaven, Greenland		
Oligoclase	Newcastle County, Del.		
	St. Lawrence County, N. Y.		
	Delaware County, Pa.		
	Mitchell County, N. C.		
	Macon County, N. C.		
Omphacite. (See augite.)			
Oolite. (See calcite.)			
Opal (cacholong, hydrophane).	Erandique, Honduras	Queretaro, Mexico	
	Dubnik, Czechoslovakia.		
	Virgin Valley, Nev.		
	Steinham, Belgium		
	Bohemia, Germany		
	Faroe Islands		
	Silesia, Germany		
	Willow Creek, Idaho		
	Veresvagas, Hungary		
	Divide, Colo.		
	Madison River, Mont.		
	Ruditz, Moravia		
	California		
Geyserite		Yellowstone, Wyo.	
Silicified wood.	Jackson's Hole, Mont.		Granger, Wyo.
Tabasheer			Calcutta, India.
Orthoclase (moonstone).	Globe, Ariz.	Newcastle County, Del.	
	Penticton, British Columbia.		
	Mourne Mountains, Ireland.	Akazu, Owari, Japan.	
	Mino Province, Japan	Meisan, Korea	
	Fianarantsoa, Madagascar.	Uto, Sweden	
	Auburn, Maine		
	Goodsprings, Nev.		
	Little Rock Creek, Mitchell County, N. C.		
	Ceylon		
Leelite		Chester County, Pa.	
		Lenni, Pa.	
Lennilite		do	
Delawarite		do	
Parahopeite	Salmo, British Columbia.		
Pargasite. (See hornblende.)			
Pectolite	Great Notch, N. J.		
	Middletown, Calif.		

Table 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Pectolite—Con.	Thetford, Quebec	----	
	Landalfoot, Scotland	----	
Peristerite. (See albite.)			
Petalite	Londonderry, Western Australia.	----	
	Greenwood, Maine	----	
	South-west Africa	----	
	Uto, Sweden	----	
Castorite	Elba Island	----	
Phosgenite	Derbyshire, England	----	
	Monte Poni, Sardinia	----	
Phosphorite. (See apatite.)			
Pirssonite	Searles Lake, Calif.	----	
Pisolite. (See calcite.)			
Plumbocalcite. (See calcite.)			
Pollucite	----	Custer, S. Dak.	
Probertite	Ryan, Calif.	----	
Pseudosmaragd. (See beryl.)	----	----	
Pyromorphite	Mies, Bohemia	Cumberland, England.	
	Cornwall, England	----	
	Phoenixville, Pa.	----	
	Wolfsberg, Germany	----	
Pyrophyllite:			
Agalmatolite	China	----	
Pyroxene. (See also diallage, diopside, enstatite, jadeite, spodumene.)	Franklin, N. J.	----	
Quartz:			
Chalcedony	Pascadero Beach, Calif	Cripple Creek, Colo.	
	Death Valley, Calif.	Tampa Bay, Fla.	
	Auvergne, France	----	
	Loch Neagh, Ireland	----	
	Iceland	----	
	Oniski, Japan	----	
	Sonora, Mexico	----	
	Guanajuato, Mexico	----	
	Black Hills, S. Dak.	----	
	Laredo, Tex.	----	
	Antiqua, West Indies	----	
	Opal, Wyo.	----	
Agate	Brazil	San Luis Potosi, Mexico.	
	Chagres River, Canal Zone.	----	
	Laramie County, Wyo.	----	
	Bohemia	----	
Jasper	San Francisco, Calif.	Bridger Basin, Wyo.	
	Colorado	----	
Quincite. (See sepiolite.)			

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Razoumovskyn. (See allophane.)			
Reichite. (See calcite.)			
Retzite. (See laumontite.)			
Rhaetizite. (See kyanite.)			
Rhodochrosite	Pachuca, Mexico		
	Marquette County, Mich.		
Rhodophosphite. (See apatite.)			
Ruby. (See corundum.)			
Sacchurite. (See andesine.)			
Saponite:			
Cerolite	Texas, Pa	Dixons quarry, Del.	
	Frankenstein, Germany.	Bluemont, Md	
		Kosewitz, Germany.	
Sapphire. (See corundum.)			
Saussurite. (See zoisite.)			
Scapolite	Long Hill, Conn	Greenville, Quebec	
	Bolton, Mass		
	Pierrepont, N. Y		
	Ottawa County, Quebec.		
	Texas, Md		
	Tsarasaotra, Madagascar.		
	Arendal, Norway		
	Easton, Pa		
Scheelite	Inyo, Kern, and San Bernardino Counties, Calif.	Yuenna, New South Wales.	Hyden, Alaska.
		Bolivia	
		Monroe, Conn	Rouis, Austria.
			Dragoon Mts., Ariz.
	Santiago, Chile	Ryndo, Korea	Schlaggenwald, Bohemia.
	Kai, Japan	Murray, Idaho	Mohave Desert, Calif.
	Carrock Fell, England	Riesengrund, Germany.	Leadville, Colo.
	Hill City, S. Dak		Otomezaka, Japan.
	White Pine County, Nev.	Pitkoranda, Finland.	Traversella, Italy.
	Jardine, Mont	New Zealand	Sonora, Mexico.
	Perak, Malay States	Iron Mountain, N. Mex.	
		Minerva, Nev	
		Sinaloa, Mexico	
Scheelitine. (See stolzite.)			
Selenite. (See gypsum.)			

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Selensulfur. (See sulfur.)			
Senarmontite	-----	El Antimonio, Sonora, Mexico.	
Sepiolite	North Clay City, Nev	Bare Hills, Md	
Quincite	Cher, France	-----	
Serpentine (metaxite). (See also deweylite, saponite.)	Montville, N. J	Crestmore, Calif	
	Modum, Norway	Lupipko, Finland	
Chrysotile	Globe, Ariz	Larchowfu Mountains, Shantung, China.	
	New Haven, Conn		
	Easton, Pa	-----	
Iddingsite	Conejos, Colo	Ryan, Inyo County, Calif.	
Silicified wood (See opal.)			
Sillimanite:			
Fibrolite	-----	Paris, Maine	Brandywine Springs, Del.
		Auvergne, France	
Smithsonite	Marion County, Ark	-----	
	Cumberland, England	-----	
	Laurium, Greece	-----	
	Masua, Sardinia	-----	
	Franklin, N. J	-----	
Sodalite (molybdosodalite):	Vesuvius, Italy	-----	
Hackmanite	-----	Kola Peninsula, Russia.	
		Bancroft, Ontario	
		Magnet Cove, Ark	
		Kangerdluarsk, Greenland.	
Solfaterite. (See alunogen.)			
Sphalerite	Clear Creek County, Colo.	Kremmling, Colo	Santander, Spain.
		Southampton, Mass.	Pulaski, Va.
	Oruro, Bolivia	Galena, Kans	Banner district, Idaho.
	Roxbury, Conn	Butler, Tenn	
	Perkiomen, Pa	-----	
	Kapnik, Rumania	-----	
	Tsumeb, South-west Africa.	-----	
	Rodna, Rumania	-----	
	Zlatoust, Siberia	-----	
Sphene	St. Gotthard, Switzerland.		
	-----	Ceylon	Sparta, N. J.
Spinel	Taos County, N. Mex	-----	
Spodumene	-----	-----	Hiddenite, N. C.
Hiddenite	-----	-----	
Steargilite. (See montmorillonite.)			
Steatite. (See talc.)			

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Stevensite. (See montmorillonite.)			
Stibianite. (See stibiconite.)			
Stibiconite	Oruro, Bolivia		
	Sarawak, Borneo		
	Empire district, Nev.		
Stibianite		Potosi, Bolivia	
Stolzite:			
Scheelitine	Altenberg, Saxony		
Stroganovite. (See meionite.)			
Strontianite	Strontian, Scotland		
Sulfur:			
Selensulfur	Cianciana, Sicily		
Sussexite	Franklin, N. J.		
Szenchenyiite (See arfvedsonite.)			
Tabasheer. (See opal.)			
Taeniolite	Magnet Cove, Ark.		
Talc (steatite)	Franklin, N. J.	Manhattan, Nev.	
	St. Lawrence County, N. Y.		
	Alma, Colo.		
	Rockland, Maine		
	Sonora, Mexico		
	Luca Almenia, Spain		
Lucianite		Villar de Puerco, Spain.	
Tautoklin. (See dolomite.)			
Tawmawite. (See epidote.)			
Terlinguaite	Terlingua, Tex.		
Thomsonite	Golden, Colo.	Kandern, Bohemia	
Harringtonite		Belfast, Ireland	
Thulite. (See zoisite.)			
Topaz	Grosmont, Western Australia.	New England, New South Wales.	Minas Geraes, Brazil.
		Minas Geraes, Brazil.	Scheckenstein, Germany.
			Sanarka River, Russia.
Tourmaline	King's Bridge, N. Y.	Franklin, N. J.	
		Etchison, Md.	
Tremolite (calamite, hexagonite, chromtremolite).	Canaan, Conn.	Kragero, Norway	Stirling Hill, N. J.
	St. Marcel, Italy	Outokumpo, Finland.	
	Rock Raven, Md.		
	Lee, Mass.		
	Fowler, N. Y.		
Byssolite		Johns Mansville Mines, Quebec.	
Tridymite	Durango, Mexico		
Trimerite	Langban, Sweden		

TABLE 2.—*Sources of minerals showing infrared luminescence*—Continued

Mineral	Sources of minerals showing infrared luminescence of strength indicated		
	Weak	Medium	Strong
Ulexite	Mount Blanco, Inyo County, Calif.		
Valentinite	Constantine, Algiers		
Valleite. (See anthophyllite.)			
Vanadinite	Yuma County, Ariz.		
	Tucson, Ariz.		
	Silver district, Ariz.		
Vanuxemite. (See hemimorphite.)			
Wavellite	Llallagua, Bolivia		
	Barnstable, England		
Fischerite	Hungary		
Willemite	Sussex County, N. J.		
Wollastonite	Cordova, Argentina	Lugo, Spain	
	Chelsea, Ontario		
	Natural Bridge, N. Y.		
	Easton, Pa.		
Wulfenite	Yuma County, Ariz.		
	Tiger, Ariz.		
	Pribram, Bohemia		
	Organ Mountains, N. Mex.		
Wurtzite	Butte, Mont.		
Xanthophyllite	Slatoust, Siberia		
Yttrofluorite. (See fluorite.)			
Zeolites. (See laumontite, mesolite, natrolite, thomsonite.)			
Zoisite (thulite, saussurite).		Mount Rosa, Switzerland.	

TABLE 3.—*Abundance of infrared and visible luminescence in minerals*

Mineral	Number of —		Infrared luminescence		Visible fluorescence	
			Percent of —		Percent of —	
	Specimens	Localities	Specimens	Localities	Specimens	Localities
Actinolite	63	31	1	3	0	0
Adularia	45	10	2	10	0	0
Agalmatolite. (See pyrophyllite.)						
Agate. (See quartz.)						
Albite (peristerite)	70	25	3	4	1	4
Alexandrite. (See chrysoberyl.)						
Allophane	16	12	6	8	30	30
Malthacite	1	1	100	100	100	100
Collyrite	8	1	60	100	60	100
Razoumovskyn	2	1	100	100	100	100
Alunite	25	12	8	20	8	20
Alunogen:						
Solfaterite	1	1	100	100	100	100

TABLE 3.—*Abundance of infrared and visible luminescence in minerals*—Continued

Mineral	Number of —		Infrared luminescence Percent of —		Visible fluorescence Percent of —	
	Specimens	Localities	Specimens	Localities	Specimens	Localities
Amazonstone. (See microcline.)						
Amblygonite	23	10	10	10	10	20
Amphibole. (See actinolite, anthophyllite, arfvedsonite, tremolite.)						
Anapaite:						
Messelite	4	1	20	100	20	100
Analcime	84	19	2	5	2	5
Andalusite	31	15	30	20	30	30
Chiastolite	18	10	20	30	20	40
Andesine	24	11	8	9	8	9
Sacchurite	2	1	100	100	100	100
Andradite:						
Demantoid	15	5	10	20	0	0
Anglesite	60	16	7	20	30	60
Anhydrite	44	17	7	10	5	6
Anorthite[1]	19	10	5	10	5	10
Anthophyllite	24	13	8	15	0	0
Apatite (phosphorite)	174	30	50	60	50	50
Fluorapatite	1	1	100	100	0	0
Dahllite	11	5	10	20	20	40
Rhodophosphite	1	1	100	100	100	100
Manganapatite	3	1	30	100	30	100
Apophyllite	112	23	7	10	20	30
Aquamarine. (See beryl.)						
Aragonite	115	36	20	40	40	70
Arfvedsonite:						
Szechenyiite	1	1	100	100	100	100
Augite:						
Omphacite	3	1	70	100	0	0
Axinite	51	12	2	10	10	20
Barite	185	45	7	10	10	10
Baudisserite. (See magnesite.)						
Bauxite	13	7	7	10	7	10
Bentonite. (See montmorillonite.)						
Beryl (emerald, aquamarine)	215	32	20	30	3	10
Pseudosmaragd	1	1	100	100	0	0
Botryogen:						
Idrizite	1	1	100	100	100	100
Brucite	28	11	10	7	30	40
Bustamite	12	3	30	30	30	30
Byssolite. (See tremolite.)						
Cacholong. (See opal.)						
Calamite. (See tremolite.)						
Calcite (manganocalcite, cuprocalcite, reichite, oolite, pisolite, plumbocalcite)	470	73	20	40	30	50
Calcium larsenite	7	1	90	100	30	100
Californite. (See idocrase.)						
Cassinite. (See hyalophane.)						
Castorite. (See petalite.)						
Celestite	92	23	15	30	30	50

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[1] Coating?

TABLE 3.—*Abundance of infrared and visible luminescence in minerals*—Continued

Mineral	Number of —		Infrared luminescence		Visible fluorescence	
			Percent of —		Percent of —	
	Specimens	Localities	Specimens	Localities	Specimens	Localities
Cerolite. (See saponite.)						
Cerussite	150	31	4	10	10	30
Cervantite	12	9	70	80	0	0
Chalcedony. (See quartz.)						
Chiastolite. (See andalusite.)						
Chiolite	7	2	60	100	0	0
Chlorite. (See cookeite, colerainite.)						
Chromtremolite. (See tremolite.)						
Chrysoberyl	33	8	3	10	10	10
Alexandrite	6	1	100	100	10	100
Chrysotile. (See serpentine.)						
Colemanite (neocolemanite)	33	2	60	100	100	100
Colerainite	3	1	100	100	100	100
Collyrite. (See allophane.)						
Confolensite. (See kaolinite.)						
Cookeite	13	3	40	70	0	0
Corundum (ruby, sapphire)	170	26	60	50	10	20
Creedite	8	2	10	50	100	100
Crestmoreite	7	1	100	100	100	100
Cristobalite	30	14	3	7	30	30
Melanophlogite	7	1	10	100	10	100
Cryolite	27	3	40	100	0	0
Cryolithionite	3	1	100	100	0	0
Cuprite	73	26	1	4	0	0
Cuprocalcite. (See calcite.)						
Cuproscheelite. (See cuprotungstite.)						
Cuprotungstite (cuproscheelite)	14	8	40	50	90	80
Danburite	34	10	9	10	20	30
Datolite	109	16	1	6	5	20
Delawarite. (See orthoclase.)						
Demantoid. (See andradite.)						
Deweylite (gymnite)	21	8	80	60	80	60
Diallage	14	11	10	10	0	0
Diamond	20	6	10	30	0	0
Diaspore	33	11	20	50	15	20
Diopside (lavrovite, melacolite)	55	17	5	20	0	0
Dolomite (gurhofite)	60	25	5	10	20	30
Tautoklin	1	1	100	100	100	100
Emerald. (See beryl.)						
Enstatite	23	9	4	10	0	0
Epidote:						
Tawmawite	2	2	50	50	0	0
Ersbyite. (See meionite.)						
Euclase	7	4	30	20	30	20

TABLE 3.—*Abundance of infrared and visible luminescence in minerals*—Continued

Mineral	Number of —		Infrared luminescence		Visible fluorescence	
			Percent of —		Percent of —	
	Specimens	Localities	Specimens	Localities	Specimens	Localities
Feldspars. (See adularia, albite, andesine, anorthite, hyalophane, microcline, oligoclase, orthoclase.)						
Fibrolite. (See sillimanite.)						
Fischerite. (See wavellite.)						
Fluorapatite. (See apatite.)						
Fluorite	274	46	40	60	50	60
Yttrofluorite	5	1	100	100	100	100
Fuchsite. (See muscovite.)						
Garnet. (See andradite, grossularite.)						
Gaylussite	10	6	30	10	30	20
Gearksutite	9	3	20	30	20	30
Geyserite. (See opal.)						
Glagerite. (See halloysite.)						
Greenockite	30	10	60	80	10	40
Grossularite	43	26	30	20	0	0
Gurhofite. (See dolomite.)						
Gymnite. (See deweylite.)						
Gypsum (selenite)	123	38	15	20	40	50
Gyrolite	4	4	20	20	70	70
Hackmanite. (See sodalite.)						
Halite	57	19	7	10	20	50
Halloysite (indianaite, glagerite)	21	18	30	30	20	30
Hambergite	3	2	30	50	30	50
Hanksite	16	1	6	100	40	100
Harringtonite. (See thomsonite.)						
Hauynite	20	4	5	20	5	20
Hedyphane	10	3	30	30	10	30
Hemimorphite:						
Vanuxemite	6	1	100	100	100	100
Hexagonite. (See tremolite.)						
Hiddenite. (See spodumene.)						
Hornblende:						
Pargasite	4	3	70	70	0	0
Howlite	16	2	40	100	30	100
Hyalophane:						
Cassinite	6	1	20	100	0	0
Hydrocerussite	12	5	20	60	10	20
Hydronephelite. (See natrolite.)						
Hydrophane. (See opal.)						
Hydrotalcite	8	3	20	30	0	0
Iddingsite. (See serpentine.)						
Idocrase:						
Californite	10	2	50	100	0	0
Idrizite. (See botryogen.)						
Indianaite. (See holloysite.)						

TABLE 3.—*Abundance of infrared and visible luminescence in minerals*—Continued

Mineral	Number of —		Infrared luminescence		Visible fluorescence	
			Percent of —		Percent of —	
	Specimens	Localities	Specimens	Localities	Specimens	Localities
Jadeite	18	5	50	100	0	0
Jasper. (See quartz.)						
Jurupaite	3	1	100	100	100	100
Kaolinite:						
Lithomarge	3	3	30	30	30	30
Confolensite	1	1	100	100	100	100
Kyanite (rhaetizite)	59	25	80	80	3	4
Lanarkite	5	1	20	100	40	100
Laubanite. (See natrolite.)						
Laumontite:						
Leonhardite	3	2	30	50	30	50
Retzite	1	1	100	100	0	0
Lavrovite. (See diopsode.)						
Lazulite	28	9	3	10	0	0
Leadhillite	21	9	5	20	10	20
Leelite. (See orthoclase.)						
Lennilite. (See orthoclase.)						
Leonhardite. (See laumontite.)						
Lepidolite	50	17	4	6	0	0
Leucophanite	4	1	70	100	70	100
Leucophoenicite	9	6	50	10	0	0
Lithomarge. (See kaolinite.)						
Lucianite. (See talc.)						
Magnesite (baudisserite)	40	25	20	20	20	20
Malthacite. (See allophane.)						
Manganapatite. (See apatite.)						
Manganocalcite. (See calcite.)						
Marshite	5	2	80	100	80	100
Matlockite	4	2	70	50	70	50
Meionite:						
Ersbyite	2	2	50	50	50	50
Stroganovite	2	1	50	100	50	100
Melacolite. (See diopside.)						
Melanophlogite. (See cristobalite.)						
Mellite	8	2	30	100	90	100
Mesolite	23	9	10	20	10	30
Messelite. (See anapaite.)						
Metaxoite. (See serpentine.)						
Micas. (See lepidolite, muscovite, taeniolite.)						
Microcline (amazonstone)	95	22	20	10	0?	0?
Mimetite	50	14	2	7	0	0
Molybdosodalite. (See sodalite.)						
Montmorillonite (steargilite, bentonite)	19	12	70	60	70	60
Stevensite	9	1	90	100	90	100
Montroydite	3	1	70	100	0	0
Moonstone. (See orthoclase.)						

TABLE 3.—*Abundance of infrared and visible luminescence in minerals*—Continued

Mineral	Number of —		Infrared luminescence		Visible fluorescence	
			Percent of —		Percent of —	
	Specimens	Localities	Specimens	Localities	Specimens	Localities
Mooreite	2	1	50	100	50	100
Muscovite:						
Fuchsite	14	10	7	10	0	0
Natrolite:						
Laubanite	2	1	50	100	50	100
Hydronephelite	5	5	40	40	40	40
Neocolemanite. (See colemanite.)						
Nepheline	34	12	6	15	3	8
"Nitrate salts"	9	4	20	20	20	20
Okenite	10	4	30	50	50	50
Oligoclase	35	12	20	30	6	20
Omphacite. (See augite.)						
Oolite. (See calcite.)						
Opal (cacholong, hydrophane)	197	68	15	10	20	30
Geyserite	7	2	40	50	20	50
Silicified wood	8	5	40	60	60	50
Tabasheer	3	1	70	100	70	100
Orthoclase (moonstone)	132	42	9	20	6	10
Leelite	3	2	70	100	70	100
Lennilite	4	1	50	100	50	100
Delawarite	1	1	100	100	100	100
Parahopeite	5	2	50	60	50	60
Pargasite. (See hornblende.)						
Pectolite	55	11	15	40	30	50
Peristerite. (See albite.)						
Petalite:	27	11	3	5	3	5
Castorite	2	2	50	50	0	0
Phosgenite	22	8	15	20	40	40
Phosphorite. (See apatite.)						
Pirssonite	23	1	20	100	0	0
Pisolite. (See calcite.)						
Plumbocalcite. (See calcite.)						
Pollucite	18	5	6	20	6	20
Probertite	5	1	60	100	0	0
Pseudosmaragd. (See beryl.)						
Pyromorphite	94	26	10	20	7	20
Pyrophyllite:						
Agalmatolite	5	3	40	30	60	40
Pyroxene	48	10	2	10	2	10
(See also diallage, diopside, enstatite, jadeite, spodumene.)						
Quartz:						
Chalcedony	112	40	15	30	30	60
Agate	95	25	5	20	15	40
Jasper	84	42	3	7	7	7
Quincite. (See sepiolite.)						
Razoumovskyn. (See allophane.)						
Reichite. (See calcite.)						
Retzite. (See laumontite.)						
Rhaetizite. (See kyanite.)						
Rhodochrosite	73	18	3	10	4	20

TABLE 3.—*Abundance of infrared and visible luminescence in minerals*—Continued

Mineral	Number of —		Infrared luminescence Percent of —		Visible fluorescence Percent of —	
	Specimens	Localities	Specimens	Localities	Specimens	Localities
Rhodophosphite. (See apatite.)						
Ruby. (See corundum.)						
Sacchurite. (See andesine.)						
Saponite:						
Cerolite	7	4	90	100	90	100
Sapphire. (See corundum.)						
Saussurite. (See zoisite.)						
Scapolite	75	13	20	70	20	80
Scheelite	93	30	60	90	100	100
Scheelitine. (See stolzite.)						
Selenite. (See gypsum.)						
Selensulfur. (See sulfur.)						
Senarmontite	6	3	20	30	0	0
Sepiolite	18	14	10	15	20	30
Quincite	8	1	60	100	60	100
Serpentine (metaxite) (See also deweylite, saponite.)	65	24	5	10	5	10
Chrysotile	20	12	20	30	20	20
Iddingsite	7	2	30	100	50	100
Silicified wood. (See opal.)						
Sillimanite:						
Fibrolite	5	4	60	70	60	70
Smithsonite	88	27	9	20	30	40
Sodalite (molybdosodalite)	39	12	5	8	10	15
Hackmanite	5	5	60	60	100	100
Solfaterite. (See alunogen.)						
Sphalerite	210	51	9	20	3	8
Sphene	105	21	8	10	1	5
Spinel	70	14	9	15	6	15
Spodumene	30	13	7	8	7	8
Hiddenite	12	1	90	100	0	0
Steargilite. (See montmorillonite.)						
Steatite. (See talc.)						
Stevensite. (See montmorillonite.)						
Stibianite. (See stibiconite.)						
Stibiconite	3	3	100	100	0	0
Stibianite	1	1	100	100	0	0
Stolzite:						
Scheelitine	1	1	100	100	0	0
Stroganovite. (See meionite.)						
Strontianite	25	10	4	10	60	60
Sulfur (selensulfur)	86	35	2	3	1	2
Sussexite	9	4	20	20	0	0
Szechenyiite. (See arfvedsonite.)						
Tabasheer. (See opal.)						
Taeniolite	3	2	30	50	30	50
Talc (steatite)	53	23	20	20	20	20
Lucianite	1	1	100	100	100	100
Tautoklin. (See dolomite.)						
Tawmawite. (See epidote.)						

TABLE 3.—*Abundance of infrared and visible luminescence in minerals*—Continued

Mineral	Number of —		Infrared luminescence		Visible fluorescence	
			Percent of —		Percent of —	
	Specimens	Localities	Specimens	Localities	Specimens	Localities
Terlinguaite	6	2	15	50	70	50
Thomsonite	58	19	5	10	7	15
Harringtonite	3	2	30	50	30	50
Thulite. (See zoisite.)						
Topaz	165	26	15	15	10	10
Tourmaline	280	39	3	5	10	10
Tremolite (calamite, hexagonite, chromtremolite)	68	22	20	40	20	50
Byssolite	12	9	8	10	8	10
Tridymite	18	9	15	10	15	10
Trimerite	7	1	100	100	0	0
Ulexite	29	8	3	10	20	30
Valentinite	17	9	6	10	6	10
Valleite. (See anthophyllite.)						
Vanadinite	78	15	6	15	0	0
Vanuxemite. (See hemimorphite.)						
Wavellite	66	12	6	20	40	70
Fischerite	3	2	30	50	70	100
Willemite[2]	93	12	4	8	90	80
Wollastonite	34	12	15	40	60	70
Wulfenite	87	23	20	20	0	0
Wurtzite	23	8	4	10	0	0
Xanthophyllite	10	3	10	30	0	0
Yttrofluorite. (See fluorite.)						
Zeolites. (See laumontite, mesolite, natrolite, thomsonite.)						
Zoisite (thulite):						
Saussurite	31	18	3	6	0	0

[2] Infrared questioned.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Actinolite	Franklin, N. J	None	Zero	Faint.
Adularia	St. Gotthard, Switzerland	do	do	Bright.
Agalmatolite. (See pyrophyllite.)				
Agate. (See quartz.)				
Albite	Narsarsuk, Greenland	do	do	Average.
Peristerite	Hybla, Ontario	do	do	Do.
Alexandrite. (See chrysoberyl.)				
Allophane	Resin Hollow, Ky	Green	Medium	Bright.
Malthacite	Steindorfel, Czechoslovakia	Pale gray	Weak	Do.
Collyrite	Schemnitz, Hungary	Pale brown	do	Average.
Razoumovskyn	Kosemutz, Siberia	Gray	do	Do.
Alunite	Allumiere, France	do	do	Do.
Alunogen:				
Solfaterite	Solfaterra, Italy	None	Zero	Bright.
Amazonstone. (See microcline.)				
Amblygonite	Pala, Calif	Buff	Weak	Average.
	Harding, N. Mex	Pale brown	do	Do.
Amphibole. (See tremolite, actinolite, arfvedsonite, and anthophyllite.)				
Anapaite:				
Messelite	Messel, Germany	Pale blue green	do	Do.
Analcime	Golden, Colo	Cream white	do	Bright.
Andalusite	Lisens Alps, Tyrol	None	Zero	Average.
Chiastolite	Lancaster, Mass	Brown	Weak	Do.
	Baregas, France	do	do	Do.
Andesine	Esterel Mountains, France	Pink	do	Do.
Saccharite	Glasendorf,. Silesia	Ochre	Medium	Do.
Andradite:				
Demantoid	Siberia	None	Zero	Faint.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Actinolite	Franklin, N. J	Weak	Red, green	Red	Short.
Adularia	St. Gotthard, Switzerland	Medium	Red through violet	do	Do.
Agalmatolite. (See pyrophyllite.)					
Agate. (See quartz.)					
Albite	Narsarsuk, Greenland	Weak	Red	do	Do.
Peristerite	Hybla, Ontario	Very weak	do	do	Medium.
Alexandrite. (See chrysoberyl.)					
Allophane	Resin Hollow, Ky	Medium	Red through violet	Red, green	Short.
Malthacite	Steindorfel, Czechoslovakia	Weak	Red, green	Red	Very short.
Collyrite	Schemnitz, Hungary	do	Red, green, violet	Red (violet)	Short.
Razoumovskyn	Kosemutz, Siberia	do	Red, violet	Violet	Do.
Alunite	Allumiere, France	do	Green, blue	Green, blue	Do.
Alunogen:					
Solfaterite	Solfaterra, Italy	do	Red, green, violet	Violet	Medium.
Amazonstone. (See microcline.)					
Amblygonite	Pala, Calif	Weak	Red, blue	Red	Very short.
	Harding, N. Mex	Medium	Red, green, violet	Red (violet)	Medium.
Amphibole. (See tremolite, actinolite, arfvedsonite, and anthophyllite.)					
Anapaite:					
Messelite	Messel, Germany	Weak	Red through violet	Red through blue	Do.
Analcime	Golden, Colo	Very weak	Red through blue	Red	Do.
Andalusite	Lisens Alps, Tyrol	Medium	do	do	Short.
Chiastolite	Lancaster, Mass	Weak	Blue	Blue	Do.
	Baregas, France	do	Red through blue	Red through blue	Do.
Andesine	Esterel Mountains, France	do	Red	Red	Medium.
Saccharite	Glasendorf, Silesia	Medium	Red, green	do	Short.
Andradite:					
Demantoid	Siberia	Strong	Red through blue-violet	do	Do.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Anglesite	Crumford, England	Yellow	Medium	Average.
	Monte Poni, Sardinia	Green	Weak	Do.
Anhydrite	Celle, Germany	None	Zero	Do.
Anorthite	Pala, Calif	Pale brown	Weak	Bright.
Anthophyllite	Pylesville, Md	None	Zero	Do.
Apatite	Llallagua, Bolivia	Cream white	Medium	Average.
	Mesa Grande, Calif	Ochre	Strong	Do.
	Renfrew, Ontario	None	Zero	Do.
	Guano Island, West Indies	Pale green	Weak	Do.
	Kola Peninsula, Russia	None	Zero	Do.
	Durango, Mexico	Brown	Weak	Do.
Phosphorite	Ciply, Belgium	Pale green	do	Do.
Fluorapatite	Dundarragon, Western Australia	None	Zero	Do.
Dahllite	Manhattan, Nev	Cream white	Weak	Do.
Rhodophosphite	Horrsjoberg, Sweden	Ochre	do	Do.
Manganapatite	Westana, Sweden	do	do	Do.
Apophyllite	New Almaden, Calif	Brown	do	Do.
Aquamarine. (See beryl)				
Aragonite	Bisbee, Ariz	Cream white	do	Bright.
	Girgenti, Sicily	White	do	Average.
	Tairamura, Japan	Pink	do	Do.
Arfvedsonite:				
Szechenyiite	Burma	None	Zero	Very faint.
Augite:				
Omphacite	Fichtelgebirge, Germany	do	do	Do.
Axinite	Franklin, N. J	Red	Medium	Average.
Barite	Pribram, Czechoslovakia	Gray	do	Do.
	Cheyenne River, S. Dak	Yellow	do	Do.
Baudisserite. (See magnesite.)				
Bauxite	Floyd County, Ga	Gray	Weak	Do.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Anglesite	Crumford, England	Medium	Green through violet	Blue, blue-violet	Short.
	Monte Poni, Sardinia	Weak	Green through blue-violet	Blue	Do.
Anhydrite	Celle, Germany	do	Green, blue	Green, blue	Very short.
Anorthite	Pala, Calif	Medium	Red through blue-violet	Red, green	Medium.
Anthophyllite	Pylesville, Md	Weak	Red, violet	Violet	Very short.
Apatite	Llallagua, Bolivia	Medium	Red through violet	Red through blue	Long.
	Mesa Grande, Calif	Strong	do	Green, blue	Do.
	Renfrew, Ontario	Weak	Red through blue	Red	Medium.
	Guano Island, West Indies	do	Red through violet	Green	Short.
	Kola Peninsula, Russia	do	Red, green	Red, green	Very long.
	Durango, Mexico	Strong	Red through blue-violet	do	Medium.
Phosphorite	Ciply, Belgium	Weak	Red	Red	Short.
Fluorapatite	Dundarragon, Western Australia.	Very weak	Indeterminable	Indeterminable	Do.
Dahllite	Manhattan, Nev	Weak	Red through blue-violet	Red	Do.
Rhodophosphite	Horrsjoberg, Sweden	do	Red through blue	Red through blue	Medium.
Manganapatite	Westana, Sweden	do	Red through blue-violet	Red, green	Long.
Apophyllite	New Almaden, Calif	do	Red through blue	Red through blue	Do.
Aquamarine. (See beryl.)					
Aragonite	Bisbee, Ariz	Medium	do	do	Short.
	Girgenti, Sicily	Weak	Red through blue-violet	Red	Very short.
	Tairamura, Japan	do	Green, blue	Green	Short.
Arfvedsonite:					
Szechenyiite	Burma	Strong	Red through blue-violet	Red	Medium.
Augite:					
Omphacite	Fichtelgebirge, Germany	Medium	Red through blue	do	Do.
Axinite	Franklin, N. J	Weak	Green through blue-violet	Green through blue-violet	Very short.
Barite	Pribram, Czechoslovakia	do	do	do	Long.
	Cheyenne River, S. Dak	Very weak	Red through blue	Red through blue	Indeterminable.
Baudisserite. (See magnesite.)					
Bauxite	Floyd County, Ga	do	do	do	Do.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Bentonite. (See montmorillonite.)				
Beryl	Muzo, Colombia	None	Zero	Average.
	Kongsberg, Norway	do	do	Do.
	Alexander County, N. C.	do	do	Do.
Synthetic emerald		Red	Very weak	Do.
Pseudosmaragd	Fahlun, Sweden	None	Zero	Do.
Botryogen:				
Idrizite	Idria, Austria	Green	Medium	Do.
Brucite	Texas, Pa.	Cream white	do	Do.
Bustamite	Franklin, N. J.	Pink	Weak	Do.
Byssolite. (See tremolite.)				
Cacholong. (See opal.)				
Calamite. (See tremolite.)				
Calcite	Cumberland, England	Pink	do	Do.
	Pribram, Bohemia	do	Very weak	Do.
	Badlands, S. Dak.	Yellow green	Weak	Do.
	Franklin, N. J.	Red	Strong	Do.
Reichite	Alston Moor, England	do	do	Do.
Oolite	North White River, Wyo.	Pink	Weak	Do.
Pisolite	Carlsbad, Bohemia	Pale gray	Medium	Do.
Manganocalcite	Franklin, N. J.	Red	Strong	Do.
Cuprocalcite	Warren, Ariz.	Dark red	Weak	Do.
Plumbocalcite	Bleiberg, Austria	Cream white	do	Do.
Calcium larsentie	Franklin, N. J.	None	Zero	Do.
	do	Yellow	Medium	Do.
Californite. (See idocrase.)				
Cassinite. (See hyalophane.)				
Castorite. (See petalite.)				

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Bentonite. (See montmorillonite.)					
Beryl	Muzo, Colombia	Very strong	Red through ultraviolet	Red (ultraviolet)	Short.
	Kongsberg, Norway	Medium	Red through blue	Red	Do.
	Alexander County, N. C	Strong	Red through blue-violet	do	Very short.
Synthetic emerald		Very strong	Red through ultraviolet	Red (ultraviolet)	Medium.
Pseudosmaragd	Fahlun, Sweden	Medium	Red through blue-violet	Red	Short.
Botryogen:					
Idrizite	Idria, Austria	Weak	Green through blue-violet	Green through blue-violet	Medium.
Brucite	Texas, Pa	Very weak	Indeterminable	Indeterminable	Do.
Bustamite	Franklin, N. J	Weak	Red, green	Red	Do.
Byssolite. (See tremolite.)					
Cacholong. (See opal.)					
Calamite. (See tremolite.)					
Calcite	Cumberland, England	do	Green, blue	Green	Very short.
	Pribram, Bohemia	do	Green through blue-violet	Green, blue	Very long.
	Badlands, S. Dak	do	Red through blue-violet	Red through blue	Short.
	Franklin, N. J	do	Red through blue	Green	Do.
Reichite	Alston Moor, England	Very weak	Indeterminable	Indeterminable	Very short.
Oolite	North White River, Wyo	Weak	Red, green, violet	Red (violet)	Medium.
Pisolite	Carlsbad, Bohemia	Medium	Red through violet	do	Do.
Manganocalcite	Franklin, N. J	do	do	Red, green, (violet)	Short.
Cuprocalcite	Warren, Ariz	Weak	Red, violet	Red (violet)	Long.
Plumbocalcite	Bleiberg, Austria	Very weak	Red through violet	Red through violet	Very short.
Calcium larsenite	Franklin, N. J	Weak	Red through blue	Red, green	Long.
	do	do	Red, green	Red	Do.
Californite. (See idocrase.)					
Cassinite. (See hyalophane.)					
Castorite. (See petalite.)					

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Celestite	Borate, Calif	Cream white	Medium	Average.
Cerolite. (See saponite.)				
Cerussite	Tsumeb, South-west Africa	do	Weak	Do.
	Davidson's mine, N. C	Yellow	Medium	Bright.
Cervantite	Gulzora, New South Wales	None	Weak	Average.
	Toliman, Queretaro, Mexico	do	do	Bright.
Chalcedony. (See quartz.)				
Chiastolite. (See andalusite.)				
Chiolite	Ivigtut, Greenland	do	Zero	Do.
	Miask, Ural Mountains, Russia	do	do	Do.
Chlorite. (See cookeite, colerainite.)				
Chromtremolite. (See tremolite.)				
Chrysoberyl	Ceylon	do	do	Average.
Alexandrite	Katherinenburg, Ural Mountains, Russia.	Red	Very weak	Do.
	Ural Mountains, Russia	None	Zero	Do.
Chrysotile. (See serpentine.)				
Colemanite	Furnace Creek, Calif	Cream white	Weak	Do.
Neocolemanite	Lang, Calif	Yellow	Medium	Do.
Colerainite	Nottingham, Pa	Gray brown	Very weak	Do.
Collyrite. (See allophane.)				
Confolensite. (See kaolinite.)				
Cookeite	Buckfield, Maine	None	Zero	Do.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Celestite	Borate, Calif	Weak	Red through blue	Red through blue	Short.
Cerolite. (See saponite.)					
Cerussite	Tsumeb, South-west Africa	Very weak	Indeterminable	Indeterminable	Medium.
	Davidson's mine, N. C	Weak	Red through violet	Red through blue	Do.
Cervantite	Gulzora, New South Wales	do	Green through blue–violet	Blue	Long.
	Toliman, Queretaro, Mexico.	Medium	do	do	Medium.
Chalcedony. (See quartz.)					
Chiastolite. (See andalusite.)					
Chiolite	Ivigtut, Greenland	do	do	Red, green	Short.
	Miask, Ural Mountains, Russia.	Weak	Red through blue	Red through blue	Very short.
Chlorite. (See cookeite, colerainite.)					
Chromtremolite. (See tremolite.)					
Chrysoberyl	Ceylon	Very weak	Green, blue	Green, blue	Medium.
Alexandrite	Katherinenburg, Ural Mountains, Russia.	Strong	Red through violet	Red	Short.
	Ural Mountains, Russia	Medium	Red through blue–violet	Red, green	
Chrystotile. (See serpentine.)					
Colemanite	Furnace Creek, Calif	Weak	do	Red through blue–violet	Very short.
Neocolemanite	Lang, Calif	do	Red through violet	Green (violet)	Medium.
Colerainite	Nottingham, Pa	do	Red	Red	Do.
Collyrite. (See allophane.)					
Confolensite. (See kaolinite.)					
Cookeite	Buckfield, Maine	do	Red, green	do	Do.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Corundum	Rabun County, Ga	None	Zero	Average.
	Belgrade, Mont	do	do	Do.
	Amity, N. Y	Red	Very weak	Do.
	Buck Creek, N. C	None	Zero	Do.
	Ceylon	do	do	Do.
Sapphire	do	do	do	Do.
Synthetic ruby		Red	Strong	Do.
Creedite	Wagon Wheel Gap, Colo	Pale blue	Weak	Bright.
Crestmoreite	Crestmore, Calif	Pale gray	do	Do.
Cristobalite	Saplores, Durango, Mexico	Green	Strong	Average.
Melanophlogite	Girgenti, Sicily	Pale brown	Medium	Do.
Cryolite	Pikes Peak, Colo	None	Zero	Bright.
	Ivigtut, Greenland	do	do	Average.
Cryolithionite	do	do	do	Bright.
Cuprite	Wheal Phoenix, Cornwall, England	do	do	Average.
Cuprocalcite. (See calcite.)				
Cuproscheelite. (See cuprotungstite.)				
Cuprotungstite	Tonechi, Mexico	Green	Medium	Do.
Cuproscheelite	La Paz, Mexico	Gray	do	Faint.
Danburite	Danbury, Conn	Pale brown	Weak	Average.
Datolite	Tadjik, Russia	Cream white	Medium	Do.
Delawarite. (See orthoclase.)				
Demantoid. (See andradite.)				
Deweylite	Newcastle, Del	Pale ochre	Weak	Bright.
	Delight, Md	None	Medium	Average.
Gymnite	Fleims, Tyrol	Pale green	do	Bright.
Diallage	Franklin, N. J	None	Zero	Average.
Diamond	South Africa	do	do	Do.
Carbonado	Brazil	do	do	Bright.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Corundum	Rabun County, Ga	Strong	Red through blue–violet	Red	Medium.
	Belgrade, Mont	Weak	Green, blue	Green	Very short.
	Amity, N. Y	Strong	Red through blue–violet	do	Do.
	Buck Creek, N. C	Very strong	Red through ultraviolet	Red (ultraviolet)	Do.
	Ceylon	Strong	Red through blue–violet	Green	Do.
Sapphire	do	Weak	Green, blue	Green, blue	Medium.
Synthetic ruby		Very strong	Red through ultraviolet	Red through blue (ultraviolet).	Short.
Creedite	Wagon Wheel Gap, Colo	Weak	Red through violet	Red through violet	Medium.
Crestmoreite	Crestmore, Calif	do	Red, violet	Violet	Do.
Cristobalite	Saplores, Durango, Mexico	Medium	Red through violet	Violet, red, blue	Long.
Melanophlogite	Girgenti, Sicily	do	do	Red (violet)	Medium.
Cryolite	Pikes Peak, Colo	do	Red through blue	Red, green	Short.
	Ivigtut, Greenland	Weak	do	Red through blue	Very short.
Cryolithionite	do	do	Red, violet	Violet	Do.
Cuprite	Wheal Phoenix, Cornwall, England.	do	Red, green	Red	Very long.
Cuprocalcite. (See calcite.)					
Cuproscheelite. (See cuprotungstite.)					
Cuprotungstite	Tonechi, Mexico	Medium	Red through blue	do	Long.
Cuproscheelite	La Paz, Mexico	Weak	Red, green	do	Very long.
Danburite	Danbury, Conn	do	Red through blue	do	Medium.
Datolite	Tadjik, Russia	Medium	Red through violet	Red (violet)	Short.
Delawarite. (See orthoclase.)					
Demantoid. (See andradite.)					
Deweylite	Newcastle, Del	do	do	Red, green	Do.
	Delight, Md	do	Red through blue	Red	Do.
Gymnite	Fleims, Tyrol	do	Red through blue–violet	do	Medium.
Diallage	Franklin, N. J	do	Red through violet	do	Do.
Diamond	South Africa	Weak	Green through blue–violet	do	Do.
Carbonado	Brazil	Medium	Red through blue–violet	Red, green	Do.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Diaspore	Schemnitz, Czechoslovakia	None	Zero	Average.
	Laurel Creek, Ga.	Brown	Weak	Do.
Diopside	Franklin, N. J	None	Zero	Do.
Melacolite	Sing Sing, N. Y	do	do	Bright.
Lavrovite	Baikal Lake, Siberia	do	do	Average.
Dolomite	St. Louis, Mo	do	do	Bright.
	do	Brown	Weak	Do.
	Traversella, Italy	Pink	do	Average.
Gurhofite	Cold Spring, N. Y	do	Very weak	Do.
Tautoklin	Freiberg, Saxony	Pale green	Weak	Bright.
Emerald. (See beryl.)				
Enstatite	Talcville, N. Y	None	do	Average.
Epidote:				
Tawmawite	Myitkyina, Burma	Dark red	Very weak	Do.
Ersbyite. (See meionite.)				
Euclase	Villa Rica, Brazil	do	Medium	Faint.
Feldspar. (See orthoclase, adularia, microcline, hyalophane, albite, oligoclase, andesine, anorthite.)				
Fibrolite. (See sillimanite.)				
Fischerite. (See wavellite.)				
Fluorapatite. (See apatite.)				
Fluorite	Corocoro, Bolivia	Pale blue	Weak	Average.
	Alston Moor, England	do	Medium	Do.
	St. Louis, Mo	Yellow	do	Do.
	Clay Center, Ohio	do	Strong	Do.
	Amelia Courthouse, Va	Green	Weak	Do.
Yttrofluorite	Hundholmen, Norway	Yellow	Medium	Do.
	Northern Norway	do	do	Do.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Diaspore	Schemnitz, Czechoslovakia	Weak	Red through blue-violet	Red	Medium.
	Laurel Creek, Ga.	do	Red through blue	Red through blue	Do.
Diopside	Franklin, N. J.	Medium	Red	Red	Do.
Melacolite	Sing Sing, N. Y.	Weak	Red through violet	Red (violet)	Do.
Lavrovite	Baikal Lake, Siberia	Strong	Red through blue-violet	Red, blue	Long.
Dolomite	St. Louis, Mo.	Medium	Red through blue	Red	Short.
	do	Weak	Red through blue-violet	do	Medium.
	Traversella, Italy	Very weak	Indeterminable	Indeterminable	Short.
Gurhofite	Cold Spring, N. Y.	Weak	Red, violet	Violet	Medium.
Tautoklin	Freiberg, Saxony	Medium	Red through blue	Red	Do.
Emerald. (See beryl.)					
Enstatite	Talcville, N. Y.	Weak	Red	Red	Long.
Epidote:					
Tawmawite	Myitkyina, Burma	Medium	Red through blue-violet	do	Medium.
Ersbyite. (See meionite.)					
Euclase	Villa Rica, Brazil	Strong	Red, green	do	Short.
Feldspar. (See orthoclase, adularia, microcline, hyalophane, albite, oligoclase, andesine, anorthite.)					
Fibrolite. (See sillimanite.)					
Fischerite. (See wavellite.)					
Fluorapatite. (See apatite.)					
Fluorite	Corocoro, Bolivia	do	Red through blue-violet	do	Do.
	Alston Moor, England	Weak	Red	do	Medium.
	St. Louis, Mo.	Medium	Red through green	do	Do.
	Clay Center, Ohio	Strong	Red through blue-violet	Red through blue	Short.
	Amelia Courthouse, Va.	Weak	Red through violet	Red	Very short.
Yttrofluorite	Hundholmen, Norway	Medium	Red through blue-violet	Green, blue	Medium.
	Northern Norway	Weak	Green, blue	do	Do.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Fuchsite. (See muscovite.)				
Garnet. (See grossularite, andradite.)				
Gaylussite	Ragtown Lake, Nev	Cream white	Weak	Average.
Gearksutite	St. Peter's Dome, Colo	Red	Medium	Do.
Geyserite. (See opal.)				
Glagerite. (See halloysite.)				
Greenockite	Llallagua, Bolivia	do	Very weak	Do.
	do	None	Zero	Do.
	Topaz, Calif	do	do	Do.
	Franklin, N. J	do	do	Do.
	Bishopton, Scotland	do	do	Do.
Grossularite	North Thomson River, British Columbia.	do	do	Do.
Gurhofite. (See dolomite.)				
Gymnite. (See deweylite.)				
Gypsum	Montmarte, France	Brown	Weak	Do.
	Galapagos Islands	Cream white	Medium	Bright.
	Lockport, N. Y	Brown	Weak	Do.
Gyrolite	New Almaden, Calif	do	do	Average.
Hackmanite. (See sodalite.)				
Halite	Borax Lake, Calif	Cream white	Medium	Bright.
	Stazunia, Poland	Yellow	do	Average.
Halloysite	Pala, Calif	Brown	Weak	Do.
	Bedford, Ind	Gray	Medium	Bright.
Indianaite	do	Cream white	Weak	Do.
Glagerite	Bergnersreuth, Bavaria	None	Zero	Average.
Hambergite	Helgaraen, Norway	Orange pink	Weak	Do.
Hanksite	Searles Lake, Calif	None?	Zero	Do.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Fuchsite. (See muscovite.)					
Garnet. (See grossularite, andradite.)					
Gaylussite	Ragtown Lake, Nev	Medium	Red through blue-violet	Red through blue	Short.
Gearksutite	St. Peter's Dome, Colo	do	Red through violet	Red (violet)	Do.
Geyserite. (See opal.)					
Glagerite. (See halloysite.)					
Greenockite	Llallagua, Bolivia	Strong	do	Green, blue	Medium.
	do	Weak	Red through blue-violet	do	Do.
	Topaz, Calif	do	Green, blue	do	Do.
	Franklin, N. J	Medium	Green through blue-violet	Blue, blue-violet	Do.
	Bishopton, Scotland	Strong	Red through blue	Red, green	Do.
Grossularite	North Thomson River, British Columbia.	Weak	Red, blue, blue-violet	Red	Short.
Gurhofite. (See dolomite.)					
Gymnite. (See deweylite.)					
Gypsum	Montmarte, France	Very weak	Red through blue	Red through blue	Medium.
	Galapagos Islands	Medium	Red through blue-violet	Red through blue-violet	Do.
	Lockport, N. Y	Weak	Red through violet	Red through violet	Do.
Gyrolite	New Almaden, Calif	do	Red through blue-violet	Red through blue-violet	Do.
Hackmanite. (See sodalite.)					
Halite	Borax Lake, Calif	do	Indeterminable	Indeterminable	Short.
	Stazunia, Poland	Medium	Red through violet	Red through blue-violet	Medium.
Halloysite	Pala, Calif	do	Red through blue-violet	Red, green	Short.
	Bedford, Ind	Weak	do	do	Medium.
Indianaite	do	Medium	Red, green, violet	Red (violet)	Short.
Glagerite	Bergnersreuth, Bavaria	do	do	do	Do.
Hambergite	Helgaraen, Norway	Weak	Blue-violet through ultraviolet.	Ultraviolet	Medium.
Hanksite	Searles Lake, Calif	Very weak	Indeterminable	Indeterminable	Do.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Harringtonite. (See thomsonite.)				
Hauynite	Laacher See, Germany	None	Zero	Average.
Hedyphane	Franklin, N. J	do	do	Do.
	do	Cream white	Weak	Do.
Hemimorphite:				
Vanuxemite	Stirling Hill, N. J	Pale gray	Medium	Do.
Hexagonite. (See tremolite.)				
Hiddenite. (See spodumene.)				
Hornblende:				
Pargasite	Rossie, N. Y	None	Zero	Do.
	Edenville, N. Y	do	do	Do.
Howlite	Lang, Calif	Red brown	Weak	Do.
	Wentworth, Nova Scotia	Cream white	do	Do.
Hyalophane:				
Cassinite	Media, Pa	None	Zero	Do.
Hydrocerussite	Wanlockhead, Scotland	do	do	Do.
Hydronephelite. (See natrolite.)				
Hydrophane. (See opal.)				
Hydrotalcite	Somerville, N. Y	do	do	Do.
Iddingsite. (See serpentine.)				
Idocrase:				
Californite	Lindsay, Calif	do	do	Do.
	North Thompson River, British Columbia	do	do	Do.
Idrizite. (See botryogen.)				
Indianaite. (See halloysite.)				

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Harringtonite. (See thomsonite.)					
Hauynite	Laacher See, Germany	Very weak	Indeterminable	Indeterminable	Short.
Hedyphane	Franklin, N. J	Medium	Red through blue	Red	Long.
	do	Very weak	Indeterminable	Indeterminable	Indeterminable.
Hemimorphite:					
Vanuxemite	Stirling Hill, N. J	Medium	Red, violet	Red	Short.
Hexagonite. (See tremolite.)					
Hiddenite. (See spodumene.)					
Hornblende:					
Pargasite	Rossie, N. Y	Strong	Red through blue-violet	do	Medium.
	Edenville, N. Y	Medium	Red, blue	do	Short.
Howlite	Lang, Calif	Weak	Red through blue	Green	Medium.
	Wentworth, Nova Scotia	Medium	Red through blue-violet	Red through blue	Short.
Hyalophane:					
Cassinite	Media, Pa	do	Red, green	Red	Medium.
Hydrocerussite	Wanlockhead, Scotland	Weak	Red through blue	Red through blue	Do.
Hydronephelite. (See natrolite.)					
Hydrophane. (See opal.)					
Hydrotalcite	Somerville, N. Y	do	do	Green	Do.
Iddingsite. (See serpentine.)					
Idocrase:					
Californite	Lindsay, Calif	Very strong	Red through blue-violet	Red	Short.
	North Thompson River, British Columbia.	Medium	Red through violet	Red (violet)	Medium.
Idrizite. (See botryogen.)					
Indianaite. (See halloysite.)					

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Jadeite	Magoung, Burma	None	Zero	Average.
	Buena Vista de Cueller, Durango, Mexico.	do	do	Do.
	Tenochutlan, Vera Cruz, Mexico	do	do	Do.
Jasper. (See quartz.)				
Jurupaite	Crestmore, Calif	Blue gray	Medium	Do.
Kaolinite:				
Lithomarge	Banat, Hungary	Pale brown	do	Do.
Confolensite	Confolens, France	Cream white	do	Do.
Kyanite	Litchfield, Conn	None	Zero	Do.
	Hurricane Mountain, N. C	do	do	Do.
	Hillswick, Scotland	do	do	Do.
	St. Gotthard, Scotland	do	do	Do.
Rhaetizite	Pfitsch, Tyrol	Cream white	Very weak	Do.
Lanarkite	Leadhills, Scotland	Pale yellow	Medium	Do.
Laubanite. (See natrolite.)				
Laumontite:				
Leonhardite	Zillerthal, Tyrol	Cream white	Weak	Do.
Retzite	Vivero, Lugo, Spain	None	Zero	Do.
Lavrovite. (See diopside.)				
Lazulite	Horrsjoberg, Sweden	do	do	Do.
Leadhillite	Leadhills, Scotland	Brown	Weak	Do.
Leelite. (See orthoclase.)				
Lennilite. (See orthoclase.)				
Leonhardite. (See laumontite.)				
Lepidolite	Elba	None	Zero	Bright.
Leucophanite	Laven, Norway	Pale pink	Weak	Do.
Leucophoenicite	Franklin, N. J	None	Zero	Average.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Jadeite	Magoung, Burma	Very strong	Red through violet	Red (violet)	Medium.
	Buena Vista de Cueller, Durango, Mexico.	Strong	Red through blue–violet	Red	Do.
	Tenochutlan, Vera Cruz, Mexico.	Weak	Red, blue, blue–violet	do	Do.
Jasper. (See quartz.)					
Jurupaite	Crestmore, Calif	Strong	Red through blue, violet	Green (violet)	Do.
Kaolinite:					
Lithomarge	Banat, Hungary	Medium	do	Red	Short.
Confolensite	Confolens, France	do	Red, green, violet	Violet	Do.
Kyanite	Litchfield, Conn	Strong	Red through violet	Red	Medium.
	Hurricane Mountain, N. C.	do	do	do	Do.
	Hillswick, Scotland	Weak	Red, green	Red, green	Do.
	St. Gotthard, Scotland	Medium	Red through violet	Red (violet)	Short.
Rhaetizite	Pfitsch, Tyrol	do	do	do	Medium.
Lanarkite	Leadhills, Scotland	Weak	Indeterminable	Indeterminable	Do.
Laubanite. (See natrolite.)					
Laumontite:					
Leonhardite	Zillerthal, Tyrol	do	Red through violet	Green	Do.
Retzite	Vivero, Lugo, Spain	Medium	Red, green	Red	Do.
Lavrovite. (See diopside.)					
Lazulite	Horrsjoberg, Sweden	do	do	do	Do.
Leadhillite	Leadhills, Scotland	Weak	Red through violet	Red through blue (violet)	Do.
Leelite. (See orthoclase.)					
Lennilite. (See orthoclase.)					
Leonhardite. (See laumontite.)					
Lepidolite	Elba	Medium	Red through blue	Red, green	Very short.
Leucophanite	Laven, Norway	do	do	Red	Very long.
Leucophoenicite	Franklin, N. J	Very weak	Red	do	Indeterminable.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Lithomarge. (See kaolinite.)				
Lucianite. (See talc.)				
Magnesite	Delight, Md	Pale green	Weak	Bright.
	Hoboken, N. J	Cream white	do	Average.
Baudisserite	Baudissero, Italy	Cream gray	do	Do.
Malthacite. (See allophane.)				
Manganapatite. (See apatite.)				
Manganocalcite. (See calcite.)				
Marshite	Chuquicamata, Chile	Red	Medium	Do.
	Broken Hill, New South Wales	do	do	Faint.
Matlockite	Derbyshire, England	Yellow	do	Average.
	Cromford, England	Brown	do	Do.
Meionite:				
Ersbyite	Pargas, Finland	Pale blue	Weak	Do.
Stroganovite	Baikal Lake, Siberia	Cream white	do	Do.
Melacolite. (See diopside.)				
Melanophlogite. (See cristobalite.)				
Mellite	Antern, Saxony	Ochre	do	Do.
	Tula, Russia	Brown	Very weak	Do.
Mesolite	Golden, Colo	Green	Medium	Do.
	Belfast, Ireland	Cream white	Very weak	Bright.
Messelite. (See anapaite.)				
Metaxoite. (See serpentine.)				
Mica. (See muscovite, lepidolite, taeniolite.)				

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Lithomarge. (See kaolinite.)					
Lucianite. (See talc.)					
Magnesite	Delight, Md	Medium	Red through blue	Red, green	Short.
	Hoboken, N. J	Weak	do	Red through blue	Very short.
Baudisserite	Baudissero, Italy	do	Red, violet	Violet	Medium.
Malthacite. (See allophane.)					
Manganapatite. (See apatite.)					
Manganocalcite. (See calcite.)					
Marshite	Chuquicamata, Chile	Weak	Blue–violet, violet	do	Do.
	Broken Hill, New South Wales.	do	Blue through ultraviolet	Blue–violet, violet (ultraviolet).	Do.
Matlockite	Derbyshire, England	Medium	Green through violet	Blue–violet (violet)	Do.
	Cromford, England	Weak	Blue, blue–violet	Blue, blue–violet	Do.
Meionite:					
Ersbyite	Pargas, Finland	Weak	Red, green	Red	Medium.
Stroganovite	Baikal Lake, Siberia	do	Red	do	Do.
Melacolite. (See diopside.)					
Melanophlogite. (See cristobalite.)					
Mellite	Antern, Saxony	do	Green, blue	Green, blue	Very short.
	Tula, Russia	Medium	Red through blue	Red	Do.
Mesolite	Golden, Colo	Weak	do	Red through blue	Medium.
	Belfast, Ireland	Medium	Red through blue–violet	Red	Short.
Messelite. (See anapaite.)					
Metaxoite. (See serpentine.)					
Mica. (See muscovite, lepidolite, taeniolite.)					

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Microcline	Pikes Peak, Colo	None	Zero	Average.
	do	do	do	Do.
	Fianarantsoa, Madagascar	do	do	Do.
Mimetite	Tsumeb, South-West Africa	do	do	Do.
Molybdosodalite. (See sodalite.)				
Montmorillonite	Paris, Maine	Pink	Weak	Do.
	Glen Riddle, Pa	Gray	Medium	Do.
Steargillite	Montmorillon, France	Dark red	Weak	Bright.
Bentonite	Yamagata Prefecture, Japan	Pink	do	Do.
Stevensite	West Paterson, N. J	Cream white	Medium	Average.
Montroydite	Terlingua, Tex	None	Zero	Do.
Moonstone. (See orthoclase.)				
Mooreite	Stirling Hill, N. J	Red	Strong	Do.
Muscovite:				
Fuchsite	Brevard, N. C	None	Zero	Do.
Natrolite:				
Laubanite	Steinbruch, Silesia	White	Medium	Do.
Hydronephelite	Brevig, Norway	Pink	do	Do.
Neocolemanite. (See colemanite.)				
Nepheline	Val di Noto, Sicily	Peach pink	Weak	Do.
	Kirovsk, U. S. S. R	None	Zero	Do.
Nitrate salts	Clark's Cove, Va	Pale gray	Medium	Bright.
Okenite	Crestmore, Calif	Pale blue	Weak	Average.
	Godhaven, Greenland	Cream white	do	Do.
Oligoclase	Fine, N. Y	None	Zero	Do.
	Mitchell County, N. C	Buff	Weak	Do.
Omphacite. (See augite.)				
Oolite. (See calcite.)				

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Microcline	Pikes Peak, Colo	Weak	Red through violet	Violet	Long.
	do	Medium	Red through blue-violet	Red	Do.
	Fianarantsoa, Madagascar	do	Red	do	Medium.
Mimetite	Tsumeb, South-West Africa.	Weak	Blue through violet	Blue-violet	Do.
Molybdosodalite. (See sodalite.)					
Montmorillonite	Paris, Maine	Strong	Red through blue	Red	Short.
	Glen Riddle, Pa	Weak	Red, green, violet	Red (violet)	Medium.
Steargillite	Montmorillon, France	Medium	do	do	Short.
Bentonite	Yamagata Prefecture, Japan.	do	do	do	Do.
Stevensite	West Paterson, N. J	Strong	Red through blue-violet	Red	Do.
Montroydite	Terlingua, Tex	Medium	Red	do	Long.
Moonstone. (See orthoclase.)					
Mooreite	Stirling Hill, N. J	do	Red through violet	Green (violet)	Short.
Muscovite:					
Fuchsite	Brevard, N. C	Strong	Green, blue	Green	Very short.
Natrolite:					
Laubanite	Steinbruch, Silesia	Medium	Red, green, violet	Red (violet)	Short.
Hydronephelite	Brevig, Norway	Weak	Red	Red	Medium.
Neocolemanite. (See colemanite.)					
Nepheline	Val di Noto, Sicily	Very weak	Red through violet	Red through violet	Indeterminable.
	Kirovsk, U. S. S. R	Weak	Red, green	Red	Long.
Nitrate salts	Clark's Cove, Va	do	Red, green, violet	Red (violet)	Medium.
Okenite	Crestmore, Calif	do	Red through blue-violet	Green	Do.
	Godhaven, Greenland	do	do	Red through blue-violet	Do.
Oligoclase	Fine, N. Y	do	Red through violet	Red (violet)	Do.
	Mitchell County, N. C	do	Red through blue-violet	Green	Do.
Omphacite. (See augite.)					
Oolite. (See calcite.)					

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Opal	Queretaro, Mexico	Pale yellow	Weak	Average.
	Dubnik, Czechoslovakia	White	Very weak	Do.
	Faroe Islands	do	do	Bright.
	Divide, Colo	Pale green	Weak	Do.
Cacholong	Ruditz, Moravia	Cream white	do	Do.
Hydrophane	Veresvagas, Hungary	do	do	Bright.
Geyserite	Yellowstone, Wyo	Pale yellow	Medium	Average.
Silicified Wood	Granger Wyo	Dark orange	Very weak	Do.
Tabasheer	Calcutta, India	Pale brown	Weak	Do.
Orthoclase	New Castle County, Del	Olive green	do	Do.
	Auburn, Maine	None	Zero	Do.
Moonstone	Ceylon	Red	Weak	Do.
Leelite	Chester County, Pa	Pale yellow	Medium	Do.
Lennilite	Lenni, Pa	Gray green	do	Do.
Delawarite	do	Red	Weak	Do.
Parahopeite	Salmo, British Columbia	Pale orange	do	Do.
Pargasite. (See hornblende.)				
Pectolite	Great Notch, N. J	Cream white	do	Bright.
	Thetford, Quebec	do	do	Average.
	Landalfoot, Scotland	do	do	Do.
Peristerite. (See albite.)				
Petalite	Greenwood, Maine	Buff	do	Do.
Castorite	Elba	None	Zero	Do.
Phosgenite	Derbyshire, England	Yellow	Medium	Do.
	Monteponi, Sardinia	do	Weak	Do.
Phosphorite. (See apatite.)				
Pirssonite	Searles Lake, Calif	None	Zero	Bright.
Pisolite. (See calcite.)				
Plumbocalcite. (See calcite.)				
Pollucite	Tim Mountain, Custer, S. Dak	Cream white	Very weak	Do.
Probertite	Ryan, Calif	None	Zero	Do.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Opal	Queretaro, Mexico	Weak	Red through blue	Red	Very short.
	Dubnik, Czechoslovakia	do	do	do	Do.
	Faroe Islands	do	Green	Green	Do.
	Divide, Colo	do	Red through blue	Red through blue	Medium.
Cacholong	Ruditz, Moravia	do	do	do	Do.
Hydrophane	Veresvagas, Hungary	do	Red	Red	Do.
Geyserite	Yellowstone, Wyo	Medium	Red through violet	Red (violet)	Long.
Silicified Wood	Granger, Wyo	Strong	Red through blue	Red through blue	Medium.
Tabasheer	Calcutta, India	do	Red through violet	Red	Do.
Orthoclase	New Castle County, Del	Medium	Red through blue	do	Short.
	Auburn, Maine	Very weak	Red, green, violet	Red (violet)	Medium.
Moonstone	Ceylon	Weak	Red, violet	do	Do.
Leelite	Chester County, Pa	Medium	Red, green, blue, violet	do	Short.
Lennilite	Lenni, Pa	do	Red, green, violet	do	Do.
Delawarite	do	Weak	do	do	Medium.
Parahopeite	Salmo, British Columbia	do	do	do	Do.
Pargasite. (See hornblende.)					
Pectolite	Great Notch, N. J	do	Red through blue	Red through blue	Very short.
	Thetford, Quebec	do	Red through blue–violet	Red	Do.
	Landalfoot, Scotland	do	Red through blue	Red through blue	Medium.
Peristerite. (See albite.)					
Petalite	Greenwood, Maine	Weak	Red, green	Red, green	Very short.
Castorite	Elba	Medium	Green, blue	Green, blue	Medium.
Phosgenite	Derbyshire, England	Very weak	Blue–violet, violet	Violet	Indeterminable.
	Monteponi, Sardinia	Weak	Blue through violet	Blue through violet	Short.
Phosphorite. (See apatite.)					
Pirssonite	Searles Lake, Calif	Very weak	Red	Red	Medium.
Pisolite. (See calcite.)					
Plumbocalcite. (See calcite.)					
Pollucite	Tim Mountain, Custer, S. Dak.	Medium	Red through violet	Red through blue–violet	Short.
Probertite	Ryan, Calif	Weak	Red, violet	Violet	Medium.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Pseudosmaragd. (See beryl.)				
Pyromorphite	Cumberland, England	Brown	Very weak	Average.
	Phoenixville, Pa	do	do	Do.
Pyrophyllite:				
Agalmatolite	China	Cream white	Weak	Do.
Pyroxene	Franklin, N. J	None	Zero	Faint.
(See also diopside, spodumene, jadeite, diallage, enstatite.)				
Quartz:				
Chalcedony	Tampa, Fla	Yellow	Weak	Average.
	Guanajuato, Mexico	do	do	Do.
	Death Valley, Calif	do	Medium	Do.
Agate	Chagres River, Canal Zone	do	do	Bright.
	San Luis Potosi, Mexico	Brown	Very weak	Average.
Jasper	San Francisco, Calif	do	Weak	Do.
	Bridger Basin, Wyo	None	Zero	Do.
Quincite. (See sepiolite.)				
Razoumovskyn. (See allophane.)				
Reichite. (See calcite.)				
Retzite. (See laumontite)				
Rhaetizite. (See kyanite.)				
Rhodochrosite	Marquette County, Mich	Pink	Medium	Do.
Rhodophosphite. (See apatite.)				
Ruby. (See corundum.)				
Sacchurite. (See andesine.)				

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Pseudosmaragd. (See beryl.)					
Pyromorphite	Cumberland, England	Medium	Red through blue	Red	Long.
	Phoenixville, Pa	Weak	Red, green	do	Do.
Pyrophyllite:					
Agalmatolite	China	do	Red through blue	Red, green	Medium.
Pyroxene (See also diopside, spodumene, jadeite, diallage, enstatite.)	Franklin, N. J	Weak	Red	Red	Medium.
Quartz:					
Chalcedony	Tampa, Fla	Medium	Red, green	do	Short.
	Guanajuato, Mexico	Weak	Red	do	Do.
	Death Valley, Calif	do	Red, green	Red, green	Medium.
Agate	Chagres River, Canal Zone	do	Red	Red	Indeterminable.
	San Luis Potosi, Mexico	Medium	Red through blue-violet	Red, green	Short.
Jasper	San Francisco, Calif	Weak	Red, green	do	Medium.
	Bridger Basin, Wyo	Medium	Red through blue-violet	Red through blue-violet	Do.
Quincite. (See sepiolite.)					
Razoumovskyn. (See allophane.)					
Reichite. (See calcite.)					
Retzite. (See laumontite.)					
Rhaetizite. (See kyanite.)					
Rhodochrosite	Marquette County, Mich	Weak	Green, blue	Green, blue	Very short.
Rhodophosphite. (See apatite.)					
Ruby. (See corundum.)					
Sacchurite. (See andesine.)					

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Saponite:				
Cerolite		Yellow	Weak	Average.
Sapphire. (See corundum.)				
Saussurite. (See zoisite.)				
Scapolite	Bolton, Mass	Cream white	do	Do.
	Arendal, Norway	Red	Very weak	Do.
	Greenville, Quebec	Yellow	Strong	Do.
Scheelite	Mohave Desert, Calif	Pale yellow	Medium	Do.
	Dragoon Mountains, Ariz	Pale brown	do	Bright.
	Atolia, Calif	White	do	Do.
	Carrock Fell, England	Gray blue	Weak	Average.
Scheelitine. (See stolzite.)				
Selenite. (See gypsum.)				
Selensulfur. (See sulfur.)				
Senarmontite	Sonora, Mexico	None	Zero	Do.
Sepiolite	Bare Hills, Md	do	do	Bright.
	North Clay City, Nev	White	Weak	Average.
Quincite	Cher, France	Pale gray	do	Do.
Serpentine	Montville, N. J	Pink	do	Bright.
Metaxite	Crestmore, Calif	Pale green	Medium	Average.
Chrysotile	New Haven, Conn	None	Zero	Bright.
Iddingsite	Conejos, Colo	Yellow	Weak	Average.
(See also saponite, deweylite.)				
Silicified wood. (See opal.)				
Sillimanite:				
Fibrolite	Paris, Maine	Red	do	Do.
Smithsonite	Marion County, Ga	Brown	Very weak	Do.
	Alston, England	Rose red	Weak	Do.
	Musua, Sardinia	Brown	do	Do.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Saponite:					
Cerolite		Weak	Red through blue-violet	Red	Medium.
Sapphire. (See corundum.)					
Saussurite. (See zoisite.)					
Scapolite	Bolton, Mass	do	Red through blue	do	Very short.
	Arendal, Norway	do	Red through blue-violet	Green	Do.
	Greenville, Quebec	Medium	Blue through ultraviolet	Violet (ultraviolet)	Short.
Scheelite	Mohave Desert, Calif	Strong	Red through blue	Red	Very long.
	Dragoon Mountains, Ariz	Medium	Red, green	do	Do.
	Atolia, Calif	Weak	Red through violet	Red (violet)	Do.
	Carrock Fell, England	Medium	Red, green	Red	Medium.
Scheelitine. (See stolzite.)					
Selenite. (See gypsum.)					
Selensulfur. (See sulfur.)					
Senarmontite	Sonora, Mexico	Medium	Green through blue-violet	Green, blue	Medium.
Sepiolite	Bare Hills, Md	do	Red through blue	Red	Short.
	North Clay City, Nev	Weak	do	Red through blue	Do.
Quincite	Cher, France	do	Red, violet	Red (violet)	Medium.
Serpentine	Montville, N. J	do	Red, green, violet	do	Do.
Metaxite	Crestmore, Calif	Medium	Red, green	Red	Short.
Chrysotile	New Haven, Conn	Weak	Red through blue	Red through blue	Medium.
Iddingsite	Conejos, Colo	do	do	Red, green	Do.
(See also saponite, deweylite.)					
Silicified wood. (See opal.)					
Sillimanite:					
Fibrolite	Paris, Maine	do	Red through blue, violet	Red (violet)	Do.
Smithsonite	Marion County, Ga	Weak	Blue, blue-violet	Blue, blue-violet	Long.
	Alston, England	do	Red through blue-violet	Red through blue-violet	Medium.
	Musua, Sardinia	do	Blue	Blue	Short.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Sodalite	Vesuvius, Italy	Pink	Weak	Average.
	Monte Somma, Italy	do	do	Do.
Molybdosodalite	do	Orange	do	Do.
Hackmanite	Magnet Cove, Ark	Dark red	Medium	Bright.
	Kola, Russia	Pink	do	Average.
Solfaterite. (See alunogen.)				
Sphalerite	Kremmling, Colo	None	Zero	Do.
	Oruro, Bolivia	do	do	Do.
	Cherokee County, Kans	Pink	Weak	Bright.
	Rodna, Transylvania	None	Zero	Faint.
	Tsumeb, South-West Africa	Orange	Medium	Average.
	Banner district, Idaho	Red	Weak	Do.
Sphene	Tavetsch, Switzerland	None	Zero	Do.
Spinel	Ceylon	Red	Weak	Do.
	Sparta, N. J	do	Very weak	Do.
Spodumene	Taos County, N. M	Cream white	Weak	Do.
Hiddenite	Hiddenite, N. C	None	Zero	Do.
Steargilite. (See montmorillonite.)				
Steatite. (See talc.)				
Stevensite. (See montmorillonite.)				
Stibianite. (See stibiconite.)				
Stibiconite	Empire district, Nev	do	do	Do.
Stibianite	Potosi, Bolivia	do	do	Do.
Stolzite:				
Scheelitine	Altenberg, Saxony	do	do	Do.
Stroganovite. (See meionite.)				
Strontianite	Strontian, Scotland	Olive green	Weak	Do.
Sulfur:				
Selensulfur	Cianciana, Italy	None	Zero	Do.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Sodalite	Vesuvius, Italy	Weak	Blue through violet	Blue through violet	Short.
	Monte Somma, Italy	do	Red	Red	Do.
Molybdosodalite	do	Medium	Blue through violet	Blue through violet	Do.
Hackmanite	Magnet Cove, Ark	do	do	Violet	Medium.
	Kola, Russia	do	do	do	Short.
Solfaterite. (See alunogen.)					
Sphalerite	Kremmling, Colo	do	Red through blue–violet	Red through blue–violet	Long.
	Oruro, Bolivia	Weak	do	Red	Do.
	Cherokee County, Kans	do	Green	Green	Short.
	Rodna, Transylvania	do	Green through blue–violet	Green through blue–violet	Long.
	Tsumeb, South-West Africa	Very weak	Blue, blue–violet	Blue, blue–violet	Medium.
	Banner district, Idaho	Strong	Red through violet	Red through blue	Long.
Sphene	Tavetsch, Switzerland	Weak	Red through blue–violet	Red, blue	Medium.
Spinel	Ceylon	Medium	do	Red, green	Very short.
	Sparta, N. J	Strong	do	Green	Short.
Spodumene	Taos County, N. M	Weak	Red through violet	Red through blue (violet)	Medium.
Hiddenite	Hiddenite, N. C	Strong	do	Red	Do.
Steargilite. (See montmorillonite.)					
Steatite. (See talc.)					
Stevensite. (See montmorillonite.)					
Stibianite. (See stibiconite.)					
Stibiconite	Empire district, Nev	Medium	Green, blue	Green, blue	Long.
Stibianite	Potosi, Bolivia	do	Red, green, violet	Red (violet)	Short.
Stolzite:					
Scheelitine	Altenberg, Saxony	Weak	Red, green	Red	Long.
Stroganovite. (See meionite.)					
Strontianite	Strontian, Scotland	Very weak	Green, blue	Green, blue	Very short.
Sulfur:					
Selensulfur	Cianciana, Italy	do	Red through blue	Red through blue	Medium.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Sussexite	Franklin, N. J	None	Zero	Bright.
Szechenyiite. (See arfvedsonite.)				
Tabasheer. (See opal.)				
Taeniolite	Magnet Cove, Ark	Pink	Weak	Do.
Talc	Edwards, N. Y	Cream white	do	Average.
	Manhattan, Nev	None	Zero	Do.
Steatite	Sonora, Mexico	Gray	Very weak	Do.
Lucianite	Villar de Puerco, Spain	Blue gray	Medium	Bright.
Tautoklin. (See dolomite.)				
Tawmawite. (See epidote.)				
Terlinguaite	Terlingua, Tex	Red	Very weak	Average.
Thomsonite	Kandern, Bohemia	Pale brown	do	Bright.
Harringtonite	Belfast, Ireland	do	do	Do.
Thulite. (See zoisite.)				
Topaz	Minas Geraes, Brazil	Brown	do	Do.
	Villa Rica, Brazil	do	Weak	Do.
	Scheckenstein, Saxony	None	Zero	Do.
Tourmaline	Franklin, N. J	Brown	Weak	Do.
	King's Bridge, N. J	Green	do	Faint.
Tremolite	St. Marcel, Italy	Cream white	do	Bright.
	Stirling Hill, N. J	Pale brown	Very weak	Average.
	Lee, Mass	Green	Weak	Do.
Chromtremolite	Outokumpo, Finland	None	Zero	Do.
Hexagonite	Edwards, N. Y	Cream white	Weak	Do.
Calamite	Canaan, Conn	Pale yellow	Medium	Do.
Byssolite	Johns Mansville Mines, Quebec	Orange	Weak	Do.
Tidymite	Durango, Mexico	Gray	do	Do.
Trimerite	Langban, Sweden	None	Zero	Do.
Ulexite	Mount Blanco, Calif	Cream white	Weak	Bright.
Valentinite	Constantine, Algiers	Green	Very weak	Average.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Sussexite	Franklin, N. J	Weak	Red through blue	Violet	Medium.
Szechenyiite. (See arfvedsonite.)					
Tabasheer. (See opal.)					
Taeniolite	Magnet Cove, Ark	do	Red, green, violet	Red (violet)	Short.
Talc	Edwards, N. Y	do	Red through blue	Red through blue	Medium.
	Manhattan, Nev	Medium	do	Red	Do.
Steatite	Sonora, Mexico	Weak	Red, green	Red, green	Do.
Lucianite	Villar de Puerco, Spain	Medium	Red, green, violet	Violet	Short.
Tautoklin. (See dolomite.)					
Tawmawite. (See epidote.)					
Terlinguaite	Terlingua, Tex	Very weak	Green, blue	Green, blue	Medium.
Thomsonite	Kandern, Bohemia	Medium	Red through blue–violet	Red, green	Short.
Harringtonite	Belfast, Ireland	do	Red through blue	Red	Medium.
Thulite. (See zoisite.)					
Topaz	Minas Geraes, Brazil	Strong	Red through violet	Red, green	Short.
	Villa Rica, Brazil	Medium	Red through blue–violet	do	Do.
	Scheckenstein, Saxony	do	do	do	Do.
Tourmaline	Franklin, N. J	do	Red through violet	Red	Medium.
	King's Bridge, N. J	Very weak	Red	do	Do.
Tremolite	St. Marcel, Italy	Weak	Red through blue–violet	do	Do.
	Stirling Hill, N. J	Strong	do	Red, blue	Short.
	Lee, Mass	Weak	Red, green	Red	Medium.
Chromtremolite	Outokumpo, Finland	do	Red, blue	Red, blue	Short.
Hexagonite	Edwards, N. Y	do	Red through blue–violet	Green, blue	Medium.
Calamite	Canaan, Conn	do	do	Red, blue	Do.
Byssolite	Johns Mansville Mines, Quebec.	Medium	Red through violet	Red through blue (violet)	Short.
Tidymite	Durango, Mexico	Weak	Red through violet	Red (violet)	Very long.
Trimerite	Langban, Sweden	Strong	Green through blue–violet	Green, blue	Long.
Ulexite	Mount Blanco, Calif	Weak	Red through blue–violet	Red, green	Medium.
Valentinite	Constantine, Algiers	do	Red, green	do	Do.

TABLE 4.—*Characteristics of infrared luminescence in selected mineral specimens*—Continued

Mineral	Locality	Visible fluorescence		Infrared reflection
		Color	Intensity	
Valleite. (See anthophyllite.)				
Vanadinite	Yuma County, Ariz	None	Zero	Average.
	Tucson, Ariz	do	do	Do.
Vanuxemite. (See hemimorphite.)				
Wavellite	Llallagua, Bolivia	Green	Weak	Do.
	Barnstable, England	do	Medium	Do.
Fischerite	Hungary	do	Weak	Do.
Willemite	Sussex County, N. J	do	Medium	Bright.
Wollastonite	Chelsea, Ontario	Brown	Weak	Do.
	Easton, Pa	Cream white	do	Average.
Wulfenite	Yuma County, Calif	None	Zero	Do.
	Organ Mountains, N. Mex	do	do	Do.
Wurtzite	Butte, Mont	do	do	Do.
Xanthophyllite	Zlatoust, Siberia	do	do	Do.
Yttrofluorite. (See fluorite.)				
Zeolite. (See natrolite, mesolite, thomsonite, laumontite.)				
Zoisite	Mount Rosa, Switzerland	do	do	Do.
Thulite	Pine Nut Mountains, Nev	Pale brown	Medium	Do.
Saussurite	Voll, Switzerland	None	Zero	Faint.

Mineral	Locality	Infrared luminescence			
		Strength	Range of excitation	Maximum of excitation	Emission wavelength
Valleite. (See anthophyllite.)					
Vanadinite	Yuma County, Ariz	Very weak	Indeterminable	Indeterminable	Medium.
	Tucson, Ariz	do	Red, blue, blue-violet	Blue-violet	Long.
Vanuxemite. (See hemimorphite.)					
Wavellite	Llallagua, Bolivia	Weak	Red through blue-violet	Red through blue-violet	Short.
	Barnstable, England	do	do	Green, blue	Medium.
Fischerite	Hungary	do	do	Green	Do.
Willemite	Sussex County, N. J	do	Red through blue	Red through blue	Do.
Wollastonite	Chelsea, Ontario	do	Red through blue-violet	do	Do.
	Easton, Pa	do	Red through blue	do	Do.
Wulfenite	Yuma County, Calif	do	Red	Red	Long.
	Organ Mountains, N. Mex	do	do	do	Medium.
Wurtzite	Butte, Mont	do	Red through blue-violet	Green	Long.
Xanthophyllite	Zlatoust, Siberia	do	Red, blue, violet	Violet	Medium.
Yttrofluorite. (See fluorite.)					
Zeolite. (See natrolite, mesolite, thomsonite, laumontite.)					
Zoisite	Mount Rosa, Switzerland	Medium	Red through blue	Red, green	Short.
Thulite	Pine Nut Mountains, Nev.	Weak	Red	Red	Medium.
Saussurite	Voll, Switzerland	Strong	Red through blue	do	Do.

LITERATURE CITED

Bailly, R. J., and Holke, K. A., 1944, Microscope and refractometer for infrared light [abs.]: Am. Mineralogist, v. 35, p. 277–278.

Cannon, R. S., Jr., and Murata, K. J., 1944, Estimating molybdenum content of scheelite or calcium tungstate by visual color of its fluorescence: U. S. Patent 2,346,661, April 18.

Claffy, E. W., 1953, Composition, tenebrescence, and luminescence of spodumene minerals: Am. Mineralogist, v. 38, p. 919–931.

Dake, H. C., and DeMent, J. A., 1941, Fluorescent light and its applications: Brooklyn, N. Y., Chem. Publishing Co., 256 p.

DeMent, J. A., 1945, Fluorochemistry: Brooklyn, N. Y., Chem. Publishing Co., 796 p.

Déribéré, Maurice, 1943, Les applications practiques de la luminescence: Ann Arbor, Mich., Edwards Bros., 263 p.

Deutschbein, Otto, 1932, Die linienhafte Emission und Absorption der Chromosphore, Part II: Annalen der Physik, ser. 5, Band 14, Heft 7, p. 729–754.

Dhéré, Charles, and Biermacher, Oscar, 1936, La feuille de Géranium vivante émet un rayonnement de fluorescence qui s'étend dans l'infrarouge jusqu'à λ 830 mμ: Acad. Sci. Paris Comptes rendus, tome 203, no. 6, p. 412–414.

Engelhardt, Ernst, 1912, Lumineszenzerscheinungen der Mineralien im ultravioletten Licht: Weida in Thüringen, Druck von Thomas & Hubert, 39 p.

Garlick, G. F. J., 1949, Luminescent materials: Oxford, Clarendon Press, 245 p.

Griffin, D. R., Hubbard, Ruth, and Wald, George, 1947, The sensitivity of the human eye to infra-red radiation: Optical Soc. America Jour., v. 37, no. 7, p. 546–554.

Haberlandt, Herbert, and Köhler, Alexander, 1939, Über die blaue Fluoreszenz von naturlichen Silikaten im ultravioletten Lichte und über synthetische Versuche an Silikatschmelzen mit eingebautem zweiwertigem Europium: Naturwissenschaften, Jahrg. 27, Heft 17, p. 275.

Holst, G., deBoer, J. H., Teves, M. C., and Veenemans, C. F., 1934, An apparatus for the transformation of light of long wavelength into light of short wavelength: Physica, v. 1, p. 297–305.

Inman, J. K., Mroz, A. M., and Weyl, W. A., 1948, The fluorescence of cadmium sulfide *in* Cornell University Conference on Luminescence, preparation, and characteristics of solid luminescent materials: New York, John Wiley & Sons, p. 182–189.

Köhler, Alexander, and Haberlandt, Herbert, 1934, Lumineszenzanalyse von Apatit, Pyromorphit und einigen anderen Phosphaten: Chemie der Erde, Band 9, Heft 1, p. 88–89.

Krejci-Graf, Hanna, and Krejci-Graf, Karl, 1934, Fluoreszenzfarben von Mineralien: Zeitschr. Kristallographie, Band 88, Heft 3, p. 260–264.

Kröger, F. A., 1948, Some aspects of the luminescence of solids: New York and Amsterdam, Elsevier Publishing Co., 310 p.

Kunz, G. F., and Baskerville, Charles, 1903, The action of radium, roentgen rays and ultra-violet light on minerals and gems: Science, new ser., v. 18, no. 468, p. 769–783.

Lashkarev, V. E., and Kossonogova, K. M., 1946, Infra-red luminescence of cuprous oxide: Akad. Nauk SSSR Doklady, tom 54, no. 2, p. 125–126.

Malmquist, David, 1935, Mikrophotographische Aufnahmen von Achsenbildein opaher Mineralien im Ultrarot; Zentralbl. Mineralogie, Geologie u. Paläontologie, Abt. A, no. 7, p. 209–13.

Melhase, John, 1935, Fluorescent minerals from California: Mineralogist, v. 3, p. 3–4, 38.

Moon, P. H., 1936, The scientific basis of illuminating engineering: New York, McGraw-Hill, 608 p.

Morton, G. A., and Flory, L. E., 1946a, An infrared image tube and its military applications: R.C.A. Review, v. 7, no. 3, p. 385–413.

——— 1946b, Infrared image tube: Electronics, v. 19, no. 9, p. 112–114.

Nichols, E. L., and Howes, H. L., 1926, Note on the rare earths as activators of luminescence: Optical Soc. America Jour., v. 13, no. 5, p. 573–587.

Palache, Charles, Berman, H. M., and Frondel, Clifford, 1944, Dana's system of mineralogy: New York, John Wiley & Sons, 7th ed., v. 1, 834 p.

——— 1951, Dana's system of mineralogy, New York, John Wiley & Sons, 7th ed., v. 2, 1124 p.

Pauli, W. E. 1911, Über ultraviolette and ultrarote Phosphoreszens: Annalen der Physik, ser. 4, Band 34, Heft 4, p. 739–779.

Pringsheim, Peter, 1949, Fluorescence and phosphorescence: New York, Interscience Publishers, 794 p.

Przibram, K., 1937, Fluorescence of the bivalent rare earths: Nature, v. 139, no. 3512, p. 329.

Schulman, J. H., Evans, L. W., Ginther, R. J., and Murata, K. J., 1947, The sensitized luminescence of manganese-activated calcite: Jour. Applied Physics, v. 18, no. 8, p. 732–739.

Servigne, Marcel, 1938, Sur l'émission infrarouge de luminescence de quelques elements rares: Acad. Sci. Paris Comptes rendus, tome 207, no. 20, p. 905–907.

——— 1939, Nouvelles remarques sur les émissions infrarouges de luminescence des elements rares: Acad. Sci. Paris Comptes rendus, tome 209, no. 3, p. 210–212.

——— 1940, Sur la photoluminescence des scheelites: Acad. Sci. Paris Comptes rendus, tome 210, no. 12, p. 440–442.

Skogland, J. F., 1929, Tables of spectral energy distribution and luminosity for use in computing light transmissions and relative brightnesses from spectrophotometric data: U. S. Natl. Bur. Standards Misc. Pub. 86.

Strunz, Hugo, 1941, Mineralogische Tabellen: Leipzig, Becker & Erler, 287 p.

Tanaka, T., 1924a, On the active agents in luminescent calcites, aragonites and dolomites: Optical Soc. America Jour., v. 8, no. 3, p. 411–418.

——— 1924b, On the active agents in luminescent zinc sulfides, willemites and kunzites: Optical Soc. America Jour., v. 8, no. 5, p. 659–67.

Venkateswaran, C. S., 1935, The fluorescence of ruby, sapphire, and emerald: Indian Acad. Sci. Proc., v. 2, sec. A, p. 459–465.

Walther, Paul, 1936, Fluorescent minerals from many localities: Mineralogist, v. 4, p. 5–6, 10.

Warren, T. S., 1944, List of fluorescent minerals: Mines Mag., v. 34, no. 7, p. 342–343, 363.

Weyl, W. A., 1942, Fluorescence of glass: Indus. and Eng. Chemistry, v. 34, p. 1035–41.

Zodac, Peter, 1936, Some observations on fluorescence and phosphorescence: Rocks and Minerals, v. 11, no. 5, p. 68–72.

Zworykin, V. K., and Morton, G. A., 1936, Applied electron optics: Optical Soc. America Jour., v. 26, no. 4, p. 181–189.

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