observed up to the present are those recorded by H. Rubens and E. Aschkinass@@1 (∙0061 cms. or 610,000 Å).

5. *Methods of Rendering Gases Luminous.—*The extreme flexi- bility of the phenomena shown by radiating gases renders it a matter of great importance to examine them under all possible conditions of luminosity. Gases, like atmospheric air, hydrogen or carbon dioxide do not become luminous if they are placed in tubes, even when heated up far beyond white heat as in the electric furnace. This need not necessarily be interpreted as indicating the impossibility of rendering gases luminous by temperature only, for the transparency of the gas for luminous radiations may be such that the emission is too weak to be detected. When there is appreciable absorption as in the case of the vapours of chlorine, bromine, iodine, sulphur, selenium and arsenic, luminosity begins at a red heat. Thus G. Salet@@2 observed that iodine gives a spectrum of bright bands when in contact with a platinum spiral made white hot by an electric current, and J. Evershed@@3 has shown that in this and other cases the temperature at which emission becomes appreciable is about 700°. It is only recently that owing to the introduction of carbon tubes heated electrically the excitement of the luminous vibrations of molecules by temperature alone has become an effective method for the study of their spectra even in the case of metals. Hitherto we were entirely and still are generally confined to electrical excitation or to chemical action as in the case of flames.

In the ordinary laboratory the Bunsen flame has become universal, and a number of substances, such as the salts of the alkalis and alkaline earths, show characteristic spectra when suitably placed in it. More information may be gained with the help of the oxyhydrogen flame, which with its higher temperature has not been used as frequently as it might have been, but W. N. Hartley has employed it with great success, and in cyanite (a silicate of aluminium) has found a material which is infusible at the temperature of this flame, and is therefore suitable to hold the substance which it is desired to examine. An interesting and instructive manner of introducing salts into flames was discovered by A. Gouy, who forced the air before it entered the Bunsen burner, through a spray produce containing a salt in solution. By this method even such metals as iron and copper may be made to show some of their charac- teristic lines in the Bunsen burner. The spectra produced under these circumstances have been studied in detail by C. de Watteville@@4

Of more frequent use have been electric methods, owing to the greater intensity of the radiations which they yield. Especially when large gratings are employed do we find that the electric arc alone seems sufficient to give vibrations of the requisite power. The metals may be introduced into the arc in various ways, and in some cases where they can be obtained in sufficient quantity the metallic electrodes may be used in the place of carbon poles.

The usual method of obtaining spectra by the discharges from a Ruhmkorff coil or Wimshurst machine needs no description. The effects may be varied by altering the capacity and self-induction of the circuit which contains the spark gap. The insertion of self-induction has the advantage of avoiding the lines due to the gas through which the spark is taken, but it introduces other changes in the nature of the spark, so that the results obtained with and without self-induction are not directly comparable. Count Gramont@@6 has been able to obtain spectroscopic evidence of the metalloids in a *mineral* by employing powerful condensers and heating the electrodes in an oxyhydrogen flame when these (as is often the case) are not sufficiently conducting.

When the substance to be examined spectroscopically is in solution the spark may be taken from the solution, which must then be used as kathode of air. The condenser is in this case

not necessary, in fact better results are obtained without it. Lecoq de Boisbaudran has applied this method with considerable success, and it is to be recommended whenever only small electric power is at the disposal of the observer. To diminish the resistance the current should pass through as small a layer of liquid as possible. It is convenient to place the liquid in a short tube, a platinum wire sealed in at the bottom to convey the current reaching to the level of the open end. If a thick- walled capillary tube is passed over the platinum tube and its length so adjusted that the liquid rises in it by capillary action just above the level of the tube, the spectrum may be examined directly, and the loss of light due to the passage through the partially wetted surface of the walls of the tube is avoided.

For the investigation of the spectra of gases at reduced pressures the so-called Plücker tubes (more generally but incorrectly called Geissler tubes) are in common use. When the pressure becomes very low, inconvenience arises owing to the difficulty of establishing the discharge. In that case the method introduced by J. J. Thomson might with advantage be more frequently employed. Thomson@@6 places spherical bulbs inside thick spiral conductors through which the oscillating discharge of a powerful battery is led. The rapid variation in the intensity of the magnetic field causes a brilliant electrodeless discharge which is seen in the form of a ring passing near the inner walls of the bulb when the pressure is properly adjusted. A variety of methods to render gases luminous should be at the com­mand of the investigator, for nearly all show some distinctive peculiarity and any new modification generally results in fresh facts being brought to light. Thus E. Goldstein@@7 was able to show that an increase in the current density is capable of destroying the well-known spectra of the alkali metals, replacing them by quite a new set of lines.

6. *Theory of Radiation.—*The general recognition of spectrum analysis as a method of physical and chemical research occurred simultaneously with the theoretical foundation of the connexion between radiation and absorption. Though the experimental and theoretical developments were not necessarily dependent on each other, and by far the larger proportion of the subject which we now term “ Spectroscopy ” could stand irrespective of Gustav Kirchhoff’s thermodynamical investigations, there is no doubt that the latter was, historically speaking, the immediate cause of the feeling of confidence with which the new branch of science was received, for nothing impresses the scientific world more strongly than just that little touch of mystery which attaches to a mathematical investigation which can only be understood by the few, and is taken on trust by the many, provided that the author is a man who commands general confidence. While Balfour Stewart’s work on the theory of exchanges was too easily understood and therefore too easily ignored, the weak points in Kirchhoff’s developments are only now beginning to be perceived. The investigations both of Balfour Stewart and of Kirchhoff are based on the idea of an enclosure at uniform temperature and the general results of the reasoning centre in the conclusion that the introduction of any body at the same temperature as the enclosure can make no difference to the streams of radiant energy which we imagine to traverse the enclosure. This result, which, accepting the possibility of having an absolutely opaque enclosure of uniform temperature, was clearly proved by Balfour Stewart for the total radiation, was further extended by Kirchhoff, who applied it (though not with mathematical rigidity as is sometimes supposed) to the separate wave-lengths. All Kirchhoff’s further conclusions are based on the assumption that the radiation transmitted through a partially transparent body can be expressed in terms of two independent factors (1) an absorption of the incident radiation, and (2) the radiation of the absorbing medium, which takes place equally in all directions. It is assumed further that the absorption is proportional to the incident radiation and (at any rate approximately) independent of the temperature, while the radiation is assumed to be a function of the temperature

*@@@l Wied. Annalen* (1898), 65, p. 241.

@@@2 *Ann.* *Chim. Phys.* (1873), 28.

*@@@i Phil. Mag.* (1895), 39, p. 460.

*@@@4 Phil. Trans.* (1904), 204, A. p. 139.

*@@@6 Comptes rendus,* vols. 121, 122, 124.

@@@β *Phil.* *Mag.* 32, pp. 321, 445.

*@@@7 Vertr. d. phys. Ges.* (1904), 9, p. 321