BIBLIOGRAPHY OF SCIENTIFIC LITERATURE RELATING TO HELIUM

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1 Prepared by E. R. Weaver, Bureau of Standards, Washington, D. C.
I. INTRODUCTION

It is particularly appropriate at this time to issue a bibliography of the scientific literature relating to helium. The development, during the war, of great fractionating plants capable of separating from natural gas a sufficient quantity of helium to supply a fleet of airships has aroused the keen interest, not only of engineers and scientists, but also of the general public in the unique properties of this gas.

The year 1918 certainly marks the beginning of a new era in the history and use of helium. Before that time only a few liters of the gas had ever been collected, and the cost per liter was enormous. The separation of millions of liters of the gas at a very moderate cost, therefore, makes the gas at once available for many purposes which formerly seemed impossible of accomplishment.

Helium has probably been the most interesting of all the elements to the theoretical scientist on account of the romantic history of its discovery, its occurrence in a remarkable condition of solid solution in many minerals, its formation as a product of the disintegration of the radioactive elements, its liquefaction after a decade of unsuccessful attempts by some of the world's greatest experimenters, the attainment by its use of temperatures below those at which the resistances of pure metals vanish, its many unique physical properties, and the many important theoretical conclusions which have been drawn from its behavior.

All of these points of interest have been the subjects of very thorough investigation. The important developments of the future will probably be along the line of the applications of helium, many of which have already been suggested; but in order to make the most of these possible applications it is necessary to know the properties on which they are based. It is as a guide to these properties that, it is hoped, this bibliography will find its chief usefulness.

This bibliography was first prepared at the beginning of the development of helium for balloon-gas purposes and was intended as an aid in that enterprise. It has since been brought up to date, and is believed to contain practically everything published up to January 1, 1919, except reviews and other articles containing no original work which were published in inaccessible foreign journals and contained no material which was not available in English or American publications. Such articles have been purposely omitted.
II. ARRANGEMENT OF TITLES

The arrangement of material under each subhead has, in general, been such that closely related articles occur together in their chronological order. The bibliography is thus, in effect, a brief outline history of the subject. An exception to this arrangement is made in the case of articles on the occurrence of helium, which have been arranged alphabetically according to the authors' names. This was done because the papers by different authors are usually but slightly related to each other, and the chronological development seems of less importance than the bringing together of the papers, often numerous, of each author.

III. DISCOVERY AND IDENTIFICATION

1. DISCOVERY

JANSSEN. Compt. rend., 67, p. 838; 1868: Discovery of new spectrum lines in sun, since found to belong to helium.


HILLEBRAND, W. F. Am. J. Sci. (3), 40, p. 384; 1890: Observed the presence in uraninite of gases since found to be helium and nitrogen. Condensed form of following reference.

HILLEBRAND. Bull. U. S. Geol. Survey, No. 78, p. 43; 1890: Chemical and spectroscopic tests of gases obtained from uraninite led to conclusion that gas was nitrogen.


CROOKES. Chem. News, 71, p. 151; 1895: Measured the wave lengths of the spectrum lines of the gas isolated from cleveite by Ramsay and identified the gas as helium.


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2. ELEMENTARY NATURE OF HELIUM


IV. OCCURRENCE OF HELIUM

1. IN MINERALS

[See also formation from radioactive substances.]

Debiene, A. Ann. phys. (g), 2, pp. 478–488; 1904: Preparation of helium from fluor spar crystals. Contains also an account of unsuccessful efforts to obtain helium from other sources.
Lange, H. Z. naturw., 82, pp. 1–34, 1910; Chem. Abs., 4, p. 2920: Studien über die zammensetzung heliumführender Mineralien. (Studies on the structure of helium-bearing minerals.)
Moss. Trans. Roy. Dublin Soc. (2), 8, p. 153; 1904: Removal of helium from minerals by evacuation. Can obtain only a little over 1 per cent of total by this method.

1 The material under this heading is arranged alphabetically according to authors' names because of the general slight relation between papers by different authors.
Bibliography of Helium Literature


PIUTTI. Radium, 8, pp. 204-205, 1911; Chem. Abs., 6, p. 1255: The presence of helium in autunite and the period of life of ionium.


STRUTT. Nature, 85, p. 6, 1911; Chem. Abs., 5, p. 626: Helium and geological time. An answer to Piutti’s hypothesis of absorption to account for the presence of helium in rocks.


VALENTINER, S. Kali, 6, pp. 1-3; Chem. Abs., 8, p. 480; Neues Jahrb. Min. Geol., 1913, 1 Ref., p. 195: Helium content of blue rock salt.


2. OCCURRENCE IN MINERAL WATERS


Moureu. Compt. rend., 139, pp. 852-855, 1904: The chemical composition of the mixture of radioactive gases liberated from the waters of certain hot springs.


Moureu and Biquard. Compt. rend., 143, pp. 795-797, 1906: Helium in certain springs. Gas from one of the springs contained 5.34 per cent helium.

Moureu and Biquard. Compt. rend., 146, pp. 435-437, 1908: Recent researches on the rare gases from hot springs.


3. OCCURRENCE IN NATURAL GAS


Czako, E. Zeit. Anorg. Chem., 83, pp. 249-277, 1913; Chem. Abs., 7, p. 3450: The helium content and radioactivity of natural gases. The production of helium discharged yearly from two of the wells examined would require the disintegration of 165,000 and 28,000 tons of Ra, respectively.


Bibliography of Helium Literature

Moureau, C., and Le Pape, A. Compt. rend., 158, pp. 598–603, 1913; Chem. Abs., 8, 1699: Helium from fire damp and the radioactivity of coal. Helium evolved from one mine is equal to 12 cu. m. per day. Radioactivity of gas and coal does not account for it.


Voller, A., and Walter, B. Hamburger Wiss. Inst., 28, 1910; Chem. Abs., 5, p. 3510; Petroleum, 6, p. 1062: Helium and argon in the natural gas of Neuen-gamme. Contained 0.01–0.02 per cent helium.

4. OCCURRENCE IN AIR


V. FORMATION OF HELIUM

1. FROM RADIOACTIVE SUBSTANCES


Stark. J. Separate publication 1903: Dissozierung und umwandlung chemischer atome. (The dissociation and transformation of chemical atoms.)


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GIESEL, F. Ber., 38, p. 2299, 1905: Proof of formation of helium from radium bromide.


DEWAR, J. Proc. Roy. Soc., Lond., 82, p. 404, 1910; Chem. Abs., 4, p. 2410: Long-period determination of the rate of production of helium from radium. Found 0.463 cu. mm. per gram per day.


BOLTWOOD and RUTHERFORD. Phil. Mag., 22, pp. 586-604, 1911; Chem. Abs., 6, p. 26: Production of helium from radium. Find rate of 156 cu. mm. per year per gram of radium.


BRUNER, L., and BEKIER, E. Physik Z., 15, pp. 240-241, 1914; Chem. Abs., 8, p. 1700: Attempt to reverse the reaction RaEm=RaA+He ion by means of an electric discharge in helium gas.

MARCKWALD, W. Physik Z., 15, pp. 440-441, 1914; Chem. Abs., 8, p. 2845: Experiments on the decomposition of radium emanation in a helium atmosphere. No indication that disintegration of radium emanation can be retarded was found.


GIESEL, F. Ber., 40, p. 3011-3017, 1907; Chem. Abs., 2, 755: The first decomposition products of actinium and the formation of helium from actinium.


SODDY. Umschau, 13, pp. 375-377, 1907: Production of helium from uranium and thorium.

STRUTT, R. J. Nature, 81, p. 158, 1909; Chem. Abs., 4, p. 412: Rate of helium production from the complete series of uranium products. Finds 10.4 \times 10^{-8} \text{ cu. cm. per year per gram of } U_3O_8.


SODDY. Phil. Mag., 16, pp. 513-520, 1908; Chem. Abs., 8, p. 281: Attempts to detect the production of helium from the primary radio elements. One result gave 2 \times 10^{-12} \text{ gram helium per year per gram of thorium.}

Bibliography of Helium Literature


2. SUPPOSED FORMATION OF HELIUM FROM NONRADIOACTIVE SUBSTANCES


Debierre, A. Ann. Phys. (9), 2, pp. 478-488, 1914; Chem. Abs., 10, p. 2325: Experiments on the production of helium. All efforts to produce it by chemical reactions were unsuccessful.

VI. SEPARATION AND PURIFICATION OF HELIUM


Dewar, J. German Patent No. 169314, 1905: Preparation of helium from air by absorption of other gases in wood charcoal at a low temperature.


LaSociete L'AIR LIQUIDE. British Patent No. 22316 of 1908: Liquifaction and rectification process for separating helium and neon from the air.


VII. PROPERTIES OF HELIUM

1. ELECTRICAL AND MAGNETIC PROPERTIES

[See also spectrum.]

GILL, E. W., and PIDDUCK, F. E. Phil. Mag. 23, pp. 837-849, 1912; Chem. Abs., 6, 2430: Ionization by collision in helium.
HÖCHHEIM, E. Dissertation (Marburg, 1909): The dielectric constant of helium.

2. SPECTRUM OF HELIUM

[See also electric properties and theoretical discussions under Miscellaneous.]

CROOKES and LOCKYER. Compt. rend., 120, p. 1103, 1895.
LOCKYER and CROOKES. Chem. News, 72, p. 87, 1895.
Bibliography of Helium Literature

Tscherneck. Pflügers Archiv., 88, p. 95, 1902: Use of the helium spectrum as a standard for wave-length measurement.
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3. OPTICAL PROPERTIES OF HELIUM


Ramsay and Travers. Proc. Roy. Soc., 62, p. 225; 1897: Refractive index of helium. The refractive index of a mixture of equal parts of helium and hydrogen is 3 per cent lower than would be calculated from the theory of mixtures.


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4. Solubility and Absorption of Helium


Berthelot. Compt. rend., 124, p. 113, 1897: Supposed chemical action of helium on benzene and carbon-disulphide vapors under the electric discharge.


5. DENSITY OF HELIUM

[See also following heading on "Pressure-volume relations."


6. PRESSURE-VOLUME RELATIONS FOR GASEOUS HELIUM

KUENEN and RANDALL. Chem. News, 72, p. 295; 1895: Pressure volume relations of helium between −216° and +237° C.


TRAVERS and JAQUEROD. Zeit. phys. Chem., 45, pp. 456–460; 1903: The apparent value of the critical constants and boiling point of helium and an attempt to liquefy the gas.

JAQUEROD and SCHEUER. Compt. rend., 140, p. 1384; 1905: Compressibility of helium.


ONNES, H. K. Bull. assoc. intern. froid., 6, pp. 103–134, 1916; Chem. Abs., 10, p. 1451: Brief survey of recent work of Leiden Cryogenic Laboratory containing, among other things, methods and results upon the maximum density of helium.


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7. DIFFUSION AND EFFUSION OF HELIUM

Ramsay and Travers. Proc. Roy. Soc., Lond., 61, p. 267; 1897: Diffusion of helium; it does not diffuse through red-hot palladium, platinum, or iron.
Ramsay. Ann. Chim. Phys. (7), 13, p. 433; 1898: Effusion of helium. Is 10 per cent greater relative to hydrogen than the difference in densities would indicate?

8. VISCOSITY OF HELIUM

[See also effusion under preceding heading.]

Schioreoh. Dissertation (Halle; 1908): The coefficient of internal friction of argon and helium.

9. SPECIFIC HEATS OF HELIUM

Thomas. Dissertation (Marburg; 1905): Determination of the specific heat of helium. The atomic heat of helium and argon.
Eggert. Dissertation (Marburg; 1910): Determination of specific heat of helium at various temperatures and its significance in connection with the kinetic theory of monatomic gases.
EGGERT, A. Ann. Physik, **44**, pp. 643–656; 1914; Chem. Abs., 8, p. 2977: Determination of the specific heat of helium at ordinary and higher temperatures. No indication that specific heat changes with temperature.

Eucken, A. Verh. deut. physik. Ges., **18**, pp. 4–17; 1916; Chem. Abs., **10**, p. 1129: Thermal behavior of some compressed and condensed gases at low temperatures. Specific heats of hydrogen (gas at several pressures and liquid), helium, argon (solid and liquid), nitrogen (liquid and two solid forms), oxygen (liquid and three solid forms), carbon monoxide (liquid and two solid forms), and carbon dioxide (solid at various temperatures). Heat of fusion, transformation, and evaporation of the various phases.


**10. THERMAL CONDUCTIVITY OF HELIUM**


**VIII. LIQUEFACTION AND PROPERTIES OF LIQUID HELIUM**


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IX. APPLICATIONS OF HELIUM

1. APPLICATION OF HELIUM TO THERMOMETRY


Onnes, H. K. Proc. Acad. Amsterdam, 10, pp. 589-591, 1908; Chem. Abs., 3, p. 132: Derivation of the pressure coefficient of helium for the international thermometer and the reduction of the readings of the helium thermometer to the absolute scale.


Jaquerod and Perrot. Compt. rend., 139, p. 789, 1904: Diffusion of helium through quartz at high temperatures makes it inapplicable for use in thermometers for measuring high temperatures.


Cario. Dissertation (Halle, 1907): Use of helium in platinum-iridium vessels at high temperatures.

2. APPLICATIONS OF LIQUID HELIUM ESPECIALLY TO DETERMINATION OF ELECTRICAL PROPERTIES OF METALS AT LOW TEMPERATURES

[See also heading on "Liquefaction and properties of liquid helium."

Onnes, H. K., is the author of all articles under this heading unless otherwise noted. Leiden, Van Bemmelen Gedenkboek, pp. 441-446; Chem. Abs., 5, p. 3186:
The attainment of temperatures considerably below the boiling point of helium. Electrician, 67, p. 637, 1911; Chem. Abs., 5, p. 3541: Electrical resistance of pure metals at liquid helium temperatures.

Proc. Acad. Amsterdam, 14, pp. 113-115, 1911; Chem. Abs., 6, p. 6; 7, p. 2327: The electrical resistance of pure metals. The sudden change in the rate at which the resistance of mercury disappears.


Comp. rend., 159, pp. 34-38, 1914; Chem. Abs., 8, p. 3264: The persistence of electric currents without electromotive force in the superconductors.


Proc. Acad. Amsterdam, 16, pp. 987-992, 1914; Chem. Abs., 9, p. 735: Hall effect and the magnetic change in resistance at low temperature. The appearance of galvanic resistance in superconductors which are brought into a magnetic field, at the threshold value of the field.


3. APPLICATIONS OF HELIUM TO PHOTOMETRY, ETC.

Tschermak, A. Pflügers, Archiv., 88, p. 95, 1901: Use of the helium spectrum as a standard for wave-length measurement.


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X. MISCELLANEOUS


Ramsay, W. Die Edle and die Radioactiven Gase (the noble and the radioactive gases) (Book), Leipzig Akad Verlaggesellschaft; Chem. Abs., 8, p. 747.


Washington, January 7, 1919.