

DEPARTMENT OF COMMERCE

CIRCULAR
OF THE
BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 81

**BIBLIOGRAPHY OF SCIENTIFIC LITERATURE
RELATING TO HELIUM**

[Second edition]
DECEMBER 21, 1922



PRICE, 10 CENTS

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ABSTRACT.

A guide to the useful literature relating to helium from the time of its discovery to January 1, 1922.

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

I. INTRODUCTION.

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. The first edition was issued in 1919 and was intended to cover the literature prior to January 1 of that year. This second edition is intended to cover the literature to January 1, 1922, and includes some references of later date. After its publication the first edition was found to be less complete than had been thought, and no claim is made for completeness in this second edition. Some articles have been purposely omitted. These include a small number of articles which, for one reason or another, have been considered of no importance or positively misleading, and 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. Other material, especially much of that dealing directly with radioactivity, the alpha-particle, and the structure of the atom, has been omitted because it is only indirectly concerned with helium. It is difficult to make a sharp distinction between articles of this class which pertain to helium and those which do not. An effort has been made to include enough representative articles on these subjects to at least serve as an introduction to their study.

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.
- FRANKLAND and LOCKYER. *Proc. Roy. Soc., Lond.*, **17**, p. 91; 1868: Announce the existence of an element in the sun unknown on earth and name it helium.
- PALMIERI. *Gazz. Chim. Ital.*, **12**, p. 556; 1882: Discovery of helium spectrum in rocks from Vesuvius.
- NASINI and ANDERLINI. *Atti. Accad. Lincei. Roma.* (5), **13**, I, p. 368; 1904: Recognition of helium in Vesuvius lavas confirming the discovery of Palmieri.
- 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.
- HILLEBRAND. *Am. Jour. Sci.* (3), **42**, p. 390; 1891: New analyses of uraninite.
- RAMSAY. *Proc. Roy. Soc., Lond.*, **58**, pp. 65, 81; 1895: Reports partial identification of helium spectrum in gas from cleveite.
- LOCKYER. *Proc. Roy. Soc., Lond.*, **58**, p. 67; 1895: Partial confirmation of Ramsay's identification of helium.
- RAMSAY. *J. Chem. Soc.* 67, pp. 684, 1107; *Chem. News*, **71**, p. 151; 1895: Discovery of helium in cleveite.
- 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.
- RUNGE and PASCHEN. *Chem. Ztg.*, **19**, p. 997; 1895: Observed double lines in spectrum of helium from minerals and cast doubt upon identity of mineral and solar helium.
- HUGGINS, W. *Chem. News*, **71**, p. 283; 1895: Differences in spectra of helium from minerals and in the sun.
- HUGGINS, W. *Chem. News*, **72**, p. 27; 1895: Observed double helium lines in solar spectrum.
- RUNGE and PASCHEN. *Math. natw. Mitt. Berlin*, p. 323; 1895: Identity of spectra of solar and mineral helium.
- WILDE. *Phil. Mag.* (5), **40**, p. 466; 1895: Identity of spectra of solar and mineral helium.
- LOCKYER. *Proc. Roy. Soc., Lond.*, **62**, p. 52; 1897: Existence of helium in fixed stars and nebulae.

- RAMSAY and TRAVERS. *Compt. rend.*, **126**, p. 1762; 1898: New atmospheric gases.
 RAMSAY. *Ann. chim. phys.* (7), **13**, p. 433; 1898: Discovery of helium.
 RAMSAY, W. *The Gases of the Atmosphere, the History of their discovery.* Book.
 London, Macmillan & Co. *Chem. Abs.*, **10**, p. 313; 1916.
 ABBOTT, C. G. *Smithsonian Report for 1918*, pp. 121-126; *Smithsonian publ. No.*
 2550; 1920: The discovery of helium and what came of it.
 LOCKYER, W. J. S. *Nature*, **105**, pp. 360-363; 1920: Helium, its discovery and
 applications.
 MOORE, R. B. *J. Frank. Inst.*, **191**, pp. 145-197; 1921: Helium, its history, prop-
 erties, and commercial development.

2. ELEMENTARY NATURE OF HELIUM.

[See also Formation of helium and Relation to subatomic phenomena.]

- RAMSAY. *Proc. Roy. Soc., Lond.* **60**, p. 53; 1896: Experiments which show the
 inactivity of helium and argon.
 RAMSAY. *Ber. d. chem. Ges.*, **31**, p. 3111; 1898: The newly discovered gases and
 their relation to the periodic law.
 RAMSAY and COLLIE. *Compt. rend.*, **123**, p. 214; *Nature*, **54**, p. 546; *Proc. Roy.*
Soc., Lond., **60**, p. 206; 1896: Homogeneity of argon and helium.
 RAMSAY and TRAVERS. *Proc. Roy. Soc., Lond.*, **62**, p. 316; 1897: Dispels the doubt
 as to the homogeneity of helium suggested in preceding reference.
 BRAUNER, B. *Chem. News*, **71**, p. 271; 1895.
 BRAUNER, B. *Chem. News*, **74**, p. 223; 1896.
 HILL, E. A. *Am. J. Sci.*, (3), **50**, p. 359; 1895.
 RAYLEIGH. *Chem. News*, **74**, p. 260; 1896.
 MATHEWS, A. P. *J. Phys. Chem.*, **17**, pp. 337-343; 1913; *Chem. Abs.*, **7**, 1899: Val-
 ence of the argon group as determined from molecular cohesion.
 SKAUPY, F. *Zeit. Physik.*, **3**, pp. 408-411; 1920; *Chem. Abs.*, **15**, p. 2024: Chemical
 affinity of the noble gases.
 ASTON, F. W. *Nature*, **105**, p. 8; 1920; *Chem. Abs.*, **14**, p. 1629: The constitution
 of the elements. Determination of the atomic weight of helium by the positive
 ray method.
 ASTON, F. W. *Sci. Progress*, **15**, pp. 212-222; 1920; *Chem. Abs.*, **15**, p. 335: Mass
 spectra and the atomic weights of the elements.
 BRINER, E. *J. Chim. Phys.*, **19**, pp. 9-10; 1921; *Chem. Abs.*, **16**, p. 181: Some nega-
 tive attempts at transformation of elements. Attempt to decompose iodine,
 hydrogen, and helium.

IV. OCCURRENCE OF HELIUM.²

1. IN MINERALS.

[See also Formation from radioactive substances.]

- ADAMS, E. P. *Am. J. Sci.* (4), **19**, p. 321; 1905: Helium in carnotite.
 BORDAS, F. *Compt. rend.*, **146**, pp. 628-630, 1908; *Chem. Abs.*, **2**, p. 1926: Search
 for small quantities of helium in minerals.
 BORDAS. *Compt. rend.*, **146**, pp. 896-898; 1908; *Chem. Abs.*, **2**, p. 2043: Helium in
 minerals containing uranium.
 BROGGER, W. C. *Pharmacia*, **1**, pp. 49-53, 65-70; 1904: Ores of uranium containing
 helium and radium.
 CLEVE. *Compt. rend.*, **120**, p. 834, 1895; *Chem. News*, **71**, p. 201, 1895: Occurrence
 of helium in cleveite.

² The material under this heading is arranged alphabetically according to authors' names because of the general slight relation between papers by different authors.

- COLLIE, J. N., and TRAVERS, M. W. *J. Chem. Soc.*, **67**, p. 684; 1895: Helium a constituent of certain minerals.
- DEBIERNE, A. *Ann. Physik* (9), **2**, pp. 478-488; 1904: Preparation of helium from fluorspar crystals. Contains also an account of unsuccessful efforts to obtain helium from other sources.
- KITCHIN, E. S., and WINTERSON, W. G. *J. Chem. Soc.*, **89**, pp. 1568-1575; 1906: Malacone, a silicate of zirconium containing helium.
- KOHLSCHUTTER, V. *Ann. Chem.*, **317**, pp. 158-189; 1901: Helium in uranium minerals.
- KOHLSCHUTTER and VOGDT. *Ber. d. chem. Ges.*, **38**, pp. 1419-1430, 2992-3002; 1905: Helium in uranium minerals.
- LANGÉ, H. *Zeit. Naturw.*, **82**, pp. 1-34, 1910; *Chem. Abs.*, **4**, p. 2920: Studien über die Zusammensetzung heliumführender Mineralien. (Studies on the structure of helium-bearing minerals.) Issued as separate publication.
- LANGLET. *Z. anorg. Chem.*, **10**, p. 289; 1895: Helium in cleveite.
- LOCKYER. *Compt. rend.*, **120**, p. 1103; 1895; *Chem. News*, **72**, p. 283; 1895: Occurrence of helium in minerals.
- MAGLI, G. *Rend. soc. chim. ital.* (2), **5**, pp. 420-423; 1914; *Chem. Abs.*, **9**, p. 1005: Helium in titanite. Occurs in amounts proportional to the radioactivity of the mineral.
- MOISSAN and DESLANDERS. *Compt. rend.*, **126**, p. 1689; 1898: Helium in cerite.
- 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.
- VON OEFELE, F. *Pharm. Zentralhalle*, **57**, pp. 83-84; 1916; *J. Chem. Soc.*, **110**, II, p. 284; 1916; *Chem. Abs.*, **10**, p. 2654: Helium in samarskite and its relation to other elements present.
- PIUTTI, A. *Radium*, **7**, pp. 146-149; 1910; *Chem. Abs.*, **4**, p. 3055: Nonradioactive minerals containing helium.
- PIUTTI. *Radium*, **7**, pp. 178-179; 1910; *Chem. Abs.*, **5**, p. 247: Helium in recent minerals.
- PIUTTI. *Nature*, **84**, pp. 543-544; 1910; *Chem. Abs.*, **5**, p. 626: The absorption of helium in salts and minerals. A hypothetical explanation of the accumulation of helium in certain minerals.
- PIUTTI. *Radium*, **8**, pp. 204-205; 1911; *Chem. Abs.*, **6**, p. 1255: The presence of helium in autinite and the period of life of ionium.
- PIUTTI. *Radium*, **10**, pp. 165-168; 1913; *Chem. Abs.*, **7**, p. 3076: Helium in glaucinum minerals.
- PIUTTI. *Atti Acad. Lincei*, **22**, pp. 140-144; 1913; *Chem. Abs.*, **7**, p. 2352: Helium and beryllium minerals.
- RAMSAY, W. *Proc. Roy. Soc., Lond.*, **59**, p. 325; 1895: Helium, a gaseous constituent of certain minerals.
- RAMSAY. *Comp. rend.*, **120**, p. 1049; 1895; *Ann. chim. phys.* (7), **13**, p. 433; 1898: Helium in meteorites.
- RAMSAY and TRAVERS. *Proc. Roy. Soc., Lond.*, **60**, p. 442; 1896: Occurrence of helium in minerals.
- STRUTT, R. J. *Nature*, **75**, p. 271; 1907; *Chem. Abs.*, **1**, p. 817: Helium and argon in common rocks.
- STRUTT. *Nature*, **75**, p. 390; 1907: An occurrence of helium in the absence of radio activity.
- STRUTT. *Proc. Roy. Soc., Lond.*, **76**, pp. 80-101; 1908: Helium and argon in rocks.
- STRUTT. *Proc. Roy. Soc., Lond.*, **80**, pp. 56-57; 1908; *Chem. Abs.*, **2**, p. 944, *Radium*, **5**, pp. 202-211; 1908: The association of helium and thorium in minerals.

- STRUTT. Proc. Roy. Soc., Lond., **80**, pp. 572-594; 1908; Chem. Abs., **3**, p. 2651: Helium and radioactivity in minerals.
- STRUTT. Proc. Roy. Soc., Lond., **81**, pp. 278-279; 1908; Chem. Abs., **3**, p. 2651: Helium in saline minerals and its probable connection with potassium.
- STRUTT, R. J. Proc. Roy. Soc., Lond., **81**, pp. 272-277; 1908; Chem. Abs., **3**, p. 615: The accumulation of helium in geological time.
- STRUTT. Chem. News, **99**, pp. 145-146; 1909; Chem. Abs., **3**, p. 2531: The leakage, of helium from radioactive minerals.
- STRUTT. Proc. Roy. Soc., Lond., **83**, pp. 76-99, 298-301; 1910; Chem. Abs., **4**, pp. 1146, 1424: The accumulation of helium in geological time.
- STRUTT. Proc. Roy. Soc., Lond., **84**, pp. 194-196; 1910; Chem. Abs., **5**, p. 28: The accumulation of helium in geological time.
- 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.
- THOMSON, J. Zeit. Physik. Chem., **25**, p. 112; 1898: Occurrence of helium in minerals. Chiefly calcium fluoride.
- TRAVERS. Nature, **71**, p. 248; 1905: Helium occurs in radioactive minerals in form of supersaturated solid solution.
- TSCHERNIK, J. J. Russ. Phys. Chem. Soc., **29**, p. 291; 1899: Helium in cerium-bearing minerals from the Caucasus.
- VALENTINER, S. Kali, **6**, pp. 1-3; Chem. Abs., **8**, p. 480; Neues Jahrb. Min. Geol., 1913, I Ref., p. 195: Helium content of blue rock salt.
- WELLS, R. C. J. Frank. Inst., **189**, pp. 779-780; 1920; Chem. Abs., **14**, p. 2456: Note on brannerite, a uranium mineral containing helium.
- WHERRY, E. T. Am. Mineral, **2**, pp. 105-108; 1917; Chem. Abs., **11**, p. 2570: The occurrence of the native elements. (Including helium.)
- WILDE, H. Phil. Mag. (5), **40**, p. 466; 1895: The occurrence of helium in cleveite.

2. OCCURRENCE IN MINERAL WATERS.

- BOUCHARD and TROOST. Compt. rend., **121**, p. 392; 1895: Helium in a spring at Caunteret in the Pyrenees.
- CZAKO, E., and LAUTENSCHLAGER. Chem. News, **108**, p. 16; 1913; Chem. Ztg., **37**, p. 936; 1913; Chem. Abs., **7**, p. 3450: Helium content of gases from Hôt Spring, at Wildbad, in the Black Forest. Gases contained 0.71 per cent helium.
- DEWAR, J. The discovery of helium and radium in the hot springs of Bath, England, 14 pp. Bath Herald Office. 1904.
- EWERS. Physik. Zeit., **7**, p. 224; 1906: Helium and argon in hot springs.
- HERRMANN, A., and PESENDORFER, F. Physik. Zeit., **6**, pp. 70-71; 1905: Radioactivity of the gases evolved from the Karlsbad springs.
- KAYSER, H. Chem. News, **72**, p. 223; 1895; Chem. Ztg., **19**, p. 1549; 1895: Helium in the gases from springs at Wildbad, in the Black Forest.
- MOUREU, C. Compt. rend., **121**, p. 819; 1895: Helium in spring water at Maizieres.
- MOUREU. Compt. rend., **135**, p. 1335; 1902: Helium in the spring Vieille Quelle, in the Pyrenees.
- 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. Compt. rend., **142**, p. 1155; 1906.
- 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.
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- NASINI, R. *Atti Acad. Lincei. Roma* (5), **13**, I, pp. 217, 367; 1904; Helium in certain Italian springs.
- PESENDORFER, F. *Chem. Ztg.*, **29**, p. 359; 1905; Helium in the Karlsbad springs.
- PRYTZ and THORKELSSON. *Kgl. Danske. Vidensk. Selsk. Forh.*, p. 317; 1905; The occurrence of helium in warm island springs.
- RAYLEIGH. *Chem. News*, **72**, p. 223; 1895; Helium in gases from the springs at Bath.
- SIEVEKING and LAUTENSCHLAGER. *Physik. Zeit.*, **13**, pp. 1043-1051; 1912; *Chem. Abs.*, **7**, 1841; *Ber. physik. Ges.*, **14**, p. 910; 1913; Helium in hot springs and natural gases. No direct relation between radioactivity and helium content was found.
- TROOST and OUVARD. *Compt. rend.*, **121**, p. 798; 1895; Helium in spring water at Cauterets.

3. OCCURRENCE IN NATURAL GAS.

- CADY, H. P., and MCFARLAND, D. F. *Trans. Kan. Acad. Sci.*, **26**, Part II, p. 802; 1907; *Sci.*, **24**, p. 344; 1906; *Chem. Abs.*, **1**, p. 1528; Helium in Kansas natural gas. Some samples contained as much as 2 per cent. Geological zones of approximately equal helium content were located.
- CADY, H. P., and MCFARLAND, D. F. *J. Am. Chem. Soc.*, **29**, pp. 1524-1536; 1907; *Chem. Abs.*, **2**, p. 386; The occurrence of helium in natural gas and the composition of natural gas. Helium is found in practically all natural gas in amounts which increase, in general, with increasing nitrogen and decreasing hydrocarbon content.
- CZAKO, E. *Zeit. anorg. Chem.*, **82**, 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.
- ERDMANN, E. *Ber. d. chem. Ges.*, **43**, pp. 777-782; 1910; *Chem. Abs.*, **4**, p. 1957; Helium-containing gases of the German potash beds.
- HARRIS, J. E. G. *J. Inst. Petroleum Tech.*, **7**, No. 27, pp. 14-16; 1921; Helium in a sample of natural gas from Egypt.
- MCLENNAN, J. C. *Can. Dept. of Mines Bull.*, **31**, 72 pp.; 1920; Report on sources of helium in the British Empire.
- MILNER, H. B. *Nature*, **109**, pp. 112; 1922; *Chem. Abs.* **16**, p. 1132; Helium in natural gas.
- MOUREAU, C., and LEPAPE, A. *Compt. rend.*, **155**, pp. 197-200; 1912; *Chem. Abs.*, **6**, p. 3075; Some natural gaseous mixtures particularly rich in helium. Discourses gases from eight French sources.
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- ROGERS, G. S. *U. S. Geol. Survey Professional Paper No. 121*, 110 pp.; 1921; Helium-bearing natural gas.
- SATTERLY, J., and MCLENNAN, J. C. *Trans. Roy. Soc., Can.*, **12**, III pp. 153-160; 1918-1919; *Chem. Abs.*, **13**, p. 2309; The radioactivity of the natural gases of Canada.
- SEIBEL, C. W. Paper read before meeting of the Am. Chem. Soc., Apr. 10-14, 1917; *Abs. in Met. Chem. Eng.*, May, 1917; Helium and associated elements in Kansas natural gas.
- VOLLER, A., and WALTER, B. *Hamburger Wiss. Inst.*, **28**, p. —; 1910; *Chem. Abs.*, **5**, p. 3510; *Petroleum*, **6**, p. 1062; Helium and argon in the natural gas of Neuengamme. Contained 0.01-0.02 per cent helium.

4. OCCURRENCE IN AIR.

- RAYLEIGH and RAMSAY. Proc. Roy. Soc., Lond., **59**, p. 198; 1896; Proc. Roy. Soc., Lond., **60**, p. 206; 1896: Helium in the air. Negative results.
- TRAVERS. Proc. Roy. Soc., Lond., **60**, p. 449; 1896: Separation of helium from the air.
- KAYSER, H. Chem. Ztg., **19**, p. 1549; 1895: Helium in the air.
- FRIEDLANDER. Z. physik. Chem., **19**, p. 657; 1896: Helium in the air. Estimated to be one part per billion.
- CROOKES, W. Chem. News, **78**, p. 198; 1898: Helium in the air.
- RAMSAY and TRAVERS. Proc. Roy. Soc., Lond., **67**, p. 329; 1900: Helium in the air. Isolated by fractionation.
- DEWAR, J. Proc. Roy. Soc., Lond., **68**, pp. 360-366; 1901; Proc. Roy. Soc., Lond., **74**, 127; 1904: Separation of helium from the air.
- RAMSAY. Proc. Roy. Soc., Lond., **76**, p. 111; 1905: Amount of helium in the air. One part in 245,300 by volume.
- BORDAS, F., and TOUPLAIN. Compt. rend., **147**; pp. 591-594; 1908: Helium in the air.
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- PIUTTI, A. Radium, **7**, pp. 142-146; 1910; Chem. Abs., **5**, p. 247: Helium in the air of Naples and Vesuvius.

V. FORMATION OF HELIUM.

1. FROM RADIOACTIVE SUBSTANCES.

- RAMSAY and SODDY. Proc. Roy. Soc., Lond., **72**, p. 204; 1903; Zeit. phys. Chem. **47**, pp. 490-494; 1904; Physik Zeit., **4**, p. 229; 1903: The production of helium by radium.
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- SCHENK. Sitz. Ber. Akad. Wiss., Berlin, **37**; 1904: Formation of helium from radium.
- RUTHEFORD. Phil. Mag. (6), **10**, p. 290; 1905; Arch. sc. phys. nat., **19**, pp. 31, 125; 1905: Formation of helium from radium.
- DEBIERNE. Compt. rend., **141**, p. 383; 1905: Helium from radium salts and actinium.
- GIEZEL, F. Ber. d. chem. Ges., **38**, p. 2299; 1905: Proof of formation of helium from radium bromide.
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- DEWAR, J. Proc. Roy. Soc., Lond., **81**, pp. 280-286; 1908; Chem. News, **98**, pp. 188-190; Chem. Abs., **3**, pp. 281, 616: The rate of production of helium from radium.
- DEWAR, J. Proc. Roy. Soc., Lond., **83**, p. 404; 1910; Chem. Abs., **4**, p. 2410: Long-period determination of the rate of production of helium from radium. Found 0.463 mm.³/g. per day.

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[See also Electrical properties and Relation to subatomic phenomena.]

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[See also following heading: Pressure-volume relations for gaseous helium.]

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