cracks the increase in tensile strength might be connected with the rapid diminution of cross section by soaking in water.

The two last-mentioned explanations remain valid when the crystal surface is levelled with other solvents; on the other hand, it is possible that some solvents do not enter into the crystal. We have found that soaking rocksalt in concentrated sulfuric acid, as well as with H_2SO_4+25 percent SO_3 gives exactly the same results as with water, the same fact was proved for potassium iodide crystals when placed in water or methyl alcohol.[9] It would be of great importance if the spectroscopic method of Barnes could be extended to these cases.

The penetration of water into rocksalt crystals indicates the existence of fissures and crevices, as Barnes has pointed out. We have directly made visible such inhomogeneities of rocksalt by photoelectric[10] and ultramicroscopic methods.[11] Contrary to Barnes, however, we should not suppose a connection with the secondary structure of crystals as postulated by Zwicky. As recently shown by Orowan,[12] the calculations of Zwicky are incorrect. Incorrect[13] also are the statements of Buerger concerning changes of the translation mechanism in the group of alkali halides[14] which Zwicky claims as a proof of a secondary structure in rocksalt and the other alkali halides.[15] There is at present no theoretical or experimental support for the existence of a Zwicky secondary structure in rocksalt. As far as I see, the same situation holds for every other crystal. The beautiful results of Goetz with bismuth crystals are consistent with the existence of inhomogeneities which are not regularly distributed in the interior of crystals.

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February 1, 1933.

[9] E. Rexer, Zeits. f. Physik **72**, 613 (1931).
[10] A. Smekal, Wien, Akad. Anz. 1926, p. 195; 1927, pp. 22, 46.
[11] E. Rexer, Zeits. f. Physik **76**, 735 (1932).
[12] E. Orowan, Zeits. f. Physik **79**, 573 (1932).
[13] Cf. W. Schütze, Zeits. f. Physik **76**, 135, 149 (1932).
[14] M. J. Buerger, Amer. Min. **15**, 114, 226 (1930).
[15] F. Zwicky, Helv. Phys. Acta **4**, 49 (1931).

The Mass of Be^9 and the Atomic Weight of Beryllium

The mass of Be^9 was measured from five spectra as 9.0155 ± 0.0006 units on the $O^{16}=16$ scale. Be^{9+} was compared with C^+ by means of the ratios $Be^{9+} : C^{12+} :: C^{12+} : CH_4^+$. In Fig. 1, spectrum 1 is a reproduction of a contact print of one of the spectra of this type. The mass of Be^9 was also compared with that of Ne^{20++} by use of the approximate ratios $Be^{9+} : Ne^{20++} :: C^+ : CH^+$ as shown in Fig. 1, spectra 1 and 2. The value obtained from five

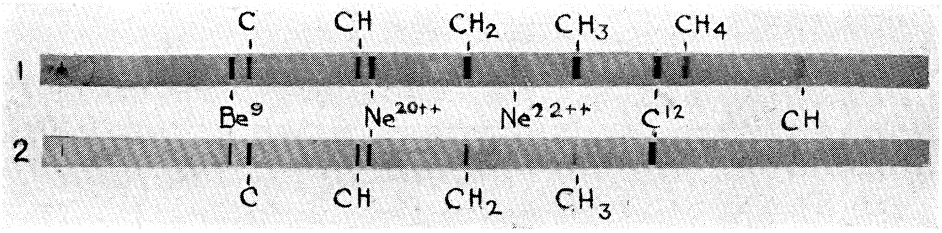

FIG. 1. Mass-spectra of Be^9 and associated lines. Natural size.
(1) $Be^{9+} : C^{12+} :: C^{12+} : CH_4^+$. (2) $Be^{9+} : Ne^{20++} :: C^{12} : CH^+$.

spectra by using this latter ratio was 9.0154 ± 0.0008 when referred to $Ne^{20}=19.9967$.[1] The other reference masses were $C^{12}=12.0036$ and $H^1=1.00778$ as given by Aston.[2] Attempts to measure the mass of Be^9 by the ratios $Be^{9+} : O^{++} :: OH_2^+ : O^+$ have not succeeded so far as oxygen appears to be "cleaned up" in the presence of the $BeCl_2$ used to provide the beryllium ions. Except for the runs in which oxygen was present a satisfactory source of Be ions was provided by the evaporation from the cathode of anhydrous $BeCl_2$ with subsequent ionization in a discharge run in neon. This type of source has been described before.[3]

There are several interesting considerations which follow from this determination of the mass of Be^9.

(1) It appears improbable that the nucleus of Be^9 consists of two α-particles and one neutron,[4] or of two α-particles and one proton and one electron, as the sum of the masses of the suggested components is less than the mass of the stable Be^9 nucleus.

(2) Allowing for the presence of one part in 2000 of Be^8,[5] the atomic weight of beryllium on the chemical scale is 9.0130 ± 0.0007, which is considerably lower than the value

[1] K. T. Bainbridge, Phys. Rev. **43**, issue of March 15, 1933. Paper presented before American Physical Society, Dec. 28, 1932.
[2] F. W. Aston, Proc. Roy. Soc. **A115**, 487 (1927).
[3] K. T. Bainbridge, Phys. Rev. **39**, 847, 1021 (1932).
[4] F. Perrin, C. R. **194**, 1343 (1932).
[5] W. W. Watson and Allan E. Parker, Phys. Rev. **37**, 167 (1931).

9.0179 ± 0.0009 which Hönigschmid and Birkenbach[6] obtained by chemical means.

(3) The packing fraction of Be^9 is $+17.2$ which is located well off the packing fraction "curve" for elements of even atomic number.

(4) Curie and Joliot[7] have calculated the mass of Be^9 and obtained a value 9.0109 on the $O^{16}=16$ scale under the assumptions that $Be^9+\alpha \rightarrow C^{12}+$neutron, that the energy of the neutron is 7.8×10^6 electron-volts, that no γ-rays are emitted in the process of disintegration, and that the Be neutrons have the same mass as the B neutrons. On the other hand the work of Meitner and Philipp[8] and of Rasetti[9] in conjunction with that of Becker and Bothe[10] strongly indicates that γ-rays do accompany the emission of neutrons from beryllium when it is bombarded by α-particles. Taking the process of disintegration to be $Be^9+\alpha \rightarrow C^{12}+\text{neutron}+h\nu$ and the mass of Be^9 to be 9.0155 and the mass[11] of the neutron 1.0067, 12.1×10^6 electron-volts are available for the energies of the neutron and γ-ray. Under this mode of disintegration 7.8×10^6 electron-volt neutrons[7] might be accompanied by 4.3×10^6 electron-volt γ-quanta. It is an open question whether the γ-rays found experimentally,[12] are produced as a primary process in the disintegration of the beryllium or whether, as indicated in the recent experiments of Auger,[13] the γ-rays are produced by a secondary process as a result of inelastic neutron impacts in nearby materials. The production of γ-rays by both processes may of course take place concurrently.

(5) Sufficient energy is available from the combination $Be^9+\alpha+E_\alpha$ so that a large number of disintegration mechanisms are theoretically possible. The evidence available at present is best satisfied by the reaction $Be+\alpha \rightarrow C^{12}+\text{neutron}+h\nu$. The experiments which have been performed up to the present time have not been such as to eliminate alternative modes of disintegration. One such possible mechanism, for example, might be $Be^9+\alpha \rightarrow 3\alpha+\text{neutron}+h\nu$, which might be a "capture" or a "non-capture" process.

Although the measured mass of Be^9 cannot be used at present for an evaluation of the mass of the neutron, it is hoped that this Be^9 mass determination may help ultimately in the solution of the questions attendant on the disintegration of beryllium by different agents.

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Bartol Research Foundation of the
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February 10, 1933.

[6] O. Hönigschmid and L. Birkenbach, Ber. Chem. Ges. **55B**, 4 (1922). The atomic weight of beryllium from the ratio $BeCl_2/Ag$ is given as 9.0179 with a "mean error" ±0.0013.

[7] I. Curie and F. Joliot, Nature **130**, 57 (1932); I. Curie, F. Joliot and P. Savel, C. R. **194**, 2208 (1932).

[8] L. Meitner and K. Philipp, Naturwiss. **20**, 929 (1932).

[9] F. Rasetti, Zeits. f. Physik **78**, 165 (1932).

[10] H. Becker and W. Bothe, Zeits. f. Physik **76**, 421 (1932).

[11] J. Chadwick, Proc. Roy. Soc. **A136**, 692 (1932). The mass of the neutron is 1.0067 ± 0.0010 from Chadwick's disintegration data and Aston's mass values for N^{14}, B^{11} and He^4 (reference 2). The probable error has been calculated here in the customary manner on the basis that Aston's limits of error are equal to three times the probable errors of his measurements. Two other sets of data permit an upper and a lower limit to be placed on the mass of a neutron, assuming the existence of only one type of neutron.

The emission of neutrons by the process $Li^7+\alpha \rightarrow B^{10}+n$ gives an *upper limit* for the mass of a neutron 1.0063 ± 0.0008 from the mass data of J. Costa (Ann. de Physique **4**, 425 (1925)) and F. W. Aston (reference 2) and the disintegration experiments of I. Curie, F. Joliot and P. Savel (reference 7) and M. de Broglie and L. Leprince-Ringuet (C. R. **194**, 1616 (1932)).

If the nucleus of H^2 is composed of one proton and one neutron, 1.0057 ± 0.0002 is a *lower limit* for the mass of a neutron (K. Bainbridge, Phys. Rev. **41**, 115 (1932)).

[12] Wilson chamber β-ray tracks in a magnetic field, I. Curie and F. Joliot, C. R. **194**, 708, 1229 (1932). P. Auger ibid., 877. By absorption and coincidence method, H. Becker and W. Bothe, Naturwiss. **20**, 757 (1932) and reference 10; F. Rasetti, Naturwiss. **20**, 252 (1932).

[13] P. Auger, C. R. **196**, 170 (1933).

Cosmic-Ray Bursts

In cloud-chamber experiments the frequent occurrence of associated tracks has been observed.[1] It has been pointed out that a simple binary collision cannot explain all the associated tracks.[2]

During the course of photographing cosmic-ray tracks in a magnetic field of 15,000 gauss, one exposure was obtained showing a group of twelve tracks. The tracks, which occurred "early," were coincident in time as shown by the fact that the diffusion of the ions broadened all the tracks to the same extent. The individual ions were clearly resolved.

Seven of the tracks are clearly seen to originate at a common point in the upper portion of the chamber, probably in the wall material. There are in addition five tracks which do not come accurately from this point of origin, but do diverge from the same region of the chamber, their directions perhaps having been changed by scattering

[1] Skobelzyn, Zeits. f. Physik **54**, 686 (1929); Auger and Skobelzyn, C. R. **189**, 55 (1929); Locher, Phys. Rev. **39**, 883 (1932); Millikan and Anderson, Phys. Rev. **40**, 325 (1932); Anderson, Phys. Rev. **41**, 405 (1932).

[2] Millikan and Anderson, reference 1; Anderson, reference 1.

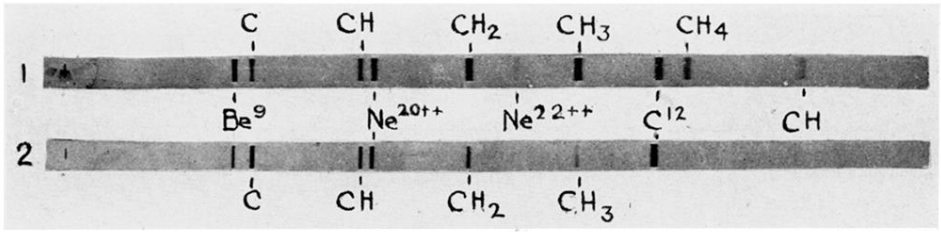

FIG. 1. Mass-spectra of Be^9 and associated lines. Natural size.
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