ford, a member of the G. Allan Hancock Expedition to the Gulf of California in 1937. No filtration or condensation of the large catch was made. It was simply dipped from the surface of the gulf and preserved without change of volume. It was included in a series of catches of phytoplankton given to me for study.

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SPECIAL ARTICLES

RADIOACTIVITY OF POTASSIUM AND GEOLOGICAL TIME

HOLMES and Lawson,[1] in considering the effect of the radioactive elements on the age of the earth, have discussed the possible effects of uranium, thorium, potassium and rubidium. In their treatment of potassium and rubidium they considered all the isotopes to be radioactive, although they mentioned that their calculations would be materially different were this radioactivity confined to certain rare isotopes.

Potassium is known[2] to emit two hard β rays of velocity 0.83 c and 0.93 c in proportions 60 to 28. Holmes and Lawson assumed 0.85 c as a fair average in estimating λ, the disintegration constant. By considering all the isotopes to be equally radioactive they computed $\lambda = 4.6 \times 10^{-13}$ year^{-1} and the half life $T = 1.5 \times 10^{12}$ years. Hevesy[3] assigned the radioactivity to K^{41} and by assuming $K^{39}/K^{41} = 20$ for the abundance ratio estimated $T = 7.5 \times 10^{10}$. This value has also been accepted by Rutherford, Chadwick and Ellis.[4] Various other estimates presented in the literature are close to this value.

The radioactivity of potassium has recently been shown by Smythe and Hemmendinger[5] to be confined largely to K^{40}. The abundance ratios for the various isotopes of potassium have been measured with considerable accuracy; these ratios have been determined for shales and for commercial potassium salts. The values are $K^{39}/K^{41} = 14.20 \pm 0.02$ and $K^{39}/K^{40} = 8300 \pm 100$; this gives $K^{39} + K^{40} + K^{41}/K^{40} = 9000$.[6] The half life and disintegration constant must now be changed accordingly, the corrected values becoming $\lambda = 4.13 \times 10^{-9}$ year^{-1} and $T = 1.67 \times 10^{8}$ years. The new constants materially change the conclusion of Holmes and Lawson that in early Archaean rocks (age 10^9 years) the heat evolved in the dissociation of potassium was but one per cent. more than at present.

The ratio of the amount of K^{40} present at various geological ages compared with that in existence to-day is given in Table 1. These values are computed from the equation $N^t/N^0 = e^{-\lambda t}$ where N^t, the concentration of K^{40} at the present time, is taken as unity.

TABLE 1

tYears	K^{40}	U	Th
10^6	1.0042		
10^7	1.0418		
10^8	1.511		
3×10^8	3.452		
10^9	62.18	1.162	1.0053
1.43×10^9	360.0		
3×10^9	2.4×10^5		
10^{10}	9.65×10^{17}		

The amounts of uranium and thorium are included at 10^9 years for comparison; the calculations are based on the values 1.5×10^{-11} years^{-1} and 5.33×10^{-12} years^{-1} respectively for the disintegration constants.

The values given above may now be used to calculate an approximate upper limit for the age of the earth and for the time of congealing of the earth's crust. Obviously the earth could not be 10^{10} years old, for if it were it would have been composed almost entirely of K^{40}. Since K^{40} disintegrates into Ca^{40}, an upper limit for the age of the earth must be set by the amount of Ca^{40} in existence at the present time. The relative concentrations of Ca^{40} and K^{40} in the earth's crust are $Ca^{40}/K^{40} = 1.4 \times 10^4$. The upper limit for the age of the earth is, in consequence, slightly less than 3×10^9 years.

A tentative date for the congealing of the earth's crust may be obtained by assuming that radioactivity is a controlling factor in maintaining the internal temperature of the earth. At a surface temperature of 1,000° C., a fair value for fusion of the earth's crust, the heat lost by radiation under black body conditions will be 360 times that lost at present. A supply of this amount of heat must be added to compensate the loss through radiation. At the present time the amount of radioactive energy liberated by potassium, uranium and thorium is of the same order of magnitude; at 10^9 years, however, it will be seen from the table that the energy liberated from K^{40} is far in excess of that from uranium and thorium. K^{40} alone at 1.4×10^9 years is capable of supplying the entire additional loss of energy through radiation. This is almost identical to the date of congealing of the earth's crust as estimated from the uranium-lead ratio.

The relative abundance of K^{40} at 3×10^8 years is included in the table, since this is the probable date of the carboniferous era. There is considerable evidence indicating that the pronounced effect of potas-

[1] A. Holmes and R. W. Lawson, *Phil. Mag.*, 2: 1218, 1926.
[2] D. Bocciarelli, *Atti, accad. Lincei*, 17: 830–33, 1933.
[3] G. Hevesy, *Nature*, 120: 838, 1927.
[4] Sir Ernest Rutherford, J. Chadwick and C. D. Ellis, "Radiations from Radioactive Substances," Cambridge, 1930.
[5] W. R. Smythe and A. Hemmendinger, *Phys. Rev.*, 51: 178, 1936.
[6] A. Keith Brewer, *Phys. Rev.*, 48: 640, 1935. A. Keith Brewer, *Jour. Am. Chem. Soc.*, 58: 370, 1936. A. O. Nier, *Phys. Rev.*, 48: 283, 1935.

sium on germination and growth is due in part to its radioactivity. It is an interesting speculation, therefore, that the enhanced K^{40} content may have been a contributing factor to the carboniferous age.

The writer is especially indebted to Dr. R. C. Wells, of the U. S. Geological Survey, for suggesting the necessity for these calculations, and to Dr. A. Bramley and Dr. W. E. Deming for suggestions and for checking the calculations.

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A POSSIBLE ACID SEED SOAK FOR THE CONTROL OF BACTERIAL CANKER OF THE TOMATO

THE discovery that bacterial canker of tomato (*Aplanobacter michiganense* E. F. S.) may be controlled by fermenting the fruit pulp prior to seed extraction[2] has led to a study of the toxicity of fermenting pulp to the causal organism. Toxicity tests made by a method corresponding to the one used by McCown[3] demonstrated an unquestionable toxic action of the fermenting fruit pulp upon the bacterial canker pathogen. In several tests the pathogen maintained its viability in unfermented juices for from 60 to 100 hours and in 96-hour fermented juices for only one half to two and one half hours.

Distillates obtained from juices fermented for 240 hours and lethal to the pathogen in less than one hour were neutralized by the addition of barium hydroxide and their toxicity tested. The pathogen remained viable in the neutralized juices for 2,180 hours. In a similar experiment the barium salts were acidified with sulfuric acid, using methyl orange indicator and the barium sulfate removed. The resulting freed acids, when adjusted to the original volume, were as toxic as the untreated distillates.

Analysis of the fermented juices revealed that acetic and lactic acids were the acids formed most abundantly during fermentation. From .35 to .58 per cent. acetic acid and from .45 to .72 per cent. lactic acid were usually found in fruit juices which had fermented for a 96-hour period. A preliminary test of the effectiveness of those acids as seed soaks in the control of bacterial canker was undertaken.

Seed was extracted from fruit picked from plants infected with bacterial canker and aliquot parts soaked in .15 per cent., .3 per cent. and .6 per cent. acetic acid solutions for 3, 6, 12, 24, 48 and 96 hours. A similar series was soaked in .3 per cent., .6 per cent. and 1.2 per cent. lactic acid solution and in combinations of the respective concentrations of the two acids for the same periods of time. For comparison, aliquots of seed from the same lot were treated with copper sulfate 1 pound to 8 gallons for 21½ hours, with mercury bichloride 1–1,000 for ten minutes and with hot water 54 degrees centigrade for one hour. In order to compare the effectiveness of the seed treatments with fermentation, a portion of the pulp of the same infested fruit material was set aside to ferment for 96 hours and the seed then extracted. All treatments were applied immediately following extraction and before the seed had an opportunity to dry. Germination tests revealed that none of the treatments were particularly injurious. The seed was not milled and cleaned before the germination tests were made and for that reason there was a greater variation in the germination of different samples and a generally lower germination than is usually observed in first grade seed.

Representative amounts of seed of each treatment were planted in the field during the summer of 1936, and records taken of the number of diseased plants which developed from the seed of each treatment. The results are summarized in Table I. The various concentrations of each acid and the combination of acids for the various treatment durations are grouped together to condense the table.

TABLE 1

THE EFFECT OF ACID, CHEMICAL, HOT WATER AND FERMENTATION SEED TREATMENTS ON SEED GERMINATION AND THE CONTROL OF BACTERIAL CANKER

Treatment	Plants		Per cent.	
	Tested	Diseased	Diseased	Germination
Untreated, immediate extraction	1,336	1,086	81.28	90.0
Acetic acid soaks (all treatments)	3,751	3	0.08	87.1
Acetic and lactic acid soaks (all treatments)	4,003	9	0.225	83.38
Lactic acid soaks (all treatments)	4,140	26	0.62	82.97
$CuSo_4$ 1 lb.—8 gal. 21½ hours	418	26	6.22	81.0
$HgCl_2$ 1–1000—10 minutes	517	32	6.19	91.5
Hot water 54° C.—1 hour	427	33	7.73	93.5
Fermentation 96 hours	532	1	0.188	90.0

Two of the three plants which developed the disease following the acetic acid treatment were from the seed lot treated with an acid concentration of .6 per cent. for 6 and 96 hours, respectively, and the other one from seed treated with a .15 per cent. acid concentration for 96 hours. In the lactic and combination lactic and acetic acid series, the greatest amount of disease developed from seed lots treated with the lower acid concentrations for shorter durations of time. No canker developed in any of the 1,147 plants grown from seed treated with a combination of .6 per cent. acetic acid and 1.2 per cent. lactic acid for any duration.

[1] Authorized by the director of the Bureau of Plant Industry on March 6, 1937.

[2] H. L. Blood, *Proc. Utah Acad. of Sci.*, 10: 19–23, 1933.

[3] Monroe McCown, *Phytopath.*, 19: 285–293, 1929.