SUOMALAISEN TIEDEAKATEMIAN TOIMITUKSIA
ANNALES ACADEMIÆ SCIENTIARUM FENNICÆ

SARJA SERIES A

II. CHEMICA

101

STRONTIUM 90 IN FINNISH GRASS AND COW'S MILK

BY

O. PAAKKOLA, R. NÄSÄNEN, D. MERTEN and J. K. MIETTINEN

Department of Chemistry, University of Helsinki
Bundesforschungsanstalt für Milchwirtschaft, Kiel
Biochemical Institute, Helsinki

HELSINKI 1960
SUOMALAINEN TIEDEAKATEMIA

A short note on these results appeared in Nature 189(1961)324-5.

19

Dear

I ... our papers ~~entitled~~ elated

hes ... 1 published ~~in~~

... y other reprints on

this su ... stribution.

Thanking you in advance, I am,

Yours sincerely,

[signature]

2/9/61

With the Compliments of
Doctor Jorma K. Miettinen

BIOCHEMICAL INSTITUTE
KALEVANKATU 56 — HELSINKI

SUOMALAISEN TIEDEAKATEMIAN TOIMITUKSIA
ANNALES ACADEMIÆ SCIENTIARUM FENNICÆ

SARJA
SERIES A

II. CHEMICA

101

STRONTIUM 90 IN FINNISH GRASS AND COW'S MILK

BY

O. PAAKKOLA, R. NÄSÄNEN, D. MERTEN and J. K. MIETTINEN

Department of Chemistry, University of Helsinki
Bundesforschungsanstalt für Milchwirtschaft, Kiel
Biochemical Institute, Helsinki

HELSINKI 1960
SUOMALAINEN TIEDEAKATEMIA

Communicated 14 October 1960

KESKUSKIRJAPAINO
HELSINKI 1960

Strontium 90 in Finnish Grass and Cow's Milk

Of the long-lived fission products found in agricultural produce as a result of atmospheric fallout, ^{90}Sr and ^{137}Cs are generally considered to present the major hazard to the consumer. Therefore we have started a research project to gain preliminary information on the amounts of these nuclides in the most important phases of the food-chain soil-plant-animal-man in Finland.

In this paper results are reported on the ^{90}Sr in the first series of samples. Most of these samples have also been analysed for ^{137}Cs; the results of these analyses will be published separately (1).

In most western countries, in which 65—85 % of the calcium in the average diet derives from milk and milk products (2), the most important links in the above-mentioned food-chain are grass and milk. In Finland, the proportion of the dietary calcium provided by milk and milk products is among the highest in the world, 85 % for the urban (3) and 84.5 % for the rural population (4). This percentage is of the same magnitude in the other Scandinavian countries — *e.g.* in Norway also 85 % (5), whilst in England it is 75 % (6, 7), and in Germany (West) 75.9 % (8).

To obtain information both on the general level of ^{90}Sr in the milk and on the magnitude of the local variation in a country, two kinds of survey should be made (6): a »country-wide» survey, in which samples are collected and mixed to represent the milk consumed by a large part of the population, and a »special area» survey, in which samples are taken from individual farms in which the ^{90}Sr content of the milk is suspected to be higher than the average. The »country-wide» survey of the British Radiobiological Laboratory (6) comprises milk samples taken fortnightly from over 200 milk depots, which represent more than 40 % of the total milk produced in the United Kingdom. The »special area» survey made by the same laboratory comprises 6 farms in regions having a high annual rainfall, three of the farms even being located at an altitude higher than 400 m. Both British (6, 13) and Norwegian (11) investigations have shown a good correlation between the amounts of annual rainfall and of ^{90}Sr deposited per km^2 or present in grass and milk. Recent studies in different countries have also shown a pronounced seasonal variation in the ^{90}Sr contents of grass and milk (6, 9, 10, 11, 12). The peak values of 1958 were found in England (6, 12) and Germany (9) in June-July, in Norway in July-August (11).

In this survey our aim has been to obtain preliminary information both

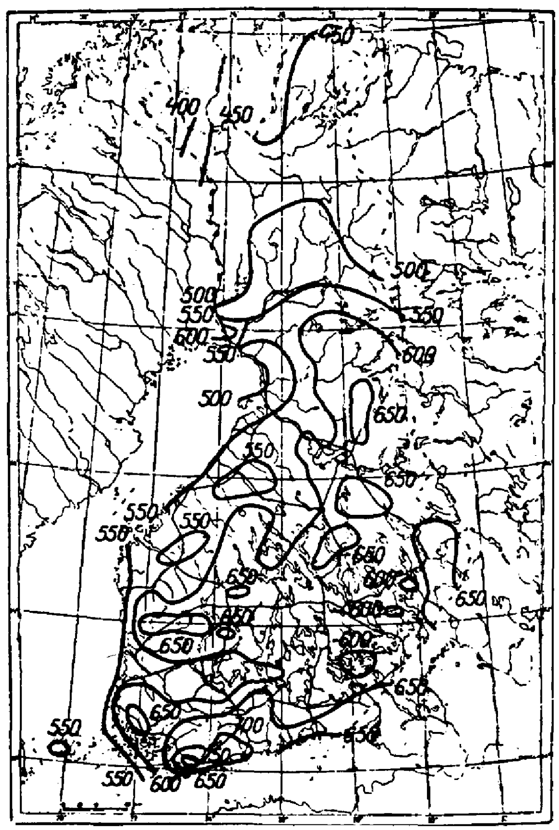

Fig. 1. Annual rainfall in Finland in mm, mean in years 1886—1935, *acc.* to V. V. KORHONEN (21).

on possible variations in the ^{90}Sr content of milk and grass in different parts of Finland and on the general level of ^{90}Sr in the milk of the region of highest milk production at the end of the summer season 1959.

Regarding the annual rainfall no great local variations exist in Finland (Fig. 1). Nearly all the milk is produced in areas where the annual rainfall is between 500 and 700 mm (Fig. 2). More than half the total milk production takes place south of the line Savonlinna-Jyväskylä-Vaasa.

The general level of ^{90}Sr in the milk in this area was studied by taking representative skim milk samples (Table 1, Nos. 10—15) from two milk powder factories, »A», Nastola, and »B», Somero (Fig. 3). Each of these samples represents one day's milk intake — usually 60—80,000 l. — from more than ten big dairies located within *ca.* 100 km radius around the factory. The samples from factory »A» (Nos. 10—13) can be considered to represent the general or »country-wide» samples of Southeast Finland, those from »B» (Nos. 14—15) correspondingly the general samples of Southwest Finland.

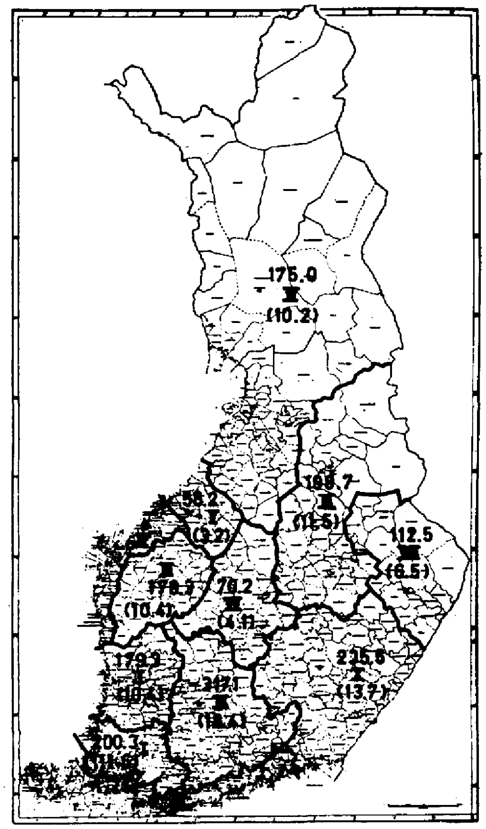

Fig. 2. Milk received by Finnish co-operative dairies in 1958 in millions kgs and as percent of total received (1.722 milj. kg). — Co-operative dairies represent 79.3 % of milk received by all dairies (2.172 milj. kg).

The local milk and grass samples were taken between Aug. 29 and Sept. 6, 1959, from 8 experimental farms located between latitudes 60° and 67°N (Table 1, Nos. 1—8) and from a private farm located at lat. 69°N (No. 9). Experimental farms have the advantage that all data on farming, *e.g.* the diet of the cattle, can be checked at any time, even later. On the experimental farms selected for the present study the soil type and pH are fairly comparable (Table 1). The calcium status of the soil, exchangeable soil calcium as $CaCO_3$ tons/ha in a soil stratum 20 cm deep (Table 1, last column) is satisfactory or tolerable. Mäenpää's farm (No. 9) is tolerable regarding pH but its calcium status is poor. In each case the cattle had been solely on pasture for about three months, except for 2—3 weeks in August, when ca. 10 % additional fodder, usually cereal grown on the same farm in the previous year, had been given because the pastures had been exhausted (the summer of 1959 was exceptionally dry in Finland).

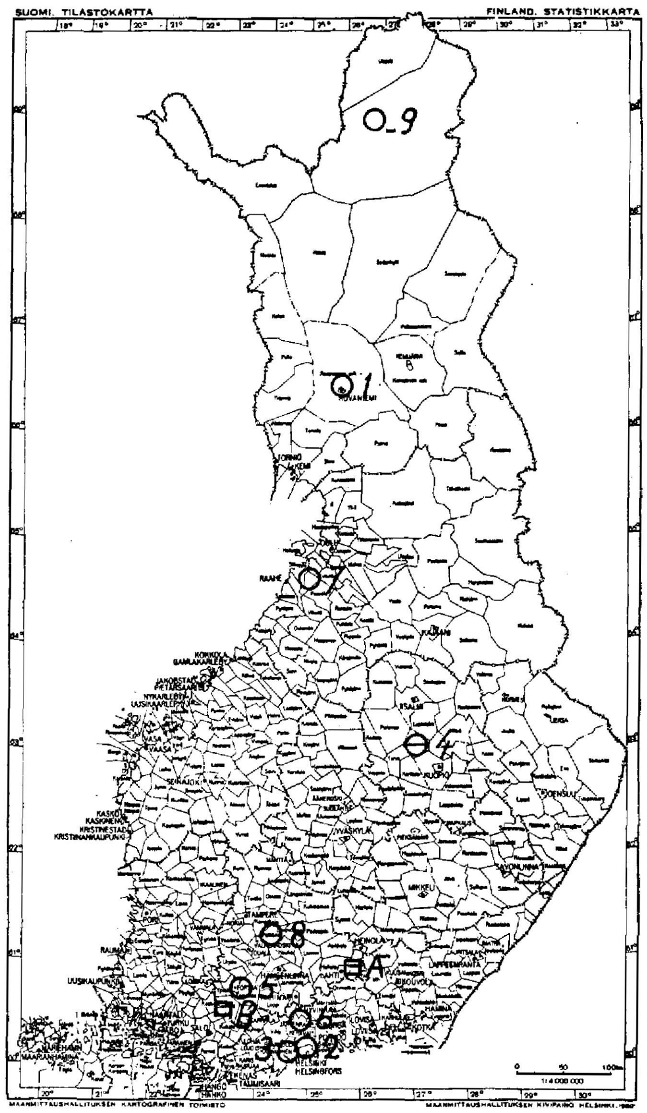

Fig. 3. Location of the experimental farms (Nos. 1—9) and milk powder factories (A and B) used in sampling.

Analyses of the milk samples

Ten-litre samples of bulked whole milk, representative of one day's production of the cows, were taken at the farms, 20 ml of 3.5 % formaldehyde added for preservation and the sample sent by mail in a polyethylene bottle to the Kuivamaito Oy factory at Nastola, where it was dried to

Table 1

Origin of the Milk and Grass Samples

Sample No.	Name of farm or powdered milk factory	Place	Latitude °N	Date of sampling 1959	Type of milk	Type of soil	pH	exch. calcium t $CaCO_3$/ha
	Local samples:							
1	State Experimental Farm, *Apukka*	Rovaniemi	66	Aug. 29¹)	whole	finesand	5.5	5.3 (2–8)
2	Helsinki Univ. Experimental Farm, *Viik*	Helsinki	60	Aug. 29	»	finesand clay	6.3	19
3	Helsinki Univ. Experimental Farm, *Malminkartano*	»	60	Aug. 31	»	fine finesand	6.0	14.1
4	State Experimental Farm, *Halola*	Maaninka	63	Sept. 1	»	» »	5.5–6.5	8.5
5	State Experimental Farm, *Jokioinen*	Forssa	61	Aug. 30	»	mud clay & heavy clay	5.8	12.4
6	Experimental Farm of Hankkija, *Anttila*	Hyrylä	60	Aug. 31	»	fine sand clay	5.5	7.5
7¹	State Experimental Farm, *Kreuksela*	Revonlahti	65	Sept. 2	»	peat	5.0	9
7²	State Experimental Farm, *Kreuksela*	»	65	»	»	fine sand	5.2	5.3
8	State Experimental Farm, *Myttäälä*	Pälkäne	61	Aug. 29	»	finesand	5.7	9.3
9	E. Mäenpää's farm, *Toivonniemi*	Kaamanen	69	Sept. 6	»	fine finesand	4.8	0.9
	General samples:							
10	Kuivamaito Oy, factory A	Nastola	60–61	May 1	skim	—	—	—
11	—»— —»—	—»—	—»—	June 23	»	—	—	—
12	—»— —»—	—»—	—»—	Aug. 15	»	—	—	—
13	—»— —»—	—»—		Nov. 17²)	»	—	—	—
14	—»— factory B	Somero	—»—	May 30	»	—	—	—
15	—»— —»—	—»—	—»—	June 1	»	—	—	—

¹) grass sample taken Sept. 10.
²) ash (made at 450 °C) available to other laboratories for comparison.

powder by the spray method with a laboratory machine (NIRO Atomizer). Samples 10—15 were taken from the product of the two factories of the Kuivamaito Oy. They were similarly dried by the spray method on a commercial scale from skim milk.

The milk powder was burned to a semicarbonized form over Bunsen burners in porcelain evaporation dishes. The final ashing was done in quartz dishes at 450°C in a muffle furnace. For each analysis 15 g of ash, corresponding to about 2 l of milk, was used.

In the chemical separation of ^{90}Sr the procedure of Bryant, Morgan and Spicer (14) was followed, except for the following phases.

The manipulations corresponding to § 8 of Appendix I 2 were made as follows: strontium was precipitated as carbonate by adding solid ammonium carbonate and heating on a water bath. The precipitate was separated by centrifugation, dissolved in a small amount of 6 N HCl and transferred to a 100 ml polyethylene bottle with 20 ml of water. 1 ml of yttrium carrier was added and Sr-Y equilibrium allowed to form for at least 14 days.

§ 9 was omitted.

§ 10 was changed to the following: The solution was transferred from the bottle to a 40 ml centrifuge tube and made alkaline with CO_2-free ammonia. The clear centrifugate was transferred to a 100 ml measuring flask for a flame photometric determination of strontium. The precipitate was dissolved in 6 N HNO_3 and diluted to 10—15 ml, 10 ml of strontium-carrier was added as a hold-back carrier and a new ammonia precipitation was performed. (Strontium carrier was added to prevent co-precipitation of the remaining active strontium on the highly absorbing $Y(OH)_3$ precipitate.) The centrifugate was rejected. The time of the first yttrium precipitation was noted.

Strontium recovery was determined by a flame photometer (Zeiss) using the wave length 460.7 $m\mu$. The determinations were based on 3 strontium standards.

The radioactivity of the yttrium precipitation was determined with a Tracerlab anticoincidence counter CE 14, which had a background of 1.2—0.6 c/min.

Calcium was determined as the oxalate from a part of the samples gravimetrically by the method of Bryant *et al.* (14), from a part of the samples by dissolving the oxalate precipitate in 2 N H_2SO_4 and titrating with 0.1 N potassium permanganate.

The dry weight of the milk powder was determined by drying it for 24 hours at 105°C because the humidity of the milk powder samples varied from 1.9 to 3.8 %.

Analyses of the grass samples

Grass samples from the farms (Nos. 1—9) representing the plots on which the cattle had been kept during the last 2—3 weeks, were dried on the farms in a dust-free place and *ca.* 10 kg of airdry grass was sent in a paper bag to the laboratory where it was burnt to ash in the same way as the milk samples. 10 g of ash was used for each analysis.

The chemical separation of ^{90}Sr was made by the method of Bryant *et al.* (14) with the same exceptions as in the milk analyses (see above). However, the grass ash was dissolved in a mixture of perchloric and nitric acids by the method of Bryant, Chamberlain, Morgan and Spicer (15). The yield of strontium and the radioactivity of the yttrium precipitates were determined as for the milk samples. Calcium was determined permanganometrically, as for a part of the milk powder samples. For dry weight determinations the grass was kept at 105—110°C for 20 hours.

The results

The results of the milk analyses are represented in Table 2, those of the grass analyses in Table 3.

Table 2

Results of calcium and ^{90}Sr analyses of the milk samples of Table 1.

Sample No.	Ca % of ash	^{90}Sr, $\mu\mu$c/g of ash	^{90}Sr, $\mu\mu$c/kg of dry weight	^{90}Sr, $\mu\mu$c/g Ca
1	16.6	0.61	35.2	3.7
2	15.5	1.00	55.4	6.7
3	17.5	0.79	45.0	4.5
4	16.2	0.67	35.3	4.2
5	14.3	0.52	30.0	3.6
6	16.0	0.78	43.7	4.9
7	16.8	1.12	61.6	6.6
8	16.6	0.98	53.0	5.9
9	17.3	2.01	96.5	11.6
10	16.5	1.61	118	9.8
11	16.8	1.63	125	9.7
12	16.4	1.31	96.3	8.0
13	17.4	1.47	118	8.4
14	17.1	1.36	106	7.9
15	16.5	1.41	109	8.6

Table 3

Results of calcium and ^{90}Sr analyses of the grass samples (Nos. 1—9 in Table 1). Mean of two determinations.

Sample No.	Ca, % of ash	^{90}Sr $\mu\mu c$/g of ash	^{90}Sr, $\mu\mu c$/kg of dry weight	^{90}Sr, $\mu\mu c$/g of Ca
1	7.46	7.19 ± 0.44	632 ± 38	96 ± 6
2	6.54	5.77 ± 0.37	594 ± 38	89 ± 6
3	5.89	7.45 ± 0.75	690 ± 79	126 ± 13
4_1	4.21	5.21 ± 0.70	517 ± 69	122 ± 16
4_2	6.39	5.75 ± 0.73	570 ± 73	92 ± 12
5	7.85	6.43 ± 0.59	528 ± 48	82 ± 7
6	6.59	5.09 ± 0.71	635 ± 90	77 ± 11
7_1	4.23	5.77 ± 0.68	704 ± 84	138 ± 17
7_2	4.78	5.90 ± 0.29	661 ± 32	123 ± 6
8	3.74	6.61 ± 0.18	609 ± 22	177 ± 3
9	9.28	20.83 ± 5.57	1581 ± 420	224 ± 60

From the results of the milk and grass analyses the ratios $\mu\mu c$ ^{90}Sr/g Ca in milk and grass have been calculated. The ratio of the values obtained, the so-called »discrimination factor» (DF) grass to milk, i.e.

$$\frac{\dfrac{\mu\mu c\ ^{90}\text{Sr in milk}}{\text{g Ca in milk}}}{\dfrac{\mu\mu c\ ^{90}\text{Sr in grass}}{\text{g Ca in grass}}} = \text{DF},$$

has been calculated and is presented in Table 4.

Table 4

Discrimination factor DF grass to milk calculated on the basis of the values reported in Tables 2 and 3:

Sample No.	DF	Sample No.	DF
1	0.039	6	0.064
2	0.075	7	0.051
3	0.036	8	0.033
4	0.040	9	0.052
5	0.044	mean 1—9	0.048

Discussion

The ^{90}Sr content of the »wide-area» milk samples (Nos. 10—15 in Tables 1 and 2) varies from 7.9 to 9.8, the mean being 8.7 $\mu\mu c$ ^{90}Sr/g Ca. The activity of the samples taken in May and June from the Eastern factory »A» (Nos. 10 and 11) is *ca.* 15 % higher than that of the corresponding samples taken in the autumn (Nos. 12 and 13) but the difference is probably not significant. The same is true regarding the difference between the spring (= May and June) values of the factories »A» (Nos. 10 and 11) and »B» (Nos. 14 and 15). It is of interest to note that a milk powder sample from Somero (factory B) taken in Sept. 1957 and analysed by the method of Bryant *et al.* (15) by one of us (D.M.), gave 7.0 $\mu\mu c$ ^{90}Sr/g of Ca.

The ^{90}Sr content of the milk samples from the experimental farms varies from 3.6 to 11.6, the mean being 5.7 $\mu\mu c$ ^{90}Sr/g Ca. This is significantly lower than the corresponding »country-wide» value for Southeast Finland, 8.0 $\mu\mu c$ ^{90}Sr/g Ca (No. 12, August 15). This may be partly due, for instance, to the fact that the productivity of the pastures of the experimental farms is considerably better than the average. The higher value of sample 9, 11.6 $\mu\mu c$ ^{90}Sr/g Ca, may correspondingly be due to the very poor soil and low productivity of the natural wet lake-coast pasture in question. This value is significantly higher than the other value from Lapland (No. 1), 3.7 $\mu\mu c$ ^{90}Sr/g Ca, but not much higher than the corresponding »wide-area» value for Southeast Finland, 8.0 $\mu\mu c$ ^{90}Sr/g Ca.

Milk produced in farms with poor pastures in South Finland would probably show similar activities, because the average (8.0 $\mu\mu c$ ^{90}Sr/g Ca) is much higher than the mean of »good» (= experimental) farms, 5.7 $\mu\mu c$ ^{90}Sr/g Ca, (Nos. 1—8).

The ^{90}Sr content of the grass sample No. 9 (Table 3) is also about twice as high as the mean of all farms. Otherwise it is not possible on the basis of the present study to say with certainty whether the relatively small differences between the individual farms are due to the difference in rainfall or in soil conditions or to other factors.

The average value for the milk of South Finland in summer 1959, 8.7 $\mu\mu c$ ^{90}Sr/g Ca, is of the same order as values for Great Britain in 1959, 9.35 $\mu\mu c$ ^{90}Sr/g Ca, (7), for Sweden in December 1957, 7.8 $\mu\mu c$ ^{90}Sr/g Ca, (16), for Germany in April to December 1959, 8.6 $\mu\mu c$ ^{90}Sr/g Ca, (19). It is slightly lower than the mean value for Norway in 1958, 11.4 $\mu\mu c$ ^{90}Sr/g Ca, but significantly lower than the corresponding Norwegian value for the first months of 1959, 17.4 $\mu\mu c$ ^{90}Sr/g Ca (11), and the Canadian values for summer 1959, *ca.* 20 $\mu\mu c$ ^{90}Sr/g Ca (20).

Since the 1959 values for the other countries are evidently also higher than the 1958 values quoted above and since our values, reported in this paper, are representative of summer conditions, when the ^{90}Sr content of milk reaches the annual maximum (9, 11), it can be concluded that the ^{90}Sr content of milk in South Finland is slightly lower than in the other countries in Northern and Western Europe. The value obtained in the present study for the discrimination factor grass-milk, 0.048, is significantly lower than that quoted in the UN Report (1), 0.16, or reported by

Milbourn *et al.* (17), 0.10—0.14, or by Cragle and Demott (18), 0.15. We have no explanation for this difference.

Acknowledgements

We are greatly indebted to the Finnish Atomic Energy Commission for financial aid which made the present study possible and to the FAO for an André Mayer International Fellowship for one of us (JKM). We also wish to express our gratitude to Prof. Jouko Vuorinen, Head of the Department of Soil Science, Agricultural Research Center, for his valuable advice and for the soil analyses, to the Directors of the Experimental Farms for their efficient co-operation and to Mr. Reijo Arasjärvi, Dipl. Eng., and the Kuivamaito Oy for invaluable aid in spray-drying the milk samples.

References

1. VUORINEN, A. P. U. and MIETTINEN, J. K., Ann. Acad. Sci. Fenn. Ser. A II, Chemica, No. 102 (1960).
2. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. New York 1958, p. 106.
3. ROINE, P.: Sosiaalinen Aikakauskirja *48* (1954) Nos. 3—4; 5—6, pp. 1—24.
4. ROINE, P. and PEKKARINEN, M.: personal comminication.
5. ALSTAD, J., KJELBERG, A., OLSEN, A. F. and PAPPAS, A. C.: Svensk Kemisk Tidskr. *71* (1959) 717.
6. Strontium 90 in Human Diet in the United Kingdom in 1958. Agricultural Research Council, Radiobiological Laboratory, Report No. *1*, 1959.
7. Strontium 90 in Milk and Agricultural Materials in the United Kingdom 1958—1959. Agricultural Research Council, Radiobiological Laboratory, Report No. *2*, 1960.
8. MERTEN, D., Welt der Milch *13* (1959) 399—400.
9. KNOOP, E. and MERTEN, D.: Kieler Milchw. Forsch. Ber. *11* (1959) 255—259.
10. AARKROG, A. and LIPPERT, J.: Environmental Radioactivity at Risø, 1959. Risø Report No. *14*, June 1960.
11. BERGH, H., FINSTAD, G., LUND, L., OTTAR, B. and WIK, T.: Svensk Kem. Tidskrift *7* (1959) 695—716, p. 711.
12. ANDERSON, W., BURTON, L. K. and CROOKALL, J. O.: Nature *184* (1959) 89—91.
13. STEWART, N. G., OSMOND, R. G. D., CROOKS, R. N., FISCHER, E. M. and OWERS, M. J.: U. K. Atomic Energy Authority, Report AERE HP/R *2790*, 1959.
14. BRYANT, F. J., MORGAN, A. and SPICER, G. S.: AERE R 3030, Harwell 1959.
15. BRYANT F. J., CHAMBERLAIN, A. C., MORGAN, A. and SPICER, G. S.: AERE HP/R 2056, Harwell 1956.
16. HÄGGROTH, S.: personal communication.
17. MILBOURN, G. M., ELLIS, F. B. and RUSSEL, R. S.: J. Nucl. Energy *A 10* (1959) 116.
18. CRAGLE, R. G. and DEMOTT, B. J.: J. Dairy Sci. *42* (1959) 1367.
19. Unpublished data, Bundesforschungsanstalt für Milchwirtschaft Kiel.
20. MCNEILL, K. G. and TROJAN, O. A. D., Nature *186* (1960). 399—400.
21. KORHONEN, V. V., Sitzungsber. der Finnischen Akad. d. Wiss., 1945, 173—192.

Printed XI. 1960.

Annales Academiæ Scientiarum Fennicæ
Series A. II. Chemica

60. Dedicated to **A. I. VIRTANEN**, Biochemistry of Nitrogen. (535 pp.) 1955. **2300:—**
61. **JÄNNES, LAURI**, Studies on the terminal oxidative reaction patterns of the carbohydrate metabolism of Corynebacterium diphtheriae. (62 pp.) 1954 .... **250:—**
62. **PEKKARINEN, LAURI**, A kinetic study of the hydrolysis of some cis-trans isomeric aliphatic esters. (77 pp.) 1954 .... **300:—**
63. **LOUNAMAA, NIILO**, Determination of trace elements in tungsten oxide by spectrographic cathode layer and colorimetric methods. (93 pp.) 1955 **300:—**
64. **TOIVONEN, N. J., SILTANEN, EERO und OJALA, KALEVI**, Über die endo-exo-Isomerie bei Verbindungen des Bicyclo-[1.2.2]-heptansystems. IV. Die endo-exo-Isomeren 2-Methylnorborneole. (11 pp.) 1955 .... **100:—**
65. **TOMMILA, EERO, TIILIKAINEN, MATTI and VOIPIO, AARNO**, The influence of the solvent on reaction velocity. X. Solvolysis of alkyl halides in acetone-water mixtures. (26 pp.) 1955 .... **125:—**
66. **VEIJOLA, VÄINÖ**, Halogenation of toluene and cumene in the liquid phase. On the mechanism of the halogenation of hydrocarbons. (84 pp.) 1955 ...... **300:—**
67. **KENTTÄMAA, JOUKO**, The hydrolysis of aluminium chloride. (39 pp.) 1955 .... **175:—**
68. **LUMME, PAAVO**, Studies on the ionization and chelation of 2-, 6- and 8-quinolinecarboxylic acids. (72 pp.) 1955 .... **300:—**
69. **KUUSINEN, T.**, Über die endo-exo-Isomerie der Camphenolsäuren. (56 pp.) 1956 .... **250:—**
70. **ELORANTA, JORMA**, The solvent effect in the hydrolysis of α-bromosubstituted lower aliphatic acids and their salts. (54 pp.) 1956 .... **300:—**
71. **VILKKI, PANU**, Iodine in the Finnish diet and its relation to goitre incidence. (60 pp.) 1956 .... **300:—**
72. **TOIVONEN, HEIKKI**, Über das Verhalten der endo-exo-Isomeren Alkohole der bicyclo-[1.2.2]-heptanreihe gegen Salpetersäure. (49 pp.) 1956 .... **250:—**
73. **KOIVISTO, AULIS**, The solvolysis of organic anions and the saponification of simple esters. (44 pp.) 1956 .... **250:—**
74. **PULKKINEN, ERKKI**, Über die Dehydratation des α- und β-Fenchols. (86 pp.) 1956 .... **400:—**
75. **AEJMELAEUS, KAJ**, Some aspects of the molecular fractionation of cellulose nitrate. (63 pp.) 1956 .... **300:—**
76. **PERILÄ, OLAVI**, Saturated fatty acids of stem cells of birch (Betula verrucosa) and aspen (Populus tremula). (49 pp.) 1956 .... **250:—**
77. **AVELA, EERO**, Untersuchungen an einigen 2, 3-disubstituierten Camphanderivaten. (84 pp.) 1956........ **350:—**
78. **HIRSJÄRVI, PEKKA and TOMMILA, EERO**, The infrared spectra of sulphonyl chlorides and sulphonic acid esters. (20 pp.) 1957 .... **150:—**
79. **ELLFOLK, NILS**, Aspartase, a study on its nature and purification. (74 pp.) 1956 .... **350:—**
80. **PIHA, SAKARI**, Studies on the blood regeneration during progressive reticulocytosis due to repeated bleedings. (99 pp.) 1956........ **350:—**
81. **HIRSJÄRVI, PEKKA**, The endo-exo-isomer ratio in alcohol mixtures resulting from reductions of some bicyclo-[1.2.2]-heptanones by methods commonly used to prepare these alcohols. (16 pp.) 1957 .... **150:—**

VERTE!