NOBLE GAS INVESTIGATIONS OF LUNA–24 DRILL CORE SOIL SAMPLES

N. B. BHAI, J. T. PADIA, M. N. RAO *and* T. R. VENKATESAN
Physical Research Laboratory, Ahmedabad–380 009

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The elemental and isotopic composition of He, Ne, Ar, Kr and Xe are determined, in six samples from various depths of the Luna–24 drill core, by rare gas mass spectrometric techniques. Our data agree well with those determined by Bogard and Hirsch (1978) for a different set of six samples from the same drill core. The concentration profiles of trapped gases show that most of these soils are sub-mature and those of cosmogenic gases show that the irradiation history of this soil column is rather complex.

INTRODUCTION

SIX samples from different depths of the lunar soil column from *Mare Crisium,* sampled by the Luna–24 automatic space probe were provided by the U.S.S.R. Academy of Sciences to Indian scientists through the Indian National Science Academy. These samples are unique in lunar study because of the fact that they represent the only samples available for studies from regions east of 40°E lunar longitude. Sample aliquots from different depths of this drill core were supplied to us for the determination of elemental and isotopic composition of noble gases using sensitive mass spectrometric techniques.

The aim of this study is to furnish detailed stepwise heating data of He, Ne, Ar, Kr and Xe for these six samples from *Mare Crisium* so as to enable intercomparisons to be made between Luna–24 samples and regolith samples from other *Mare* sites of Apollo and Luna missions. Wherever possible, the authors compared their data with those for adjacent samples of this drill core, measured by Bogard and Hirsch (1978), hereafter referred to as BH. These rare gas data throw light on the maturity and the irradiation history of the regolith samples in *Mare Crisium.*

SAMPLE DESCRIPTION

Six samples 24087, 24123, 24148, 24163, 24179 and 24190 are taken from the respective depths 87, 123, 148, 163, 179 and 190 cms of the Luna–24 drill core. According to Barsukov *et al.* (1977), these samples belong to three major stratigraphic units II, III and IV. Bulk soil samples are used for mass spectrometric analysis and care is taken to see, as far as possible, that no preferential grain sizes are selected in our sample studies. The sample amounts used are : 24087—6.97 mg; 24123—4.15 mg; 24148—2.39 mg; 24163—7.72 mg; 24179—6.54 mg; 24190—5.89 mg.

EXPERIMENTAL

The given sample, wrapped in a pure Al foil, is dropped into a molybdenum crucible and is heated for 1 hour using R. F. induction heater. Water, evolved along with the

noble gases, is removed by passing through a trap at −70 °C. The dry gas is absorbed on charcoal trap (Ch 1), kept at liquid nitrogen temperature. At the completion of induction heating, additional time period (10 min) is allowed for the residual gases to be absorbed on charcoal. Then the heater section is valved off from Ch 1 and Ch 1 is raised to 120 °C. The released gases are allowed to react with hot Ti-Zr getter at 680 °C for a period of 40 min. Active gases are gettered while the rare gases remain unabsorbed. Purified noble gases Ar, Kr, and Xe are absorbed on another charcoal trap (Ch 2) kept at liquid nitrogen temperature for a period of 50 min. At this stage, additional gettering is provided by two Vacsorb getters. Then this Ch 2 section is valved off from the rest of the extraction system. The "floating" He and Ne are let into the mass spectrometer for isotopic analysis. After a short interval, Ch 2 is shut off from the mass spectrometer and Ar is selectively desorbed from Ch 2 at −90 °C for 50 min. Since Ar abundance is rather high to be handled by our system, it is allowed to expand into the total volume of the system. A small portion is retained in the Ch 2 section and the rest of Ar is pumped away. This expansion step is repeated once again. Then a portion of the Ar gas in the Ch 2 section is let into the mass spectrometer for analysis (Agrawal *et al.*, 1974; Gopalan *et al.*, 1977; Bhai *et al.*, 1978). The same splitting procedure is followed in the case of air spikes and blanks. After the separation of Ar, Kr is selectively desorbed from Ch 2 at −40 °C for 30 min and then let into the mass spectrometer for analysis. Later, Xe is released from Ch 2 at 120 °C for 30 min and is analysed. Each sample is preceded and followed by hot blanks. Air pipettes are run to determine mass discrimination, and sensitivities of the spectrometer. Typical values for base isotope sensitivities are ^{4}He—4.2×10^{-10}; ^{22}Ne—6.9×10^{-11}; ^{36}Ar—5.8×10^{-11}; ^{84}Kr—2.7×10^{-13}; ^{132}Xe—1.7×10^{-13}—all in units of cc STP/mv and typical blanks at 1600 °C are ^{4}He—5.9×10^{-7} ; ^{22}Ne—5.7×10^{-10} ; ^{36}Ar—16×10^{-10}; ^{84}Kr—1×10^{-12} and ^{132}Xe—3×10^{-12}—all in units of cc STP.

Results and Discussion

The elemental and isotopic composition of rare gases in the six bulk soil samples are given in Tables I to V. Even though the stepwise heating analyses are carried out for all the noble gases in these samples, we are at present giving the final data for the stepwise heating analyses in case of argon and krypton. In case of helium, neon and xenon only the total values could be given and the stepwise heating results will be reported elsewhere.

Helium — The ^{3}He and ^{4}He values are given in Table I. The cosmogenic ^{3}He values are calculated using the data obtained from the tentative stepwise heating runs of all the samples.

In the 24087 sample, the present authors have found 36.91×10^{-6} cc STP/g of ^{3}He and 7.71×10^{-2} cc STP/g of ^{4}He. In a nearby sample, 24077, BH determined a ^{3}He content 14.6×10^{-6} cc STP/g in the 45–90 micron fraction and 58.1×10^{-6} cc STP/g in less than 20 micron grain size fraction which could be considered to be in good agreement with our values for the bulk sample. Similarly, the ^{4}He content of our bulk 24087 could be considered to be intermediate between the values of the two size fractions, 45–90 micron fraction (3.35×10^{-2} cc

TABLE I

Concentrations of helium contents of Luna–24 drill core soil samples

Sample	^{3}He (10^{-6}cc STP/g)	^{4}He (10^{-2} cc STP/g)
24087	36.91	07.71
24123	—	—
24148	27.65	05.56
24163	44.71	10.37
24179	15.24	03.29
24190	39.55	08.91

STP/g) and the less than 20 micron fraction (16.5×10^{-2} cc STP/g). The error associated in the contents of ^{3}He and ^{4}He is generally about 15 per cent. Comparing another sample namely 24148, studied by the present authors with a nearby sample 24149 studied by BH, the formers found 27.65×10^{-6} cc STP/g for ^{3}He in the bulk soil whereas BH have found 12.3×10^{-6} cc STP/g in the 45–90 micron fraction and 52.3×10^{-6} cc STP/g in the less than 20 micron fraction in case of ^{3}He. Here also, the values obtained for the bulk soils in the present case are intermediate between the values obtained for various size fractions by BH and this is the case with other soils also.

The amount of ^{4}He present in our samples lie within a factor 2 of the values of BH. Considering the ^{4}He contents measured in other Apollo drill cores, 60010–60009 (Bogard & Hirsch, 1976) a factor of 2 variation in ^{4}He contents could not be considered to be significant. Relative to other five samples, 24163 showed the highest contents of ^{4}He (even though it showed the smallest amounts of cosmogenic ^{3}He). The release pattern of ^{4}He in all the six samples of Luna–24 as a function of temperature is shown in Fig. 1.

Here we assume that helium is a two component system, consisting of solar wind He (with a 3/4 ratio of 4.26×10^{-4}) and spallogenic He. As a first order approximation, radiogenic He is not considered. Using the measured values, the spallogenic ^{3}He is calculated in the temperature fractions. The errors in the contents of ^3He_c are on the average estimated to be within 20–25 per cent. In the case of 24148 bulk soil the ^3He_c deduced by us is about 435×10^{-8} cc STP/g whereas BH have found $(316 \pm 56) \times 10^{-8}$ cc STP /g for 24149 in their grain size fraction. Within the limits of experimental errors, these values could be considered to be in agreement. In the case of samples from lower part of the core, 24179 and 24190 yielded ^3He_c contents of about 140×10^{-8} cc STP/g, while the grain size fractions from closeby samples 24182 and 24210 of BH yielded 197 and 172×10^{-8} cc STP/g respectively. The lowest value of ^3He_c is obtained for 24163 while BH obtained the lowest value for ^3He_c in case of 24174 sample. In spite of the general agreement between our values and those of BH, it should be pointed out that some of the variations may be attributed to minor losses of helium in soil samples on the lunar surface. The ^3He_c concentration profile observed in the six Luna–24 samples from our studies is similar to that found by BH from six other samples from Luna-24 drill core.

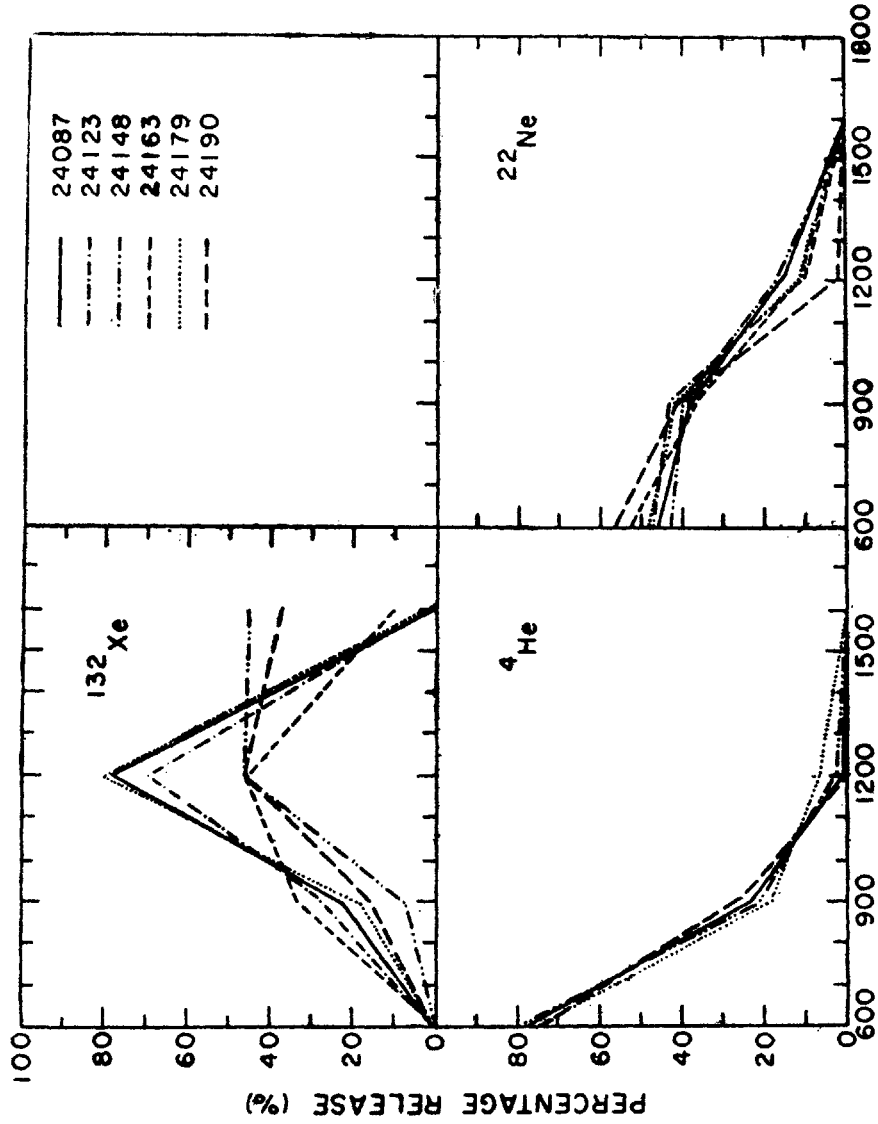

FIG. 1. Release pattern of trapped helium, neon and xenon as a function of temperature in six Luna–24 drill core bulk soil samples as determined by step-wise heating experiments.

Neon — Of all the noble gases under consideration, cosmogenic neon seems to provide important and reliable clues to the depositional history of several Apollo as well as Luna drill cores. This is because the production rates of cosmogenic neon as a function of depth are well known; the target element concentrations are always high and uniform; and finally the diffusion losses are small compared to helium. Bogard and Hirsch (1978, 1976) have studied several Apollo drill cores and have found that $^{21}Ne_c$ could be considered to be a reliable parameter for studying the depositional chronology of these lunar drill cores.

The $^{22}Ne_t$ content in the 24087 bulk soil sample given in Table II is 9.01×10^{-5} cc STP/g whereas BH have found 6.72×10^{-5} cc STP/g and 29.4×10^{-5} cc STP/g in 45–90 micron and less than 20 micron fractions respectively for a nearby sample 24077. Our bulk soil value, being intermediate, seems to compare favourably with that of BH. Similarly our results on 24148 show that bulk sample yields a ^{22}Ne content of 7.74×10^{-5} cc STP/g. For a nearby sample of the drill core, 24149, BH have found 5.68×10^{-5} cc STP/g for the 45–90 micron and 23.6×10^{-5} cc STP/g for less than 20 micron fractions respectively. The ^{22}Ne values for our six Luna-24 samples, in general, do not show major differences from those of BH and indicate that these values compare favourably with the neon contents of other mature soils. Only in the case of 24163 the ^{22}Ne content is higher than all the other samples. The values of ^{22}Ne in several samples (45–90 micron fractions) from different depths of the Apollo 16 drill core 60010–60009 (Bogard & Hirsch, 1976) vary between $6–7 \times 10^{-5}$ cc STP/g which compare favourably with our ^{22}Ne data given in Table II. The release pattern of ^{22}Ne as a function of temperature in six samples of Luna-24 drill core is shown in Fig. 1.

TABLE II

Concentration of neon contents of six Luna-24 drill core soil samples

Sample	20/22	21/22	^{22}Ne (10^{-5}cc STP/g)
24087	12.46 ± 0.12	0.040 ± 0.001	7.63 ± 0.8
24123	12.76 ± 0.13	0.037 ± 0.001	7.38 ± 0.7
24148	12.25 ± 0.12	0.037 ± 0.001	7.74 ± 0.
24163	12.49 ± 0.13	0.035 ± 0.001	8.45 ± 0.9
24179	12.51 ± 0.13	0.037 ± 0.001	7.96 ± 0.8
24190	12.77 ± 0.13	0.038 ± 0.001	7.25 ± 0.7

The cosmogenic neon data for the six Luna-24 drill core samples are calculated assuming that the measured neon is a mixture of two components—solar wind and GCR spallation. For the solar wind, 20/22 = 12.8 and 21/22 = 0.032 (Eberhardt *et al.*, 1972) and for GCR spallation 20/22 = 0.90 and 21/22 = 0.96 are used here (Kirsten *et al.*, 1972). In the case of 24087, the present authors have calculated a $^{21}Ne_c$ content of 76.04×10^{-8} cc STP/g in the bulk soil data and BH have found 84.7×10^{-8} cc STP/g for the 45–90 micron fraction from the nearby 24077 sample. Even though our 24123 shows $^{21}Ne_c$ content similar to 24109 of BH, our 24148 sample shows somewhat less $^{21}Ne_c$ compared to the 45–90 micron size

fraction of 24149. As there is no reason to suspect a preferential loss of neon in our sample compared to that of BH, the authors attribute this decrease of $^{21}Ne_c$ by about 25 per cent in our sample 24148 compared to that of 24149 (BH) to mineralogical differences associated with these two samples. Also, in this context, it is necessary to point out that the trapped He, Ne and Ar measured in our Luna–24 samples show that there are no preferentially large grain sizes in our samples. The average grain sizes of our samples seem to be less than 150 microns in general, as found from the optical microscopic observations. In case of 24163, the lowest amount of $^{21}Ne_c$ i.e., 33×10^{-8} cc STP/g is observed whereas in the nearby sample 24174, BH have found 38.4×10^{-8} cc STP/g in the 150–250 micron fraction and 57.4×10^{-8} cc STP/g in the 45–90 micron fraction. The drill core samples below 24163, (163 cm depth) i.e., 24179 and 24190 and particularly 24190, seem to show an increasing trend in the $^{21}Ne_c$ content. A similar behaviour is observed by BH in the case of 24182 and 24210 samples.

Argon — The elemental and isotopic composition of Ar for six Luna–24 samples determined by the step-wise heating analyses are given in Table III. Major portion of ^{36}Ar is released from these samples at about 1200 °C and only very small amounts of ^{36}Ar could be found in the 1600 °C temperature step. In the case of 24087 sample, the 600 °C and 900 °C temperature fractions yielded 38/36 ratios of 0.178 and 0.179 respectively. Also, in case of 24123 and 24163, the 600 °C temperature fractions resulted in low 38/36 ratios compared to the solar wind value of 0.187. Such phenomena are not observed in other samples 24148, 24179 and 24190. Further work is in progress to understand these differences.

The higher temperature fractions in all these samples generally showed 38/36 ratios higher than 0.187, indicating the presence of cosmogenic argon. The cosmogenic argon is calculated by the following equation :

$$^{38}Ar_c = 1.52 \times (36_m) \frac{(38/36)_m - (38/36)_t}{(38/36)_c - (38/36)_t}$$

where $(38/36)_t = 0.187$; $(38/36)_c = 0.6$ and m, c and t refer to measured, cosmogenic and trapped values. In general, about 30 per cent errors are associated with the calculated $^{38}Ar_c$ contents of these samples. These errors are partly due to the argon splitting procedure employed by us as mentioned earlier. Maximum precautions were taken to reduce the relative discrepancies by reproducing the experimental conditions between the six Luna–24 samples. However, occasionally, difficulties crept in and the corresponding temperature fractions, in Table III, are denoted by a star. The $^{38}Ar_c$ content of 24087 sample was estimated to be 74.5×10^{-8} cc STP/g and a corresponding value for 24077 was not available from the results given by BH. Again in case of 24148 sample, the authors have found $(75 \pm 24) \times 10^{-8}$ cc STP/g whereas the value given by BH for 24149 sample is $(40 \pm 7) \times 10^{-8}$ cc STP/g. However, for the 24163 and 24179 there are fairly high values of $^{38}Ar_c$ even though the value of 24163 is low compared to the other Luna–24 samples. This discrepancy between our 24163 value and that of BH for 24174 may be partly due to the argon splitting procedure discussed earlier. Finally, samples 24190 in present case and 24210 in case of BH show the lowest $^{38}Ar_c$ contents.

TABLE III

Concentration and isotopic composition of argon in Luna–24 soil samples

Sample No.	Temperature (°C)	38/36	40/36	^{36}Ar (10^{-8} cc STP/g)
24087	600	0.178 ± 0.010	2.58 ± 0.038	08.60 ± 0.900
	900	0.179 ± 0.010	0.42 ± 0.004	11.51 ± 2.2*
	1200	0.190 ± 0.003	0.65 ± 0.007	25.35 ± 5.800
	1600	0.227 ± 0.005	—	00.080 ± 0.002
	Total	0.184 ± 0.004	0.96 ±0.012	45.54 ± 9.600
24123	600	0.179 ± 0.003	2.61 ± 0.370	01.17 ±0.180
	900	0.190 ± 0.003	0.46 ± 0.004	15.67 ± 1.700
	1200	0.190 ± 0.003	0.60 ± 0.006	07.13 ± 1.750
	1600	0.209 ± 0.004	—	01.10 ± 0.010
	Total	0.190 ± 0.005	0.58 ± 0.006	24.98 ±5.400
24148	600	0.185 ± 0.003	—	02.21 ± 0.250
	900	0.190 ± 0.003	0.24 ± 0.002	14.84 ± 1.500
	1200	0.189 ± 0.003	0.29 ± 0.003	07.08 ± 1.750
	1600	0.194 ± 0.004	—	00.30 ± 0.040
	Total	0.189 ± 0.003	0.23 ± 0.002	24.43 ± 5.000
24163	600	0.177 ± 0.010	2.37 ± 0.038	02.35 ± 0.250
	900	0.187 ± 0.003	2.56 ± 0.039	24.05 ± 6.450
	1200	0.191 ± 0.003	0.28 ± 0.003	08.93 ± 0.950
	1600	0.222 ± 0.005	—	00.05 ± 0.020
	Total	0.187 ± 0.004	0.197 ± 0.040	35.38 ± 9.500
24179	600	0.185 ± 0.004	—	00.87 ± 0.220
	900	0.187 ± 0.003	0.36 ± 0.004	16.46 ± 3.800
	1200	0.193 ± 0.003	0.29 ± 0.003	07.57 ± 1.600
	1600	0.203 ± 0.005	—	00.07 ± 0.030
	Total	0.189 ± 0.004	0.33 ± 0.003	24.97 ± 5.200
24190	600	0.186 ± 0.004	5.37 ± 0.110	00.52 ± 0.160
	900	0.189 ± 0.003	0.78 ± 0.008	13.75 ± 2.800
	1200	0.190 ± 0.003	—	07.45 ± 0.300
	1600	0.194 ± 0.005	6.42 ± 0.8*	00.68 ± 0.130
	Total	0.189 ± 0.004	0.80 ± 0.010	22.40 ± 4.500

*Large error seems to be associated with these values.

The 40/36 ratios in the 600 °C temperature steps of all these samples are about 2.4 (5.4 in case of 24190). This ratio is suggestive of surface—correlated (solar wind) Ar being associated with this temperature. In case of 900 °C and 1200 °C temperature fractions, this ratio varies mostly from 0.3 to 0.7. Bogard and Hirsch (1976) have found that five soils from the Apollo–16 drill core 16009 have 40/36 ratios 1.64–1.89 and Heymann *et al.* (1975) have found that surface and near-surface soil from Apollo–16 site show 40/36 ratios varying from 0.4 to 4. These low 40/36 ratios may be due to the lower abundance of radiogenic ^{40}Ar in the volume correlated component present in the relatively retentive sites, which in turn may be due to the

lower abundance of K-rich component (KREEP) in Luna–24 soils (Ma & Schmitt, 1977).

The stepwise heating data given in Table III, reveal that more ^{36}Ar is released in the 900 °C temperature fraction compared to 600 °C or 1200 °C temperature fractions. However, in the 1600 °C temperature fractions, only nominal amounts of ^{36}Ar (less than 1%) are released. Our ^{36}Ar contents for 24087 i.e., 40.5×10^{-5} cc STP/g and for 24148 i.e., 24.43×10^{-5} cc STP/g seem to compare favourably with the ^{36}Ar values of 24077 and 24148 given by BH. Again 24163 sample showed relatively large amount of ^{36}Ar when compared to other samples, even though it yielded the lowest amount of $^{38}Ar_c$. The ^{36}Ar contents of these samples compare well with those of several sub-mature lunar soils.

Krypton and Xenon — The stepwise heating data of krypton in the six Luna–24 samples are given in Table IV. The krypton data seem to be, in general, consistent with the assumption that they are a mixture of solar wind and spallogenic krypton. In most of the samples spallogenic krypton seems to be present in the 900 °C and 1200 °C temperature fractions. Major portion of the trapped krypton is released in the 1200 °C temperature step. Our total ^{84}Kr contents agree well with those of BH.

The total xenon contents for these samples are given in Table V and the release pattern of ^{132}Xe as a function of temperature is shown in Fig. 1. The stepwise heating data are being processed and they will be reported elsewhere.

Samples 24087, 24123 and 24179 showed ^{132}Xe release patterns very similar to each other, with about 70–80 per cent of ^{132}Xe released in the 1200 °C temperature fraction. However, samples 24148, 24163 and 24179 showed xenon release patterns different from the above samples.

In the topmost surface sample 24087, the authors have determined a ^{132}Xe content of 2.24×10^{-8} cc STP/g whereas BH have determined in 24077 (close to our sample) a ^{132}Xe content of 1.33×10^{-8} and 5.69×10^{-8} cc STP/g respectively in the 45–90 micron and less than 20 micron size fractions. Our value seems to be intermediate to those of BH. In the case of 24148 bulk sample, a ^{132}Xe content of 3.55×10^{-8} cc STP/g has been measured whereas BH have found for the same isotope 0.93×10^{-8} cc STP/g in the 45–90 micron size fraction and 3.68×10^{-8} cc STP/g in the less than 20 micron fraction. BH finds a decreasing trend in the ^{132}Xe in the samples 24174, 24182 and 24210. Our data for the 24163 and 24179 and 24190 do not show this decreasing trend. The total $^{132}Xe_t$ contents of these samples compare favourably with those of sub-mature soils from Apollo missions (Agrawal *et al.*, 1974).

The isotopic composition of xenon released in different temperature fractions is assumed to be a mixture of trapped solar wind and spallation xenon. As the Ba + REE contents of these Luna–24 samples are about 60 ppm (Ma & Schmitt, 1977; Nyquist *et al.*, 1977), the amount of GCR spallation xenon is small and it is rather difficult to accurately evaluate the spallation ^{126}Xe in the total melting runs. In this study, ^{128}Xe is chosen as indicator isotope for spallation xenon. Stepwise heating techniques are ideally suited to resolve the small isotopic excesses accurately. Presently resolution of multicomponent xenon mixtures in Luna–24 samples are in progress. These results are likely to provide a better picture of the spallation xenon component in these samples.

TABLE IV

Concentration and isotopic composition of krypton in Luna-24 soil samples

Sample No.	Temperature (°C)	80/84	82/84	83/84	86/84	(84) (10^{-8}ccSTP/g)
24087	600	0.0237 ± 0.0009	0.1618 ± 0.0049	0.1496 ± 0.0045	0.3341 ± 0.0067	0.184 ± 0.037
	900	0.0426 ± 0.0021	0.1880 ± 0.0056	0.1823 ± 0.0055	0.2776 ± 0.0115	3.978 ± 0.597
	1200	0.0432 ± 0.0018	0.2019 ± 0.0040	0.2026 ± 0.0041	0.2973 ± 0.0089	12.012 ± 1.300
	1600	0.0450 ± 0.0023	0.1490 ± 0.0045	0.1056 ± 0.0032	0.2360 ± 0.0071	0.356 ± 0.090
	Total	0.0429 ± 0.0020	0.1970 ± 0.0060	0.1950 ± 0.0060	0.2916 ± 0.0090	16.530 ± 3.300
24123	600	0.0501 ± 0.0020	0.1948 ± 0.0058	0.1887 ± 0.0057	0.3264 ± 0.0065	0.39 ± 0.080
	900	0.0396 ± 0.0015	0.1923 ± 0.0058	0.2021 ± 0.0061	0.3139 ± 0.0063	9.48 ± 0.950
	1200	0.0394 ± 0.0019	0.1936 ± 0.0059	0.2021 ± 0.0061	0.3251 ± 0.0065	9.05 ± 0.920
	1600	0.0485 ± 0.0029	0.2189 ± 0.0066	0.1974 ± 0.0059	0.3465 ± 0.0140	0.39 ± 0.080
	Total	0.0389 ± 0.0023	0.1935 ± 0.0058	0.2011 ± 0.0060	0.3201 ± 0.0065	19.31 ± 2.900
24148	900	0.0434 ± 0.0022	0.1974 ± 0.0059	0.1987 ± 0.0060	0.2951 ± 0.0071	6.77 ± 1.100
	1200	0.0413 ± 0.0021	0.2054 ± 0.0062	0.2080 ± 0.0063	0.3058 ± 0.0068	7.46 ± 0.750
	1600	0.0434 ± 0.0024	0.1817 ± 0.0055	0.1828 ± 0.0061	0.2750 ± 0.0075	4.12 ± 0.620
	Total	0.0425 ± 0.0017	0.1971 ± 0.0060	0.1989 ± 0.0060	0.2949 ± 0.0088	18.35 ± 2.700
24163	900	0.0389 ± 0.0016	0.1995 ± 0.0059	0.1979 ± 0.0060	0.3007 ± 0.0075	2.18 ± 0.450
	1200	0.0431 ± 0.0017	0.1995 ± 0.0061	0.2019 ± 0.0056	0.2986 ± 0.0073	13.71 ± 1.650
	1600	0.0396 ± 0.0016	0.1994 ± 0.0062	0.1974 ± 0.0059	0.2966 ± 0.0071	11.43 ± 2.300
	Total	0.0413 ± 0.0017	0.1995 ± 0.0060	0.1997 ± 0.0060	0.2979 ± 0.0075	27.32 ± 5.500
24179	900	0.0395 ± 0.0016	0.1930 ± 0.0057	0.1912 ± 0.0056	0.2936 ± 0.0070	7.89 ± 1.180
	1200	0.0421 ± 0.0018	0.2054 ± 0.0061	0.2061 ± 0.0059	0.3146 ± 0.0072	14.22 ± 1.710
	1600	0.0353 ± 0.0015	0.1876 ± 0.0054	0.1893 ± 0.0061	0.2766 ± 0.0085	0.30 ± 0.070
	Total	0.0411 ± 0.0018	0.2008 ± 0.0060	0.2006 ± 0.0060	0.3060 ± 0.0075	22.41 ± 4.500
24190	600	0.0554 ± 0.0021	0.1993 ± 0.0063	0.2022 ± 0.0059	0.3060 ± 0.0065	4.68 ± 0.950
	900	0.0451 ± 0.0019	0.2015 ± 0.0058	0.2070 ± 0.0060	0.3091 ± 0.0068	11.72 ± 1.760
	1200	0.0393 ± 0.0017	0.1694 ± 0.0068	0.1273 ± 0.0045	0.2361 ± 0.0085	2.56 ± 0.600
	1600	—	—	—	—	—
	Total	0.0467 ± 0.0019	0.1966 ± 0.0069	0.1951 ± 0.0063	0.2985 ± 0.0075	18.96 ± 3.800

TABLE V

Concentration of xenon contents of six Luna-24 drill core soil samples

Sample	124/132	126/132	128/132	129/132	130/132	131/132	134/132	136/132	^{128}Xe ($\times 10^{-12}$ cc STP/g)
24087	0.0069 ±0.00018	0.0072 ±0.00018	0.0868 ±0.0017	1.0483 ±0.0207	0.1682 ±0.0033	0.8206 ±0.0165	0.3601 ±0.0072	0.3029 ±0.0060	22383.8 ± 2238
24123	0.0057 ±0.00014	0.0057 ±0.00014	0.0854 ±0.0016	1.0427 ±0.0209	0.1651 ±0.0033	0.8319 ±0.0166	0.3715 ±0.0074	0.3004 ±0.0060	24230 ± 2423
24148	0.0072 ±0.00018	0.0078 ±0.00020	0.0857 ±0.0017	1.0695 ±0.0214	0.1604 ±0.0033	0.8383 ±0.0168	0.3730 ±0.0074	0.3090 ±0.0061	35544.4 ± 3554
24163	0.0053 ±0.00014	0.0058 ±0.00014	0.0837 ±0.0016	1.0463 ±0.0200	0.1625 ±0.0032	0.8151 ±0.0163	0.3671 ±0.0072	0.3006 ±0.0060	28271.0 ± 2827
24179	0.0056 ±0.00014	0.0055 ±0.00014	0.0853 ±0.0017	1.0271 ±0.0204	0.1580 ±0.0032	0.8179 ±0.0164	0.3730 ±0.0074	0.3120 ±0.0062	26609.1 ± 2661
24190	0.0075 ±0.00019	0.0077 ±0.00019	0.0851 ±0.0016	1.0689 ±0.0214	0.1619 ±0.0031	0.8275 ±0.0165	0.3762 ±0.0075	0.2975 ±0.0061	25795.5 ± 2580

Cosmogenic Gases and Clues to the Depositional History of Luna–24 Drill Core— The spallogenic $^{3}He_c$, $^{21}Ne_c$ and $^{38}Ar_c$ data from the six samples of Luna–24 drill core studied here seem to indicate that the contents of the cosmogenic isotopes in this drill core cannot be explained by a simple *in-situ* irradiation of this (about 190 cm) regolith column. There is evidence for the pre-irradiation of these soil samples before they are deposited at the Luna–24 drill core site. The $^{3}He_c$ and $^{21}Ne_c$ data discussed above indicate that samples 24163 and probably 24179 are relatively less-irradiated compared to other samples.

The experimental data for the first 3 samples from the top seem to partially fit to the Reedy-Arnold model (1972). However, samples below these depths ex. 24190 definitely show large excess of cosmogenic gases, bearing little relationship to the upper samples of the core, from the view point of *in-situ* regolith deposition.

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