Performance of the NGX High-Resolution Multiple Collector Noble Gas Mass Spectrometer

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Abstract  This paper describes the design, setup, and performance of a new analytical system installed at Lancaster University, UK, to determine noble gas isotopes in gas samples using an NGX high-resolution multiple collector noble gas mass spectrometer. The fixed position Faraday cups are configured to simultaneously measure all nine Xe isotopes whilst permitting all other noble gases, such as He, to be analyzed in peak jumping mode. The stability, sensitivity, and reproducibility of the measurements using this new noble gas analytical system were examined by repeating runs of atmospheric air. Reproducibility of the measurements obtained from 90 and 73 air standard runs are 4.2% and 0.4% for 3He/4He and 21Ne/30Ne, respectively. There is no significant difference in the 40Ar/36Ar ratio measurements with various 40Ar abundances, suggesting good sensitivity and pressure linearity of the NGX instrument. The standard errors for 124Xe/130Xe, 126Xe/130Xe, 128Xe/130Xe, 129Xe/130Xe, 131Xe/130Xe, 132Xe/130Xe, 134Xe/130Xe and 136Xe/130Xe in 46 air measurements are 0.782%, 0.804%, 0.053%, 0.029%, 0.029%, 0.029%, 0.030%, and 0.031%, respectively. In contrast, the corresponding reference values from Basford et al. (1973) are 0.342%, 0.505%, 0.148%, 0.139%, 0.153%, 0.076%, 0.156%, and 0.138%, respectively. This suggests that multicollection measurements of Xe isotopes on Faraday cups using the NGX have higher precision than the previous results except for 124Xe and 126Xe, where low abundances affect the measurement precision. Compared to traditional peak jumping single-collector mass spectrometers, the NGX has significantly decreased analytical time in Xe analysis by allowing simultaneous measurements of all isotopes. As a consequence, high analytical precision can be achieved.

Plain Language Summary  Noble gases are regarded as ideal tracers in many research areas of Earth and environmental sciences. They are useful in understanding subsurface processes associated with crustal fluid systems, crust-mantle interactions, and the origin and evolution of planets. However, expansion in our application of these tools requires continuous improvements in analytical techniques via instrument development. In this paper, we describe a newly designed mass spectrometer system to analyze noble gas isotopes with significantly improved precision. The NGX noble gas mass spectrometer reported in this manuscript is the first high-sensitivity multicollector noble gas mass spectrometer specifically designed for the simultaneous measurements of all nine Xe isotopes. It enables the use of Xe isotopes together with other noble gases in many research topics, such as tracing subsurface pollution processes and investigating the history of the Earth’s evolution over geological time. This is a step forward in the analytical capacity for the research field of isotope geochemistry.

1. Introduction

Noble gases, namely helium (He), neon (Ne), argon (Ar), krypton (Kr), and xenon (Xe), have proven to be powerful tools for understanding geological systems due to their properties of low abundance and chemical inertness (Ozima & Podosek, 2002; Porcelli et al., 2002). For example, noble gases, such as 3He and 4He, can provide new insights into the rates and sources of groundwater recharge, residence times, and flow dynamics in groundwater studies (Beyerle et al., 2000; Ingram et al., 2007; Zhou & Ballentine, 2006; Zhou et al., 2005). Noble gas isotopic and abundance measurements can also be used to constrain the origin of CO₂ and its interaction with the groundwater system in the subsurface, which improves our understanding of the long-term storage potential of CO₂ in natural geological reservoirs (Giffin et al., 2008; Karolytę et al., 2019; Zhou et al., 2012). In addition, extensive energy production and exploration worldwide have raised concerns over drinking water contamination and other environmental risks. Noble gases are unaffected by
inorganic or organic chemical reactions and are only sensitive to physical processes, such as multiphase interactions (e.g., mixing, diffusion, and phase partitioning), which make them ideal tracers for investigating the origin and evolution of subsurface fluids in oil and gas systems (Hilton, 1996; Hunt et al., 2012; Pinti & Marty, 1995; Prinzhofer & Battani, 2003; Roulleau et al., 2016). By applying noble gas isotopes in tracing elevated hydrocarbon concentrations in drinking water systems near natural gas wells, the environmental and economic sustainability of shale-gas extraction can be evaluated (Darrah et al., 2014, 2015).

Noble gas studies have also played an essential role in constraining mantle degassing (Gilfillan et al., 2019), investigating earthquakes and volcanic activities (Italiano et al., 2001; Tedesco et al., 1998), reconstructing paleoclimate conditions (Andrews & Lee, 1979; Castro & Goblet, 2003; Mazor, 1972), and interpreting ocean circulation histories (Chavrit et al., 2016).

Due to the low abundances of noble gases on Earth, as well as the analytical challenges, the stability, sensitivity, and reproducibility of a noble gas analytical system must be carefully examined when running samples. Several studies have described and discussed noble gas analytical systems in various labs using Quadrupole Mass Spectrometer (QMS) or magnetic deflection mass spectrometers, for example, VG-5400 (Beyerle et al., 2000; Jicha et al., 2016; Ma et al., 2015; Mark et al., 2009; Sano et al., 1982; Stanley et al., 2009). Multicollector noble gas mass spectrometers have recently become widely used due to significant improvements in measurement precision and accuracy. Jicha et al. (2016) showed that a multicollector mass spectrometer used for 40Ar/39Ar dating improved nearly an order of magnitude greater in analytical precision than traditional single-collector instruments. In addition to improvements in precision, the nitrogen isotopes measured by a static type collection noble gas mass spectrometer (VG-5400) have shown that this approach can minimize sample depletion and memory effects in flight tubes, improving both measurement statistics and accuracy (Barry et al., 2012). However, previous reports only focused on the multicollection of relatively lighter and more abundant noble gas isotopes, such as Ar. Instrument development for heavier noble gas isotopes (e.g., Xe) as tracers in the earth sciences is rare.

This paper describes a newly designed mass spectrometer analytical system for the extraction, purification, separation, and determination of noble gas isotopes, including their abundances and isotopic ratios. The high-resolution multiple collector NGX noble gas mass spectrometer used in this study is manufactured by Isotopx, UK. It is the first high-sensitivity multicollector noble gas mass spectrometer that has been specifically designed for the simultaneous collection of all nine Xe isotopes. We present in this paper procedures for noble gas elemental and isotopic analysis, measurement accuracy and precision, reproducibility, and sensitivity using the NGX system, particularly the performance of the simultaneous collection of nine isotopes of Xe on nine different Faraday collectors, which is described in detail.

2. Design of the NGX High-Resolution Multiple Collector Noble Gas Mass Spectrometer

An NGX noble gas mass spectrometer manufactured by Isotopx, Ltd. has recently been installed at the Subsurface Fluid Isotope Geochemistry Laboratory at Lancaster University, UK, for noble gas abundance and isotopic ratio determination (Figure 1). This multicollector mass spectrometer is newly designed and fully automated with high precision in isotope ratio measurement. The NGX is equipped with a high-sensitivity “Nier” type gas source and a low volume static vacuum analyzer. It is characterized by a series of fixed collectors (mix of Faradays and Multiplier) that can be configured during the design and manufacture process. The collector array of the NGX at Lancaster University includes nine Faraday cups in fixed positions (H1-H4, Ax, and L1-L4) and one ion counting multiplier (L6). The Faraday cups are denoted as H1, H2, H3, H4, Ax, L1, L2, L3, and L4. H values represent high mass cups, Ax represents the axial cup, and L values represent low mass cups. L6 denotes the ion counting multiplier on the low mass side of the array to count noble gas isotopes on small samples. These fixed position Faraday cups are configured to simultaneously measure all nine Xe isotopes (Figure 1) whilst permitting all other noble gas isotopes such as 3He to be analyzed in peak jumping mode. The NGX operates at an accelerating voltage of up to 8 kV, ensuring high-sensitivity and enhanced mass resolution (resolution >600). This resolution is sufficient to resolve hydrocarbons and many other interfering species from the center of the peaks of interest. The NGX uses a large, 27 cm radius air-cooled electromagnet with an effective radius of 54 cm, which routinely operates at
up to m/q 270. NGX's magnet is fitted with an exit lens or “pole piece” capable of rotating the focal plane at the collector. Thereby, the collector focal plane becomes perpendicular to the ion trajectory (Figure S1 in Supporting Information S1). This design helps lower the collector volume and improve collector efficiency.

The Faraday amplifiers of the NGX can be fitted with either $10^{11}$ or $10^{12}$ gain resistors. The $10^{12}$ amplifiers are excellent in lowering down noise levels. The noise tests for $10^{11}$ and $10^{12}$ gain resistors mounted in the same amplifier over integration periods of 1–300 s are presented in Table S1 of Supporting Information S1. The $10^{12}$ Omega resistors have a relatively lower noise level by a factor of 1.5 compared to the $10^{11}$ Omega resistors over integration periods ranging from 1 to 40 s. The better performance in lowering down noise level makes the $10^{12}$ Omega amplifier an ideal option for measuring small amounts of noble gas samples where the ion beam intensity is relatively low.

There is a bespoke software package running with the NGX mass spectrometer. It consists of NGX-Inlet Prep Bench Control, NGX Instrument Control and Iconia, which enables the operation of data acquisition, processing and system hardware unit control. Detail of the NGX software package is included in Supporting Information S1.

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**Figure 1.** NGX multicollector noble gas mass spectrometer comprises an ion source, an analyzer (magnet), and 10 collectors (Faraday cups H1-H4, Ax, and L1-L4; multiplier L6). The diagram shows beam separation and focusing of all nine Xe isotopes into each single Faraday collector. The multiplier L6 is used for detecting noble gas isotopes with low abundances, such as $^3$He (modified from Mark et al., 2009).
3. Experimental Procedure

3.1. Gas Extraction

In the laboratory at Lancaster University, the sample copper tubes are mounted on an all-metal ultra-high vacuum (UHV) system designed specifically for extraction, purification, and separation of noble gases (Figure 2). Once the sample is connected, the gas is released from the copper tube to the line and flows into

**Figure 2.** Schematic diagram of the fully automated all-metal noble gas extraction line at Lancaster University (modified from Li et al. [2020]).
the M7-M8-M9 section, where a Baratron gauge (20 mTorr–10,000 Torr) is fitted to measure and record the gas pressure. The M7-M8-M9 section is used to store the sample gas for subsequent analysis. The M4-M5-M6-M7 section can dilute the gas sample with two mounted pumps if a high amount of gas is monitored in the M7-M8-M9 section. If required, the M2-M3-M4 section serves as a “backup” for adding more gas samples to the M7-M8-M9 section. The volumes of the M2-M3-M4, M4-M5-M6-M7, and M7-M8-M9 sections are 33.5, 58.3, and 69.4 cm$^3$, respectively.

3.2. Gas Purification

Once the gas sample is isolated in the M7-M8-M9 section and the pressure has been determined using the Baratron monometer on the preparation line, the gas sample is ready for the next step of gas purification to mainly introduce noble gases into the mass spectrometer for the determination of noble gas abundances and isotopic ratios. Generally, the purification process takes advantage of the non-reactive property of the noble gases by chemically removing active species from the extracted gas sample. The purification process can be achieved by two steps described below using a furnace and two gas getters.

Most natural gas samples are mixtures of different gases, such as CH$_4$, CO$_2$, N$_2$, H$_2$, and O$_2$. The gas is first introduced into a pre-heated Ti-sponge furnace at 800 °C for 20 min. Then the furnace is removed to leave the Ti-sponge to cool down to room temperature for 20 min. The external water bath can assist in cooling down the Ti-sponge when needed. Then the sample is subsequently expanded into the preparation line fitted with two GP-50 Ti-Zr alloy gas getters (SAES Getters) at different temperatures for 15 min. One getter close to A2 is held at 350°C while the other close to A7 remains at room temperature. As a result, by using a combination of a titanium sponge and two GP-50 getters, the majority of reactive gases (hydrocarbons, H$_2$S, CO, and CO$_2$, etc.) in the sample can be broken down and removed from the system with no effect on noble gases.

3.3. Gas Separation

Due to gas interferences (e.g., HD on $^3$He, $^{40}$Ar$^{++}$ on $^{20}$Ne, and $^{44}$CO$_2^{++}$ on $^{22}$Ne), noble gas concentrations and isotopic ratios cannot be measured when they are in a mixture. See Text S2 in Supporting Information S1 for detail of resolving peaks. Also, there is usually several orders of magnitude difference between noble gas concentrations in air standards and actual gas samples. Therefore, after removing reactive gases, the mixture of “pure” noble gases (He, Ne, Ar, Kr, and Xe) needs to be separated into their respective noble gas species before measurement, which can be achieved using a series of cryogenic traps. Initially, heavier noble gases (Ar, Kr, and Xe) are trapped onto an activated charcoal cold finger and immersed into an external liquid nitrogen bath for 15 min. The remaining gases (He and Ne) are absorbed onto a cryogenic cold trap (Janis), which was pre-cooled at 10 K for 15 min. After all gases are trapped onto cold traps, the temperature on the cryogenic trap is raised to 50 K for 15 min to release He into the line. After several cycles of expansion and dilution processes, “pure” He is admitted into the NGX noble gas mass spectrometer for He abundance and isotope determination. After He measurement, the cryogenic trap is then warmed up to 95 K for 15 min to release Ne into the line. Following the same operation as He, Ne isotopes can be measured on the NGX mass spectrometer.

Notably, during noble gas measurement in the NGX mass spectrometer, the sample preparation line is continually pumped by a turbo-molecular pump backed up with a rotary pump at a vacuum in the range of $10^{-7}$ mbar to avoid any residual gases in the line to affect the subsequent analyses.

Once Ne isotope measurement is finished, the charcoal trap is then heated to 210 K for 15 min. The previously ‘absorbed’ Ar and Kr are subsequently released and expanded into the line. After several cycles of expansion and dilution similar to He and Ne, a small aliquot of Ar and Kr is isolated and simultaneously inlet into the NGX mass spectrometer for abundance and isotopic analyses. During Ar - Kr measurement, the heater on the cold finger needs to be turned off, and the cold finger is then cooled down to the liquid nitrogen temperature ($T = 77$ K).

To minimize the effect of large amounts of Ar onto the release of Xe from the activated charcoal, three separation cycles as follows are required to separate Xe from Ar and Kr effectively. First, the temperature on the charcoal trap is raised to 210 K for 15 min to desorb Ar and Kr remaining on the charcoal into the
preparation line. Then, these released gases are pumped off for another 15 min. Simultaneously, the temperature on the charcoal is warmed to 450 K for the release of Xe. Once the pumping is finished, the released Xe in the cold finger is expanded into the line for another 5 min. After that, the gases in the line are reabsorbed onto the charcoaled trap at 210 K. The second and third cycles follow the same procedure to ensure the complete separation of Xe from Ar and Kr prior to Xe isotope determination. Determination of separation temperatures of noble gases is detailed in Text S3 of Supporting Information S1.

3.4. Blank and Air Standard

Due to changes in instrument sensitivity (e.g., electronics) and efficiency of the sample cleaning process lowering over time, potentially affecting the noble gas analyses, it is necessary to run procedural blanks and standards to check system sensitivity and stability associated with each sample analysis. As shown in this study, air is used as the standard for all noble gas measurements. A procedural blank is conducted following the exact same procedure of sample measurement prior to each sample run. Both the blank and standard measurements give an overview of the overall changes of the mass spectrometer system. Besides the role of checking system sensitivity and stability, blank and air standard runs can also provide useful information on whether there are any possible leaks or residual background gases left over from previous measurements in either the preparation line or the mass spectrometer itself. The noble gas elemental abundances and isotopic ratios for each sample are calculated by comparison with air standards after blank correction. Blank contribution is at least three orders of magnitude lower than any air standard measurements.

4. Performance of the NGX Mass Spectrometer

4.1. Reproducibility

To test the reproducibility and stability of the instrument, air aliquots were repeatedly analyzed using the NGX fully automated system. Figures 3a and 3b show the variation of $^3$He/$^4$He and $^{21}$Ne/$^{20}$Ne as a function of $^4$He and $^{20}$Ne intensity, respectively. The internal precisions for the He isotopic composition of a set of 90 air standards of between $5.75 \times 10^{-13}$ and $3.40 \times 10^{-12}$ moles (intensities of $4.74 \times 10^{-18}$ and $2.81 \times 10^{-17}$ amps) are between 2.52% and 9.63% for $^3$He/$^4$He (1σ). The internal precisions for the Ne isotopic composition of a set of 73 standards of between $1.75 \times 10^{-13}$ and $7.50 \times 10^{-13}$ moles (intensities of $2.42 \times 10^{-17}$ and $1.04 \times 10^{-16}$ amps) are between 0.26% and 1.25% for $^{21}$Ne/$^{20}$Ne (1σ). Reproducibility of the measurements obtained from 90 and 73 standard runs are 4.2% and 0.4% for $^3$He/$^4$He and $^{21}$Ne/$^{20}$Ne, respectively.
All He standards except six standards are in good agreement with an average measured $^3$He/$^4$He ratio of $1.33 \times 10^{-6}$ within the 1σ uncertainty, having $^3$He/$^4$He ratios from $1.19 \times 10^{-6}$ to $1.47 \times 10^{-6}$. The reference $^3$He/$^4$He ratio used is $1.40 \times 10^{-6}$ reported by Mamyrin (1970). For Ne isotopes, all standards except six standards have $^{21}$Ne/$^{38}$Ne ratios ranging from 0.002914 to 0.002964, which are compatible with an average measured $^{21}$Ne/$^{20}$Ne ratio of 0.002932 within the 1σ uncertainty. The reference $^{21}$Ne/$^{20}$Ne ratio used is 0.002959 reported by Eberhardt et al. (1965).

Figure 4. The linearity of $^{40}$Ar/$^{36}$Ar ratios with changes in $^{40}$Ar intensity showing constant $^{40}$Ar/$^{36}$Ar ratios irrespective of $^{40}$Ar intensity. Error bars are 1σ.

4.2. Sensitivity

Similarly, in order to determine the relationship between system sensitivity and partial pressure of noble gases, the performance of Ar measurements has been monitored by analyzing different amounts of air. Figure 4 shows the linearity of $^{40}$Ar/$^{36}$Ar with changes in $^{40}$Ar intensity. There is no significant difference in the $^{40}$Ar/$^{36}$Ar ratio with the $^{40}$Ar signal size ranging from 0.036 $\times$ $10^{-11}$ to 5.94 $\times$ $10^{-11}$ amps, suggesting good sensitivity and pressure linearity of the $^{40}$Ar/$^{36}$Ar ratios of the NGX instrument.

4.3. Multicollection of Various Isotopes

The large radius magnet of the NGX provides sufficient mass dispersion capable of static multicollection of various noble gas isotopes, particularly focusing on nine Xe isotopes in the case of Lancaster University’s configuration. In addition, as the collector focal plane is perpendicular to the ion trajectory, by using modified magnet exit poles, the peak top can be optimized to be flat irrespective of collector position across the focal plane. The simultaneous collection of nine isotopes of Xe on nine different Faraday collectors is shown in Figure 5.

Figure 6 shows variation of different Xe isotopic ratios with $^{132}$Xe intensity ranging from $0.5 \times 10^{-12}$ to $1.4 \times 10^{-12}$ amps, indicating the relatively constant Xe isotopic ratios with different amounts of $^{132}$Xe. Xe isotopic ratios are 0.0227–0.0246 ($^{124}$Xe/$^{130}$Xe), 0.0214–0.0223 ($^{128}$Xe/$^{130}$Xe), 0.4696–0.4720 ($^{128}$Xe/$^{138}$Xe), 6.4821–6.5051 ($^{129}$Xe/$^{138}$Xe), 5.2025–5.2218 ($^{131}$Xe/$^{138}$Xe), 6.5939–6.6190 ($^{132}$Xe/$^{138}$Xe), 2.5608–2.5700 ($^{134}$Xe/$^{138}$Xe), and 2.1749–2.1825 ($^{136}$Xe/$^{138}$Xe). The purple dashed lines indicate the standard errors for the weighted mean of Xe isotopic ratios of 46 air measurements. Both internal precision (counting stats) and external precision (reproducibility) component are taken into account for the calculations of the standard errors for the weighted mean of Xe isotopic ratios of 46 air measurements. The standard errors of the weighted mean for $^{124}$Xe/$^{130}$Xe, $^{126}$Xe/$^{130}$Xe, $^{128}$Xe/$^{130}$Xe, $^{129}$Xe/$^{130}$Xe, $^{131}$Xe/$^{130}$Xe, $^{132}$Xe/$^{130}$Xe, $^{134}$Xe/$^{130}$Xe and $^{136}$Xe/$^{130}$Xe in 46 air measurements are 0.782%, 0.804%, 0.053%, 0.029%, 0.029%, 0.029%, 0.030%, and 0.031%, respectively. In contrast, the corresponding reference values from Basford et al. (1973) are 0.342%, 0.505%, 0.148%, 0.139%, 0.153%, 0.076%, 0.156%, and 0.138%, respectively. Figure 7 shows the deviation of measured Xe isotopes from the air shots relative to $^{130}$Xe. The discrepancies for $^{124}$Xe/$^{130}$Xe, $^{126}$Xe/$^{130}$Xe, $^{128}$Xe/$^{130}$Xe, $^{129}$Xe/$^{130}$Xe, $^{131}$Xe/$^{130}$Xe, $^{132}$Xe/$^{130}$Xe, $^{134}$Xe/$^{130}$Xe and $^{136}$Xe/$^{130}$Xe ratios are 0.49%, 0.69%, 0.22%, 0.08%, 0.06%, 0.04%, 0.10%, and 0.12%, respectively. The standard errors of the weighted mean for those Xe isotopic ratios (purple dashed lines in Figure 6) are also shown in Figure 7.

Therefore, except for $^{124}$Xe and $^{126}$Xe, whose low abundance affects the measurement precision, all Xe isotope ratios in atmospheric xenon have been analyzed with improved precision compared to the reference values in Basford et al. (1973).

4.4. The Application of Xe for Understanding Geological History

Isotopic composition of Xe isotopes in geological samples has enormous applications in earth sciences. Xe isotope signatures are well documented and have been discussed by many researchers. For example, the excesses of $^{124}$Xe, $^{126}$Xe, and $^{128}$Xe in the Timmins mine fluids, Canada, are associated with xenon isotope changes in the ancient atmosphere and give an estimated mean residence time for deep fracture fluid of
Figure 5. All nine Xe isotope beams (from $^{136}$Xe to $^{124}$Xe) were simultaneously detected on Faraday collectors (H4-H1, Ax, L1-L4). Note: Mass 115.558 in the figure corresponds to $^{130}$Xe before a calibration of mass on the NGX mass spectrometer.

Figure 6. The performance of measuring different Xe isotopic ratios as a function of $^{132}$Xe intensity. The reference Xe isotopic ratios are cited from Basford et al. (1973). The purple dashed lines indicate the standard errors for the weighted mean of Xe isotopic ratios of 46 air measurements. Error bars are 1σ.
about 1.5 billion years (Holland et al., 2013). Xe isotope data suggest that ancient pockets of water could survive the crustal fracturing process and remain in the crust for billions of years (Holland et al., 2013). Xe isotopes, together with other noble gases, can also be used to investigate the evolution of Earth's atmosphere over the geological timescale. Xe, the heaviest noble gas in the atmosphere on Earth and Mars, is lower in abundance than what would be predicted if assuming noble gases in planetary atmospheres were following the same abundance pattern as in chondritic meteorites. Heavy Xe isotopes in Earth and Mars atmosphere are much more enriched relative to the light isotopes when compared to other cosmo-chemical Xe components (Avice & Marty, 2020; Avice et al., 2018). Escape of Xe from the Earth can be studied by noble gas and O, S, H systematics. The termination of the isotopic fractionation of Xe was interpreted as a signal of the end of the hydrogen escape and onset of moderate oxygen levels (Avice et al., 2018). High precision analysis of chondritic krypton and xenon in gases from Yellowstone, USA, has provided crucial constraints on the source and timing of volatile (C, N, H₂O, and noble gases, etc.) delivery to Earth (Broadley et al., 2020). Improved precision for heavy noble gas analysis, particularly Xe, represents a significant step forward in applying isotope techniques to better our understanding of the origin and evolution of the Earth.

5. Conclusions
A newly constructed noble gas extraction, purification, and separation system has been interfaced with an NGX multicollector noble gas mass spectrometer at Lancaster University, UK. It is designed for high accuracy noble gas abundance and isotope measurements. The repeated air standard measurements have proven that this new system can provide ample sensitivity and high reproducibility for noble gas analyses. The major feature of this system is the simultaneous collection of beams for all nine Xe isotopes using low-noise, high-sensitivity Faraday collectors, which improves overall precision and permits shorter analytical times. The sample preparation and measurements are fully automated and allow complete noble gas isotope analysis to be carried out in approximately 3 hr, which offers a powerful tool for investigating geological and environmental processes. The NGX multicollector mass spectrometer system at Lancaster University can be applied for various research in earth sciences, where noble gases act as an ideal tracer set for subsurface fluid dynamics.

Data Availability Statement
The raw data are archived at Earthchem Library (https://doi.org/10.26022/IEDA/112114).

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