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**Helium migration pattern in ultra-deep marine strata: A case study of the
Sinian–Cambrian reservoirs in the Anyue gas field**

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Abstract

The Sinian–Cambrian reservoirs in the Anyue gas field contain over one trillion cubic meters of natural gas. These reservoirs are close to basement helium sources and have well-developed ancient formation water as a potential carrier. However, helium concentrations in the gas field remain abnormally low. Traditional studies lack quantitative constraints on helium migration patterns, hampering evaluation of helium enrichment potential in ultra-deep strata. In this study, 23 samples noble gas isotope were analysed to trace helium sources and migration mechanisms. The results demonstrate that: (1) Helium in the Anyue gas field is crustal-derived. The Sinian reservoir has higher R/R_a ratios (0.008–0.047) and greater crustal helium proportion than the Cambrian reservoir (0.003–0.019). (2) The $^{20}\text{Ne}/^{36}\text{Ar}$, $^{84}\text{Kr}/^{36}\text{Ar}$, $^{132}\text{Xe}/^{36}\text{Ar}$ ratios indicate open-system behavior for both the Sinian and Cambrian gas reservoirs. The Sinian has stronger He–N₂ correlation ($R^2=0.82$) and more atmospheric noble gases, indicating more intense basement groundwater circulation. (3) Helium in the Sinian reservoir is primarily derived from exsolution of water-soluble helium from basement formation water. Helium in the Cambrian reservoir mainly originates from the Qiongzhusi source rocks, with minor exogenous contribution. (4) The Poor fault connectivity and overpressure in the Cambrian (pressure coefficient 1.51–1.70) collectively resulted in inefficient helium migration pathways. Additionally, limited tectonic uplift during the Himalayan period prevented large-scale ascent of near-basement groundwater. This study establishes a quantitative model for helium differential enrichment controlled by basement groundwater circulation. It provides a

theoretical framework for integrated helium exploration in cratonic basins.

Keywords: Inert gas isotope; Sinian–Cambrian; Fluid migration; Himalayan period;
Helium enrichment; Ultra-deep strata

1. Introduction

Helium is a critical strategic resource, playing an irreplaceable role in high-end manufacturing, cryogenic superconductivity, aerospace, and other fields (Labidi et al., 2021; Liu et al., 2024; Yi et al., 2025). With increasing demand, identifying effective helium enrichment mechanisms and exploration targets has become a frontier topic in petroleum geochemistry (Qin et al., 2024). Industrial-scale helium is typically enriched in hydrocarbon-rich petroleum reservoirs (Ballentine and Sherwood Lollar, 2002; Chakin et al., 2007; Qin et al., 2022), where helium migration efficiency and accumulation conditions are key factors controlling reservoir helium abundance. Helium is primarily generated from the α -decay of radioactive elements such as uranium and thorium in the crust. After being released from mineral lattices, it undergoes primary migration, then enters pore water for secondary migration, dissolving into groundwater. Groundwater helium content gradually accumulates over geological time (Warr et al., 2015; Qin et al., 2023); consequently, dissolved helium concentrations are higher in near-basement groundwater. The Weiyuan gas field in the Sichuan Basin is a typical example of near-basement helium enrichment and shares the same tectonic unit as the Anyue gas field. Helium migration pathways are

indicative of the relationship between natural gas and water in reservoirs and are of great significance for identifying helium sources and guiding natural gas exploration.

The effective preservation of helium in natural gas reservoirs depends on migration pathways, conditions and carriers. Previous noble gas geochemical studies suggest multiple migration pathways (Li et al., 2020; Zhu et al., 2025). Helium concentration variations imply distinct mechanisms: high-helium reservoirs may receive water-dissolved helium from basement rocks, whereas low-helium reservoirs may be dominated by helium directly from the Qiongzhusi Formation source rocks (Zhu et al., 2025). Regarding migration conditions, the Longwangmiao Formation exhibits favorable temperature–pressure conditions for dissolved-gas migration and subsequent degassing to form free gas (Qin et al., 2018). In terms of migration carriers, two-stage gas-water interaction occurred during natural gas accumulation and preservation, revealing the important carrier role of groundwater (Li et al., 2020). However, systematic evaluation of helium and noble gas migration in ultra-deep reservoirs is lacking, leaving the primary control on differential helium enrichment unresolved—specifically, whether it is source input or fluid migration efficiency linked to ancient formation-water circulation.

This study analyzes noble gas (He, Ne, Ar, Kr, Xe) elemental and isotopic compositions ($^3\text{He}/^4\text{He}$, $^{40}\text{Ar}/^{36}\text{Ar}$) in natural gases from the Anyue field. Based on atmospheric-derived noble gas signatures, He-N₂ relationships, and the dilution effect of hydrocarbon gases, a migration system is established to: (1) reconstruct helium migration pathways and evaluate the role of near-basement ancient formation water in

helium enrichment; (2) quantitatively assess the relative contributions of helium and natural gas from the Qiongzhusi Formation; and (3) identify pressure-release pathways that facilitated upward migration of helium-bearing water. Our results provide new insights into the mechanisms of helium accumulation in ultra-deep carbonate reservoirs and establish exploration indicators for the Sichuan Basin and analogous basins globally.

2. Regional Geological Setting

The Anyue gas field is located in the Leshan–Longnüsi palaeo-uplift tectonic belt of the Sichuan Basin (He et al., 2023; Xu et al., 2020), within the transitional zone between the central Sichuan gentle palaeo-uplift structural region and the southeastern Sichuan high-steep structural region (Dai, 2024; Yang et al., 2022)(Fig. 1a). This palaeo-uplift currently exhibits a NE-trending nose-shaped uplift, and the area as a whole belongs to a stable cratonic basin (Fig. 1c) (Luo et al., 2015; Wang and Liu, 1999). Since the formation of the palaeo-uplift in the Sinian, the top surface of the Dengying Formation and its adjacent strata in the core of the palaeo-uplift have consistently developed giant structural traps with a uniform closure contour, remaining in a structurally high position over a long period, thus representing a favourable target area for hydrocarbon accumulation (Guo et al., 2022; Xie et al., 2021; Yang et al., 2019).

The main reservoirs of the Sinian–Cambrian systems in the Anyue gas field include the second and fourth members of the Sinian Dengying Formation, as well as

the Cambrian Longwangmiao Formation and Canglangpu Formation (Li et al., 2022; Li et al., 2014). The principal source rock is the Lower Cambrian Qiongzhusi Formation shale. This shale is rich in high- to over-mature sapropelic organic matter (sapropelic kerogen) and constitutes a high-quality source rock with not only high hydrocarbon generation potential (Guo et al., 2022) but also considerable helium generation potential. The Qiongzhusi Formation has a thickness ranging from 150 to 578 m in the Anyue area, exhibiting an overall pattern of thickening eastward and thinning westward (Fig. 1b) (He et al., 2024; Wei et al., 2015a; Wei et al., 2015b).

3. Sampling and Experimental Methods

Noble gases in the atmosphere are present in relatively high concentrations (Barry et al., 2016). Consequently, natural gas and similar samples are susceptible to atmospheric contamination during collection, which may cause measured data to deviate from true values. To minimise the effects of air contamination and sampling procedures on analytical results, it is necessary to perform a leak test on the double-valve high-pressure stainless steel cylinders used for noble gas analysis. In this study, 13 samples from the Sinian system and 10 samples from the Cambrian system were collected from the Anyue gas field. The composition and isotopic ratios of noble gas samples were analysed at the Oil and Gas Resources Research Center, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences. Noble gas isotope analyses were performed using a Noblesse SFT mass spectrometer. After the measurements were completed, the raw data were processed to remove sample data contaminated by air. To ensure data reliability, atmospheric contamination

correction was carried out for all samples. Samples with $^{40}\text{Ar}/^{36}\text{Ar} < 1000$ were excluded. Repeated tests were conducted for 5 samples, and the analytical error of isotope ratios was controlled within $\pm 5\%$. All results meet the requirements of noble gas geochemistry research.

4. Noble Gas Results

4.1 Helium

The helium content of the Anyue gas field is generally low. The ^4He content in the Longwangmiao Formation ranges from 12.21×10^{-5} to $16.98 \times 10^{-5} \text{ cm}^3 \text{ (STP)/cm}^3$, with a mean value of $13.72 \times 10^{-5} \text{ cm}^3 \text{ (STP)/cm}^3$. In the Dengying Formation, the ^4He content ranges from 11.11×10^{-5} to $22.05 \times 10^{-5} \text{ cm}^3 \text{ (STP)/cm}^3$, with a mean value of $18.72 \times 10^{-5} \text{ cm}^3 \text{ (STP)/cm}^3$.

The measured $^3\text{He}/^4\text{He}$ ratios (R) were normalized to the atmospheric $^3\text{He}/^4\text{He}$ ratio ($R_a = 1.4 \times 10^{-6}$). The R/R_a values range from 0.003 to 0.019 (mean=0.007) in the Longwangmiao Formation and from 0.008 to 0.062 (mean=0.031) in the Dengying Formation (Table 1).

The crustal $^3\text{He}/^4\text{He}$ ratio is approximately $0.02 R_a$, whereas the mantle ratio ranges from 6 to $8 R_a$. The R/R_a values in both the Dengying and Longwangmiao formations exhibit crustal characteristics. The Sinian has higher crustal helium accumulation efficiency than the Cambrian.

4.2 Neon

The ^{20}Ne content in the Dengying Formation ranges from 4.235×10^{-10} to $13295 \times 10^{-10} \text{ cm}^3 \text{ (STP)/cm}^3$, and ranges from 2.039×10^{-10} to $3.278 \times 10^{-10} \text{ cm}^3$

(STP)/cm³ in the Longwangmiao Formation. The ²⁰Ne in the samples is mainly derived from groundwater that previously equilibrated with the atmosphere or from sealed pore water, subsequently entering the subsurface fluid system through interphase interactions. The atmospheric ²⁰Ne/²²Ne ratio is 9.8. In the Anyue gas field, the ²⁰Ne/²²Ne ratios of the Dengying and Longwangmiao formations range from 9.84 to 11.51 and from 10.13 to 10.88, all higher than the atmospheric ratio.

Based on the correlation between R/R_a and ⁴He/²⁰Ne in the Anyue gas field (Fig. 2), noble gases exhibit distinct distributional differences between the Dengying and Longwangmiao formations. The ³He/⁴He values of the Longwangmiao Formation are generally lower than those of the Dengying Formation, whereas the ⁴He/²⁰Ne values show the opposite trend (Table 1; Fig. 2).

4.3 Argon

The ⁴⁰Ar/³⁶Ar ratios of both formations are significantly elevated relative to the atmospheric value (298.6). This indicates that radiogenic ⁴⁰Ar, produced by the radioactive decay of ⁴⁰K in crustal rocks, constitutes the dominant source of argon in the two gas reservoirs. The similarity in mean ⁴⁰Ar/³⁶Ar values between the Dengying Formation (3935.37) and the Longwangmiao Formation (3827.69) suggests comparable degrees of radiogenic argon accumulation or similar source rock characteristics.

5. Discussion

5.1 Relationship between groundwater and noble gases

5.1.1 Noble gases derived from groundwater

²⁰Ne, ³⁶Ar, ⁸⁴Kr and ¹³²Xe are mainly derived from the atmosphere and enter subsurface fluid systems via atmospheric saturated water (ASW) (Ballentine and Sherwood Lollar, 2002; Burnard et al., 2013). Noble gas elemental ratios in natural gas provide key evidence for the physico-chemical conditions during gas accumulation and migration (Aeschbach-Hertig and Solomon, 2013; Ballentine and Sherwood Lollar, 2002; Li et al., 2020). In an open system, gases continuously exsolve from groundwater, and light noble gases (e.g., ²⁰Ne) partition preferentially into the gas phase owing to their lower Henry's law constants, resulting in ²⁰Ne/³⁶Ar ratios lower than the first bubble value. Conversely, heavy noble gases (⁸⁴Kr, ¹³²Xe) have higher solubilities in water, leading to ⁸⁴Kr/³⁶Ar and ¹³²Xe/³⁶Ar ratios higher than the first bubble value (Ballentine and Sherwood Lollar, 2002). These differential fractionation patterns serve as criteria for identifying open systems. The Weiyuan gas field (Cambrian, Fig. 3b) exhibits lower ²⁰Ne/³⁶Ar and higher ¹³²Xe/³⁶Ar ratios, indicating stronger open-system fractionation (Fig. 3). The Anyue gas field has weaker open-system fractionation than the Weiyuan gas field, caused by weaker groundwater circulation and shorter migration pathways of basement formation water.

5.1.2 He and N₂

In helium-rich gas reservoirs, helium and nitrogen often exhibit a good positive correlation. (Brown, 2019; Qin et al., 2023). As a helium-poor gas field, the Anyue gas field shows different correlation characteristics between the Sinian and Cambrian systems. The Sinian system displays a high positive correlation between He and N₂, with a correlation coefficient (R^2) of 0.82 (Fig. 4). In contrast, the Cambrian system

has a correlation coefficient of 0.04, indicating a poor correlation between nitrogen and helium, similar to the situation in shale gas samples from Ziyang, Yichang, and Weiyuan (Fig. 5). The higher helium and nitrogen content of the Sinian indicate that the Sinian system is more strongly influenced by basement-derived formation water circulation.

5.2 Helium Migration Conditions

5.2.1 Uplift amplitude–pressure coupling controls on helium exsolution efficiency

The exsolution of water-dissolved helium into free gas requires a decrease in hydrostatic pressure, which lowers the gas solubility in water (Henry's law). In sedimentary basins, tectonic uplift is the most effective mechanism for regional pressure reduction. However, if overpressure persists after uplift, the enhancement of gas exsolution remains limited.

The Weiyuan gas field underwent a large uplift (4000 m), causing pressure decrease from overpressure to normal level. Pressure change induced widespread exsolution of water-dissolved helium. In contrast, the Anyue gas field experienced a smaller uplift (2500 m). The Sinian reservoir (average pressure coefficient=1.06, Wu et al., 2014; Zhou et al., 2016) allowed partial exsolution, as evidenced by its higher ^4He content and open-system noble gas fractionation patterns (Fig. 4). The Cambrian reservoir, however, maintains strong overpressure (pressure coefficient 1.51–1.70 (Wu et al., 2014; Zhou et al., 2016)) despite similar uplift (Figure 6). This post-uplift overpressure suppresses bubble nucleation and gas exsolution, trapping helium in the dissolved phase. Consequently, helium exsolution efficiency in the Cambrian remains

minimal, helium present derive from sources rock other than basement water exsolution. The contrast between Anyue and Weiyuan demonstrates that without sufficient uplift and pressure release, even helium-charged basement water cannot form economic accumulations.

5.2.2 Migration pathway controls on helium supply from basement water

Even if exsolution conditions are favourable, helium-charged basement water must first reach the reservoir. This secondary transport stage is controlled by fault connectivity, hydraulic gradients, and stratigraphic architecture.

In the Anyue gas field, the Sinian reservoir lies stratigraphically closer to the basement and is directly overlain by permeable carrier beds, allowing sustained influx of helium-charged formation water. In contrast, the Cambrian reservoir suffers from two interconnected limitations. First, faults that could connect basement aquifers to the Cambrian reservoir are poorly developed in the Anyue area (Zhang et al., 2024). Furthermore, the strong overpressure in the Cambrian reduces hydraulic gradients, further restricting transport.

Therefore, the Cambrian reservoir fails at the secondary migration stage before exsolution even becomes relevant. Basement-derived water-dissolved helium cannot reach the reservoir in significant quantities, which explains why helium in the Cambrian is predominantly supplied by in-situ generation from the Qiongzhusi Formation source rocks, with only a minor exogenous contribution (Fig. 7). The Sinian reservoir, by contrast, maintains an open migration pathway and is limited only by moderate exsolution efficiency (as discussed in Section 5.2.1).

This interpretation is further supported by helium migration behaviour. Helium migrates predominantly in a water-dissolved state and can hardly migrate over long distances as a free gas. If helium in the Sinian reservoir only came from the overlying Cambrian(Zhu et al., 2025), the $^3\text{He}/^4\text{He}$ ratios of Cambrian would be higher or very similar than the Sinian. Therefore, A large part of the Sinian helium is derived from exsolution of basement formation water, whereas the Cambrian helium is primarily sourced from the Qiongzhusi Formation, with only minor exogenous contribution.

5.3 Quantitative assessment of helium exsolved from formation water

5.3.1 Natural gas generation and its dilution effect

A quantitative assessment of helium exsolution from formation water requires first establishing the baseline helium generation from the source rock and the dilution effect exerted by concomitant natural gas. The calculations are as follows.

The Qiongzhusi Formation is the primary source rock for natural gas in the Anyue gas field (Ning et al., 2025; Zhang et al., 2022), with current proven reserves up to $1.03 \times 10^{12} \text{ m}^3$ (Chen et al., 2022). The hydrocarbon generation intensity is calculated using the residual organic carbon–Monte Carlo method (Yang, 2020),:

$$Q_{\text{gas}} = H \times \rho \times \text{TOC} \times K_{\text{gas}}$$

Q_{gas} is hydrocarbon generation intensity ($10^8 \text{ m}^3/\text{km}^2$); H is source rock thickness = 0.3 km; ρ = source rock density = $2.4 \times 10^8 \text{ t/km}^3$; TOC = total organic carbon content = 1.5%; K_{gas} = gas generation rate = $540 \text{ m}^3/\text{t TOC}$

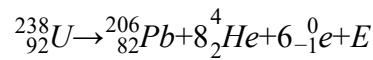
The volume of natural gas generated per cubic meter of source rock is 19.44 m^3 . High hydrocarbon generation potential exerts a notable dilution effect on helium

concentration..

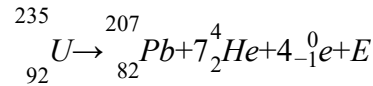
5.3.2 Quantifying helium exsolved from formation water

The Qiongzhusi Formation contains average U and Th concentrations of 10.78 µg/g and 12.8 µg/g, respectively (Ning et al., 2025). Helium is produced by α-decay of these radioactive elements(Chakin et al., 2007; Lang et al., 2024; Liu et al., 2011).

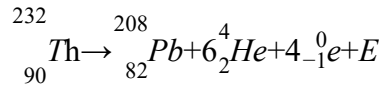
The decay equations and half-lives are as follows (1-4):



$$t_{1/2} = 44.68 \times 10^8 \text{ a} \quad (1)$$



$$t_{1/2} = 7.10 \times 10^8 \text{ a} \quad (2)$$



$$t_{1/2} = 140.1 \times 10^8 \text{ a} \quad (3)$$

$$G_{\text{He}} = (U \times G_U) + (\text{Th} \times G_{\text{Th}}) \quad (4)$$

G_U and G_{Th} represent the amounts of ${}^4\text{He}$ produced by radioactive decay of uranium and thorium, respectively.

Taking the formation age of the Cambrian base boundary as 541 Ma, the calculated volume of helium generated per cubic meter of source rock is 0.002675 m³. The ratio of helium to natural gas generated per unit volume of source rock is 0.0001367 (0.0137%). Since the different migration efficiency between helium and natural gas, the actual contribution of in-situ helium from the source rock to the reservoir is below 0.0137%.

The natural gas of Qiongzhusi migrated upward into the Cambrian

Longwangmiao Formation and downward into the Sinian Dengying Formation(Dai, 2024; Wang et al., 2016).The proportion of helium derived from water exsolution can be estimated by subtracting the background helium contribution (Qiongzhusi source rock generation: $V_{He(bg)}$) from the measured helium content:

$$C_{He} = \frac{(V_{He(meas)} - V_{He(bg)})}{V_{He(meas)}} \times 100\%$$

Calculations indicate that helium accounts for only 1.2% of the total helium in the Cambrian reservoir, but constitutes 27.75% in the Sinian reservoir. Given the differential migration velocities of helium and natural gas from the source rock into the reservoir, these values represent the minimum proportions of water-exsolved helium; the actual contributions are likely higher. The ratio of water-exsolved helium between the Cambrian and Sinian reservoirs is approximately 1:31, quantitatively demonstrating that the Sinian reservoir received significantly more helium from basement groundwater exsolution than the Cambrian reservoir. Collectively, the higher migration efficiency and greater fractionation coefficient in the Sinian reservoir confirm that near-basement groundwater circulation plays a critical role in enhancing helium migration efficiency.

5.4 Research Limitations

The established helium differential enrichment quantitative model is only applicable to stable cratonic basins with complete Sinian-Cambrian marine sequences and weak late tectonic transformation. For basins that experienced strong orogenic extrusion, large-scale fault destruction or massive mantle fluid upwelling, the controlling mechanisms of helium migration will change significantly, and the model

cannot be directly applied without parameter re-calibration. Despite the above limitations, the fluid migration control framework proposed in this paper still provides a reliable reference for helium resource evaluation of ultra-deep marine gas reservoirs in similar cratonic settings.

6. Conclusions

(1) Helium in the Anyue gas field is purely crustal-derived with no mantle contribution; the Sinian reservoir has higher ^4He content and R/R_a ratios (0.008–0.062) than the Cambrian reservoir (0.003–0.019).

(2) The Sinian reservoir exhibits open-system behaviour with stronger He–N₂ correlation ($R^2=0.82$) and greater influence from basement groundwater circulation, whereas the Cambrian reservoir is a relatively closed system with poor He–N₂ correlation ($R^2=0.04$).

(3) Helium sources differ between the two reservoirs: Sinian helium is mainly derived from exsolution of water-dissolved helium in basement formation water; Cambrian helium is primarily sourced from the Qiongzhusi Formation source rocks.

(4) Poor fault connectivity, strong overpressure (pressure coefficient 1.51–1.70) and limited Himalayan uplift collectively suppressed vertical migration of helium-rich groundwater, resulting in low helium enrichment in the Cambrian.

(5) Basement groundwater circulation, fault development, pressure regime and uplift amplitude jointly control differential helium enrichment in ultra-deep marine strata, providing a quantitative model for helium exploration in cratonic basins.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figure captions

Fig.1 The locations of Anyue Gas Field. (a) Location of Anyue Gas Field (modified from chen et al., 2022); (b) The Sinian-Cambrian strata of Anyue Gas Field (modified from Xie et al., 2021).

Fig. 2 $^3\text{He}/^4\text{He}$ vs. $^4\text{He}/^{20}\text{Ne}$ ratios of the Anyue gas field. R/R_a values of the Longwangmiao Formation (Group 1) and Dengying Formation (Group 2) samples range from 0.003 to 0.019 and 0.008 to 0.062, respectively, indicating a strong crustal contribution.

Fig. 3 Comparison of $^{20}\text{Ne}/^{36}\text{Ar}$, $^{84}\text{Kr}/^{36}\text{Ar}$, and $^{132}\text{Xe}/^{36}\text{Ar}$ ratios with ASW for the Anyue and Weiyuan gas fields. Samples contaminated by air. The atmospheric noble gas patterns of the Sinian and Cambrian samples from the Anyue gas field deviate significantly from the air pattern, indicating that the samples are not contaminated by air. In this study, the noble gas concentrations in groundwater are assumed to be at an ASW temperature of 10 °C and an altitude of 400 m,

which correspond to the mean annual temperature and mean altitude of the central Sichuan Basin.

Fig. 4 Correlation of He and N₂ and He in the Sinian and Cambrian in the Anyue gas field.

Fig. 5 Correlation of He and N₂ in shale gas (Ziyang, Yichang, Weiyuan areas).

Fig. 6 Pressure coefficient of the Sinian-Cambrian strata

Fig. 7 Schematic diagram of helium and natural gas migration pathways in the palaeo-uplift. Helium in the Sinian natural gas is derived from the exsolution of water-dissolved helium during near-basement water circulation; helium in the Cambrian system is derived from source rock generation and minor exsolution of water-dissolved helium.

Table1 Noble gas compositions and ratios of the Longwangmiao Formation in the Anyue gas field

Well	Formation	³ He (10 ⁻¹⁰) cm ³ STP/cm ³	⁴ He (10 ⁻⁵) cm ³ STP/cm ³	²⁰ Ne (10 ⁻¹⁰) cm ³ STP/cm ³	²² Ne (10 ⁻¹⁰) cm ³ STP/cm ³	³⁶ Ar (10 ⁻⁹) cm ³ STP/cm ³	⁴⁰ Ar (10 ⁻⁵) cm ³ STP/cm ³	²⁰ Ne/ ²² Ne	⁴⁰ Ar/ ³⁶ Ar	²⁰ Ne/ ³⁶ Ar	⁸⁴ Kr/ ³⁶ Ar	¹³² Xe/ ³⁶ Ar	R/Ra
MX-124	Є ₁ l	0.045	16.982	2.813	0.259	2.716	1.029	10.88	3779.29	1.04	0.06	0.017	0.019
MX-009-3-X2	Є ₁ l	0.007	14.352	3.103	0.306	2.435	0.913	10.13	3796.73	1.29	0.06	0.018	0.003
MX-12	Є ₁ l	0.006	14.037	3.037	0.293	2.682	0.913	10.37	3397.38	1.13	0.06	0.016	0.003
MX-008-12-X1	Є ₁ l	0.009	12.213	3.119	0.302	2.819	0.908	10.32	3229.76	1.11	0.07	0.024	0.005
MX009-X2	Є ₁ l	0.012	12.492	2.039	0.194	1.566	0.711	10.53	4537.01	1.30	0.05	0.013	0.007
MX009-X6	Є ₁ l	0.007	12.213	3.278	0.307	1.554	0.657	10.67	4225.96	2.11	0.26	0.005	0.004
Average		0.014	13.715	2.898	0.277	2.295	0.855	10.48	3827.69	1.33	0.09	0.016	0.007
GS001-X28	Z ₂ d	0.885	13.473	6.877	0.632	3.754	1.145	10.88	3049.50	0.18	0.15	0.003	0.047
GS001-X30	Z ₂ d	0.962	11.114	5.524	0.523	3.686	1.277	10.57	3465.27	0.15	0.13	0.002	0.062
GS001-X35	Z ₂ d	1.411	21.516	6.807	0.633	4.749	1.493	10.81	3163.37	0.14	0.1	0.015	0.047
GS001-H27	Z ₂ d	0.798	22.047	13.295	1.238	3.135	1.348	10.74	4301.57	0.42	0.11	0.005	0.026
GS6	Z ₂ d	0.383	21.485	7.175	0.683	1.974	1.197	10.51	6028.83	0.36	0.14	0.004	0.013
GS001-X36	Z ₂ d	0.402	20.991	9.133	0.851	2.828	1.156	10.73	4086.30	0.32	0.06	0.005	0.014
GS001-X3	Z ₂ d	0.917	21.725	4.235	0.368	3.594	1.399	11.51	3893.92	0.12	0.05	0.003	0.030
MX120	Z ₂ d	0.205	17.428	13.113	1.332	9.037	3.158	9.84	3494.21	0.15	0.10	0.011	0.008
Average		0.745	18.72	8.27	0.783	4.095	1.522	10.70	3935.37	0.23	0.11	0.006	0.031

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