

Geochemically Inspired Synthesis of Mesoporous Silica

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Introduction & Background

Mesoporous SiO₂

- Pores with diameter of 2-50 nm
- Good catalysts
- May have contributed to the formation of more complex organics in the prebiotic earth

Mineral Weathering

- Acidic media dissolves mineral until saturation
- Silica reprecipitates on the mineral
- Silica spends some time dissolved in solution

Surfactants

- Form geometric micelles under different conditions
- Acts as a template for the silica to condense around

Hypothesis

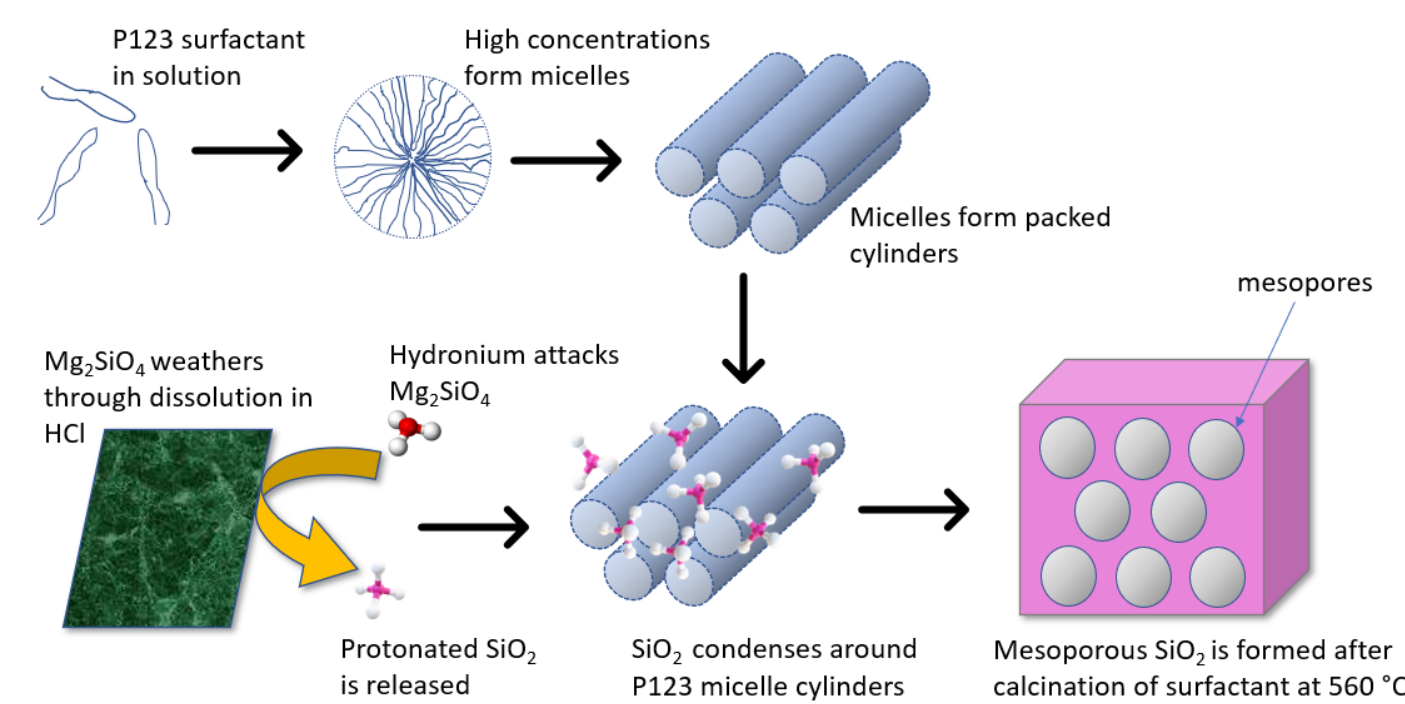
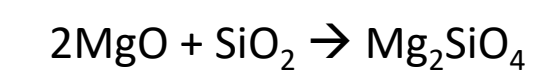


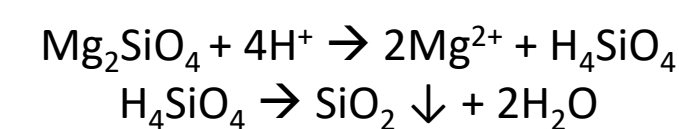
Figure 1. The Hypothetical pathway to form mesoporous SiO₂

Experimental

Mg₂SiO₄ is formed according to the following solid state reaction at 1000 °C:



Dissolve the Mg₂SiO₄ in HCl solution (<2 pH) to precipitate SiO₂:



Different reaction conditions were tested:

- Reaction temperatures: 50 °C, 70 °C, and 90 °C
- pHs: -0.2, 0.2, and 0.6
- Reaction times: 24 h, 18 h, and 12 h
- Silica Source: Mg₂SiO₄ and fumed SiO₂

XRD was performed to verify the formation of Mg₂SiO₄

FTIR was performed to verify a SiO₂/P123 composite formation

N₂ sorption was performed to measure the specific surface area
BJH method was used to analyze the pore size distribution

Results & Discussion

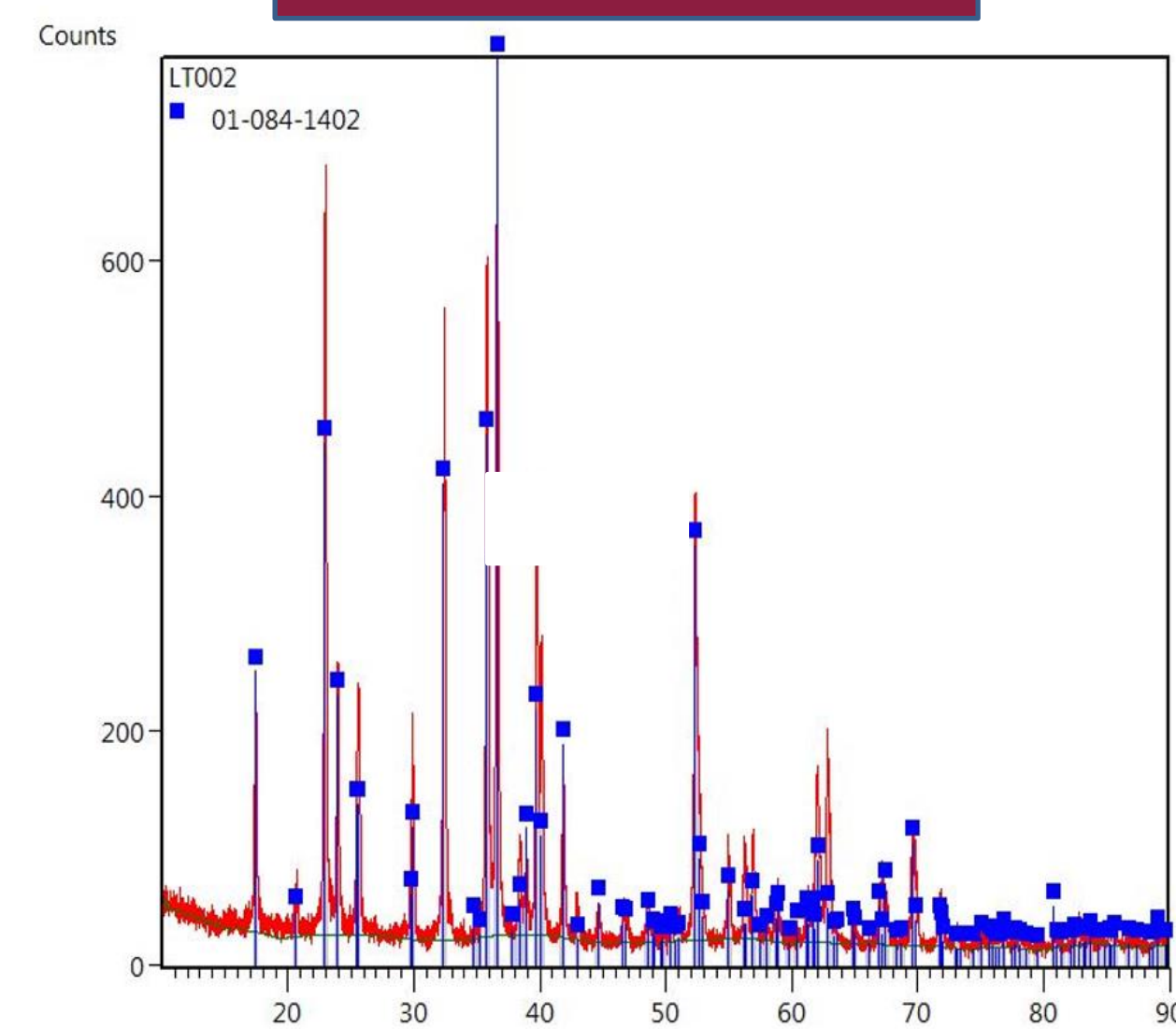


Figure 2. XRD confirmation of Mg₂SiO₄ formation

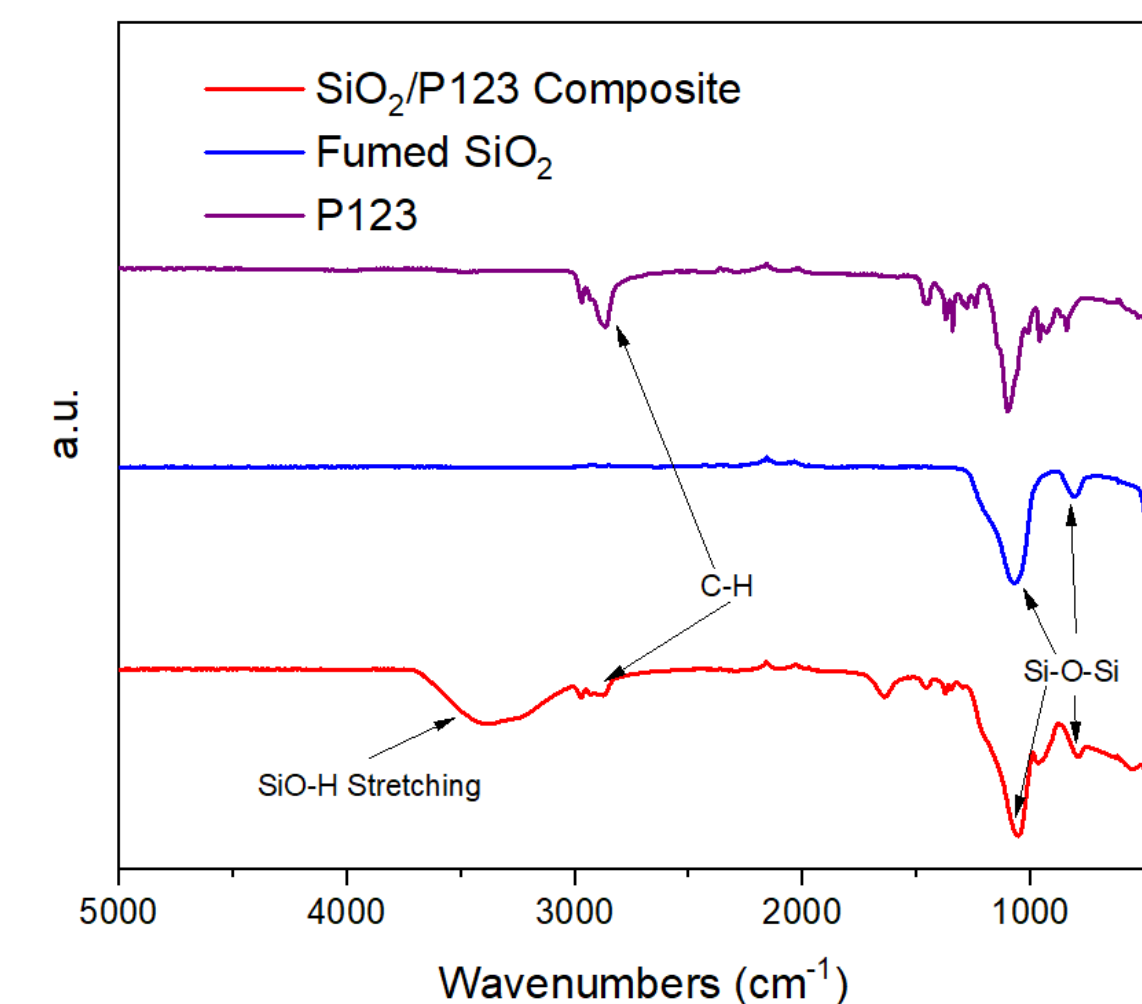


Figure 3. FTIR spectra of P123, Fumed SiO₂, and SiO₂/P123

Wavenumbers (cm ⁻¹)	Bonds
3100-3700	O-H in SiOH symmetrical stretching
2800-3000	C-H stretch
1460	C-H bending in methyl groups
1300-1600	C-H bending in isopropyl groups
1130	R-O-R' dipole moment
800-1010	Si-O-Si
450	Si-O Rocking

Figure 2 shows that Mg₂SiO₄ was successfully synthesized at 1000 °C. Figure 3 demonstrates that the SiO₂/P123 composite before calcination contains peaks that are characteristic of both SiO₂ and P123 surfactant. What follows is a comparison of BJH and BET data at different reaction conditions.

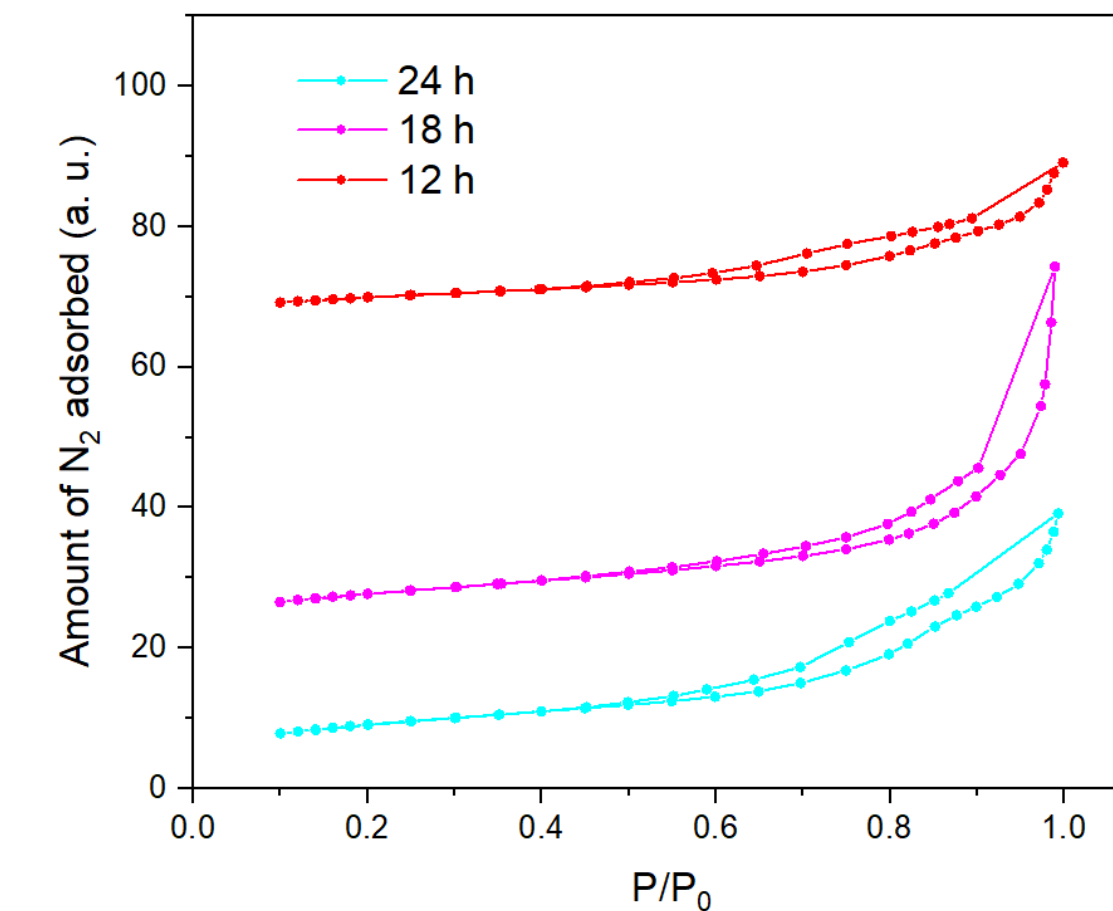


Figure 4. BET isotherms of SiO₂ at different reaction times

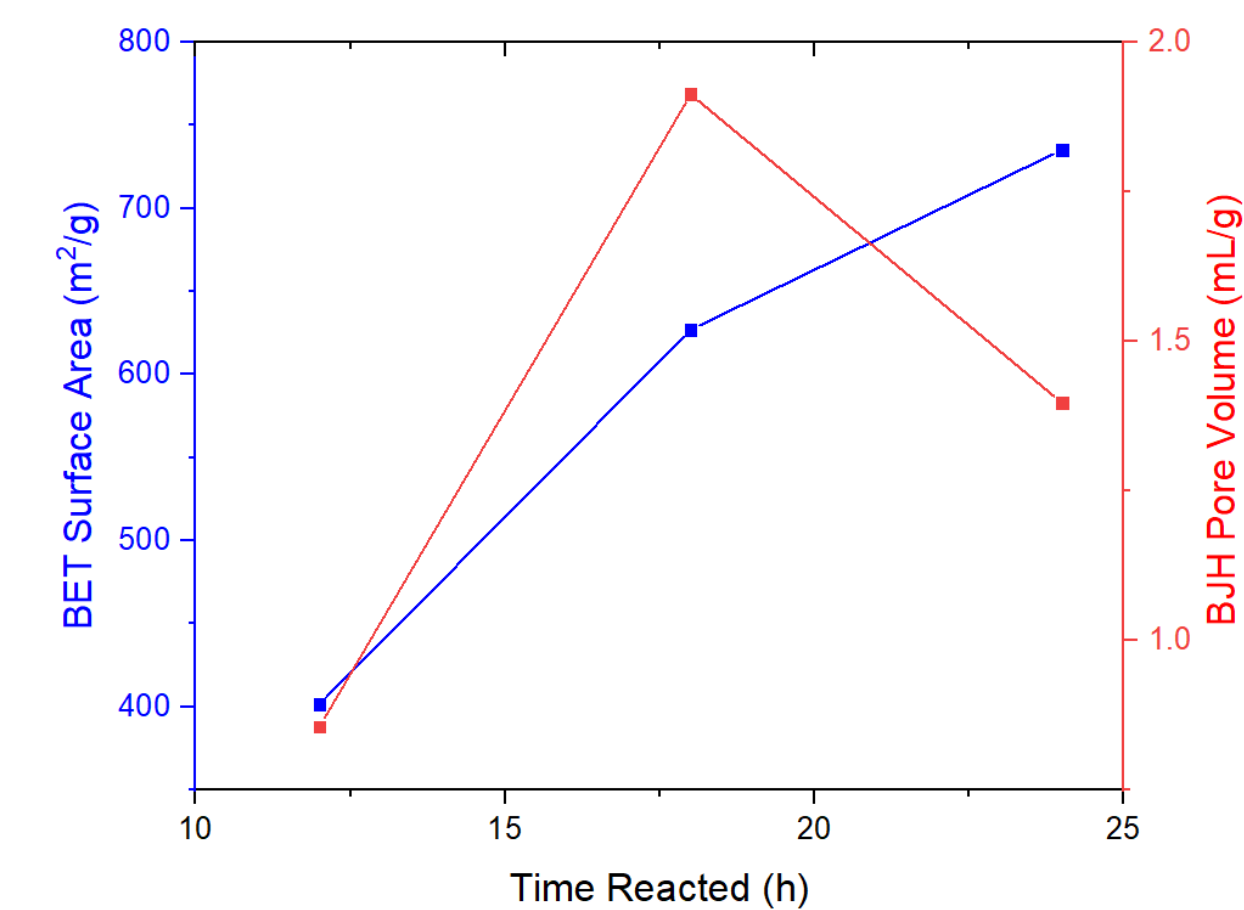


Figure 5. Effect of reaction time on BET surface area and pore volume

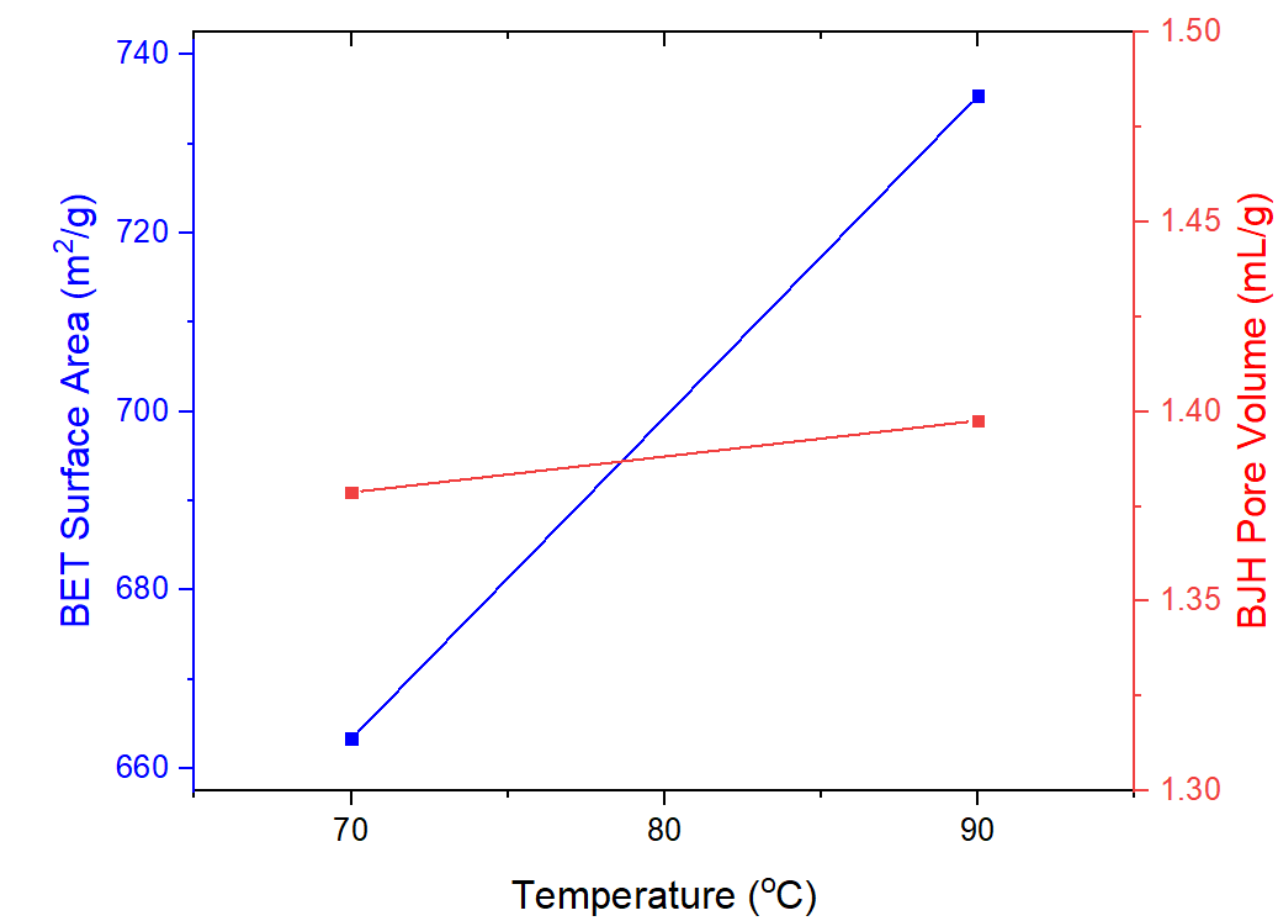


Figure 6. Effect of reaction temperature on BET surface area and pore volume

The pore size distribution demonstrates a bimodal distribution for higher pHs and lower reaction times, rendering a higher cumulative pore volume.

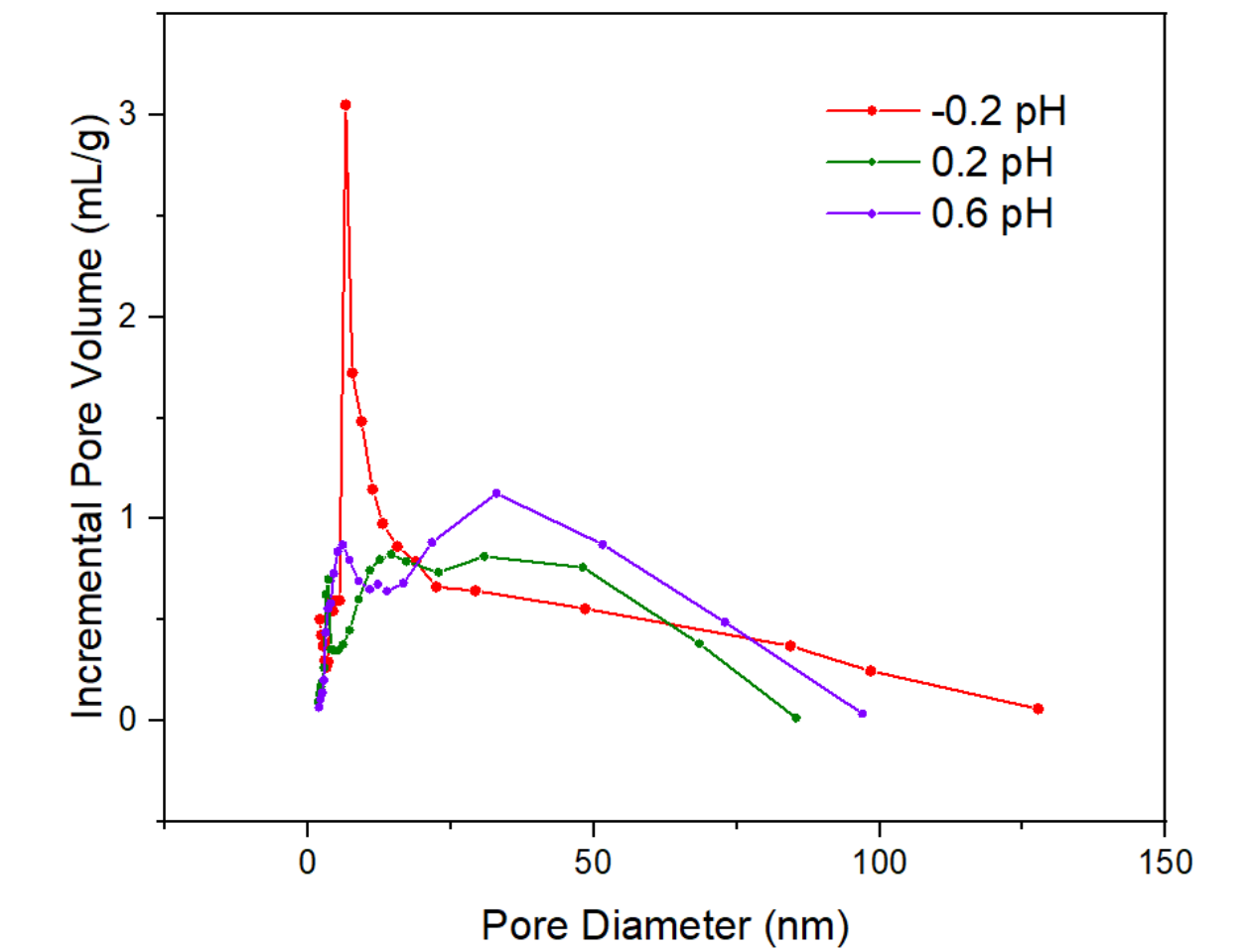


Figure 7. BJH pore size distribution of SiO₂ at different pH conditions

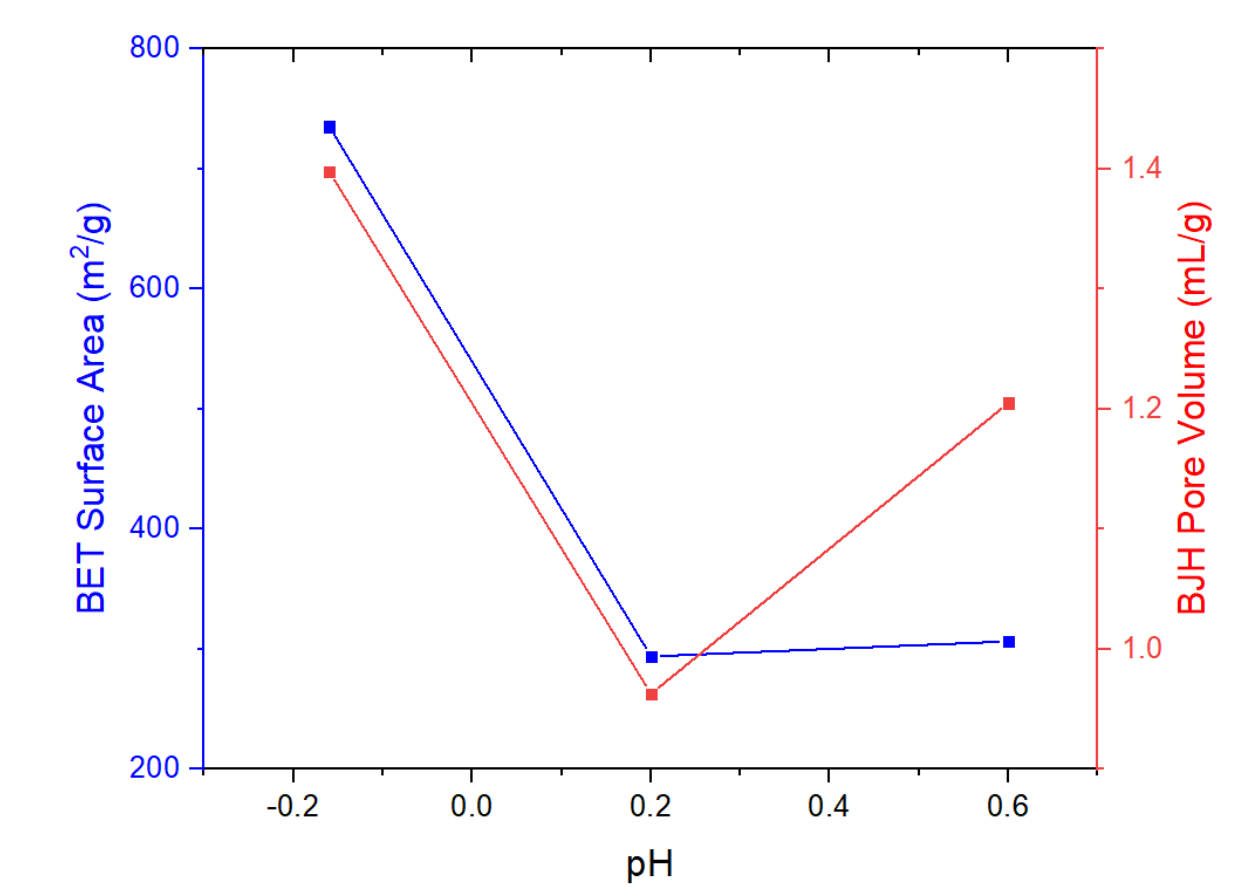


Figure 8. Effect of reaction pH on BET surface area and pore volume

Conclusions

- Mg₂SiO₄ is a viable silica source to form mesoporous SiO₂.
- The optimal condition to form mesoporous silica was 70 °C and -0.2 pH for 24 h which yielded a specific surface area of 735 m²/g and a total pore volume of 1.40 mL/g.
- At lower reaction times and higher pHs, the pore size distribution tended to be bimodal, whereas at -0.2 pH and 24 h reaction time the pore size distribution is unimodal.
- Future research should focus on whether surfactants that were present in the prebiotic earth would have functioned as soft templates as P123 in this study.

Acknowledgements

A special thanks to Dr. Albert Voskanyan, Prof. Alexandra Navrotsky, and Prof. Rick Hervig for helping with the project. This research was supported by the NSF PIRE grant, the Barrett thesis grant, and the Fulton Undergraduate Research Initiative (FURI).