NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Odyssey Research Programme

School of Physical and Mathematical Sciences

Manipulating Liquid Marble to Accumulate Molecules Against a Concentration Gradient at the Liquid-Liquid Interface

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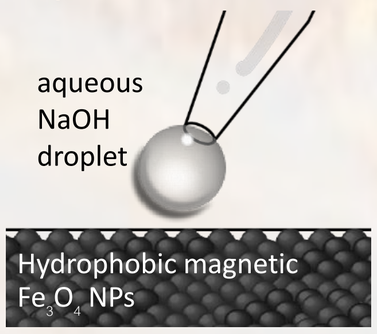
1. Introduction

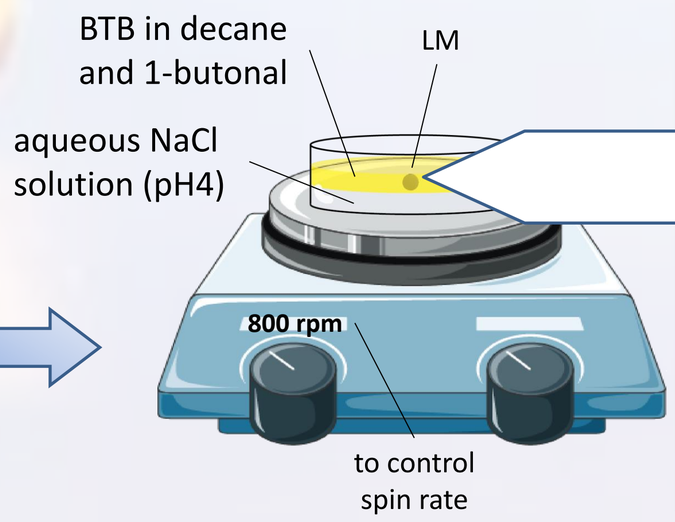
To date, liquid marble (LM) has promising applications as microreactors in chemical and biological fields. The experimental system is designed such that it would be small, cheap, and scalable. However, there is a lack of studies on its manipulations in environmental applications. Herein, we use a rotational LM to achieve direct mass transportation from the exterior phase into the microdroplet with interior hydrodynamic flow. By using spinning LM to concentrate analyte e.g. bromothymol blue dye (BTB), we enable it to be against the concentration gradient. Thus, the analyte can be more easily detected i.e. with higher sensitivity, by the UV-Vis and thus as a universal approach across all analytical techniques.

2. Methodology

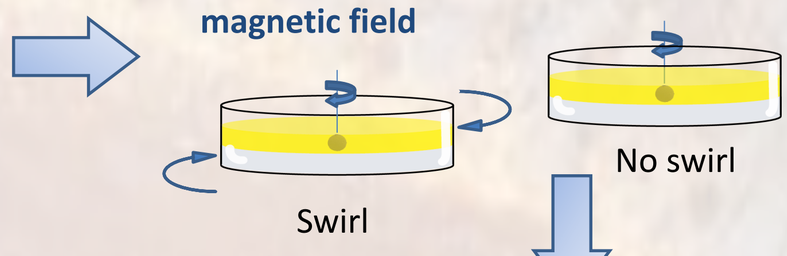
(a) Preparation of LM



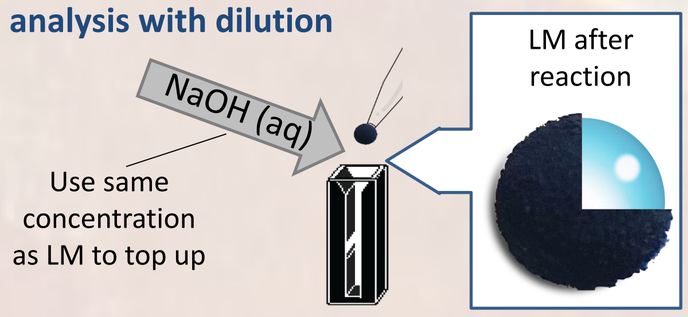
(b) Direct mass transportation within LM with applied magnetic field



(c) Swirl vs no swirl under applied magnetic field



(d) Extraction of LM for UV-vis analysis with dilution

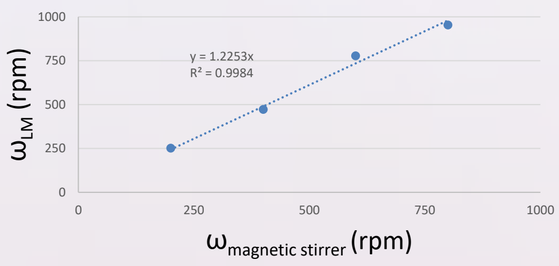


3. Findings

(a) Experimental optimisation

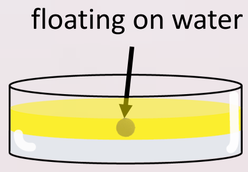
Aqueous height	5mm
Decane height	2mm
LM size	6uL
LM spin rate	~950rpm with applied 800 rpm spin rate LM (see 3b.)
Time	20 min
Aqueous layer	1M of NaCl (pH4)
Organic layer	$8x10^{-5}$M of BTB in decane and 8% of 1-butanol
LM	$1x10^{-6}$M of NaOH (pH8.5)

(b) Graph of LM spin rate against applied spin rate

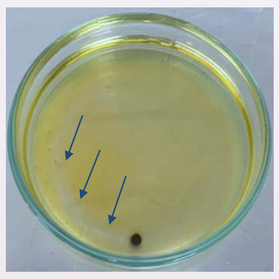


(c) LM during experiment

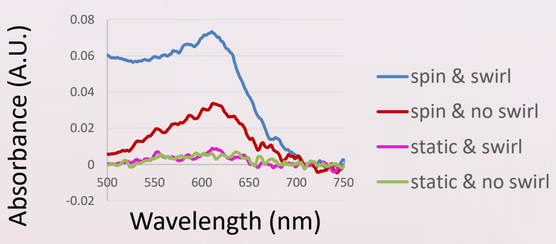
Immersed in decane, floating on water



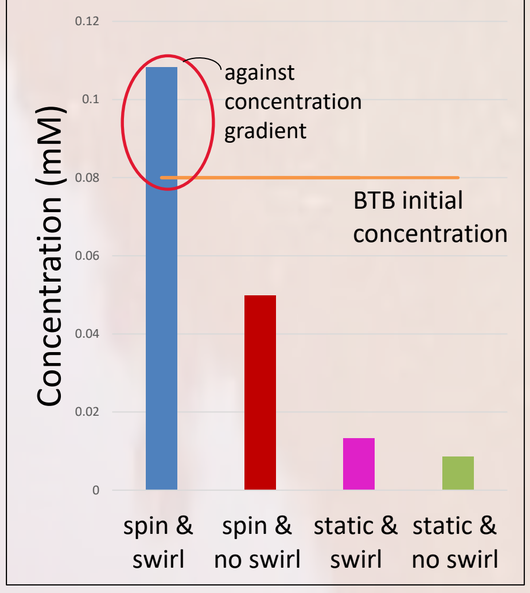
(d) Spinning LM discolorizes BTB



(e) LM UV-Vis spectroscopy after 5 minutes



(f) Actual concentration of LM after 5 minutes



4. Discussion & Conclusion

The rotation of LM has created an interior hydrodynamic flow to enable homogenization within the microdroplet. The hydrophobic and porous LM shell allows microencapsulated direct mass transportation of analyte from the exterior phase. The color change of the aqueous NaOH droplet and the discoloration of the organic layer indicates the presence of deprotonated BTB in LM. Additionally, the swirling method is used to overcome the specific path of spinning LM traveling with applied field. With this, the concentration of BTB in spinning LM has increased 8-folds and 12.5 folds than static LM with and without swirling respectively in 5 minutes. LM has effectively concentrated analyte, be against concentration and increased its sensitivity for machine detection.

In summary, our LM is a realistic means for sensing with appropriate indicators and concentrating analytes, especially for environmental applications.

5. References

Tian, J., Arbatan, T., Li, X., & Shen, W. (2010). Porous liquid marble shell offers possibilities for gas detection and gas reactions. *Chemical Engineering Journal, 165*(1), 347-353. doi:10.1016/j.cej.2010.06.036

Han, X., Lee, H. K., Lee, Y. H., & Ling, X. Y. (2017). Dynamic rotating liquid marble for directional and enhanced mass transportation in three-dimensional microliter droplets. *Journal of Physical Chemistry Letters, 8*(1), 243-249. doi:10.1021/acs.jpclett.6b02743

Han, X., Lee, H. K., Lim, W. C., Lee, Y. H., Phan-Quang, G. C., Phang, I. Y., & Ling, X. Y. (2016). Spinning liquid marble and its dual applications as microcentrifuge and miniature localized viscometer. *ACS Applied Materials and Interfaces, 8*(36), 23941-23946. doi:10.1021/acsami.6b07766

Semi-micro cells, self masking black walls, starna. (n.d.). https://www.starnacells.com/d_cells_s/rect/T009B.html.

6. Acknowledgements

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