Various types of Low molecular mass Dynamic Soft-materials

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Abstract: In recent years there has been growing interest in the development of low molecular mass organo-gelators (LMOGs) because of their potential applications in structure directing agents, drug delivery, stabilization of organic photochromatic material, light harvesting materials, food processing, cosmetics, and preparing dye sensitized solar cells, among others[1]. Low molecular weight compounds form stable and efficient gels with various organic solvents at low concentrations**.** One-component gelators are self-assembled either by hydrogen bonding interaction or non hydrogen bonding interactions whereas dual-component organo-gelators are assembled through the donor-acceptor interaction or hydrogen bonding interaction[2,3]. A two component organo-gelator could be observed visually with concomitant color change[4]. Electronmicrographs of the xerogels showed a fibrous structure having fibers of submicron diameters [5-7]

Keywords: *Soft-materials, organo-gelators, dynamic.*

1. INTRODUCTION

Gels are unique materials and everywhere in our daily life starting from protoplasm to shaving cream, they are fascinating solid-like materials containing mostly liquid. Gels have a broad range of applications in food, medicines, biomaterials, cosmetics, and separation technology[8]. Typical examples are, for instance gelatin pudding, anti – insect gel, hair styling gel and detergent gels. Despite the fact that gels have been known and studied since the end of the 18th century, up till now '…. The gel is one which is easier to recognize than to define……'[9]. For all practical purpose, a material is termed a gel if the whole volume of liquid is completely immobilized as usually identified by the simple "inversion test"; turn a pot of gel upside down and it is able to support its own weight without falling out onto your shoes![10, 11].

In general, gels are soft solid–like materials in which a liquid (the major component) is entrapped inside the three dimensional network of a solid (minor component). The solid phase forms a network of interconnected fibers, which prevents the fluid from flowing on a macroscopic scale, whereas on a macroscopic scale the liquid is mobile. The fluid phase fills the pores of the network and prevents the network from collapsing [2].

As a result of this structure, the gel possesses both solid-like and liquid-like characteristics. For instance, a gel is resistant to mechanical stress, a large solid-like interfacial area is present within the gel, solutes can be entrapped within the pores formed by the solid-component or slowly diffuse through the gel and the fluid-component can be used as a reaction medium. Due to these unique characteristics gels are very interesting, both from a scientific and an industrial prospective.

2. Classification of Gels:

A gel is comprised of two components - gelator(s) and solvent(s). The solid-like appearance of the gel is due to the immobilization of the solvent molecules in the three-dimensional (3D) network formed by the gelator molecules. If chemical bond formation among gelator molecules is responsible for such a 3D network, the resulting gel is called a chemical gel (e.g., polyethylene polyester, polyamide, poly- (vinyl alcohol) etc.). On the other hand, if the 3D network is formed by a self-assembly process (non-covalent interactions such as hydrogen bonding, $\pi - \pi$ stacking, van der Waals interactions etc.), the resulting gel is termed a supramolecular or physical gel. One component and two components gelators contain one and two types of molecules respectively.

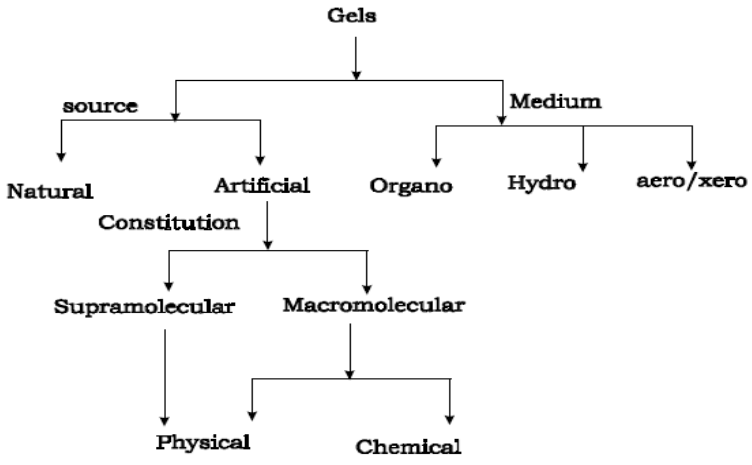
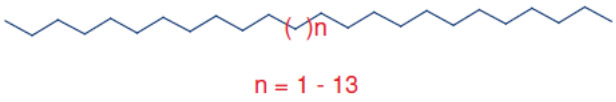


Figure 1: Classification of Gels

Among various types of gelators, the studies of low molecular mass organo-gelators (LMOGs) have gained renewed interest in recent years because of their various potential applications as well as their importance in supramolecular chemistry.

2.1 Representative LMOGs:

A: LMOG's based upon elongated hydrocarbons:



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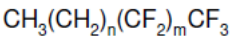

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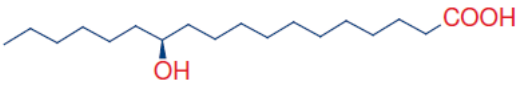

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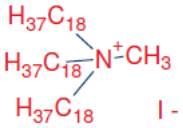

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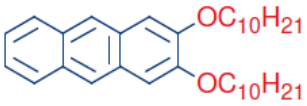
B: LMOG's based upon aromatic units:



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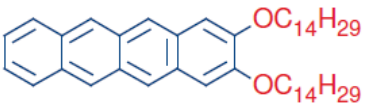

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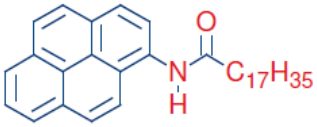

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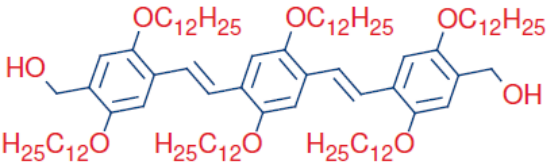

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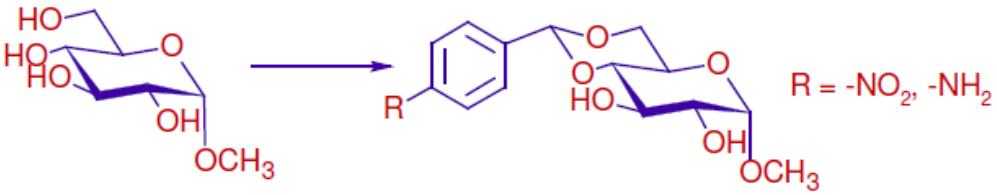
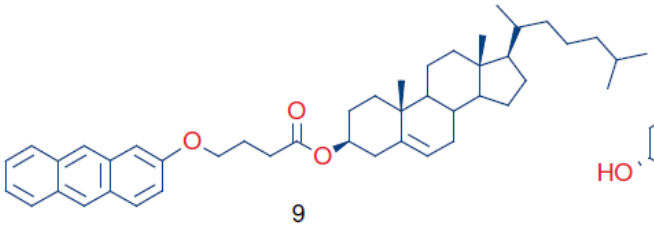
C: LMOGs based upon sugars:



D: LMOG's based on Steroids:



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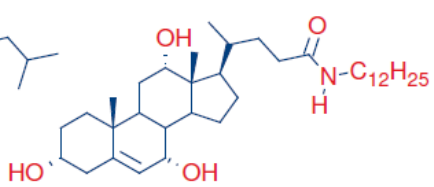

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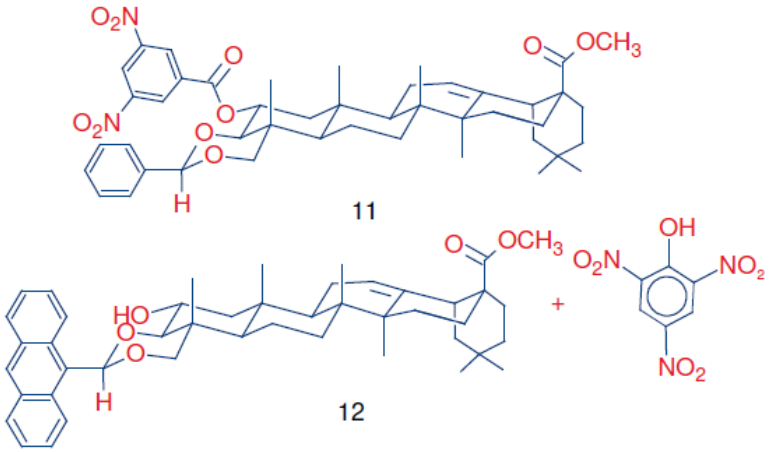
E: LMOG's based on Terpenoids:



3. Preparation of Gel:

Gels from low molecular mass organic compounds are usually prepared by heating the gelator in an appropriate solvent and then allowing the resulting solution to cool at room temperature. When the solvent does not flow under gravity, the resulting soft solid-like material is called gel. The low molecular mass organic compounds self-assemble in one dimension to form a fibrous network. The solvent molecules are then trapped inside the network and in macroscopic scale their movements are lost [6].

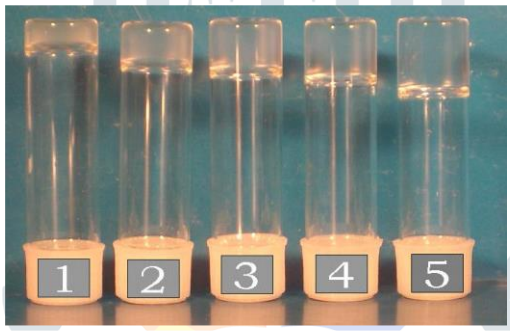


Figure 3: Inverted vials containing gels from **11** and propan-2-ol

4. Gel Melting:

A plot of the gel-to-sol transition temperature Tgel is shown in figure 4(a). With increasing gelator concentration, the Tgel values increase indicating stronger intermolecular interactions. Thermochromic behavior has been demonstrated in the case of two component organogel system **12** fugure 4(b). A new chargetransfer band (490nm) is formed during gelation which disappears during melting. Efficient gelation takes place when both the components are present in 1:1 stoichiometric ratio [4].

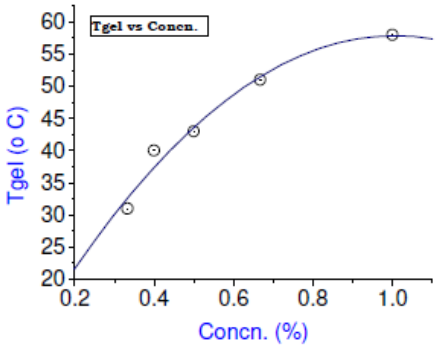


Figure 4(a): Plot of Tgel vs Concn.

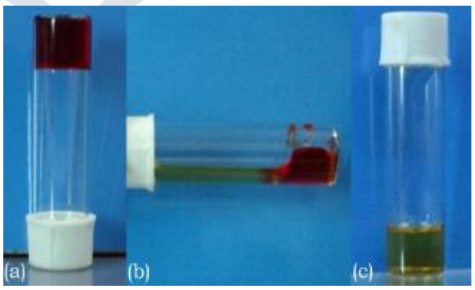


Figure 4(b): Melting of gel is observed with concomitant color change

5. Morphology:

The morphology of the gels are studied by various microscopic techniques like SEM, TEM, AFM etc. All these studies reveal a fibrous network structure formed by self-assembly of the molecules in one dimension.

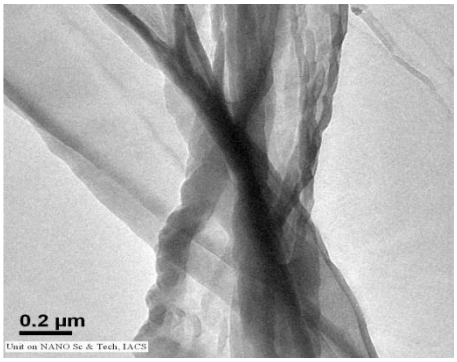


Figure 5(a): TEM image of xero gel

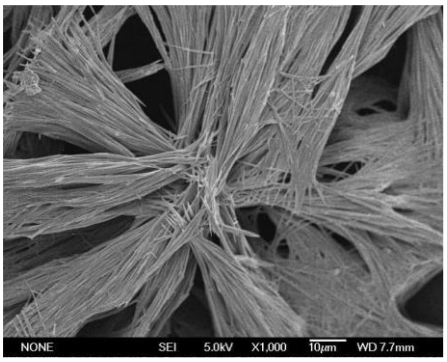


Figure 5(b): SEM image of xero gel

6. Application of LMOGs:

Low molecular weight gels are considered as viscoelastic, thermoreversible, solid-like or liquid-like material. When the bulk solvents are entrapped within an appropriate three dimensional network under suitable condition it form gel. LMW gels can find use in numerous applications like catalysis, separation technology, sensors, food, cosmetics, and pharmaceuticals. Because of the demand for personal care products, foods, pharmaceuticals, and new biomedical applications [1, 2].

7. Conclusion:

Various types of low molecular weight compounds have been utilized to form different types of gels. There are large structural diversity but have the common feature that they are able to gelate a number of solvents through intermolecular self-assembly. The structures vary from very simple molecules like alkanes [12] or falty acids [13], carbohydrate [14-27] or amino acid [28- 43] derivatives, etc. The interactions leading to self-assembly are may be due to hydrogen bonding, π-π stacking, metal coordination, and coulomb forces. Solvophobic and entropic effects may also play a role. In most cases, assembly is not the result of one type of interaction, but rather due to a combination of a number of these types of interactions.

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REFERENCES:

1. M. George, R.G. Weiss, *Acc. Chem. Res.* (2006), 39, 489.
2. N.M. Sangeetha, U. Maitra, *Chem. Soc. Res.*, (2005), 34, 821.
3. B.G. Bag, S.K. Dinda, *Pure & Appl. Chem.*, **2007**, 79 (11), 2031 – 2038.
4. B.G. Bag, G.C. Maity, S.K. Dinda, *Org. Lett.* (2006), 8, 5457.
5. B.G. Bag, P.P. Dey, S.K. Dinda, W.S. Sheldrick, I.M. Oppel, *Beil. J. Org. Chem*, **2008**, 4, 24.
6. B.G. Bag, S.K. Dinda, P.P. Dey, V.A. Mallia,R.G. Weiss, *Langmuir*, **2009**, 25, 8663 – 8671.
7. B.G. Bag, R. Majumdar, S. K. Dinda, P. P. Dey, G. C. Maity, V. A. Mallia, Richard G. Weiss, Langmuir, **2013**, 29, 6, 1725-2092
8. (a) *Polymer gels Fundamentals and Biomedical Applications* (Eds. D. De Rossi, K. Kajiwara, Y. Osada, A.Yamauchi), Plenum Press, New York, 1991; (b) *Hydrogels in Medicine and Pharmacy; Vol. III: Properties and applications* (Ed. N.A. Peppas), CRC Press, Boca Raton, **1987**).
9. D. Jordan Lloyd in *Colloid Chemistry I* (Ed. J. Alexander), Chemical Catalog Company, New York, **1926**, 767 – 782.
10. P. Dastidar. *Chem. Soc. Rev.* **2008**, *37*, 2699–2715.
11. Marc-Oliver M. Piepenbrock, Gareth O. Lloyd, Nigel Clarke,and Jonathan W. Steed. *Chemical Reviews* **2010**, Vol. 110, No. 4, 1960-2004.
12. (a) D. J. Abdallah, R. G. Weiss, *Langmuir* **2000**, *16*, 352-355; (b) D. J. Abdallah, S. A. Sirchio, R. G. Weiss, *Langmuir* **2000**, *16*, 7558-7561.
13. T. Tachibana, T. Mori, K.Hori, Bull. *Chem. Soc. Jpn.* **1980**, *53*,1714-1719.
14. J. H. Jung, G. John, M. Masuda, K. Yoshida, S .Shinkai, T. Shimizu, *Langmuir* **2001**, *17*, 7229.
15. J. H. Jung, S. Shinkai, T. Shimizu, *Chem. Eur. J.* **2002**, *8*, 2684.
16. O. Gronwald, S. Shinkai, J. *Chem. Soc., Perkin Trans. 2*, **2001**, 1933.
17. K. Yoza, N. Amanokura, Y. Ono, T. Akao, H. Shinmori, M. Takeuchi, S. Shinkai, D. Reinhoudt, *Chem. Eur. J.* **1999**, *5*, 2722.
18. K. Yoza, Y. Ono, K. Yoshihara, T. Akao, H. Shinmori, M. Takeuchi, S. Shinkai, D. N. Reinhoudt, *Chem. Commun*. **1998**, 907
19. S. Kiyonaka, K. Sugiyasu, S. Shinkai, I. Hamachi, *J. Am. Chem. Soc*. **2002**, *124*, 10954.
20. S. Kiyonaka, S. Shinkai, I. Hamachi, *Chem. Eur. J.* **2003**, *9*, 976.
21. Note: Bolaamphiphiles are two-headed amphiphiles and each head contain functional group (s). The aggregation properties of the Bolaamphiphiles can be changed by changing the functionality of the head groups and linking groups.

22. I. Nakazawa, M. Masuda, Y. Okada, T. Hanada, K. Yase, M. Asai, T. Shimizu, *Langmuir* **1999**, *15*, 4757.
23. T. Shimizu, M. Masuda, *J. Am. Chem. Soc*. **1997**, *119*, 2812. 29.
24. S. Bhattacharya, S. N. G. Acharya, *Chem. Mater*. **1999**, *11*, 3504.
25. T. Imae, K. Funayama, M. P. Krafft, F. Giulieri, T. Tada, T. Matsumoto, *J. Colloid Interface Sci.* **1999**, *212*, 330.
26. S. F. Pang, D. B. Zhu, *Chem. Phys. Lett*. **2002**, *358*, 479.
27. B. Xing, C. W. Yu, K. H. Chow, P. L. Ho, D. Fu, B. Xu, *J. Am. Chem. Soc*. **2002**, *124*, 14846.
28. T Imae, Y. Takahashi, H. Muramatsu, *J. Am. Chem. Soc*. **1992**, *114*, 3414.
29. T. Imae, N. Hayashi, T. Matsumoto, T. Tada, M. Furusaka, *J. Colloid Interface Sci.* **2000**, *225*, 285.
30. M. Suzuki, M. Yumoto, M. Kimura, H. Shirai, K. Hanabusa, *Chem. Commun*. **2002**, 884.
31. M. Suzuki, M. Yumoto, M. Kimura, H. Shirai, K. Hanabusa, *Chem. Eur. J*. **2003**, *9*, 348.
32. M. Suzuki, M. Yumoto, M. Kimura, H. Shirai, K. Hanabusa, New *J. Chem.* **2002**, *26*, 817.
33. S. Franceschi, N. de Viguerie, M. Riviere, A. Lattes, New *J. Chem*. **1999**, *23*, 447.
34. T. Nakashima, N. Kimizuka, *Adv. Mater*. **2002**, *14*, 1113.
35. (a) J. Makarevic, M. Jokic, B. Peric, V. Tomisic, B. Kojic-Prodic, M. Zinic, *Chem. Eur. J*. **2001**, *7*, 3328. (b) M. Jokic, J. Makarevic, M. Zinic, *Chem. Commun.* **1995**, 1723.
36. G. Wang, A. D. Hamilton, *Chem. Commun*. **2003**, 310.
37. M. Kogiso, T. Hanada, K. Yase, T. Shimizu, *Chem. Commun.* **1998**, 1791.
38. M. Kogiso, S. Ohnishi, K. Yase, M. Masuda, T. Shimizu, *Langmuir* **1998**, 14, 4978
39. L. Frkanec, M. Jokic, J. Makarevic, K. Wolsperger, M. Zinic, *J. Am. Chem. Soc*. **2002**, *124*, 9716.
40. L. A. Estroff, A. D. Hamilton, *Angew. Chem., Int. Ed. Engl*. **2000**, *39*, 3447.
41. L. A. Estroff, L. Leiserowitz, L. Addadi, S. Weiner, A. D. Hamilton, *Adv. Mater*. **2003**, *15*, 38.
42. M. Suzuki, S. Owa, M. Yumoto, M. Kimura, H. Shirai, K. Hanabusa, *Tetradedron Letters*, **2004**, 45,
43. (a) J. H. Fuhrhop, S. Svenson, C. Boettcher, E. Rossler, H. M. Vieth, *J. Am. Chem. Soc*. **1990**, *112*, 4307; (b) J. H. Fuhrhop, P. Schnieder, J. Rosenberg, E. Boekema, *J. Am. Chem. Soc*. **1987**, *109*, 3387; (c) J. Konig, C. Boettcher, H. Winkler, E. Zeitler, Y. Talmon, J. Fuhrhop, *J. Am. Chem. Soc*. **1993**, *115*, 693; (d) C. Boettcher, H. Stark, M. van Heel, *Ultramicroscopy* **1996**, *62*, 133.