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Synthesis and Characterizations of 3-O-Esters of N-Acetyl-D-Glucosamine

Derivatives as Organogelators

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Supporting Information

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Preparation of the acid chloride intermediates

Pentanoyl chloride: To a solution of valeric acid (0.07 mL, 0.626 mmol, 1 equiv) in CH₂Cl₂ (3 mL) at 0 °C was added 1 pipette drop of diluted DMF (1 pipette drop) solution in CH₂Cl₂ (2 mL) followed by oxalyl chloride (0.06 mL, 0.689 mmol, 1.1 equiv) drop-wise. The mixture was stirred at 0 °C for 1 hour, followed by 10 hours at room temperature. The stirring was then stopped and the solvent was evaporated under rotary evaporation to obtain the 1-pentyl acyl chloride as a yellow oil. This mixture was used for the next reaction as it is.

Lauroyl chloride: To a solution of lauric acid (125 mg, 0.626 mmol, 1 equiv) in CH_2Cl_2 (3 mL) at 0 °C was added 1 pipette drop of diluted DMF (1 pipette drop) solution in CH_2Cl_2 (2 mL) followed by oxalyl chloride (0.06 mL, 0.689 mmol, 1.1 equiv) drop-wise. The mixture was stirred at 0 °C for 1 hour, followed by 10 hours at room temperature. The stirring was then stopped and the solvent was evaporated under rotary evaporation to obtain the 1-pentyl acyl chloride as a yellow oil. This mixture was used for the next reaction as it is.

5-hexynoyl chloride: To a solution of 5-hexynoic acid (0.07 mL, 0.626 mmol, 1 equiv) in CH₂Cl₂ (3 mL) at 0 °C was added 1 pipette drop of diluted DMF (1 pipette drop) solution in CH₂Cl₂ (2 mL) followed by oxalyl chloride (0.06 mL, 0.689 mmol, 1.1 equiv) drop-wise. The mixture was stirred at 0 °C for 1 hour, followed by 10 hours at room temperature. The stirring was then stopped and the solvent was evaporated under rotary evaporation to obtain the 5-hexynoic acyl chloride as a yellow oil. This mixture was used for the next reaction as it is.

6-heptynoyl chloride: To a solution of 6-heptynoic acid (0.08 mL, 0.626 mmol, 1 equiv) in CH₂Cl₂ (3 mL) at 0 °C was added 1 pipette drop of diluted DMF (1 pipette drop) solution in CH₂Cl₂ (2 mL) followed by oxalyl chloride (0.06 mL, 0.689 mmol, 1.1 equiv) drop-wise. The mixture was stirred at 0 °C for 1 hour, followed by 10 hours at room temperature. The stirring was then stopped and the solvent was evaporated under rotary evaporation to obtain the 6-heptynoic acyl chloride as a yellow oil. This was used for the next step without further purification.

4-methoxyl benzoyl chloride: To a solution of 4-methoxyl benzoic acid (1.0 g, 6.6 mmol, 1 equiv) in CH_2Cl_2 (10 mL) at 0 °C was added DMF (0.1 mL) followed by oxalyl chloride (0.61 mL, 7.2 mmol, 1.1 equiv) drop-wise. The mixture was stirred at 0 °C for 1 hour, followed by 10 hours at room temperature. The stirring was then stopped and the solvent was evaporated under rotary evaporation to obtain the 4-methoxyl benzoyl chloride as a brown oil. This mixture was used for the next reaction as it is.

1-naphthalene acetyl chloride: To a solution of 1-Naphthalene acetic acid (116 mg, 0.626 mmol, 1 equiv) in CH₂Cl₂ (3 mL) at 0 °C was added 1 pipette drop of diluted DMF (1 pipette drop) solution in CH₂Cl₂ (2 mL) followed by oxalyl chloride (0.06 mL, 0.689 mmol, 1.1 equiv) drop-wise. The mixture was stirred at 0 °C for 1 hour, followed by 10 hours at room temperature. The stirring was then stopped and the solvent was evaporated under rotary evaporation to obtain the 1-naphthalene acetyl chloride as a yellow oil. This mixture was used for the next reaction as it is.



¹H and ¹³C NMR spectra of ester derivatives

 ^1H and ^{13}C NMR spectra of compound $\boldsymbol{5}$ in CDCl_3



¹H and ¹³C NMR spectra of compound **6** in CDCl₃



 ^1H and ^{13}C NMR spectra of compound 7 in CDCl_3



 ^1H and ^{13}C NMR spectra of compound 8 in CDCl_3



 ^1H and ^{13}C NMR spectra of compound 9 in CDCl_3

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¹H and ¹³C NMR spectra of compound **10** in CDCl₃



¹H and ¹³C NMR spectra of compound **11** in d_6 -DMSO





¹H and ¹³C NMR spectra of compound **12** in d_6 -DMSO



¹H and ¹³C NMR spectra of compound **13** in CDCl₃



 ^1H and ^{13}C NMR spectra of compound 14 in CDCl_3



 ^1H and ^{13}C NMR spectra of compound 15 in CDCl_3



¹H and ¹³C NMR spectra of compound **16** in CDCl₃



 ^1H and ^{13}C NMR spectra of compound 17 in CDCl_3



¹H and ¹³C NMR spectra of compound **18** in CDCl₃

Rheological data, amplitude experiments of compounds 6, 7 and 8



EtOH:H₂O=1:1 10.0 mg/mL opaque

Compound 6				
10.0 mg/mL, EtOH/H ₂ O, 1:1				
Angular frequency	Storage modulus (G')	Loss modulus (G")	<i>G'/G''</i>	
rad/s	Pa	Pa		
0.1	1864.81	976.967	1.90877	
0.15849	2236.32	978.585	2.28526	
0.251189	2444.85	965.134	2.53317	
0.398107	2692.5	893.737	3.01263	
0.630957	2768.1	897.223	3.08519	
1.0	2988.59	865.983	3.4511	
1.5849	3143.23	841.585	3.73489	
2.51189	3288.29	824.72	3.98716	
3.98105	3460.09	864.865	4.00073	
6.30957	3565.22	809.117	4.40631	
10.0001	3674.75	848.654	4.33009	
15.849	3814.87	863.12	4.41986	
25.1188	3992.33	894.677	4.46231	
39.8105	4153.04	931.423	4.45881	
63.0957	4343.64	1005.1	4.3216	
100.0	4618.97	973.768	4.7434	

Table S1. Storage modulus (G'), loss modulus (G'') and G'/G'' value for gel formed by compound **6** in EtOH:H₂O (v/v 1/1) under different angular frequency.



EtOH:H₂O=1:2 3.3 mg/mL opaque

Compound 6 3.3 mg/mL EtOH/H ₂ O 1:2			
Angular frequency	StorageLossmodulusmodulus(G')(G'')		<i>G''</i> / <i>G''</i>
rad/s	Pa	Pa	
0.1	3564.84	1447.67	2.46247
0.15849	4044.26	1425.09	2.8379
0.251189	4207.74	1422.52	2.95795
0.398107	4446.8	1291.23	3.44385
0.630957	4626.55	1208.1	3.82961
1.0	4758.25	1139.16	4.17698
1.5849	4852.74	1160.49	4.18163
2.51189	4881.28	1081.54	4.51327
3.98105	5150.77	1010.55	5.097
6.30957	5132.28	990.278	5.18267
10.0001	5224.48	970.233	5.38477
15.849	5332.43	984.907 5.414	
25.1188	5371.46	952.735 5.6379	
39.8105	5451.18	977.366	5.57742
63.0957	5506.32	1015.3	5.42334
100.0	5499.2	1175.96	4.67635

Table S2. Storage modulus (*G'*), loss modulus (*G''*) and *G'/G''* value for gel formed by compound **6** in EtOH:H₂O (v/v 1/2) under different angular frequency.



DMSO:H₂O=1:2 5.0 mg/mL opaque

Compound 6				
5.0 mg/mL, DMSO/H ₂ O, 1:2				
Angular	Storage modulus	Loss	<i>C</i> "/ <i>C</i> "	
frequency	(G')	(<i>G''</i>)	070	
rad/s	Pa	Pa		
0.1	9299.59	2960.24	3.1415	
0.15849	10146.3	2604.74	3.89532	
0.251189	10539.8	2367.26	4.45232	
0.398107	10824.1	2246.92	4.81731	
0.630957	11050.3	2072.36	5.33223	
1.0	11267.8	1918.29	5.87388	
1.5849	11479.6	1869.11	6.14175	
2.51189	11603.7	1784.32	6.50315	
3.98105	11734.3	1659.02	7.07303	
6.30957	11928.2	1667.4	7.15377	
10.0001	12055.7	1615.43	7.46284	
15.849	12247.8	1537.79	7.96455	
25.1188	12326.6	1567.79	7.86241	
39.8105	12409.9	1446.32	8.58033	
63.0957	12586.7	1444.89	8.71118	
100.0	12408.7	1284.99	9.65665	

Table S3. Storage modulus (*G'*), loss modulus (*G''*) and *G'/G''* value for gel formed by compound **6** in DMSO:H₂O (v/v 1/2) under different angular frequency.



DMSO:H₂O=1:1 10.0 mg/mL opaque

Compound 7				
10.0 mg/mL, DMSO/H ₂ O, 1:1				
Angular	Storage	Loss	<i>G''</i> / <i>G''</i>	
frequency	modulus	modulus		
nequency	(G')	(G ")		
rad/s	s Pa Pa			
0.1	3477.82	1332.75	2.60951	
0.15849	3461.35	1246.87	2.77603	
0.251189	3790.02	1167.95	3.24502	
0.398107	3916.18	1137.3	3.4434	
0.630957	4083.9	1067.78	3.82466	
1.0	4237.69	1024.53	4.13623	
1.5849	4354.06	975.979	4.46122	
2.51189	4487.91	927.551	4.83845	
3.98105	4577.5	884.068	5.17777	
6.30957	4684.45	824.227	5.68345	
10.0001	4748.05	820.818	5.78453	
15.849	4808.88	783.312	6.13916	
25.1188	4880.99	766.272	6.36979	
39.8105	4946.53	734.973	6.73022	
63.0957	5007.9	705.421	7.09916	
100.0	5052.5	687.848	7.34537	

Table S4. Storage modulus (*G'*), loss modulus (*G''*) and *G'/G''* value for gel formed by compound 7 in DMSO:H₂O (v/v 1/1) under different angular frequency.



5.0 mg/mL opaque

Compound 8 5.0 mg/mL DMSO/H ₂ O 1:1				
Angular frequency	StorageLossmodulusmodulus(G')(G'')		<i>G'/G''</i>	
rad/s Pa		Pa		
0.1	33254.0	13842.3	2.40235	
0.15849	37895.3	13435.7	2.82049	
0.251189	39227.4	12850.2	3.05267	
0.398107	41348.3	12180.1	3.39474	
0.630957	42778.3	11530.7	3.70995	
1.0	44119.7	11101.0	3.97439	
1.5849	45448.0	10521.2	4.31966	
2.51189	46565.0	9955.66	4.67724	
3.98105	47556.8	9522.74	4.99402	
6.30957	48405.4	8988.14	5.38547	
10.0001	49172.8	8596.1	5.72036	
15.849	49642.9	8225.8	6.03502	
25.1188	50258.5	7829.76	6.41891	
39.8105	50874.4	7442.87	6.83532	
63.0957	51280.1	7229.5	7.09317	
100.0	51851.2	6986.44	7.42169	

Table S5. Storage modulus (*G'*), loss modulus (*G''*) and *G'/G''* value for gel formed by compound **8** in DMSO:H₂O (v/v 1/1) under different angular frequency.

Amplitude sweep experiments

Amplitude sweep experiment was performed by HR-2 Discovery Hybrid Rheometer from TA instrument. All gels at their minimum gelation concentration were prepared in 1-dram vial in different solvent (or solvent mixtures) and they were left undisturbed on bench for 2 hours. Sample (approximately 1 mL) was placed on the steel plate of the rheometer. The experimental temperature was 25 °C. The sample were subjected to amplitude sweep between 25-mm peltier plate and steel plate with a gap of 100 μ m. Angular frequency was set as 10.0 rad/s. Operating and processing software is TRIOS. Results were expressed as the storage modules (*G'*), loss modules (*G''*) as function of oscillation strain in a range from 0.125% to 125%.



Figure S1. Rheological properties of amplitude sweep experiment for the gel formed by compound **6** in EtOH:H₂O (v/v 1/1).



3.3 mg/mL opaque



Figure S2. Rheological properties of amplitude sweep experiment for the gel formed by compound **6** in EtOH:H₂O (v/v 1/2).



DMSO:H₂O=1:2 5.0 mg/mL opaque



Figure S3. Rheological properties of amplitude sweep experiment for the gel formed by compound **6** in DMSO:H₂O (v/v 1/2).



10.0 mg/mL opaque



Figure S4. Rheological properties of amplitude sweep experiment for the gel formed by compound 7 in DMSO:H₂O (v/v 1/1).



Figure S5. Rheological properties of amplitude sweep experiment for the gel formed by compound **8** in DMSO:H₂O (v/v 1/1).

Amplitude experiments of oil gel from compound 6





Figure S6. Rheological properties of amplitude sweep experiment for the engine oil gel (6.7 mg/mL) formed by compound 6.





Figure S7. Rheological properties of amplitude sweep experiment for the mineral oil gel (4.0 mg/mL) formed by compound 6.





Figure S8. Rheological properties of amplitude sweep experiment for the pump oil gel (4.0 mg/mL) formed by compound **6**.

Measurement of melting point ranges of gels

The gelator was dissolved in a small vial at the certain gelation concentration and heated to form the solution. The hot solution was transferred to the NMR tube, where it was allowed to cool down to form the gel. A metal ball was placed on top of the gel. The NMR tube was immersed in an oil bath which was heated gradually. T_1 is the temperature of the initial melting at which liquid was first seen. T_2 is the temperature at which the gel is estimated to be half melted. And T_3 is the temperature at which the entire gel turned into a colorless liquid when the ball fell towards the bottom of the tube.



Figure S9. At 67.2 °C, when gel formed by compound **6** (right) was melted halfway, the gel formed by compound **5** (middle) was completely melted and gel formed by compound **8** (left) was melted less than halfway.





Figure S10. At 89.0 °C when 15 mg/ml gel formed by compound 7 (middle) was melted

halfway.

Variable temperature ¹H NMR studies of compound 6, 15





Figure S11. The ¹H NMR spectra (0-10 ppm) of compound **6** from 30 °C to 55 °C in CDCl₃ (10.0 mg/mL).





Figure S12. The ¹H NMR spectra (0-10 ppm) of compound **15** from 30 °C to 55 °C in CDCl₃ (10.0 mg/mL).





Figure S13. The ¹H NMR spectra (3.4 to 6.0 ppm) of compound **15** from 30 °C to 55 °C in $CDCl_3(10.0 \text{ mg/mL})$.

FTIR studies of compound 6, 15

FTIR measurements were performed on a Bruker ALPHA Platinum ATR FTIR Spectrometer, the operating software is OPUS. The absorption spectra of all samples were obtained at room temperature in the range of 400-4000 cm⁻¹.





Figure S14. FTIR spectra for compound **6** in 400-4000 cm⁻¹ region. The green curve corresponds to the solid form, the red curve corresponds to the gel form of **6** in DMSO:H₂O (v/v 1:2) at 5.0 mg/mL.



Figure S15. FTIR spectra for compound **6** in 400-4000 cm⁻¹ region. The green curve corresponds to the solid form, the red curve corresponds to the gel form of **6** in EtOH:H₂O (v/v 1:2) at 3.3 mg/mL.



The IR spectra of the gels were measured to further elucidate the types of interactions which drive the gelation process. Figure S16 shows the IR spectra of the *p*-bromo ester compound **15**, the 39.6 mM gel formed by compound **15** in ethanol, and ethanol by itself. Comparison of the spectra of the solid gelator **15** and the gel formed with EtOH show a change in intensity in the peaks at 1589 cm⁻¹ and 843 cm⁻¹. These correspond to the aromatic C=C stretch and aromatic C-H bend, respectively. This observation suggests that π - π stacking is one of the driving forces behind the supramolecular self-assembly.



Figure S16. IR spectrum of compound **15** (blue), gel of compound **15** (20 mg/mL) in EtOH (red), and EtOH (green). The y axis are arbitrary relative values.

Gelation test for DMSO and water mixtures

This is to obtain the water gelation concentration in presence of a small amount of DMSO: The gelator molecule (2.0 mg) was added to a 1-dram vial with a sealed cap and dissolved in 0.1 mL DMSO, then 0.1 mL water was added to the solution. If a gel has formed, it is recorded, the vial was then heated and sonicated to bring the gel back into the solution phase. The solution was allowed to cool for 20-30 minutes at rt on the benchtop. Additional 0.1 mL water was added sequentially and gel test repeated unit a stable gel could no longer form.

Table S6. Gelation test in DMSO water mixture (water tolerance study) for compounds 6 and 8

	DMSO:H ₂ O mixture				
Compound					
	1:0	1:1	1:2	1:3	1:4
6	S	$G^1 10.0$	G 6.7	G 5.0	Р
8	S	$G^{1} 10.0$	G 6.7	G 5.0	Р

 G^1 , spontaneous gelation; G, gel formed after heating; S, soluble; P, precipitation. The numbers following the letters are the concentrations in mg/mL of the particular solvent mixture.

Gel photos of naproxen release studies under pH 7 and 10



Under pH =7

Figure S17. Gel pictures from the release study of naproxen from the gel formed by compound **6** (7.5 mg) in 1.5 mL of DMSO:H₂O (v/v 1:3) with naproxen (0.3 mg) in the presence of pH 7 water (1.5 mL) on top pf the gel at different time points.



Under pH =10



(7.5 mg) in 1.5 mL of DMSO:H₂O (v/v 1:3) with naproxen (0.3 mg) in the presence of pH 10 solution (1.5 mL, prepared using NaOH) on top pf the gel at different time points.





48 h curve is the same as 36 h, which means the release is over.

Figure S19. Release of naproxen from gel to aqueous phase. a) UV spectra of naproxen timed release, b) The % release at different times based con the UV absorbance at 331 nm.

Base stability experiment at pH=14

The gels were formed by weighing out 7.5 mg of compound **6**. 1.5 mL of DMSO:H₂O (v/v 1:3) was added and the mixture was heated and cooled to form a stable gel. NaOH was added to DI water to make aqueous solutions with pH 14. pH 14 solution (1.5 mL) was added on top of the gel. The gel partially decomposed.



0 h 10 h 20 h 30 h partially decomposed gel matrix

Figure S20. Gel pictures under pH 14 condition at different time points.