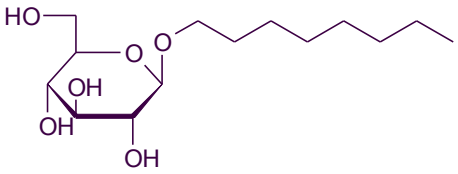
Carbohydrate Based Detergents

Detergents are water-soluble surfactants (surface-active agents) with multiple uses in protein biochemistry. Surfactants are usually amphiphilic organic compounds, containing both hydrophilic groups (heads) and hydrophobic groups (tails). The amphiphilic nature of the molecules results in their aggregation in solution to produce micelles, spherical or ellipsoid structures in which the hydrophilic head regions are in contact with the aqueous solvent, and the hydrophobic tails are sequestered in the centre of the micelle, Figure 1. Micelle formation occurs above the critical micelle concentration (CMC) for each detergent; CMC values provide an indication of the strength of hydrophobic binding and how readily molecules are incorporated into the micelle. In biology, the CMC is an important factor because above this concentration the detergent can form complexes with lipophilic proteins, whereas below it the detergent will partition into the membrane, solubilising it.

The carbohydrate based detergents, such as those offered by Carbosynth shown in table 1, are classed as non-ionic, as their hydrophilic head groups are not charged (ionised).

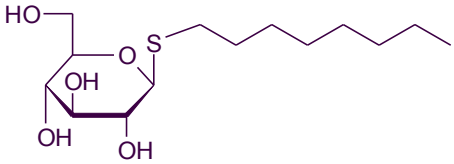
(1) Octyl β-D-glucopyranoside

Product Code: **DO05161**
CAS Number: **29836-26-8**
Chemical Formula: **$C_{14}H_{28}O_6$**
Molecular Weight: **292.37**



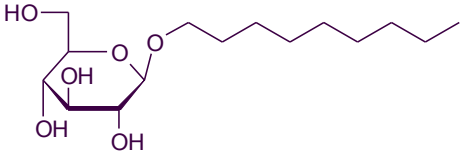
(2) Octyl β-D thioglucopyranoside

Product Code: **DO06354**
CAS Number: **85618-21-9**
Chemical Formula: **$C_{14}H_{28}O_5S$**
Molecular Weight: **308.44**



(3) Nonyl β-D-glucopyranoside

Product Code: **DN03173**
CAS Number: **69984-73-2**
Chemical Formula: **$C_{15}H_{30}O_6$**
Molecular Weight: **306.4**

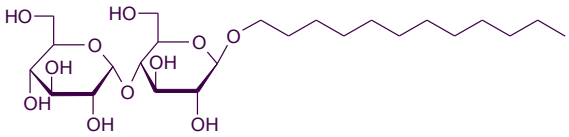


(4) Dodecyl β-D-glucopyranoside

Product Code: **DD06359**
CAS Number: **59122-55-3**
Chemical Formula: **$C_{18}H_{36}O_6$**
Molecular Weight: **348.47**

(5) Dodecyl β-D-maltopyranoside

Product Code: **DD06199**
CAS Number: **69227-93-6**
Chemical Formula: **$C_{24}H_{46}O_{11}$**
Molecular Weight: **510.62**



(6) Decyl maltose neopentyl glycol

Product Code: **DD14033**
CAS Number:
Chemical Formula: **$C_{43}H_{80}O_{22}$**
Molecular Weight: **949.08**

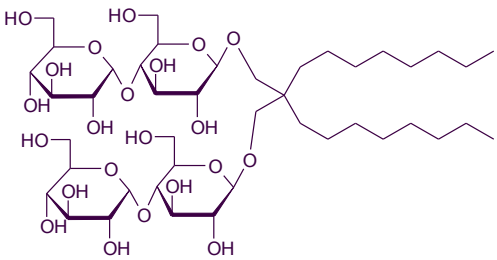


Table 1. Examples of non-ionic detergents

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Non-ionic detergents are typically mild solubilizing and dissociating agents used in the solubilisation and purification of integral membrane proteins, and frequently allow the retention of the native structure and function of the protein. Additional diverse uses include in agriculture, oil recovery applications and the cosmetics industry.[1]

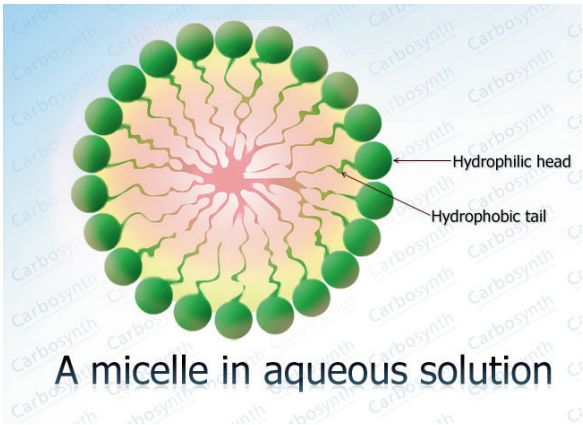
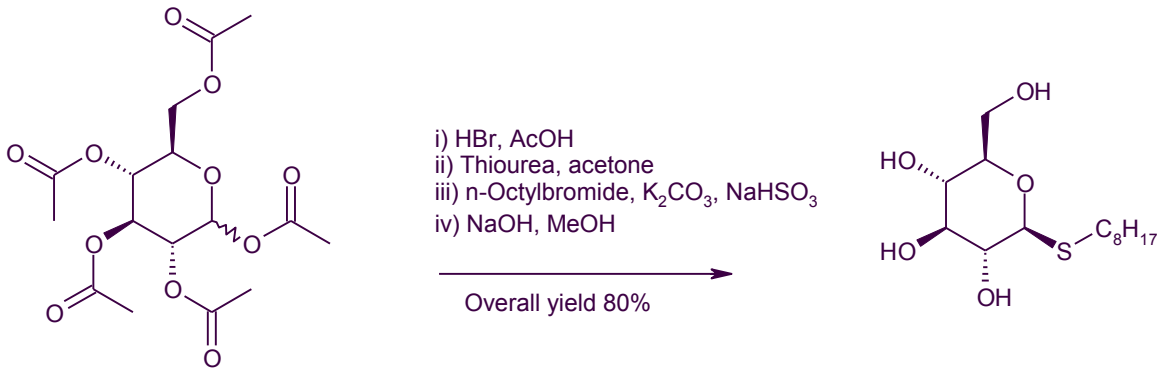


Figure 1

Octyl-β-D-glucopyranoside (1) (also referred to as octyl-β-D-glucoside, octyl glucoside or OG) is one of the most important biological detergents, as it can be readily removed from aqueous final protein extracts using dialysis or gel filtration due to its relatively high CMC (~20-26 mM)[2-4].[2,5,6] It is frequently used in the solubilisation and isolation of membrane proteins[7] and has been used above its CMC in an immunoprecipitation buffer in an optimised method for improving the selectivity of immunopurification of phospho-tyrosine peptides.[8]

Lundbaek and co-workers have used octyl glucoside in studies of the regulation of sodium channel function by the elasticity of the lipid bilayer in HEK293 cells,[9] and recently, Santos and co-workers have suggested the use of octyl glucoside as a conditioning agent for conventional and silicone-hydrogel contact lenses, where it effectively inhibited microbial adhesion of *Staphylococcus epidermis* and *Pseudomonas aeruginosa*,.[10] Uses in polyacrylamide gel electrophoresis (PAGE) have also been reported,[11,12] including in a system which allows the concentration of dilute protein from multiple two-dimensional electrophoresis gels.[13] In this process, during concentration of the protein, SDS (sodium dodecyl sulphate, an anionic (negatively charged) detergent) is replaced by the non-ionic detergent octyl glucoside which facilitates protein digestion and analysis by mass-spectroscopy (MS) directly from the gel without the need for fixation or staining.

Saito and Tsuchiya have proposed several characteristics which detergents must possess to be useful for the solubilization and purification of integral membrane proteins, including high solubilising power, no protein denaturation, high CMC, non-ionic nature and being readily available.[14] In 1984 they reported the highly efficient synthesis of octylthio β-D-glucopyranoside (2) from α-D-glucopyranose penta-acetate in 4 steps, Scheme 1.[14] Subsequent evaluation with *E. coli* membrane proteins revealed that (2) has a similar solubilising power to octyl-β-D-glucopyranoside (1), with no inactivation of proteins observed after solubilization. A significant advantage of (2) over (1), and also over dodecyl β-D-maltopyranoside (4), is a superior stability to hydrolysis, which is attributed to the greater chemical stability of the thioether bond present in (2) to the ether bonds in (1) and (4). Octylthio β-D-glucopyranoside can be stored in solution for several months without degradation compromising its reproducible use for membrane solubilisation, whereas octyl-β-D-glucopyranoside and dodecyl β-D-maltopyranoside solutions are recommended to be freshly prepared.[15] Additionally, Saito and Tsuchiya reported that octylthio β-D-glucopyranoside was resistant to enzymatic degradation by β-glucosidase, unlike octyl-β-D-glucopyranoside.



Scheme 1

Dodecyl β-D-glucopyranoside (3, also known as Lauryl monoglucoside, Dodecyl β-D-glucoside or β-C12G) and Dodecyl β-D-maltopyranoside (4, also known as DDM or Lauryl β-D-maltopyranoside) have similarly diverse uses in multiple scientific fields. For example, Engberts and co-workers have examined the effects of (3) as an additive on the properties of vesicles formed from di-*n*-hexadecyldimethylammonium bromide, ,[16] and Banipal and colleagues have investigated the mixed micelle behaviour of (3) with cationic Gemini surfactants[17] (a class of surfactants which possess more than one hydrophobic tail and hydrophilic head groups).[1] Dodecyl β-D-maltopyranoside (4) has been shown to enhance the absorption of insulin delivered via the inhaled route in animal studies.[18,19] Outer-membrane proteins (OMPs) from Gram-negative pathogenic bacteria are crucial to their virulence and as such, are potential candidates for the construction of new and effective antibacterial vaccines. Dodecyl β-D-maltopyranoside (4) is a commonly used agent for the solubilisation of OMPs and the subsequent analysis of this bacterial subproteome.[20]

A recently introduced class of maltose–neopentyl glycol (MNG) amphiphiles have shown favorable behavior in multiple membrane protein systems[21] comparable with Dodecyl β-D-glucopyranoside. These detergents, built around a central quaternary carbon atom derived from neopentyl glycol, with hydrophilic groups derived from maltose, were designed to provide a more rigid environment for membrane protein crystallization. The MNG series demonstrated enhanced protein solubilisation, structural stability and the successful crystallization of b2AR-T4L that could not be grown using the standard Dodecyl β-D-glucopyranoside - the currently highest ranked detergent for use in successful crystal growth leading to high-resolution X-ray structures.

References:

1. Sharma, P.; Sachar, S.; Kaur, G.; Thakur, P.; Bakshi, M. S.; Banipal, T. S. *J. Surface Sci. Technol.* **2007**, *23*, 131.
2. Lorber, B.; Bishop, J. B.; DeLucas, L. J. *Biochim. Biophys. Acta*. **1990**, *1023*, 254.
3. deGrip, W. J.; Bovee-Geurts, P. H. M. *Chem. Phys. Lipids* **1979**, *23*, 321.
4. Paula, S.; Sues, W.; Tuchtenhagen, J.; Blume, A. *J. Phys. Chem.* **1995**, *99*, 11742.
5. Morandat, S.; El Kirat, K. *Colloids Surf. B Biointerfaces* **2007**, *55*, 179.
6. Mimms, L. T.; Zampighi, G.; Nozaki, Y.; Tanford, C.; Reynolds, J. A. *Biochemistry* **1981**, *20*, 833.
7. Stubbs, G. W.; Smith, H. G.; Litman, B. J. *Biochim. Biophys. Acta*. **1976**, *426*, 46.
8. Zhang, G.; Neubert, T. A. *Proteomics* **2006**, *6*, 571.
9. Lundbaek, J. A.; Birn, P.; Hansen, A. J.; Søgaard, R.; Nielsen, C.; Girshman, J.; Bruno, M. J.; Tape, S. E.; Egebjerg, J.; Greathouse, D. V.; Mattice, G. L.; Koeppe II, R. E.; Andersen, O. S. *J. Gen. Physiol.* **2004**, *123*, 599.
10. Santos, L.; Rodrigues, D.; Lira, M.; Oliveira, R.; Real Oliveira, M. E.; Vilar, E. Y.; Azeredo, J. *Optom. Vis. Sci.* **2007**, *84*, 429.
11. Baron, C.; Thompson, T. E. *Biochim. Biophys. Acta*. **1975**, *382*, 276.
12. Holloway, P. J.; Arundel, P. H. *Anal. Biochem.* **1988**, *172*, 8.
13. Hatt, P. D.; Quadroni, M.; Staudenmann, W.; James, P. *Eur. J. Biochem.* **1997**, *246*, 336.
14. Saito, S.; Tsuchiya, T. *Biochem. J.* **1984**, *222*, 829.
15. Wright, J. K.; Overath, P. *Eur. J. Biochem.* **1984**, *138*, 497.
16. Jongejan, M. G. M.; Klijn, J. E.; Engberts, J. B. F. N. *J. Phys. Org. Chem.* **2006**, *19*, 249.
17. Hait, S. K.; Moulik, S. P. *Curr. Sci.* **2002**, *82*, 1101.
18. Yamamoto, A.; Umemori, S.; Muranishi, S. *J. Pharm. Pharmacol.* **1994**, *1*, 14.
19. Laube, B. L. *Respir. Care* **2005**, *50*, 1161.
20. Jagusztyn-Krynicka, E. K.; Dadlez, M.; Grabowska, A.; Roszczenko, P. *Expert Rev. Proteomics* **2009**, *6*, 315.
21. Chae, P., Rasmussen, S., Gellman, S., *Nature Methods*, **2010,** 7, 1003–1008