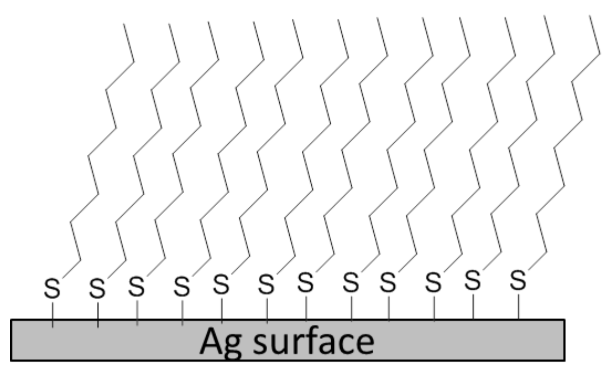
The Hydrophobic Effect

Background

Solubility is guided by the principle of “like dissolves like”. Organic chemists take advantage of this principle to separate compounds by extraction – non-polar molecules are soluble in relatively non-polar solvents such as dichloromethane and ether, where as salts and very polar molecules get dissolved in the highly polar water layer. The two extraction solvents stay as separate layers because of the hydrophobic effect, the tendency of non-polar substances to aggregate in water. This principle allows micelles and lipid bilayers to form and is one of the main driving forces behind protein folding. Hydrophobic literally means water fearing, hydrophilic, or water loving, refers to polar molecules that like to dissolve in water. To understand why hydrophobic molecules aggregate, imagine non-polar oil molecules disbursed in water. On first glance the would seem randomness of dispersal would seem entropically favorable compared to having two separate layers, however, having oil dispersed breaks up many of the favorable hydrogen bonds in water making the overall process non-spontaneous. To minimize the hydrogen bond disruptions, the hydrophobic molecules gather together and form a layer on top of water.

In this lab you will explore hydrophilic and hydrophobic interactions on surfaces. A major research area in current science is the chemistry of self-assembled monolayers (SAMs). SAMs are composed of a highly ordered, single layer of molecules on a surface. Although the thickness of SAMs is typically on the order of one billionth of meter, they can dramatically change the properties of a surface. The most widely studied type of SAMs are alkane thiols (R-SH) bonded to silver or gold. Sulfur has a strong affinity for gold and silver, when an alkane thiol comes in contact with these metals the sulfur gets bonded to the metal surface. Van der Waals forces then cause the alkyl chains to close pack in a 2D crystalline arrangement.



Procedure

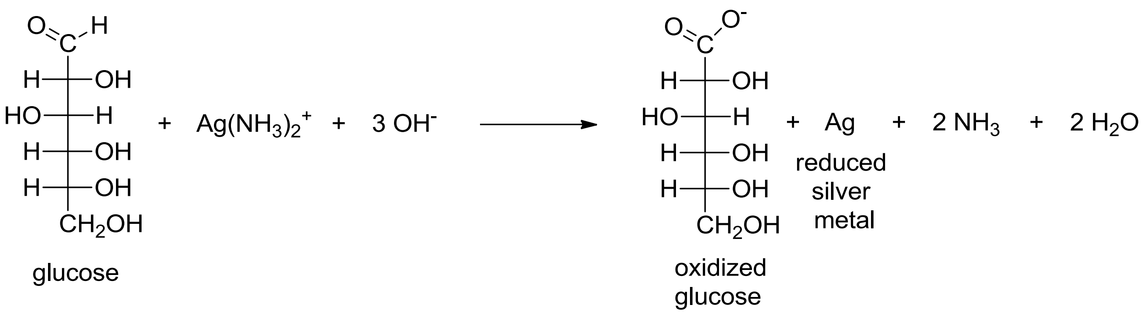
<u>Making Active Silver Ion Solution</u> Add concentrated ammonia drop wise to 10 mL of 0.1 M silver nitrate solution until the initial precipitate just dissolves. Add 5 mL of 0.8 M KOH solution; a dark precipitate will form. Add more ammonia drop wise until the precipitate just redissolves. This "active silver" solution should be used within an hour of preparation. Lightly cover when not in use. To avoid the formation of explosive silver nitride, discard any remaining active solution in the appropriate waste container and rinse the used glassware thoroughly with water. Avoid contact with the silver solution since it will stain your hands.

Formation of Silver Mirror Wash one plastic Petri dish with soap, then add tin (II) chloride solution to the dish for 30 seconds, then pour the tin (II) chloride back into the bottle using a funnel, and rinse the Petri dish with deionized water. Add enough active silver ion solution to the Petri dish to cover its surface. Add about 1 ml of 0.5 M glucose solution to the Petri dish and swirl gently to mix. After about 5 minutes you should see formation of a precipitate, and eventually a mirror, on the bottom of the Petri dish. Pour the remaining solution into a waste container, rinse the surface with deionized water and dry with a heat gun. Be careful when heating the dish, as the plastic can melt. If the dish starts to warp, allow the dish to cool for a while before heating again.

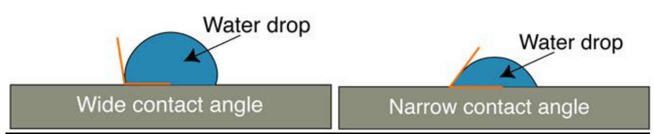
The silver mirror reaction is also known as the Tollens reaction and may be used as the Tollens test for aldehydes. In this redox reaction an aldehyde (glucose) is oxidized to a carboxylic acid.

$$2\ Ag^+\ (aq)\ +\ 2\ OH^-\ (aq) \rightarrow Ag_2O\ (s)\ +\ H_2O\ (l)$$

$$Ag_2O\ (s) + 4NH_3\ (aq) + H_2O\ (l) \rightarrow 2Ag(NH_3)_2^+\ (aq) + 2\ OH^-\ (aq)$$



Creating a Self-Assembled Monolayer Tilt the Petri dish, and cover the bottom 1/3 of the petri dish surface with alkanethiol solution in ethanol. Pour out the excess alkanethiol solution, and allow the ethanol to evaporate, leaving behind an alkanethiol monolayer. This effectively coats the surface with hydrocarbons. Keeping the Petri dish tilted, use a little ethanol to rinse any excess unbonded thiol from the petri dish. Do not let the rinse liquid touch the other half of the petri dish. Allow the surface to dry. Use a pipette to carefully touch one drop of water to each section of the Petri dish. Release as small a drop of water as possible. Draw the shapes of the water droplets that you see and estimate their contact angle. Tilt the Petri dish to almost a 90 degree angle and, from your pipette, let one drop of water fall onto a dry spot of each surface. Release as small a drop of water as possible. Record your observations.



Magic Sand Get a medium sized beaker and fill it halfway with water. Sprinkle some magic sand on top of the water and observe what happens. Continue gently adding magic sand to the top of the water until the sand drops. Pour the rest of the magic sand into the water in a steady stream and observe how the sand behaves. Separate the sand from the water. Pat the sand dry with paper towels and return to the container.

Chemicals: 0.5 M glucose, 0.8 M potassium hydroxide, 0.1M silver nitrate, 15 M ammonia, octadecanethiol, ethanol, tin (II) chloride