Answer to tutorial problem set 3

Account for the following observations in terms of the type and strength of intermolecular forces:

a. The melting point of solid xenon is −112°C and that of solid argon is −189°C.
The higher melting point for xenon is due to the larger instantaneous, fleeting dipole moments it can support compared to argon. Xenon is a larger atom with its outermost electrons further away from the nucleus compared to argon. Xenon is therefore more polarizable and the London interactions between the atoms larger.

b. The vapour pressure of diethyl ether ($CH_3CH_2OCH_2CH_3$) is greater than that of water.
There are larger London dispersion forces between the diethyl ether molecules compared to between water molecules. There are also weak dipole-dipole forces in-between diethyl ether molecules. However, these are both much weaker than the strong hydrogen bonds between water molecules. Thus, water has a much lower vapour pressure than diethyl ether.

c. The boiling point of pentane $CH_3(CH_2)_3CH_3$ is 36.1°C, whereas that of neopentane $(CH_3)_4C$ is 9.5°C.
Both molecules have the same molecular weight and are non-polar molecules. The only intermolecular forces present in neat solutions of these molecules are London dispersion forces. The linear pentane molecule has a larger surface area compared to the more spherical neopentane. Thus, pentane display a larger contact surface and the London dispersion forces in a neat solutions of pentane will be larger than for neopentane.

In classical mechanics, the magnitude of the force, *F*, is related to the distance dependence of the potential energy, E_p, by $F = -dE_p/dr$. How does the intermolecular force depend on intermolecular separation *r* for a typical intermolecular interaction that varies as $1/r^6$?

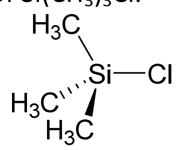
$$F = -\frac{dE_p}{dr} = -\frac{d}{dr}\frac{1}{r^6} = 6\frac{1}{r^7}$$

The surface of glass contains many −OH groups that are bonded to the silicon atoms of SiO2, which is the major component of glass. If treated with $Si(CH_3)_3Cl$ (chlorotrimethylsilane), a reaction takes place to eliminate HCl and attach the Si atom to the oxygen atom of the −OH groups.

(glass)-OH + $Si(CH_3)_3Cl$ → (glass)-$OSi(CH_3)_3$ + HCl

The modified surface is then washed with water to remove the HCl.

a. Draw the three dimensional structure of $Si(CH_3)_3Cl$.



b. List the solvents pentane, water and diethyl ether ($CH_3CH_2OCH_2CH_3$) in the order of increasing interaction with the original glass surface.
The glass surface is from the beginning quite polar (hydrophilic) because of the OH-groups. It will therefore interact very strongly with water *via* hydrogen bonds. The slightly polar solvent diethyl ether – as a result of the C-O bonds– will also interact with the polar surface, although much more weakly. There will only be very weak interactions between the glass surface and pentane.

c. List the type of interaction between the different solvents and each type of glass surface.

Interaction between the unmodified glass surface and:
Water; hydrogen bonds, dipole-dipole interactions and London dispersion forces.
Diethyl ether; dipole-dipole interactions and London dispersion forces.
Pentane; dipole-induced dipole interactions and London dispersion forces
The glass surface becomes very non-polar (hydrophobic) upon surface modification with chlorotrimethylsilane. Interaction between the modified glass surface and:
Water; dipole-induced dipole interactions and London dispersion forces.
Diethyl ether: dipole-induced dipole interactions and London dispersion forces.
Pentane: dipole-induced dipole interactions and London dispersion forces

The following molecular assembly is held together by many different intermolecular forces.

a. What forces keeps the DNA duplex fixed to the lipid membrane surface? List both the interactions between the anchor and lipid monolayer and the forces between DNA and the lipid monolayer.
   The anchor is very lipophilic and will be buried in the lipid membrane due to the hydrophobic effect. The interaction between the anchor and the fatty acid chains in the lipid membrane is mainly London dispersion interactions. On the surface of the DNA duplex there are negatively charged phosphate groups that experience a Coulomb attraction to the positively charged ammonium groups in the head groups of the lipids.
b. What is the appropriate solvent indicated in the figure? Explain why your suggested solvent is a good one.
   Water is probably the best solvent because it gives rise to a large hydrophobic effect, which is responsible for the lipid bilayer formation and anchoring effect. Water also efficiently solvates DNA – its negatively charged phosphate groups and accompanying cationic counter ions.
c. What properties should the surfaces have to support the formation of this molecular assembly?
   The head groups of the lipids are polar. The surface therefore has to be polar.