ANSWERS

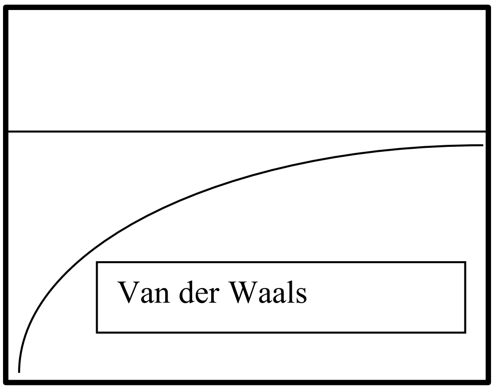
1 . a) (i) The surface potential is increasing in magnitude, (Actually becoming more negative), due to the ionization of the surface groups so that we end up with AlO^- groups on the surface. **[4 marks]**

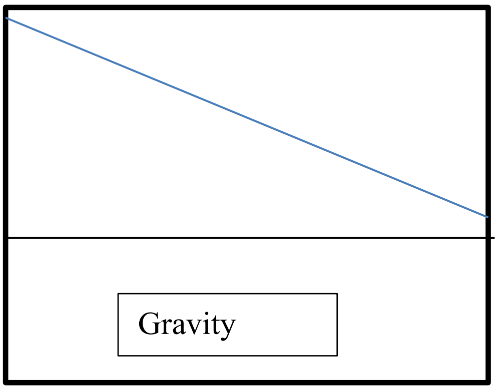
ii) The highest pH is most stable as it has the largest repulsion **[2 marks]**

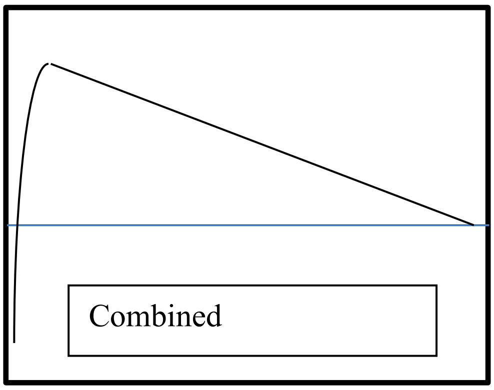
iii) add a polymer to give a repulsive interaction. A copolymer where on part of the polymer adsorbs to the surface strongly and another part which is non adsorbing, giving an adsorbed layer thickness of around 8-10 nm

[4 marks]

part b







[8 marks]

Equate the two equations to end up with $D^3 = A/12\pi\rho g h$ so that D = 14 nm

[7 marks]

c) We will neglect van der Waals forces since they are likely to be small if the film is thick.

[2 marks]

Hydrostatic pressure is 66 N.m-2

Thus equate for 1 square metre of bubble surface so that we evaluate the given equation

If the surface potential is high then tanh term = 1

Kappa can be evaluated to be 9.7 * 107

$66 = 64(6.24 * 10^{23})*(1.38*10^{-23}*300)\ \exp(-9.7 * 10^{7}*D)$ from which D will be estimated to be 79 nm

If salt is increased the film would become thinner due to the decreased electrical double layer. For full marks this could be evaluated

[2 marks for saying it 2 marks for evaluating it]

2 (a)

(i) Alkanes only have dispersion interactions, hence the dispersion contribution to the surface tension is equal to the total surface tension:

$$\gamma^{\mathrm{d}}_{\mathrm{pentane}} = \gamma^{\mathrm{total}}_{\mathrm{pentane}} = 16.1 \text{ mN/m},$$

$$\gamma^{\mathrm{d}}_{\mathrm{hexadecane}} = \gamma^{\mathrm{total}}_{\mathrm{hexadecane}} = 27.5 \text{ mN/m}.$$

[3 marks]

(ii) The Fowkes equation is applicable because pentane and hexadecane only interact with water through dispersion interactions.

[3 marks]

(iii) The Fowkes equation is given in the lecture notes:

$$\gamma^{total}_{water-alkane} = \gamma^{total}_{water} + \gamma^{total}_{alkane} - 2\sqrt{\gamma^{d}_{water}\gamma^{d}_{alkane}}\,.$$

For the water-pentane interface:

$$\gamma^{total}_{water-pentane} = \left(72.8 + 16.1 - 2\sqrt{21.8 \times 16.1}\right) \text{mN/m} = 51.4 \text{ mN/m}\,.$$

For the water-hexadecane interface:

$$\gamma^{total}_{water-hexadecane} = \left(72.8 + 27.5 - 2\sqrt{21.8 \times 27.5}\right) \text{mN/m} = 51.3 \text{ mN/m}.$$

[6 marks]

(iv) To determine whether a liquid spreads over another liquid, we calculate the spreading coefficient. For alkanes spreading upon water, the spreading coefficient is:

$$S = \gamma_{water-air} - \gamma_{alkane-air} - \gamma_{water-alkane} \approx \gamma_{water} - \gamma_{alkane} - \gamma_{water-alkane}\,,$$

where we have used the assumption that the interfacial tensions of liquids with air can be approximated by their surface tensions.

For the spreading of pentane on water:

$$S \approx (72.8 - 16.1 - 51.4) \text{ mM/m} > 0,$$

hence pentane spreads on water.

For the spreading of hexadecane on water:

$$S \approx (72.8 - 27.5 - 51.3) \text{ mM/m} < 0,$$

hence hexadecane does not spread on water.

[8 marks]

(v) A dispersant is needed for pentane.

[3 marks]

(b)

(i) Properties of coating:

- To repel a polar substance like water, the solid surface should be **hydrophobic**, that is, the Young's contact angle of the liquid on the solid should be $\theta > 90°$.
- The surface can then be made **super-hydrophobic** by changing its surface morphology: the surface should have microscale roughness, so that the apparent contact angle is $\theta^* \approx 180°$.
- In addition to these properties that impart self-cleaning performance, the coating should be durable in particular the self-cleaning properties should not degrade over time. It should be **opaque** if it is for the car body, or **transparent** if it is for the windshield. The coating for the car body may also come in different colours.

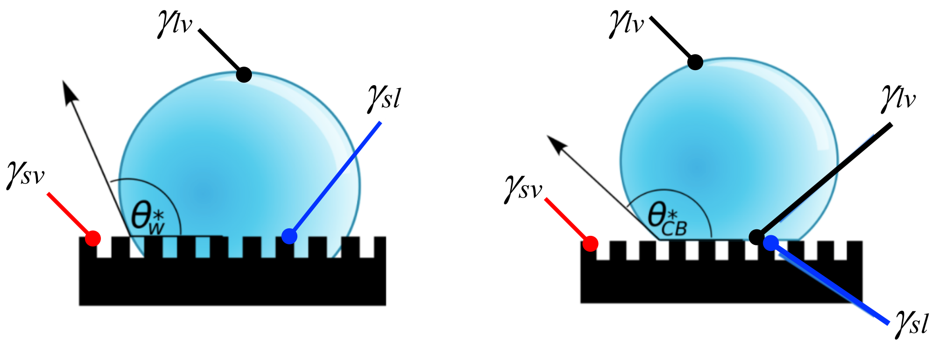
[6 marks]

(ii) The Young's contact angle is given by Young's equation: $\cos\theta = \frac{\gamma_{sv}-\gamma_{lv}}{\gamma_{lv}} = \frac{29-67}{52} = -0.73$.

The angle is $\theta \approx 137°$. The solid surface is hydrophobic as required in (i).

[3 marks]

(iii) The sketch shows the Wenzel (left) and Cassie-Baxter (right) states, with the interfacial tensions of the relevant interfaces in the system:



The most advantageous state is the one that corresponds to a larger apparent contact angle. The apparent contact angles can be calculated as follows:

Wenzel: $\cos\theta^*_W = R_W\cos\theta = 1.3 \times (-0.73) = 0.95$; hence $\theta^*_W \approx 162°$.

Cassie-Baxter: $\cos\theta^*_{CB} = 0.5 \times \cos\theta_1 + 0.5 \times \cos\theta_2 = 0.5 \times (\cos\theta_1 + \cos\theta_2)$,

with $\cos\theta_1 = \cos\theta$ and $\cos\theta_2 = \frac{\gamma_{vv}-\gamma_{lv}}{\gamma_{lv}} = \frac{0-1}{1} = -1$;

$\cos\theta^*_{CB} = 0.5 \times (-0.73 - 1) = 0.865;$ hence $\theta^*_{CB} \approx 150°$.

For the case considered, the Wenzel state gives a higher contact angle.

[8 marks]

3

a) (i) $SrTiO_3$:Nb. The band gap of 3.2 eV indicates that the material will absorb only UV light.

$$\lambda = \frac{hc}{E} x 10^9$$

Where:

λ = band gap in wavelength units (nm)

E = band gap in energy units (eV)

h = $4.14 x 10^{-15}$ eV s

c = $3 x 10^8$ m s^{-1}

The calculations tell us that $SrTiO_3$:Nb absorbs light with wavelengths below ~ 388 nm. As these wavelengths are invisible to the human eye, this material could be used to make a transparent solar cell. Silicon absorbs all visible light and some near IR light (below ~ 1089 nm) and PCDTBT absorbs visible light below ~ 690 nm.

[4 marks]

(ii)Transparent solar cells could be integrated in transparent objects such as windows, to produce electricity without obstructing visible light from getting through. Office buildings with large surfaces covered in windows, as well as cars with large windows and skylights, would benefit from a renewable electricity source without altering their design or appearance.

[4 marks]

(ii)A hypothetical transparent solar cell with absorption in the UV would absorb only a fraction of the total solar radiation. Hence, the overall power generated by such solar cell would be quite small.

[4 marks]

b) A:

I would use three types of solar cells to suit different areas of the building:

On the windows, I would use semi-transparent solar cells based on, for example, an organic polymer. This type of cells would use part of the visible solar spectrum to produce electricity, whilst still letting some light through. Depending on the band gap of the material used, the tint of the windows could be selected to please specific aesthetic requirements. The solar cells integrated in the windows would provide some filtering of the harsh light during very sunny days. The large surface area occupied by the solar cells would make up for their reduced efficiency compared to fully opaque solar cells.

On the roof, I would build the requested rooftop bar, including a gazebo to cover the whole roof. Opaque, high efficiency silicon solar cells would cover the entire surface of the gazebo. This type of cells would be effective in producing electricity efficiently. As the aim of the gazebo is to provide full shadowing, opaque solar cells would match this application very well.

On the sides of the gazebo, flexible solar cells based on polymers could be installed as roll-up, semi-transparent curtains, to provide some shading on the sides. The low weight and ability to be rolled up of flexible solar cells, printed on plastic sheets, are features particularly well suited for this application.

[10 marks]