Colloids answers

a) van der Waals forces,   [4 marks]

   Strictly it's a slightly reduced attraction due to slight edl repulsion   [1 mark]

b) i) due to the edl being longer ranged in dilute electrolyte solutions for full marks need to say Debye-Huckel coeff increases hence repulsion decreases and to say that range ought to decrease by an order of magnitude for 2 orders of magnitude decrease in salt concentration [5 marks]

   ii) Again edl decays exponentially with distance due to the potential decaying exponentially with distance, ought to put in an eqn to show this for full marks

                                                            [5 marks]

   iii) This is a little harder but is due to a lowering of the surface potential at high salt which in turn is due to the adsorption of sodium ions onto the negative glass surfaces

                                                            [5 marks]

c) This is due to more polymer adsorbing as the polymer concentration increases. Initially surface negative, and as polymer adsorbs surface potential becomes less negative, hence reduced repulsion. Eventually surface becomes neutral and as more polymer adsorbs the repulsion then increases

                                                            [10 marks]

Question 2

(a) A non-wetting liquid will form droplets, and a wetting liquid ($\theta \approx 0$) will form a film. Even for partial wetting conditions ($\theta < 90°$), if there are many droplets growing on a surface due to condensation, they will eventually merge to form a continuous film. For non-wetting liquid ($\theta > 90°$), the volume of liquid that can condense in each drop before they merge is much larger.

[3 marks]

(b) The way in which surfactants affect wettability of solid surfaces depends on the surfactant and its interactions with the solid surface:

- If the surfactant does not interact with the solid surface, but only adsorbs at the liquid-vapour interface, then the liquid-vapour surface tension will be reduced, and the contact angle will be reduced as a result. This would make things worse for drop detachment.
- If the surfactant interacts with the solid surface, two possible scenarios exist: the surfactant may adsorb with the hydrophobic tails pointing towards the water, or the hydrophilic heads, depending on the molecular interactions with the surface.
    - o If the hydrophilic heads point towards the water, then the solid-liquid interfacial tension may be further reduced, again giving a smaller contact angle
    - o The only case in which an increase in contact angle is possible is if the hydrophobic tails point towards the water (autophobic effect). For this to happen there would have to be attractive intermolecular interactions between the surfactant headgroup and the solid surface; in the case of a metal surface, electrostatic interaction.

[5 marks]

(c)   1. The solid surface can be made hydrophobic (for instance with a coating of wax or surfactants), this will give contact angles $\theta > 90°$;

2. To obtain even better performance ($\theta \approx 180°$), the surface can be made super-hydrophobic using chemical heterogeneity to obtain the Cassie-Baxter state or

3. surface roughness to obtain the Wenzel state.

[3 marks]

(d) Weight of drop: $\frac{4}{3}\pi\rho_w g R^3$ with R the radius of the drop and ρ_w density of water. Capillary force holding drop at solid surface: $\gamma_{ws}L$, with γ_{ws} the interfacial energy of the water-steel interface and L

the perimeter of the three-phase contact between liquid drop, solid surface, and vapour. Can relate L to R through contact angle: radius of contact line is $R \sin \theta$ (from geometry) hence $L = 2\pi R \sin \theta$. Equating the two forces:

$$\frac{4}{3}\pi \rho_w g R^3 = \gamma_{ws} 2\pi R \sin \theta$$

Which can be simplified to

$$R = \sqrt{\frac{3}{2}\frac{\gamma_{ws}}{\rho_w g}} \sin \theta.$$

As the contact angle $\theta > 90°$ is increased, the droplets that can roll off become smaller and smaller because $\sin \theta$ decreases.

An upper limit for R can be obtained from the Bond number: $Bo = \frac{\rho_w g R^2}{\gamma_{ws}}$. The condition for drop detachment can be set to $Bo = 1$ which gives $R = \sqrt{\frac{\gamma_{ws}}{\rho_w g}}$. This is equivalent to considering a wetting film ($\theta = 0, \sin \theta = 1$).

[12 marks]

(e) Super-hydrophobic surface for easy removal of droplets. Some points to consider:

- It would have to be made by a cheap method as large areas are needed in this application. May be formulated as a paint for ease of application on existing surfaces.

- Hierarchical microstructure with micropillars and nanoscale roughness will give Lotus effect.

- Fouling may occur on the surface. This should be minimal as water is rapidly removed from the surface during condensation; and the surface is thoroughly dried during the rest of the day.

- Stability of the materials in harsh environment could be a concern

[7 marks]

Question 3

a) i) A simple drilling mud system is composed of 25 kg's of Bentonite, 60 kg's of barite (barium sulfate) and 350 litres of fresh water. Calculate the volume and density of the mud, given the following:

Density of Bentonite = 2000 kg/m3 Volume = 25/2000 m3 = 0.0125 m3

Density of Barite = 4500 kg/m3 Volume = 60/4500 m3 = 0.0133

Density of water = 1000 kg/m3 Volume = 350 litre = 0.350 m3

Thus total volume = 0.3758 m3 = 375.8 litres

Total mass = 350+60+25= 435 kg

Density = 435/.3758 = 1157 kg/m3

[6 marks]

The role of bentonite is to increase the viscosity and to make the fluid strongly shear thinning, so that rock cuttings do not settle

[4 marks]

ii)The role of Barite is to increase the fluid density to hinder sedimentation of any cuttings

[4 marks]

iii) This could also be achieved by adding potassium or caesium formate (or acetate) at high concentrations where a density of over 2000 kg/m3 can be achieved

[4 marks]

b) Its coloured because of light interference, the thickness of the film of the order of half the wavelength of light (i.e 250 nm or thereabouts) so light will reflect of the from surface of the film and the back surface and constructively interfere . In the image in fig 6 the different colours correspond to different wavelengths and hence different thicknesses, and there are actually two orders, where the optical path length through the film is 1 wavelength and two wavelengths of light.

At the top the film is colourless (or black) since the film is now so thin that its thickness is less than half the wavelength of visible light.

[10 marks]

(c) Firstly the effect of electrolyte on zeta potential, adding electrolyte decreases the value at all pH's (taking into account the sign change)

This is due to the surface potential being affected by the ions in the electrolyte adsorbing on the surface reducing the potential.

[4 marks]

Secondly as the pH changes the zeta potential reduces and eventually becomes negative, this is due to H^+ ions on the surface coming of at low pH and then surface O-H groups ionising to O^- at even higher pH the point of zero charge being close to pH7.

[4 marks]

Finally wrt flotation at low pH when surface is +ve the −ve surfactants adsorb, make the surface hydrophobic enabling bubble to attach to the particle of goethite. At high pH the opposite is true and +ve surfactant adsorbs.

[4 marks]