IMPERIAL COLLEGE LONDON

M.Eng EXAMINATION IN CHEMICAL ENGINEERING 2020

PART IV

and

M.Sc. in ADVANCED CHEMICAL ENGINEERING

For Internal Students of Imperial College London

This paper is also taken for the relevant examination
for the Associateship

COLLOID AND INTERFACE SCIENCE

Friday 1st May 2020 14:00-15:30

Answer **ALL** questions
Question 1 35 marks
Question 2 40 marks
Question 3 25 marks

THIS EXAMINATION PAPER HAS FIVE PAGES IN TOTAL WHICH INCLUDES THIS COVER SHEET

TURN OVER FOR QUESTIONS

<u>Question 1</u> **[35 marks]**

a) Why are emulsions, Pickering or surfactant based, thermodynamically unstable? Given that they are thermodynamically unstable, why can emulsions be formed (both Pickering and Surfactant types) which are stable for more than 12 months?

10 Marks

b) You are to make a Pickering emulsion (particle stabilised emulsion) using silica nanoparticles, which are hydrophilic, and negatively charged, water and diesel. Unfortunately, it does not work. Why is this so and how could it be overcome?

5 Marks

c) A 30% oil in water mixture is to be emulsified. It is found that 1% of Sodium dodecyl sulfate added to the mixture works well, whilst a 1% dodecan1-ol added to the mixture does not, even though in both cases the interfacial tension between the oil and water drops from 30mN/m to 1 mN/m, why is this so?

5 Marks

d) Cetyltrimethyl ammonium bromide, CTAB, is a common cationic surfactant. In water it produces approximately spherical micelles, but in the presence of 2 molar sodium chloride forms long rod-like or wormlike micelles, why is this so?

5 marks

e) You are to spray a field of courgettes with an aqueous solution of a fungicide, however, the contact angle of water on a courgette leaf is around 120 degrees. Why is this a problem and how would you overcome it?

10 Marks

Question 2 **[40 marks]**

a) Plotted in Figure 1 below is a representation of the energy of interaction between two glass spheres immersed in various sodium chloride solutions at pH 5.5.

i) At this scale the interaction in 10 mM and 100 mM are entirely repulsive, why is this so?

3 marks

ii) Why is the interaction longer ranged at 10 mM compared to 100 mM?

3 marks

iii) Why are there only attractive forces at 500 mM?

3 marks

iv) Explain the shape of the curve at 200 mM

5 marks

v) To a first approximation where would you expect the interaction to start at 1 mM?

5 marks

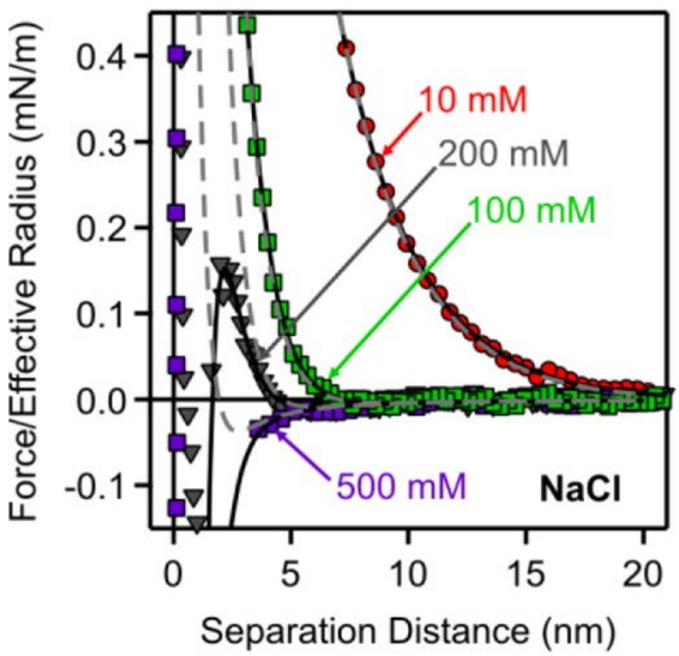

Figure 1 The interaction force between two glass spheres divided by their radii when the spheres were immersed in aqueous sodium chloride solutions of various concentrations which are indicated on the figure. Data collected at pH 5.5

b) Plotted in Figure 2 are the interactions between two glass spheres 10 micrometres (10^{--6}m) in diameter in an aqueous dispersion of non-adsorbing silica nanoparticles (approximately 30 nm in diameter) at various concentrations (see figure legend for details where ϕ is the volume fraction of the non-adsorbing particles) at pH 3 on both linear and semi-logarithmic axes

   i) Why is the curve approximately linear on the semi-logarithmic plot in the absence of any nano-particles?

3 marks

   ii) The decay lengths are 9.2-9.6 nm for all the curves, what is the origin of the repulsion and what does this imply?

5 marks

   iii) At volume fractions of the non-adsorbing silica particles 0f 0.006 and 0.01 there is an attraction commencing at a surface separation of the two large glass spheres of approximately 80 nm and reaching a minimum at approximately 55 nm, what is the origin of this attraction?

5 marks

   iv) At 0.01 volume fraction the forces seem to have a periodic nature with a wavelength of approximately 50 nm what is the origin of this?

8 marks

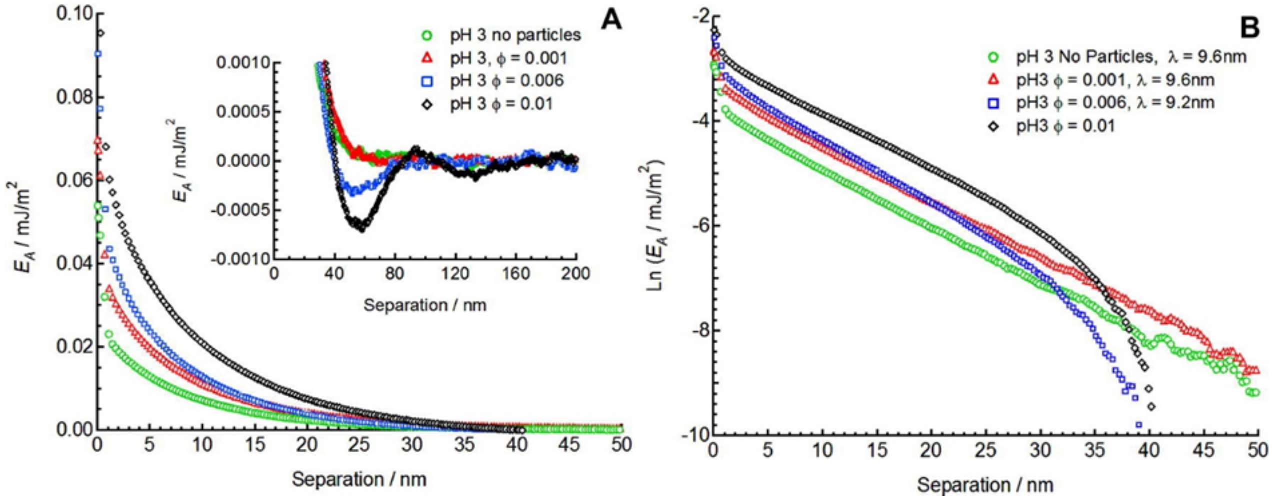

Figure 2 Plots of the energy of interaction per unit area E_A vs. separation between two glass surfaces at pH 3 as a function of volume fraction of silica nan-particles. The inset shows a magnification of the force profile. Graph B is the natural log plot of graph A.

Question 3 **[25 marks]**

a) What are the desired rheological characteristics of a drilling fluid and why?

3 marks

b) A dilute xanthan solution (xanthan is a polysaccharide) meets this rheological criterion, but on its own is generally not suitable as a drilling fluid, why is this so?

3 marks

c) What can be added to a xanthan solution which would make it more suitable as a drilling fluid?

3 marks

d) Water based drilling fluids are frequently made from Bentonite, discus the interaction of bentonite plates (which are only approximately 1 nm thick) when dispersed in fresh water and in sea water (approximately 0.5 $mol.dm^{-3}$ in electrolyte concentration). How would you expect the rheology of the bentonite to differ in these two dispersion media (i.e. pure water and sea water)?

6 marks

e) Your company has just discovered a rich seam of the ore Tenorite, CuO which is embedded largely in a sandstone (quartz) matrix, both the minerals are hydrophilic in nature. The seam is in northern Siberia and it is necessary to concentrate the ore on site using flotation to reduce transportation costs. The isoelectric pH of quartz is <2.5 and for Tenorite is 7.5+/-0.5.

List the steps required from initial processing of the ore to final product recovery.

10 marks