IMPERIAL COLLEGE LONDON

M.Eng EXAMINATION IN CHEMICAL ENGINEERING 2019

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

Monday 20th May 14:00-15:30

This examination is an **OPEN** note examination, which means that you can bring into the examination any **written material APART FROM TEXT BOOKS**

Answer **ALL** questions
Question 1 30 marks
Question 2 30 marks
Question 3 40 marks

**THIS EXAMINATION PAPER HAS EIGHT PAGES IN TOTAL
WHICH INCLUDES THIS COVER SHEET**

TURN OVER FOR QUESTIONS

Question 1 **[30marks]**

Some data acquired using the force spectroscopy mode of an atomic force microscope, AFM, are shown in Figures 1-3. The interactions measured are between a cationic (positively charged) polymer poly(diallyldimethylammonium chloride) (poly DADMAC), adsorbed to two glass surfaces. One glass surface is flat and the other is a glass sphere, which is attached to the AFM cantilever. The glass surfaces themselves are both negatively charged. The structure of poly DADMAC is given in Figure 4.

a) Figure 1 was obtained when the polymer concentration in the experiment was 3.12 mg of polymer per gram of an aqueous solution that contains 250mM sodium chloride. At this polymer concentration the glass surfaces can be taken to be fully coated with the polymer. What is the origin of the attraction between the two surfaces?

[5 marks]

b) Figure 2 was obtained at the same polymer concentration, but at more dilute sodium chloride concentrations.

i) Why does the repulsion become longer range at lower electrolyte concentrations?

[5 marks]

ii) Why does the force decay approximately exponentially with increasing surface separation?

[5 marks]

iii) Why does the maximum repulsion decrease with increasing electrolyte concentration?

[5 marks]

c) Figure 3 was obtained at 5 mM sodium chloride concentration, but at varying polymer solution concentrations. Explain the trends that are observed.

[10 marks]

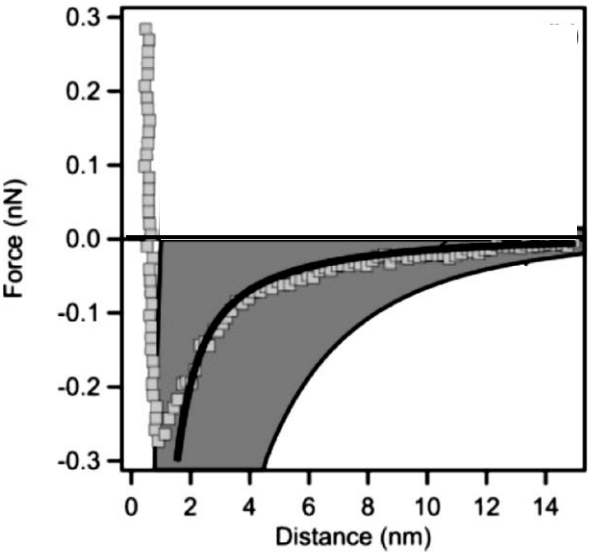

Figure 1. Interactions between two glass surfaces bearing adsorbed poly(diallyldimethylammonium chloride) immersed in 250 mM sodium chloride solution.

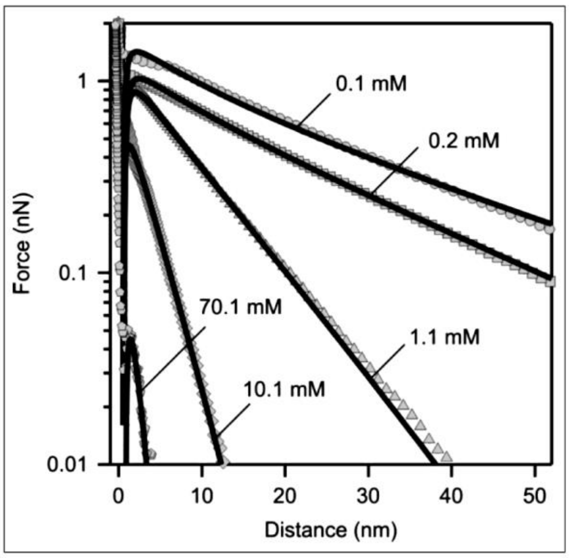

Figure 2 Interactions between two glass surfaces bearing adsorbed poly(diallyldimethylammonium chloride) immersed in varying concentrations of sodium chloride solution

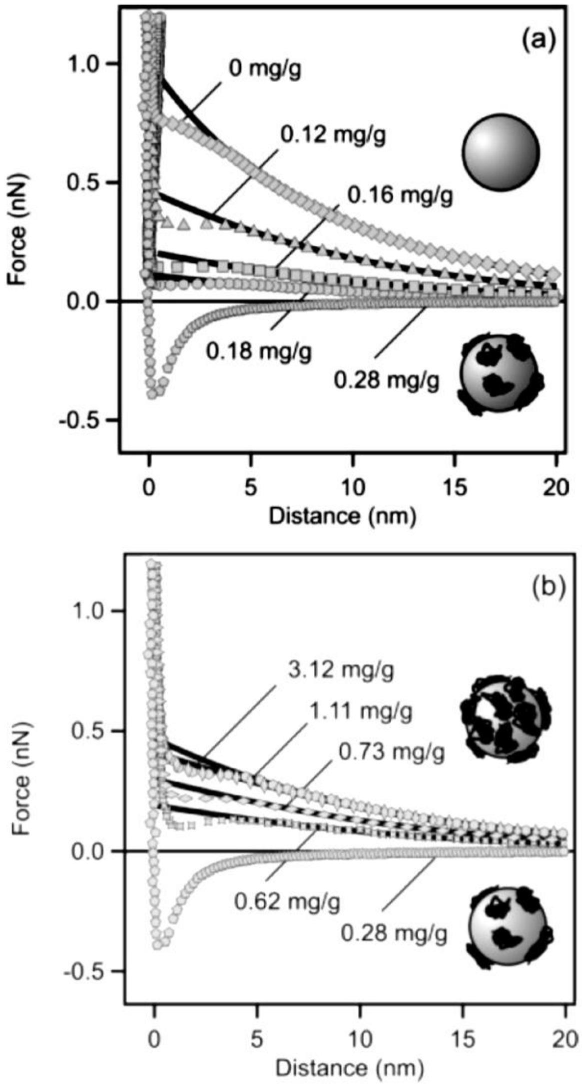

Figure 3 Interactions between two glass surfaces bearing adsorbed poly(diallyldimethylammonium chloride) immersed in 5 mM sodium chloride solution

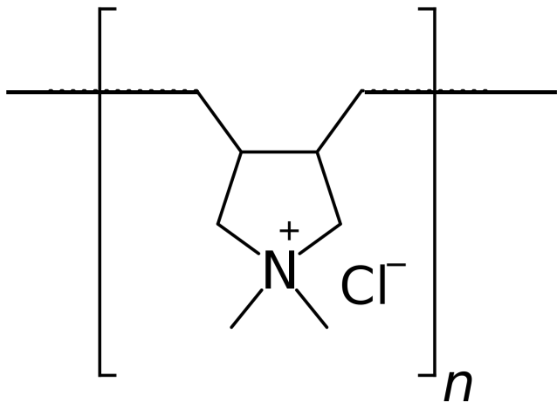

Figure 4. The structure of poly(diallyldimethylammonium chloride)

Question 2 **[30 marks]**

A vapour in contact with a solid surface, which temperature is below the saturation temperature will condense on the surface. The condensing vapour can form either liquid droplets or a continuous liquid film on the solid surface.

(a) Under what conditions can a condensing vapour form liquid droplets on a solid surface, and under what conditions does it form a continuous film?

[3 marks]

(b) In the design of condensers, it is, in principle, desirable to operate in drop-wise condensation mode, rather than film-wise condensation mode, because when the drops roll off the surface, more vapour can condense. The typical contact angle of water on clean, polished, stainless steel is 40°. How can the addition of surfactants to the water help to obtain droplets that roll off the surface?

[5 marks]

(c) Describe three different ways to modify a solid surface to ensure the formation of drops that can easily roll off.

[3 marks]

(d) In the case of drop-wise condensation, the drops are held in place by surface tension forces until they become sufficiently large to detach due to their weight. Derive an expression for the critical size of a drop that can detach from the surface, and comment on the effect of the contact angle θ. Refer to Figure 5 for the definitions of drop size and contact angle.

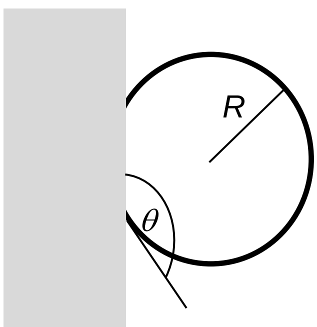

Figure 5. Definitions for part (d)

[12 marks]

(e) Harvesting atmospheric humidity and fog is a promising solution to alleviate water scarcity in arid climates. How would you design a system for passive atmospheric water capture?

[7 marks]

Question 3 **[40 marks]**

a) (i) A simple drilling mud system is composed of 25 kg of Bentonite, 60 kg of barite (barium sulfate) and 350 litres of fresh water.
Density of Bentonite = 2000 kg/m3
Density of Barite = 4500 kg/m3
Density of water = 1000 kg/m3

(i) Calculate the volume and density of the mud.

[6 marks]

(ii) What is the principle role of bentonite in a drilling fluid? Explain how this is achieved.

[4 marks]

(iii) What is the principle role of barite in a drilling fluid? Explain how this is achieved.

[4 marks]

(iv) A problem with barite is the toxicity of the barium ion. What alternatives to barite could be used to achieve the same effect?

[4 marks]

b) Consider a vertical soap film being illuminated with white light; initially the film exhibits various colours, but over time the top part of the film becomes transparent, (sometimes called black) as shown in the Figure 6, explain these effects.

[10 marks]

c) Figure 7 shows the dependence of the flotation properties of milled goethite on surface charge. The upper curves are the ζ potential as a function of pH at different sodium chloride concentrations: lower curves are the flotation recovery in 10^{-3} molar dodecyl ammonium chloride, sodium dodecyl sulfate and sodium dodecyl sulfonate. Explain as fully as you can these data.

[12 marks]

Figure 6. A soap film which has been left standing vertically for 30 minutes.

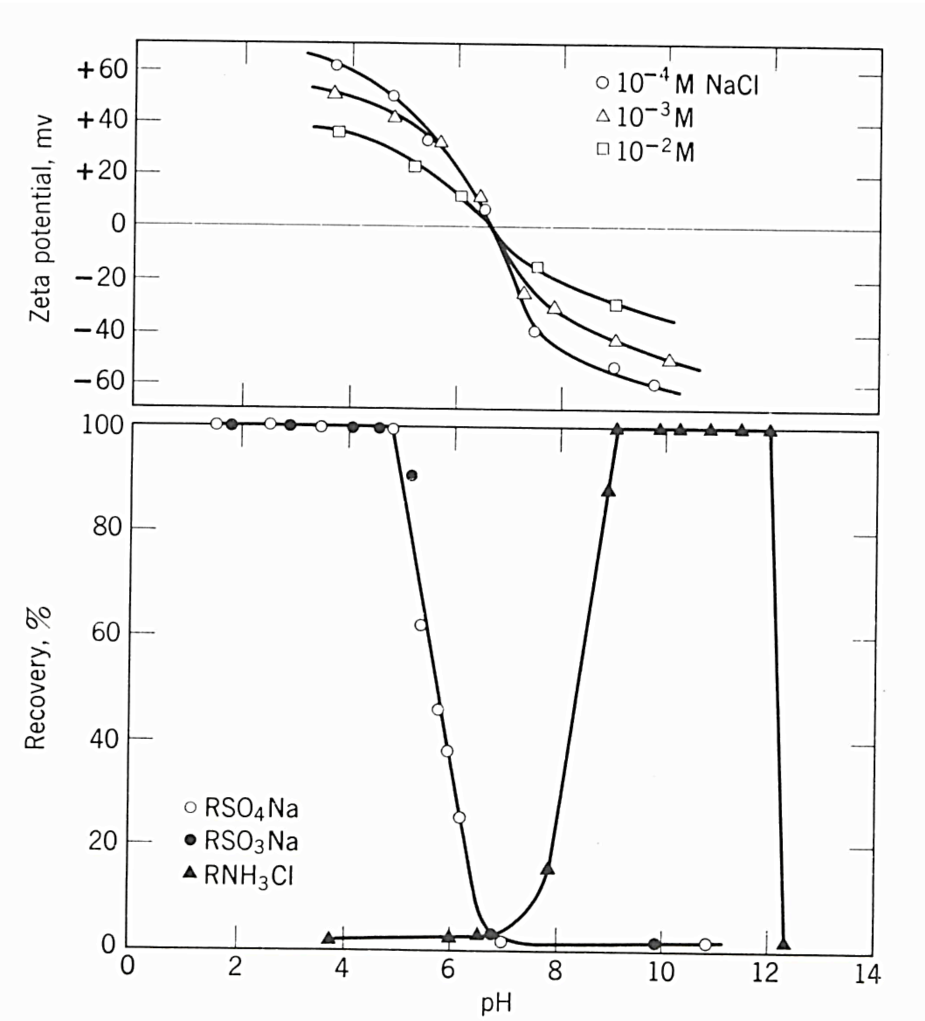

Figure 7 Upper graph the zeta potential of goethite in various sodium chloride solutions as a function of pH: lower graph the % recovery of goethite during a flotation process in presence of 3 different surfactants as a function of pH