Marks

Question 28 — Industrial Chemistry (25 marks)

(a) (i) Define *saponification*. **1**

(ii) Account for the cleaning action of soap. **3**

(b) One of the reactions used to form sulfuric acid is the reaction of oxygen with sulfur dioxide under equilibrium conditions to form sulfur trioxide. **4**

Before the reaction, the concentration of sulfur dioxide was 0.06 mol L^{-1} and the concentration of oxygen was 0.05 mol L^{-1}. After equilibrium was reached, the concentration of sulfur trioxide was 0.04 mol L^{-1}.

Calculate the equilibrium constant, K, for the reaction. Show relevant working.

(c) (i) Use a chemical equation to describe what happens when sulfuric acid is added to water in a laboratory. **2**

(ii) Describe the use of sulfuric acid as an oxidising agent, as a dehydrating agent and as a means of precipitating sulfates. Use chemical equations to illustrate your answer. **3**

(d) During your practical work, you performed a first-hand investigation involving an equilibrium reaction.

(i) Outline the procedure you used. **2**

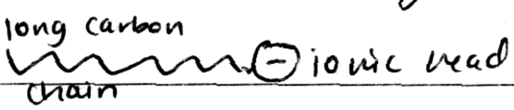
(ii) Explain how you analysed the equilibrium reaction qualitatively. **4**

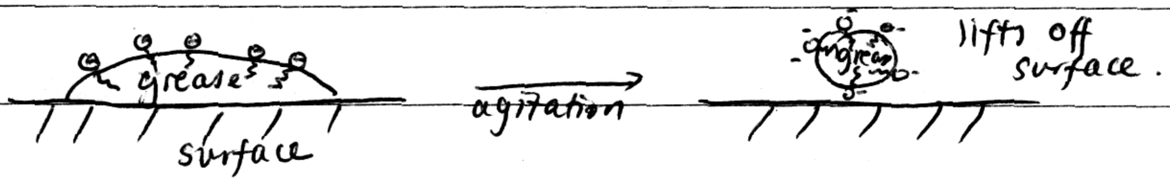
(e) Evaluate changes in industrial production methods for sodium hydroxide. **6**

Q. 28

a) i) Saponification is ~~they~~ the hydrolysis of fats and oils in a basic medium to form glycerol and the sodium salt of the fatty acids.

ii) Soap has a structure which enables it to act as a bridge between water and grease. The soaps ionic head is hydrophilic and dissolves in water whilst the ~~head~~ hydrophobic tail is non-polar and dissolves in the grease. Soap is a surfactant that reduces the surface tension of water allowing it to more easily wet particles. As a result when the water is then agitated the grease lifts off the surface. The diagram shows soaps action





b) $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

$$K = \frac{[SO_3]^2}{[O_2][SO_2]^2}$$

	$[SO_3]$	$[SO_2]$	$[O_2]$	
initial	0	0.06	0.05	
change	+ 0.04	- 0.04	- 0.02	(from mole ratio)
equilibrium	0.04	0.02	0.03	

$$\therefore K_c = \frac{(0.04)^2}{(0.03)(0.02)^2}$$

$$= 133.33 \ (mol L^{-1})^{-1}$$

c) i) $H_2SO_{4(aq)} + 2H_2O_{(l)} \rightarrow 2H_3O^+_{(aq)} + SO_4^{2-}{}_{(aq)}$ + heat

~~ii) Sulfuric acids act as an oxidising agent with metals, it can remove the water of crystallisation, $CuSO_4.5H_2O_{(s)} \xrightarrow[H_2SO_4]{conc.} 5H_2O_{(l)} + CuSO_{4(s)}$. When acting as a dehydrati~~

P.T.O

ii) Sulfuric acid can be used as an oxidising agent with more reactive metals such as Sn.

$Sn_{(s)} + 4H^+_{(aq)} + SO_4{}^{2-}_{(aq)} \rightarrow Sn^{2+}_{(aq)} + SO_{2(g)} + 2H_2O_{(l)}$

$SO_4{}^{2-}_{(aq)}$ acts as the oxidant.

When acting as a dehydrating agent it can remove the water of crystallisation from compounds

$CuSO_4 . 5H_2O_{(s)} \xrightarrow[H_2SO_4]{conc.} CuSO_{4(aq)} + 5H_2O_{(l)}$

Whilst as a precipitating substance, it is often used to identify the presence of Ba^{2+} or Pb^{2+} ions as it forms a white precipitate.

$Ba^{2+}_{(aq)} + SO_4{}^{2-}_{(aq)} \rightarrow BaSO_{4(s)}$

d) i) The equilibrium between NO_2 and N_2O_4 was ~~prepap~~ prepared by adding $HNO_{3(aq)}$ to a piece of $Cu_{(s)}$ and collecting the evolved NO_2 gas. with a syringe.

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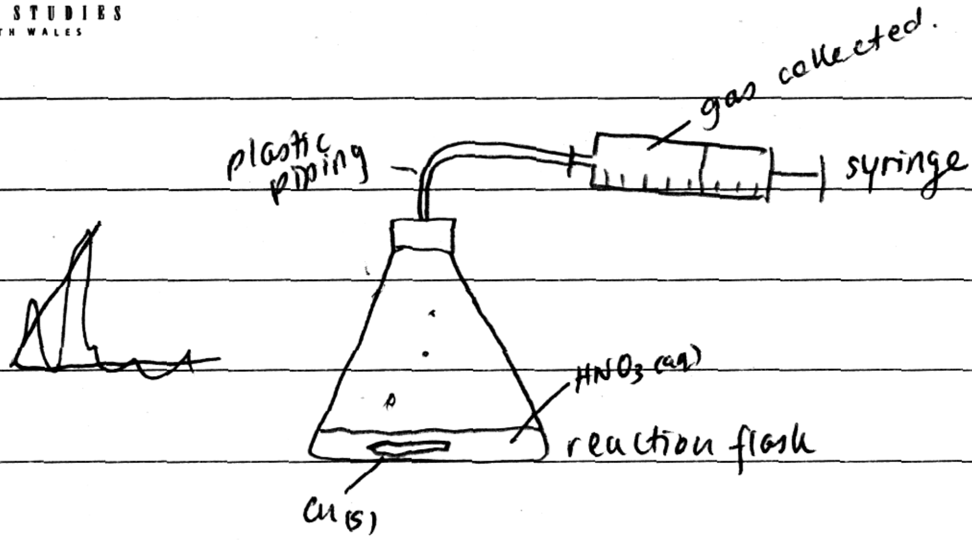

- the end of the syringe was plugged. with a rubber stopper, so that the brown NO_2 was enclosed in the syringe.
- the syringe was pushed in and out to change the pressure inside the syringe. The colour of the gas was observed.
- the syringe was then ~~a~~ placed in hot water and the colour of the gas observed.
- this ~~step~~ step was repeated using cold ice water.

ii) The reaction was analysed qualitatively by observing the colour of the gas in the syringe. In the syringe the NO_2 formed an equilibrium of $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$. When the syringe
brown — colourless.

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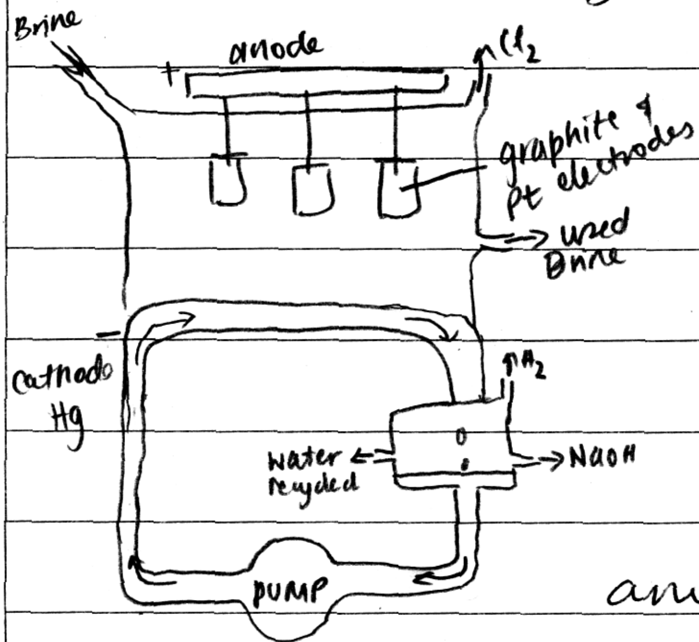
was ~~the~~ pushed in the pressure was increased and the gas decolourised. The equilibrium shifted according to Le Chateliers principle to the side with the least gas molecules to reduce the pressure, therefore it shifted to the ~~left~~ right producing more N_2O_4 and the gas was a lighter brown colour. Similarly when the syringe was pulled out the brown colour darkened as the equilibrium shift ~~the~~ to the left producing more NO_2 to increase the pressure.

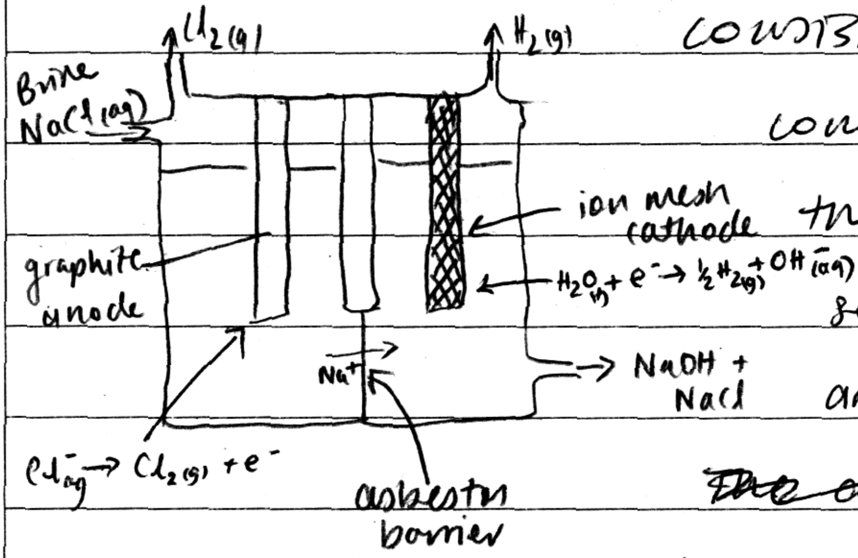
~~The~~ By placing the syringe in ~~different~~ water at different temperatures it could be determined whether the equilibrium was exothermic or endothermic. When placed in the hot water the brown colour ~~deepened~~ was darker and when placed in the cold water the brown colour lightened. This indicated that heat must be a product of this equilibrium reaction $2NO_{2(g)} \rightleftharpoons N_2O_4 + heat$.

e) The industrial production of NaOH has undergone a change in methods used from the mercury cell and diaphragm process to the membrane cell.

The mercury cell involved the use of liquid Hg that was reused ~~through~~ in the cell and acted as the cathode. Na^+ from the brine was reduced by the Hg to form an amalgam that was then dissolved in water to form the NaOH. ~~This~~



At the anode $2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$ and at the cathode $Na^+ + e^- \rightarrow Na_{(l)}$. This method had the advantage of producing considerabley pure NaOH as only Na reacted with water but the main reason this method is not commonly used is because Hg can leach into the brine solution and then discharge into the ocean. Hg is a toxic metal that ~~&~~ can bioaccumulate and is toxic to human nervous system. The diaphragm cell ~~but~~ is also not commonly used because of its health effects. This cell involves the use of an asbestos barrier which can cause health problems. The cell consists of two compartments with the asbestos barrier seperating the anode and cathode cells.



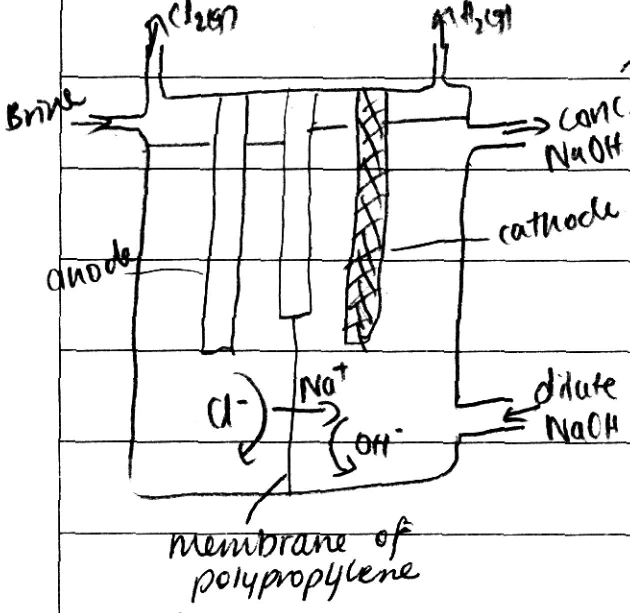
Diaphragm cell

~~The disad~~ Another disadvantage of this method is that the NaOH produced is not pure and ~1% of it is NaCl. However this method does produce large amounts of NaOH relatively cheaply compared to the other methods.

The membrane cell overcame a number

of the problems associated with the other two methods such as the toxic Hg and asbestos aswell as the problem of purity.

The membrane cell is similar in design to a diaphragm cell but the asbestos barrier is replaced with an ion exchange polymer, commonly, polypropylene.



This membrane allows Na^+ to pass through the ~~sto~~ polymer but not Cl^- ~~so~~ so a pure solution of NaOH is produced. Another advantage is that the polymer is resistant to attack from the OH^- solution meaning that it is long lasting. ~~but it is~~

~~Due to the development of poly~~

However the membrane is much more expensive than the previous two methods.

Due to improvements in polymer technology

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28 e)

the methods of producing NaOH have improved allowing a much safer and efficient process to be used.