Equilibria

Question Paper 4

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 4

Time Allowed: **64 minutes**

Score: **/53**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)** **(i)** Write the equation for a reaction in which ethylamine, $C_2H_5NH_2$, acts as a Brønsted-Lowry base.

.....

(ii) Ammonia, ethylamine and phenylamine, $C_6H_5NH_2$, are three nitrogen-containing bases.

Place these three compounds in order of basicity, with the most basic first.

most basic		least basic

(iii) Explain why you have placed the three compounds in this order.

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[4]

(b) **(i)** Write an equation for a reaction in which phenol, C_6H_5OH, acts as a Brønsted-Lowry acid.

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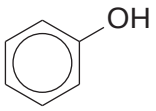
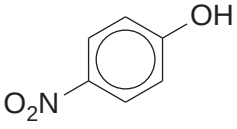
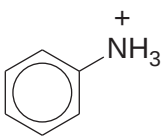
The pK_a values for phenol, 4-nitrophenol and the phenylammonium ion are given in the table.

compound	pK_a
	10.0
	7.2
	4.6

(ii) Suggest an explanation for the difference in the pK_a values of phenol and nitrophenol.

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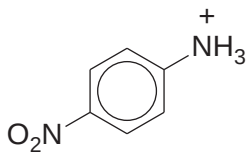
(iii) Using the information in the table opposite, predict which of the following pK_a values is the most likely for the 4-nitrophenylammonium ion.



Place a tick (✓) in the box beside the value you have chosen.

pK_a	
1.0	
4.5	
7.0	
10.0	

(iv) Explain your answer to part **(iii)**.

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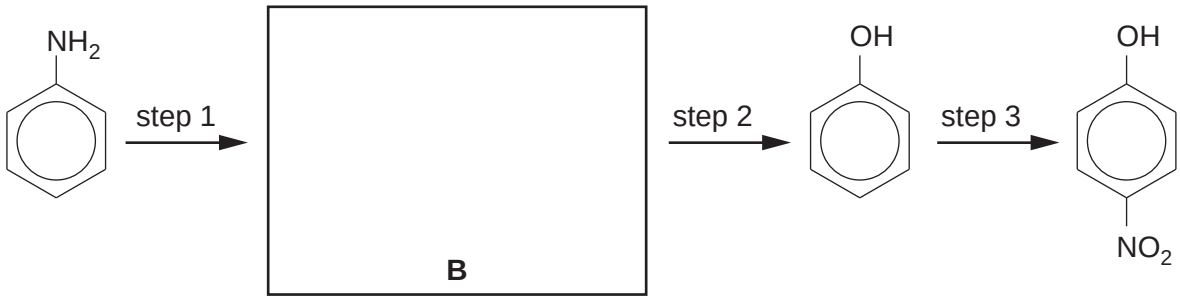
[5]

(c) Phenylamine can be converted to 4-nitrophenol by the following steps.



(i) Suggest the identity of intermediate **B** by drawing its structure in the box above.

(ii) Suggest reagents and conditions for the three steps in the above scheme.

	reagent(s)	conditions
step 1		
step 2		
step 3		

[5]

[Total: 14]

2 Nitrogen makes up about 79% of the Earth's atmosphere. As a constituent element of proteins, it is present in living organisms.

Atmospheric nitrogen is used in the Haber process for the manufacture of ammonia.

(a) Write an equation for the formation of ammonia in the Haber process.

.....[1]

(b) The Haber process is usually carried out at a high pressure of between 60 and 200 atmospheres (between 60×10^5 Pa and 200×10^5 Pa).
State **two further** important operating conditions that are used in the Haber process.
For **each** of your conditions, explain why it is used.

condition 1 .....

reason .....

condition 2 .....

reason .....[4]

(c) State **one** large-scale use for ammonia, other than in the production of nitrogenous fertilisers.

..... [1]

(d) The uncontrolled use of nitrogenous fertilisers can cause environmental damage to lakes and streams. This is known as 'eutrophication'.

What are the processes that occur when excessive amounts of nitrogenous fertilisers get into lakes and streams?

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.....[2]

In many countries, new cars have to comply with regulations which are intended to reduce the pollutants coming from their internal combustion engines.

Two pollutants that may be formed in an internal combustion engine are carbon monoxide, CO, and nitrogen monoxide, NO.

(e) (i) Outline how **each** of these pollutants may be formed in an internal combustion engine.

CO .....

.....

NO .....

.....

(ii) State the main hazard associated with **each** of these pollutants.

CO .....

NO ..... [4]

Pollutants such as CO and NO are removed from the exhaust gases of internal combustion engines by catalytic converters which are placed in the exhaust system of a car.

(f) (i) What metal is most commonly used as the catalyst in a catalytic converter?

.....

(ii) Construct **one** balanced equation for the reaction in which **both** CO **and** NO are removed from the exhaust gases by a catalytic converter.

.....[2]

[Total: 14]

3 A possible source of energy for the road vehicles of the future is hydrogen. One of the problems still to be solved is the storage of the hydrogen in the vehicle. A conventional tank holding liquid hydrogen would have to be pressurised and refrigerated. In a crash, this type of tank could break resulting in the rapid release of hydrogen and an explosion.

One alternative is to use a fuel tank packed with carbon nanotubes. The hydrogen in the tank would be adsorbed onto the surface of the nanotubes at a pressure of no more than a few atmospheres.

(a) **(i)** What is the approximate width of a carbon nanotube?

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(ii) In what structural form is the carbon in a nanotube?

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(iii) What forces could be responsible for holding the hydrogen on the surface of the nanotubes? Explain your answer.

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[4]

(b) The hydrogen atoms in a fuel tank packed with nanotubes are closer together than in liquid hydrogen. Suggest **one** advantage of this.

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..... [1]

(c) When a nanotube-packed fuel tank is full of hydrogen there is a steady pressure of hydrogen in the tank. While hydrogen gas is being removed from the fuel tank to power the car, the pressure in the fuel tank drops very little for some time. State Le Chatelier's principle, and suggest how it explains this observation.

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..... [4]

[Total: 9]

4 (a) (i) Write equations to illustrate the reactions of the following oxides with water.

phosphorus(V) oxide .....

sulfur(IV) oxide .....

(ii) When NO_2 reacts with water, nitrogen undergoes a disproportionation reaction in which one nitrogen atom decreases its oxidation number by 1 and another nitrogen atom increases its oxidation number by 1. A mixture of two acids results.
Suggest an equation for the reaction between NO_2 and water.

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(iii) In a similar disproportionation reaction, ClO_2 reacts with aqueous NaOH to produce a solution containing two chlorine-containing sodium salts.
Suggest an equation for the reaction between ClO_2 and aqueous NaOH.

.....

[4]

(b) The major source of sulfur for the manufacture of sulfuric acid by the Contact process is the de-sulfurisation of 'sour' natural gas. Many natural gas wells produce a mixture of volatile hydrocarbons (mainly CH_4 and C_2H_6) together with up to 25% hydrogen sulfide, H_2S.

(i) Complete and balance the following equation showing the complete combustion of a gaseous mixture consisting of 2 mol of CH_4, 1 mol of C_2H_6 and 1 mol of H_2S.

$$2CH_4 + C_2H_6 + H_2S + \_\_\_\_\_ \rightarrow SO_2 + \_\_\_\_\_ + \_\_\_\_\_$$

(ii) Explain why it is important to remove the H_2S before burning the natural gas industrially.

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The H_2S is removed by passing the 'sour' natural gas through a solvent containing ethanolamine. The following reaction takes place.

$$HOCH_2CH_2NH_2 + H_2S(g) \rightarrow HOCH_2CH_2NH_3^+ + SH^-$$

(iii) If a sample of natural gas contains 5% by volume of H_2S, calculate the mass of ethanolamine required to remove all the H_2S from a 1000 dm^3 sample of gas, measured under room conditions.

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The H_2S can be recovered by warming the solution to 120 °C, when the above reaction is reversed. The ethanolamine can then be recycled.

(iv) What *type* of reaction is occurring here?

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The recovered H_2S is converted to sulfur by the following two reactions.

I Part of the H_2S is burned in air.

$$H_2S + 1.5O_2 \longrightarrow SO_2 + H_2O$$

II The gas stream resulting from reaction **I** is then blended with the remaining H_2S and fed into an iron oxide catalyst bed, where sulfur and water are produced according to the following equation.

$$2H_2S(g) + SO_2(g) \longrightarrow 3S(g) + 2H_2O(g)$$

(v) Use the following data to calculate $\Delta H^{\ominus}$ for the reaction between H_2S and SO_2.

compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$H_2S(g)$	–21
$SO_2(g)$	–297
$H_2O(g)$	–242
S(g)	+11

$\Delta H^{\ominus}$ = ... kJ mol^{-1}
[8]

[Total: 12]

5 When an aqueous solution of compound **G**, $NH_2CH_2CH_2CH_2NH_2$, is titrated with HC*l*(aq), two successive acid-base reactions take place.

(a) Write equations for these two acid-base reactions.

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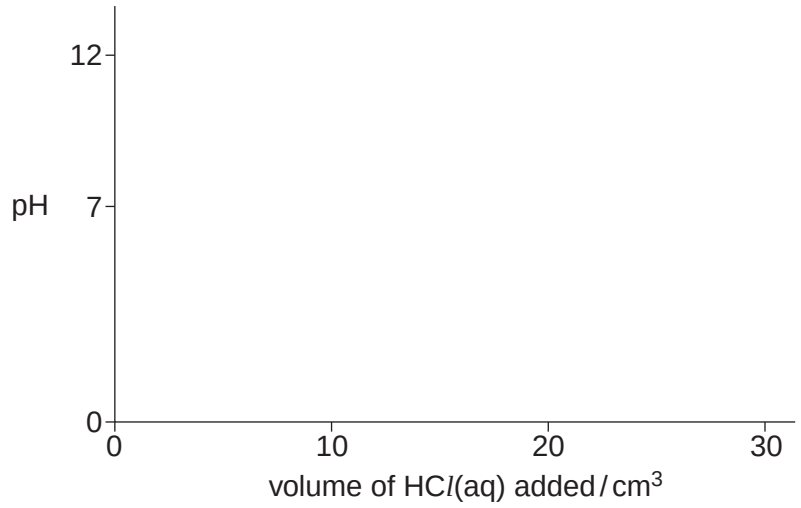
..... [2]

(b) A 0.10 mol dm^{-3} solution of **G** has a pH of 11.3. When 30 cm^3 of 0.10 mol dm^{-3} HC*l* is added to 10 cm^3 of a 0.10 mol dm^{-3} solution of **G**, the final pH is 1.6.
Using the following axes, sketch the pH changes that occur during this addition of HC*l*(aq).



[2]

[Total: 4]