Equilibria

Question Paper 10

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 10

Time Allowed: 71 minutes

Score: /59

Percentage: /100

Grade Boundaries:

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

1 The combustion of fuels in motor vehicles, trains, aeroplanes and power stations produces the pollutant gas NO_2.

(a) Write an equation to show how NO_2 is formed in these situations.

....[1]

(b) (i) How is the NO_2 removed from the exhaust gases of motor vehicles?

....

(ii) Write an equation for this process.

....
[2]

(c) Suggest whether the production of the pollutant NO_2 would be reduced if fossil fuels were replaced by hydrogen as a fuel for combustion. Explain your answer.
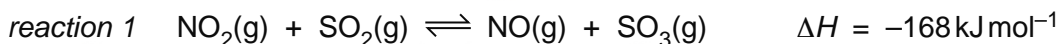
....

....[1]

(d) In the atmosphere, NO_2 acts as a catalyst for the oxidation of SO_2 to SO_3.

$$SO_2(g) \ + \ \tfrac{1}{2}\,O_2(g) \ \xrightarrow{\;NO_2\;} \ SO_3(g)$$
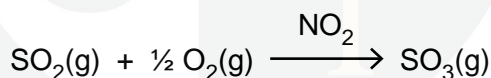
(i) What is the environmental significance of this reaction?

....

The oxidation takes place in two steps. The initial reaction is that between NO_2 and SO_2.

reaction 1 $NO_2(g) \ + \ SO_2(g) \ \rightleftharpoons \ NO(g) \ + \ SO_3(g)$ $\Delta H = -168\,\text{kJ}\,\text{mol}^{-1}$

(ii) Write an equation to show how the NO_2 is regenerated in the second step of the oxidation.

....

(iii) Write an expression for the equilibrium constant, K_p for *reaction 1*, stating its units.

$K_p =$

units ....

(iv) If equal amounts of $NO_2(g)$ and $SO_2(g)$ are allowed to react at room temperature, it is found that 99.8% of the gases have been converted into products at equilibrium. Calculate a value for K_p.

$K_p =$ ....

(v) The temperature of the atmosphere decreases with height. How will this affect the position of the equilibrium in *reaction 1*? Explain your answer.

....

....

[7]

[Total: 11]

2 Ethanolamine and phenylamine are two organic bases that are industrially important. Ethanolamine is a useful solvent with basic properties, whilst phenylamine is an important starting material in the manufacture of dyes and pharmaceuticals.

The following table lists some of their properties, together with those of propylamine.

compound	formula	M_r	boiling point/°C	solubility in water
propylamine	$CH_3CH_2CH_2NH_2$	59	48	fairly soluble
ethanolamine	$HOCH_2CH_2NH_2$	61	170	very soluble
phenylamine	⬡—NH_2	93	184	sparingly soluble

(a) Suggest why the boiling point of ethanolamine is much higher than that of propylamine. Draw a diagram to illustrate your answer.

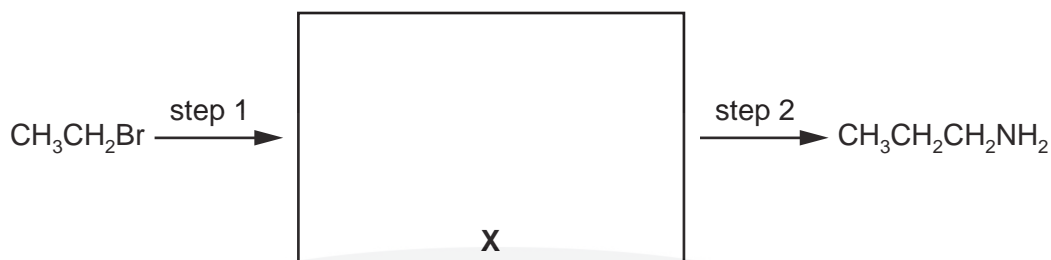...

....

[2]

(b) Describe and explain the relative basicities of propylamine and phenylamine.

....

....

....[2]

(c) Write an equation showing ethanolamine acting as a Brønsted-Lowry base.

....[1]

(d) Propylamine can be synthesised from bromoethane by the following route.

$$CH_3CH_2Br \xrightarrow{\text{step 1}} \boxed{\qquad\qquad \mathbf{X} \qquad\qquad} \xrightarrow{\text{step 2}} CH_3CH_2CH_2NH_2$$

    (i) Draw the structure of the intermediate compound **X** in the box above.

    (ii) Suggest reagents and conditions for

        step 1 ....

        step 2 ....

                                                                                                 [3]

(e) Apart from their relative basicities, ethanolamine and phenylamine differ in many of their reactions.
For **each** of these two compounds, describe **one** test that would give a positive result with the stated compound, but a negative result with the other.

ethanolamine

test ....

observation ....

phenylamine

test ....

observation ....

                                                                                                  [4]
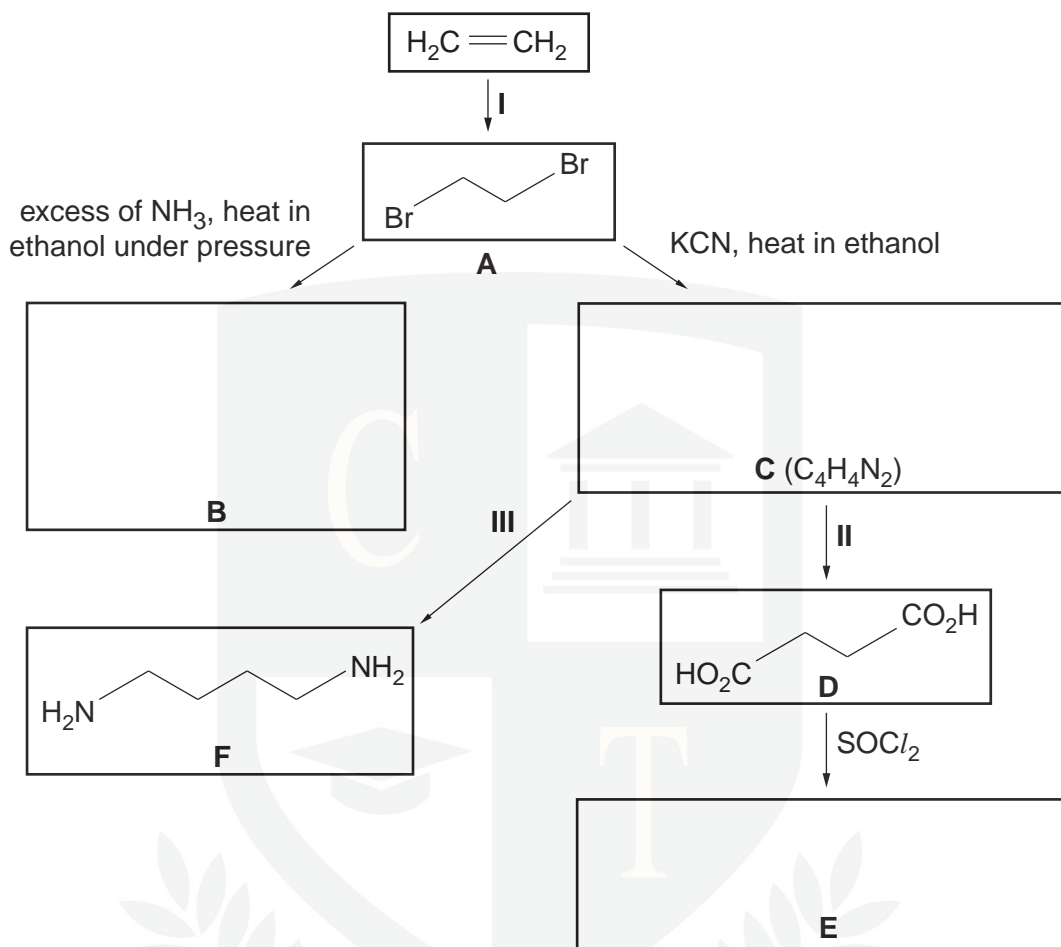
                                                                              [Total: 12]

3 The following scheme outlines the production of some compounds from ethene.

$$H_2C = CH_2$$

I

(Compound **A**: BrCH$_2$CH$_2$Br, drawn with Br and Br)

excess of NH$_3$, heat in ethanol under pressure

KCN, heat in ethanol

B

III

C ($C_4H_4N_2$)

II

F (H_2N—...—NH_2)

D (HO_2C—...—CO_2H)

SOCl_2

E

(a) (i) Suggest the reagent and conditions for reaction **I**.

....

(ii) Describe the mechanism of reaction **I** by means of a diagram. Include all whole, partial and induced charges, and represent the movements of electron pairs by curly arrows.

[3]

(b) Suggest the identities of compounds **B**, **C** and **E**, and draw their structures in the boxes opposite. [3]

(c) Suggest reagents and conditions for

reaction **II**,

....

reaction **III**.

....[2]

(d) During reaction **II** the nitrogen atoms are lost from the organic molecule. Suggest the identity of the nitrogen-containing ion produced during this reaction.

....[1]

(e) Compounds **E** and **F** react together to give a polymer and an inorganic product.

    (i) Draw **one** repeat unit of this polymer.

    (ii) Identify the inorganic product.

....[2]

(f) A $0.100\,mol\,dm^{-3}$ solution of compound **D** has a pH of 2.60.

    (i) Calculate the $[H^+]$ in this solution.

....

....

    (ii) Hence calculate the value of K_a of compound **D**.

....

....

[2]

[Total: 13]

4 A large number of organic compounds are soluble in both water and non-aqueous solvents such as hexane. If such a compound is shaken with a mixture of water and the non-aqueous solvent, it will dissolve in both solvents depending on the solubility in each.

(a) (i) State what is meant by the term *partition coefficient*.

....

....

(ii) When $100\,cm^3$ of an aqueous solution containing $0.50\,g$ of an organic compound **X** was shaken with $20\,cm^3$ of hexane, it was found that $0.40\,g$ of **X** was extracted into the hexane.

Calculate the partition coefficient of **X** between hexane and water.

(iii) If **two** $10\,cm^3$ portions of hexane were used instead of a single $20\,cm^3$ portion, calculate the total amount of **X** extracted and compare this with the amount extracted using one $20\,cm^3$ portion.

[5]

(b) PCBs are highly toxic compounds released into the atmosphere when some plastics are burned at insufficiently high temperatures. In recent years PCB residues have been found in the breast milk of Inuit mothers in northern Canada. Foods, such as oily fish, seal and whale meat, which are high in fat, form an important part of the Inuit diet.

(i) Suggest why berries and drinking water are not contaminated by PCBs in the same way that oily fish, seal and whale meat are.

....

....

....
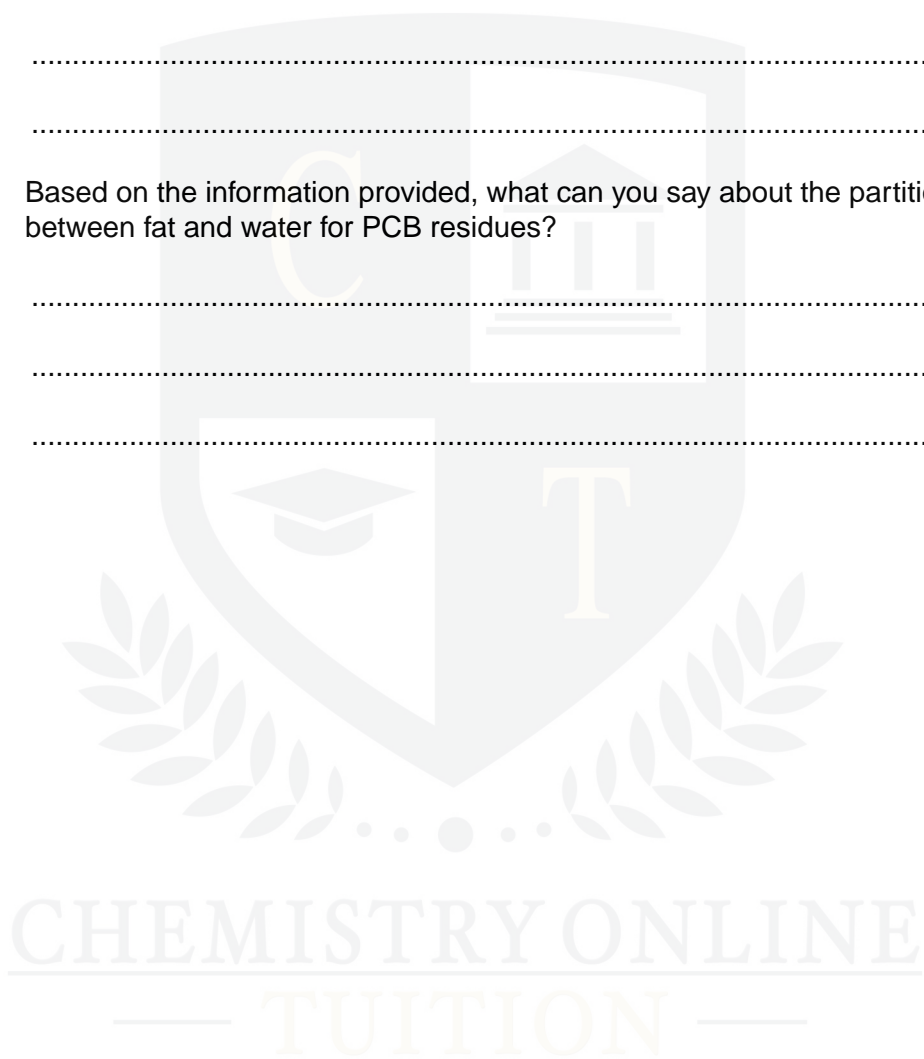
(ii) Based on the information provided, what can you say about the partition coefficient between fat and water for PCB residues?
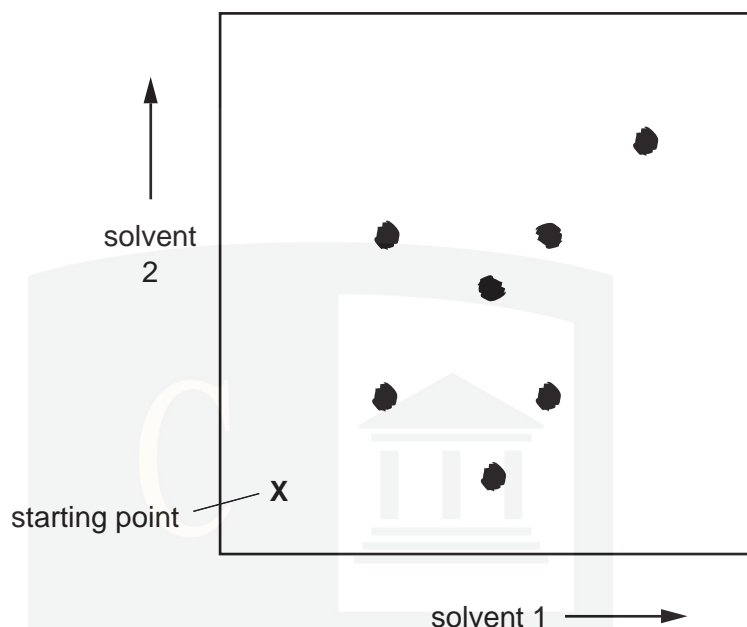
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....

....

[3]

(c) The diagram shows the result of two-way paper chromatography.

(i) How many spots were there after the first solvent had been used?

....

(ii) Circle the spot that moved very little in solvent 2, but moved a greater distance in solvent 1.

(iii) Draw a square around the spot that could be separated from the rest by using **only** solvent 1.
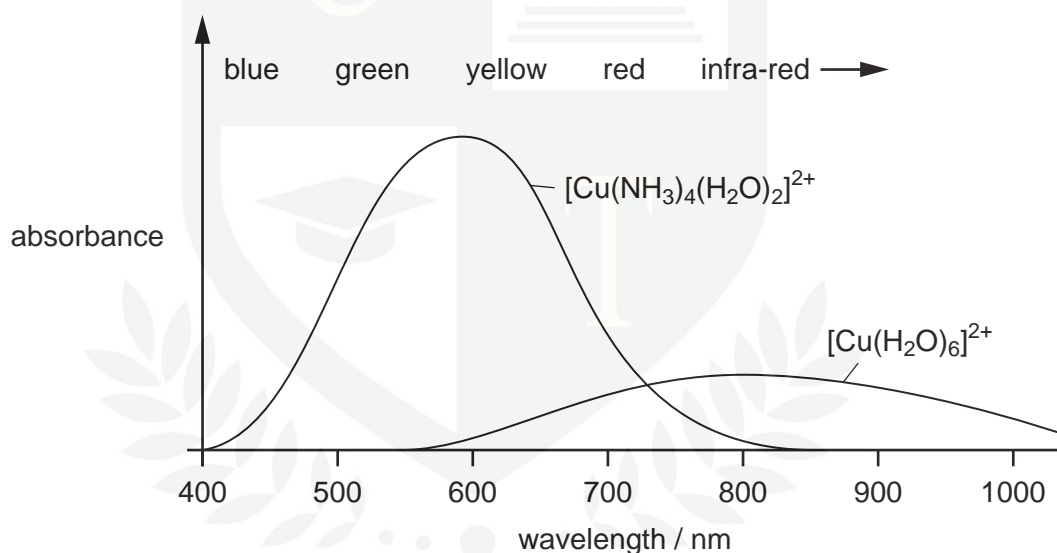
[3]

[Total: 11]

5 One major difference between the properties of compounds of the transition elements and those of other compounds is that the compounds of the transition elements are often coloured.

(a) Explain in detail why many transition element compounds are coloured.

....

....

....

....

.... [3]

(b) The following graph shows the absorption spectrum of two complexes containing copper.

(i) State the colours of the following complex ions.

$[Cu(H_2O)_6]^{2+}$ ....

$[Cu(NH_3)_4(H_2O)_2]^{2+}$ ....

(ii) Using the spectra above give **two** reasons why the colour of the $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ion is deeper (more intense) than that of the $[Cu(H_2O)_6]^{2+}$ ion.

....

....

....

(iii) Predict the absorption spectrum of the complex $[Cu(NH_3)_2(H_2O)_4]^{2+}$, and sketch this spectrum on the above graph. [6]

(c) Copper forms a complex with chlorine according to the following equilibrium.

$$Cu^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CuCl_4]^{2-}(aq)$$
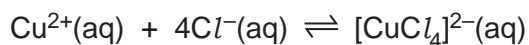
(i) Write an expression for the equilibrium constant, K_c, for this reaction, stating its units.

K_c = ... units ....

(ii) The numerical value of K_c is 4.2×10^5.
Calculate the $[[CuCl_4]^{2-}]/[Cu^{2+}]$ ratio when $[Cl^-] = 0.20\,mol\,dm^{-3}$.

....

....

[3]

[Total: 12]