Equilibria

Question Paper 7

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 7

Time Allowed: **74 minutes**

Score: **/61**

Percentage: **/100**

Grade Boundaries:

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

1 Hydrogen iodide dissociates into its elements according to the equation below.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

(a) Write the expression for the equilibrium constant, K_c.

[1]

(b) At 120 °C the equilibrium mixture contains 1.47 mol dm^{-3} of HI(g), 0.274 mol dm^{-3} each of H_2(g) and I_2(g).

Calculate the value of K_c for the equilibrium at 120 °C.

[1]

(c) Suggest and explain why it would be more difficult to determine K_c for this equilibrium at room temperature.

.....

.....

.....

.....[2]

(d) **(i)** Explain how enthalpy changes, ΔH values, for covalent bonded molecules can be calculated from bond energies.

.....

.....

(ii) Use bond energies from the *Data Booklet* to calculate ΔH for the following dissociation.

$$2HI(g) \rightarrow H_2(g) + I_2(g)$$

[3]

(e) HI dissolved in water behaves as a strong acid.

(i) Explain what is meant by a ***strong*** *acid*.

.....

(ii) Complete the equation.

$$HI + H_2O \rightarrow \text{.....} + \text{.....}$$

(iii) Identify the conjugate base of HI in this equation.

.....[3]

[Total : 10]

2 Sulphuric acid is a strong dibasic acid, which ionises in solution as follows.

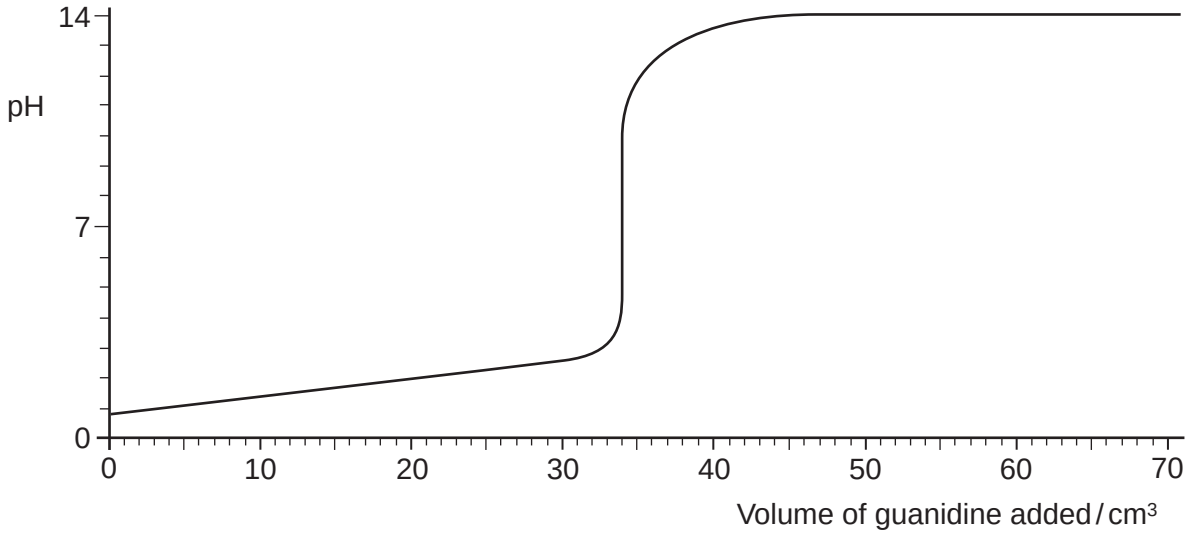
$$H_2SO_4(aq) \rightleftharpoons 2H^+(aq) + SO_4^{2-}(aq)$$

(a) The organic base guanidine contains carbon, nitrogen and hydrogen. Its reaction with acids can be represented as follows.

$$B(aq) + H^+(aq) \rightleftharpoons BH^+(aq)$$

where *B* represents the molecule of guanidine.

When a 25.0 cm^3 sample of dilute sulphuric acid was titrated against a solution of guanidine, the following titration curve was obtained.



Use this curve to answer the following questions.

(i) Is guanidine a strong or a weak base? Explain your answer.

.....

.....

(ii) The pH at the start of the titration was 0.70. Calculate the $[H^+]$, and hence the concentration of sulphuric acid, at the start of the titration.

.....

.....

.....

.....

(iii) Calculate the concentration of guanidine in the solution in mol dm^{-3}.

.....

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.....

(iv) The guanidine solution contained 8.68 g of the base per dm^3. Use your answer to **(iii)** calculate the M_r of guanidine.

..... [6]

(b) One of the major industrial uses of sulphuric acid is to convert phosphate rock (calcium fluorophosphate(V)) into 'superphosphate' for use as a fertiliser. The process can be represented by the following partially balanced equation.

$$2\ Ca_5(PO_4)_3F + 7H_2SO_4 \longrightarrow \text{.....}\ CaSO_4 + \text{.....}\ Ca(H_2PO_4)_2 + \text{.....}\ HF$$

'superphosphate'

(i) Balance the above equation.

(ii) Use your balanced equation to calculate the mass of H_2SO_4 required to manufacture 1.0 kg of superphosphate fertiliser.

.....

.....

.....

..... [4]

(c) Solutions of hydrogenphosphates make useful buffers for biochemical experiments.

$$H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H^+$$

(i) Explain what is meant by the term *buffer solution.*

.....

.....

(ii) Calculate the pH of a buffer solution that contains 0.20 mol dm^{-3} NaH_2PO_4 and 0.10 mol dm^{-3} Na_2HPO_4. [K_a ($H_2PO_4^-$) = 6.3 x 10^{-8} mol dm^{-3}]

.....

.....

..... [3]

[Total: 13]

3 In the Haber Process, ammonia is synthesised from its elements.

(a) Write an equation for the Haber process and state whether it is endo- or exo-thermic.

.....[2]

(b) What are the **three** usual operating conditions of the Haber Process?

.....

.....

.....[2]

(c) Explain the considerations which lead to the temperature you have stated in **(b)** being used.

.....

.....

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.....[2]

(d) Under certain conditions the equilibrium pressures of the three gases are

nitrogen	44.8 atm,
hydrogen	105.6 atm,
ammonia	37.2 atm.

(i) Write an expression for the equilibrium constant, K_p, for the Haber Process.

(ii) Calculate K_p from these data, giving the units.

[4]

(e) One of the uses of ammonia is to form nitrates which are used as efficient inorganic fertilisers. The uncontrolled use of these fertilisers has led to environmental problems. Briefly describe and explain these problems.

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.....

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.....

.....

.....[3]

[Total : 13]

4 **(a)** DNA fingerprinting has become a very important technique for analysing samples from living or once-living organisms.

(i) After extraction and purification, what is the first step in **analysing** a sample of DNA?

.....

..... [1]

(ii) What can be done to increase the amount of DNA for analysis?

.....

..... [1]

(iii) During electrophoresis, it is observed that amino acids can move in **different** directions or not at all, whilst DNA fragments always move in the **same** direction.

Explain these two observations.

.....

.....

.....

..... [2]

(iv) DNA fingerprinting can also be useful in archaeology.

Which of the following would **not** be suitable for analysis by DNA fingerprinting?
Put a cross (x) in the appropriate box(es).

a piece of leather from an Egyptian tomb	☐
a sample of skin from a mummified body	☐
a fragment of ancient pottery	☐
a piece of wood from a Roman chariot	☐

[1]

(b) X-ray crystallography can be used to help analyse the structure of macromolecules.

What does this technique tell us about a particular macromolecule?

.....

..... [1]

(ii) Which element will show up most strongly in the X-ray crystallography of a biological polymer of general formula $C_vH_wP_xN_yO_z$?
Explain your answer.

.....

..... [1]

(c) Explain what is meant by a *partition coefficient*.

.....

..... [1]

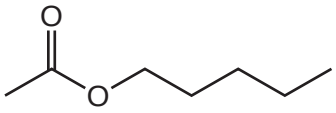
(ii) The partition coefficient of a particular pesticide between hexane and water is 6.0.
A solution contains 0.0042 g of the pesticide dissolved in 25 cm^3 of water. The solution is shaken with 25 cm^3 of hexane.

Calculate the mass of pesticide that will be dissolved in the hexane layer at equilibrium.

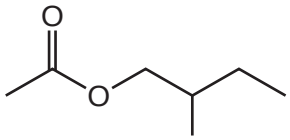
[2]

[Total: 10]

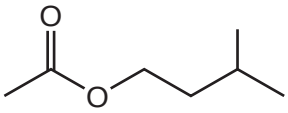
5 The following four isomeric esters with the molecular formula $C_7H_{14}O_2$ are used as artificial flavours in drinks and sweets to give a pear, banana or plum taste to foodstuffs.



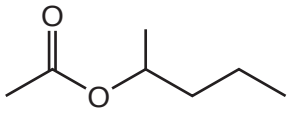
A



B



C



D

(a) In each of the spaces below, write one or more of the letters **A**-**D**, as appropriate.

(i) Which of these compounds can exist as optical isomers?

.....

(ii) On hydrolysis, which of these compounds produce(s) a secondary alcohol?

.....
[3]

(b) The hydrolysis of all these compounds produces ethanoic acid, CH_3CO_2H, as one of the products.

State the reagents and conditions needed for this hydrolysis.

..... [1]

(c) The acid dissociation constant, K_a, of ethanoic acid is 1.75×10^{-5} mol dm^{-3}.

(i) Explain why this value of K_a is

- much larger than that of ethanol, CH_3CH_2OH,

.....

.....

- smaller than that of chloroethanoic acid, $ClCH_2CO_2H$.

.....

.....

(ii) Calculate the pH of a 0.100 mol dm^{-3} solution of ethanoic acid.

[4]

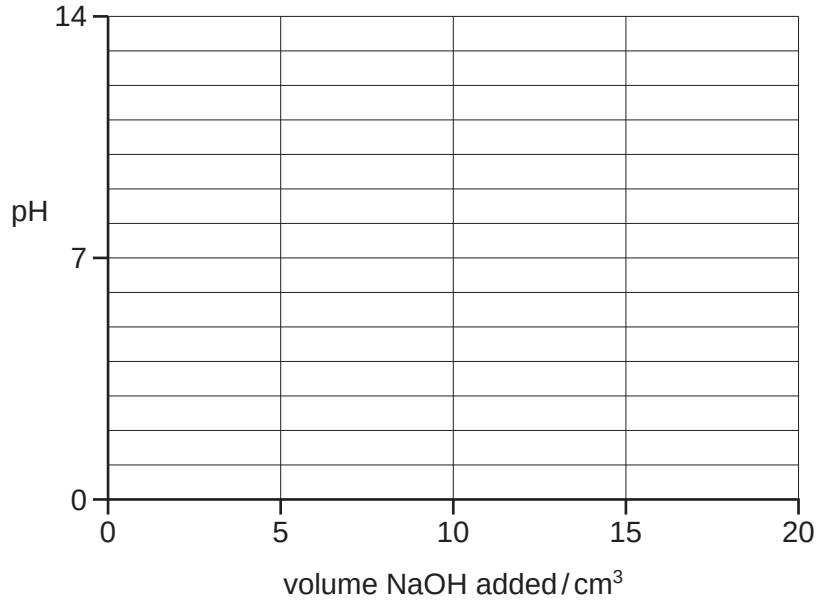
(d) 20.0 cm^3 of 0.100 mol dm^{-3} NaOH were slowly added to a 10.0 cm^3 sample of 0.100 mol dm^{-3} ethanoic acid, and the pH was measured throughout the addition.

(i) Calculate the number of moles of NaOH remaining at the end of the addition.

(ii) Calculate the [OH^-] at the end of the addition.

(iii) Using the expression $K_w = [H^+][OH^-]$ and your value in **(ii)**, calculate [H^+] and the pH of the solution at the end of the addition.

(iv) On the following axes, sketch how the pH will change during the addition of a total of 20.0 cm^3 of 0.100 mol dm^{-3} NaOH. Mark clearly where the end point occurs.



(v) From the following list of indicators, put a tick in the box by the side of the indicator you consider most suitable for this titration.

indicator	pH at which colour changes	place **one tick only** in this column
malachite green	0 - 1	
thymol blue	1 - 2	
bromophenol blue	3 - 4	
thymolphthalein	9 - 10	

[7]

[Total: 15]