

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY

2816/01

Unifying Concepts

Monday

23 JANUARY 2006

Morning

1 hour 15 minutes

Candidates answer on the question paper.

Additional materials:

Data Sheet for Chemistry

Scientific calculator

Candidate Name

Centre Number				Candidate Number			

TIME 1 hour 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer all the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [] at the end of each question or part question.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- You may use the *Data Sheet for Chemistry*.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	Max	Marks
1	16	
2	17	
3	14	
4	13	
TOTAL	60	

This question paper consists of 11 printed pages and 1 blank page.

Answer **all** the questions.

- 1 Methanoic acid, HCOOH, is a weak organic acid which occurs naturally in ants and stinging nettles.

(a) Use an equation for the dissociation of methanoic acid to show what is meant by a *weak acid*.

.....
.....[1]

(b) A $1.50 \times 10^{-2} \text{ mol dm}^{-3}$ solution of HCOOH has $[\text{H}^+] = 1.55 \times 10^{-3} \text{ mol dm}^{-3}$.

(i) Calculate the pH of this solution and give one reason why the pH scale is a more convenient measurement for measuring acid concentrations than $[\text{H}^+]$.

.....
.....
.....[2]

(ii) Write the expression for K_a for methanoic acid.

[1]

(iii) Calculate the values of K_a and $\text{p}K_a$ for methanoic acid.

[3]

(iv) Estimate the percentage of HCOOH molecules that have dissociated in this aqueous solution of methanoic acid.

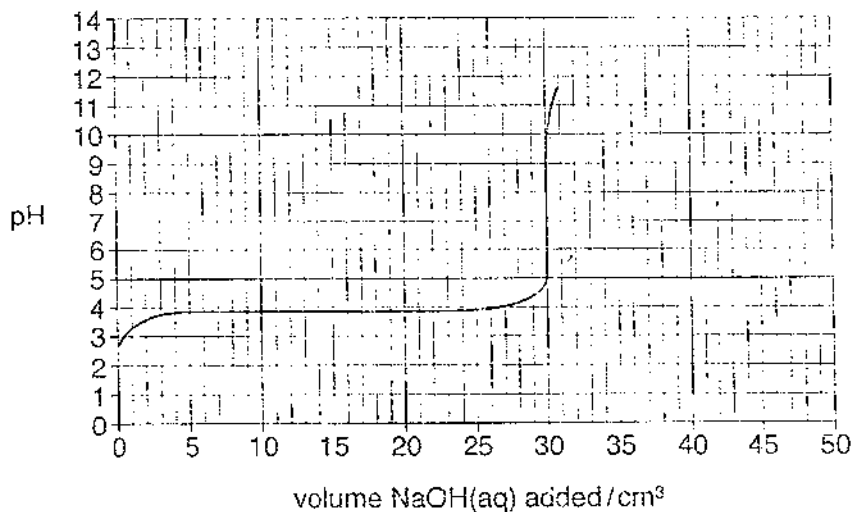
[1]

- (c) A student titrated the $1.50 \times 10^{-2} \text{ mol dm}^{-3}$ methanoic acid with aqueous sodium hydroxide.
A 25.00 cm^3 sample of the $\text{HCOOH}(\text{aq})$ was placed in a conical flask and the $\text{NaOH}(\text{aq})$ was added from a burette until the pH no longer changed.

(i) Write a balanced equation for the reaction between $\text{HCOOH}(\text{aq})$ and $\text{NaOH}(\text{aq})$.

...[1]

(ii) Part of the pH curve for this titration is shown below.



Calculate the concentration, in mol dm^{-3} , of the aqueous sodium hydroxide.

concentration = ... mol dm^{-3} [3]

(iii) Calculate the pH of the aqueous sodium hydroxide.
 $K_w = 1.00 \times 10^{-14} \text{ mol dm}^{-3}$

pH = ... [2]

- (iv) The pH ranges in which colour changes for three acid-base indicators are shown below.

indicator	pH range
metacresol purple	7.4 – 9.0
2,4,6-trinitrotoluene	11.5 – 13.0
ethyl orange	3.4 – 4.8

Explain which of the three indicators is suitable for this titration.

.....

.....

.....

.....

..... [2]

[Total: 16]

- (d) The student repeated the experiment at a higher temperature and found that less HI was present at equilibrium.

Explain what additional information this tells you about the reaction.

.....

.....

.....

.....[2]

- (e) Hydroiodic acid, HI(aq), is a strong acid that is an aqueous solution of hydrogen iodide. In the laboratory, hydroiodic acid can be prepared by the method below.

A mixture of 480 g of iodine and 600 cm³ of water was put into a flask. The mixture was stirred and hydrogen sulphide gas, H₂S(g), was bubbled through for several hours.

The mixture became yellow as sulphur separated out. The sulphur was filtered off and the solution was purified by fractional distillation. A fraction of HI(aq) was collected containing 440 g of HI in a total volume of 750 cm³.

- (i) Construct a balanced equation, with state symbols, for the preparation of hydroiodic acid.

.....

.....[2]

- (ii) Determine the percentage yield of hydroiodic acid.

[3]

- (iii) Calculate the pH of the hydroiodic acid fraction.

[2]

[To



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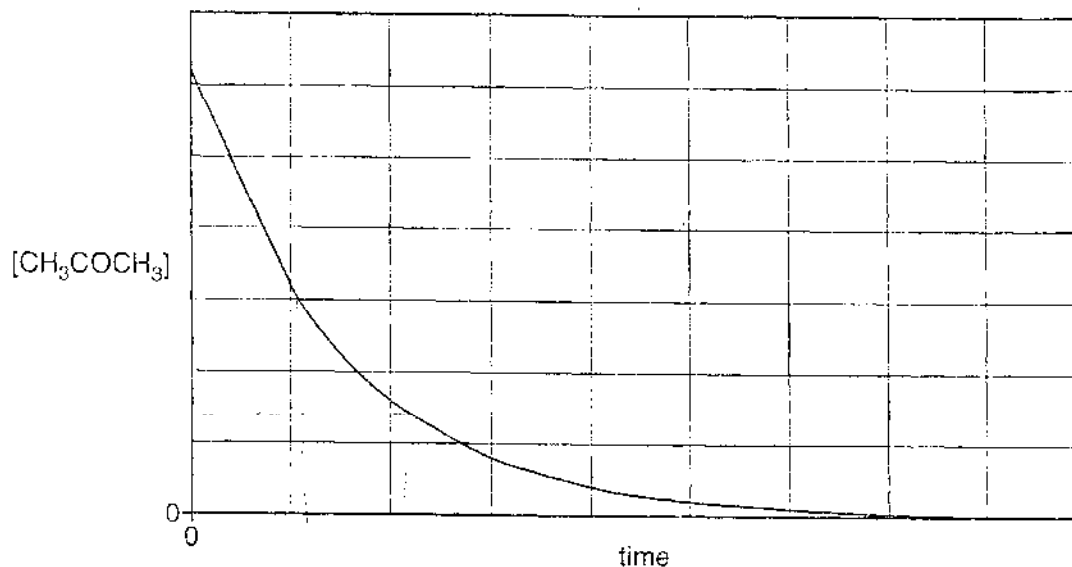
- 3 In this question, one mark is available for the quality of use and organisation of scientific terms.

Propanone reacts with iodine in the presence of dilute hydrochloric acid.

A student carried out an investigation into the kinetics of this reaction.

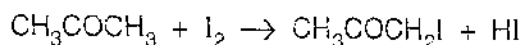
He measured how the concentration of propanone changes with time. He also investigated how different concentrations of iodine and hydrochloric acid affect the initial rate of the reaction.

The graph and results are shown below.



$[\text{CH}_3\text{COCH}_3]$ /mol dm ⁻³	$[\text{I}_2]$ /mol dm ⁻³	$[\text{H}^+]$ /mol dm ⁻³	initial rate /mol dm ⁻³ s ⁻¹
1.5×10^{-3}	0.0300	0.0200	2.1×10^{-9}
1.5×10^{-3}	0.0300	0.0400	4.2×10^{-9}
1.5×10^{-3}	0.0600	0.0400	4.2×10^{-9}

The overall equation for the reaction is given below.



This is a multi-step reaction.

- What conclusions can be drawn about the kinetics of this reaction from the student's investigation? Justify your reasoning.
- Calculate the rate constant for this reaction, including units.
- Suggest the equations for a possible two-step mechanism for this reaction. Label the rate-determining step and explain your reasoning.

9

.....
Quality of Written Communication [i] :

[Total: 10]

4 This question looks at different compounds used in medicine.

(a) Nitrous oxide, N_2O , is the gas used as a general anaesthetic.

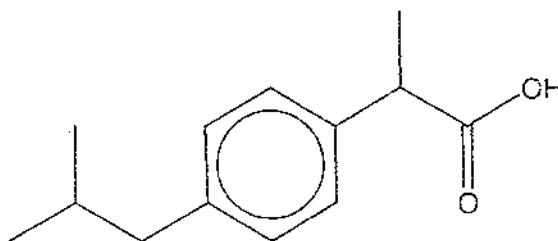
(i) What is the oxidation number of nitrogen in nitrous oxide?

.....[1]

(ii) Suggest a 'dot-and-cross' diagram for nitrous oxide. Show outer electrons only.
The sequence of atoms in a nitrous oxide molecule is N N O.

[1]

(b) The structure of the painkiller ibuprofen is shown below.



(i) Determine the molecular formula of ibuprofen.

[1]

(ii) Suggest a chemical that would react with a solution of ibuprofen to produce a gas.
Name the gas produced and write a balanced equation for the reaction.

chemical

gas

equation

[2]

- (c) Lidocaine, $C_{13}H_{20}N_2O_2$, is used as a local anaesthetic in dentistry. Lidocaine is administered by syringe as a solution containing 100 mg in 5.00 cm^3 .

Calculate the concentration, in mol dm^{-3} , of lidocaine in the syringe.

concentration = mol dm^{-3} [3]

- (d) Eugenol is used as a painkiller in dentistry. It is an organic compound of C, H and O.

A sample of 1.394 g of eugenol was analysed by burning in oxygen to form 3.74 g of CO_2 and 0.918 g of H_2O . The relative molecular mass of eugenol was shown to be 164 using a mass spectrometer.

Calculate the molecular formula of eugenol.

[5]

[Total: 13]

END OF QUESTION PAPER

**Mark Scheme 2816/01
January 2006**

Question	Expected Answers	Marks
1 (a)	partial dissociation: $\text{HCOOH} \rightleftharpoons \text{H}^+ + \text{HCOO}^-$ ✓	[1]
(b) (i)	$\text{pH} = -\log(1.55 \times 10^{-3}) = 2.81/2.8$ ✓ [H ⁺] deals with negative indices over a very wide range/ pH makes numbers manageable /removes very small numbers ✓	[4]
(ii)	$K_a = \frac{[\text{H}^+(\text{aq})][\text{HCOO}^-(\text{aq})]}{[\text{HCOOH}(\text{aq})]}$ ✓ (state symbols not needed)	[1]
(iii)	$K_a = \frac{[\text{H}^+(\text{aq})]^2}{[\text{HCOOH}(\text{aq})]} = \frac{(1.55 \times 10^{-3})^2}{0.015}$ ✓ $= 1.60 \times 10^{-4} \text{ (mol dm}^{-3}\text{)} \checkmark$ $\text{p}K_a = -\log K_a = -\log(1.60 \times 10^{-4}) = 3.80$ ✓	[3]
(iv)	Percentage dissociating = $\frac{(1.55 \times 10^{-3}) \times 100}{0.015} = 10.3\%$ / 10% ✓ (working not required)	[1]
(c) (i)	$\text{HCOOH} + \text{NaOH} \rightarrow \text{HCOONa} + \text{H}_2\text{O}$ ✓ state symbols not needed	[1]
(ii)	$n(\text{HCOOH}) = 0.0150 \times 25.00/1000 = 3.75 \times 10^{-4}$ ✓ volume of NaOH(aq) that reacts is 30 cm ³ ✓ so $[\text{NaOH}] = 3.75 \times 10^{-4} \times 1000/30 = 0.0125 \text{ mol dm}^{-3}$ ✓	[2]
(iii)	$K_w = [\text{H}^+(\text{aq})][\text{OH}^-(\text{aq})]$ ✓ $\text{pH} = -\log(1 \times 10^{-14}/0.0125) = 12.10/12.1$ ✓ (calc 12.09691001)	[3]
(iv)	metacresol purple ✓ pH range coincides with pH change during sharp rise OR pH 6-10 /coincides with equivalence point/end point ✓	[2]
		Total 16

Question	Expected Answers	Marks												
2 (a)	$K_c = \frac{[HI]^2}{[H_2][I_2]}$ ✓	[1]												
(b) (i)	<table style="display: inline-table; border: none;"> <tr> <td style="padding-right: 20px;">H₂</td> <td style="padding-right: 20px;">I₂</td> <td>HI</td> </tr> <tr> <td>0.30</td> <td>0.20</td> <td>0</td> </tr> <tr> <td>0.14</td> <td>0.04</td> <td>0.32</td> </tr> <tr> <td></td> <td style="text-align: center;">✓</td> <td style="text-align: center;">✓</td> </tr> </table>	H ₂	I ₂	HI	0.30	0.20	0	0.14	0.04	0.32		✓	✓	[2]
H ₂	I ₂	HI												
0.30	0.20	0												
0.14	0.04	0.32												
	✓	✓												
(b) (ii)	$K_c = \frac{0.32^2}{0.14 \times 0.04} = 18.28571429$ ✓ = 18 (to 2 sig figs) ✓ no units ✓ (or ecf based on answers to (i) and/or (a))	[3]												
(c)	K_c is constant ✓ Composition of mixture is the same ✓	[2]												
(d)	(Forward) reaction is exothermic (ora) ✓ because equilibrium moves to the left / K_c is less ✓	[2]												
(e) (i)	$I_2(aq) + H_2S(g) \rightarrow 2HI(aq) + S(s)$ species and balance ✓ state symbols: accept (s) for I ₂ ; (aq) for H ₂ S ✓	[2]												
(e) (ii)	amount I ₂ reacted = 1.89 mol / HI formed = 3.44 mol ✓ theoretical amount HI produced = 3.78 mol / 484 g ✓ $\% \text{ yield} = \frac{3.44 \times 100}{3.78} \text{ or } \frac{440 \times 100}{484} = 91.0 \%$ ✓	[3]												
(e) (iii)	$[HI] = \frac{3.44 \times 1000}{750} = 4.58/4.59 \text{ mol dm}^{-3}$ ✓ $pH = -\log 4.59 = -0.66$ ✓	[2]												
		Total: 17												

Question	Expected Answers	Marks
3	<p>From graph, constant half-life ✓ Therefore 1st order w.r.t. $[\text{CH}_3\text{COCH}_3]$ ✓</p> <p>From table, rate doubles when $[\text{H}^+]$ doubles ✓ Therefore 1st order w.r.t. $[\text{H}^+]$ ✓</p> <p>From table, rate stays same when $[\text{I}_2]$ doubles ✓ Therefore zero order w.r.t. $[\text{I}_2]$ ✓ Order with no justification does not score.</p> <p>rate = $k[\text{H}^+][\text{CH}_3\text{COCH}_3]$ ✓ (from all three pieces of evidence)</p> $k = \frac{\text{rate}}{[\text{H}^+][\text{CH}_3\text{COCH}_3]} = \frac{2.1 \times 10^{-9}}{0.02 \times 1.5 \times 10^{-3}} \checkmark$ <p>= $7.0 \times 10^{-5} \checkmark \text{ dm}^3 \text{ mol}^{-1} \text{ s}^{-1} \checkmark$ accept 7×10^{-5}</p> <p>rate determining step involves species in rate equation ✓</p> <p>two steps that add up to give the overall equation ✓</p> <p>The left hand side of a step that contains the species in rate-determining step ✓ i.e., for marking points 2 and 3: $\text{CH}_3\text{COCH}_3 + \text{H}^+ \rightleftharpoons [\text{CH}_3\text{COHCH}_3]^+$ $[\text{CH}_3\text{COHCH}_3]^+ + \text{I}_2 \rightarrow \text{CH}_3\text{COCH}_2\text{I} + \text{HI} + \text{H}^+$</p> <p>organises relevant information clearly and coherently, using specialist vocabulary where appropriate Use of the following four words/phrases: constant, half-life, order, doubles/x2 ✓</p>	<p>[2]</p> <p>[2]</p> <p>[2]</p> <p>[4]</p> <p>[3]</p> <p>[1]</p>
		Total: 16

