Class Adm No

Candidate Name: _____

2021 End-of-Year Exams
Pre-University 2

H1 CHEMISTRY **8873/02**

Paper 2 Structured Questions **xxth Sep 2021**

2 hours

Candidates answer on the Question paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

	Section A				Section B		
Question	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
Marks	/18	/17	/14	/8	/20	/20	/80

Section A

Answer **all** the questions in this section in the spaces provided.

For Examiners' Use

1 Chromic acid, H_2CrO_4, is commonly used as a glassware cleaning reagent in laboratories. It is prepared by adding 60.0 g of potassium dichromate(VI), $K_2Cr_2O_7$, in 150 cm^3 of warm distilled water at 35.0 °C, and then slowly adding excess concentrated sulfuric acid to produce a 1 dm^3 chromic acid solution. During this process, the solution reached a maximum temperature of 38.5 °C. [Assume for the solution, density = 1.71 g cm^{-3} ; specific heat capacity = 4.18 J g^{-1} K^{-1}.]

Chromic acid is a strong acid which dissociates according to the following equation:

$$H_2CrO_4 \rightarrow H^+ + HCrO_4^- \quad \text{---------- } K_a$$

Chromic acid is also a strong oxidising agent, in which the $HCrO_4^-$ ion produced can be used to oxidise aldehydes, with the general formula R-CHO, to carboxylic acids, R-COOH, where R represents an alkyl group. In the process, green Cr^{3+} ions are produced. The rate equation for this reaction is

$$\text{rate} = k\,[\text{R-CHO}]\,[HCrO_4^-]$$

(a) **(i)** Write a balanced ionic equation for the conversion of dichromate(VI) ions, $Cr_2O_7^{2-}$, into H_2CrO_4 during the preparation process.

…… [1]

$Cr_2O_7^{2-} + H_2O + 2H^+ \rightarrow 2H_2CrO_4$;

(ii) Calculate the amount of $K_2Cr_2O_7$ used in the preparation of chromic acid.

[1]

Amount of $K_2Cr_2O_7$ = 60.0 ÷ [2(39.1) + 2(52.0) + 7(16.0)] = 60.0 ÷ 294.2
= 0.204 mol

(iii) Hence, calculate the concentration of H_2CrO_4 in the 1 dm^3 solution formed from the preparation process outlined above.

[1]

Amount of $K_2Cr_2O_7$: $Cr_2O_7^{2-}$: H_2CrO_4 = 1 : 1 : 2 (ecf from **(a)(i)**)
Concentration of H_2CrO_4 = 2(0.204) ÷ 1 = 0.408 mol dm^{-3} ;

(iv) Calculate the mass of the 1 dm^3 chromic acid solution.

[1]

Mass of solution = 1.71 × 1000 = 1710 g ;

(v) Hence, calculate the enthalpy change for the reaction in **(a)(i)**.

[2]

Q = mcΔT = (1710)(4.18)(38.5 - 35.0) = 25 017 J
ΔH = –Q / n = –25 017 / 0.204 = –122 632 J mol^{-1} = –122 kJ mol^{-1} (3 s.f.)

For Examiners' Use

(b) **(i)** Determine the oxidation numbers of C in R-CHO and in R-COOH.

[Assume that the R group does not contribute to the oxidation number of C.]

R-CHO: …… R-COOH: …….. [1]

R-CHO: +1 ; R-COOH: +3 ;

(ii) Determine the oxidation numbers of Cr in $HCrO_4^-$ and in Cr^{3+}.

$HCrO_4^-$: …… Cr^{3+}: …….. [1]

$HCrO_4^-$: +6 Cr^{3+}: +3 ; (both)

(iii) Hence, or otherwise, determine the molar ratio in which $HCrO_4^-$ reacts with R-CHO.

$HCrO_4^-$	:	R-CHO
	:	

[1]

2 : 3

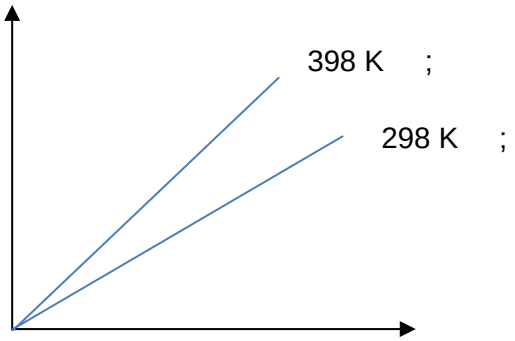
(iv) Sketch, on the axes below, how the rate of the oxidation reaction varies with the concentration of R-CHO at:

I: 298 K

II: 398 K

For this question, assume that the concentration of $HCrO_4^-$ remains constant.

[2]



ECF for rate-conc graph drawn for 0 or 2nd order but correct shows increase in T leading to increase in gradient.

(v) With the aid of a Maxwell-Boltzmann distribution diagram, explain how the rate of the reaction between R-CHO and $HCrO_4^-$ changed when the temperature was increased from 298 K to 398 K.

.....

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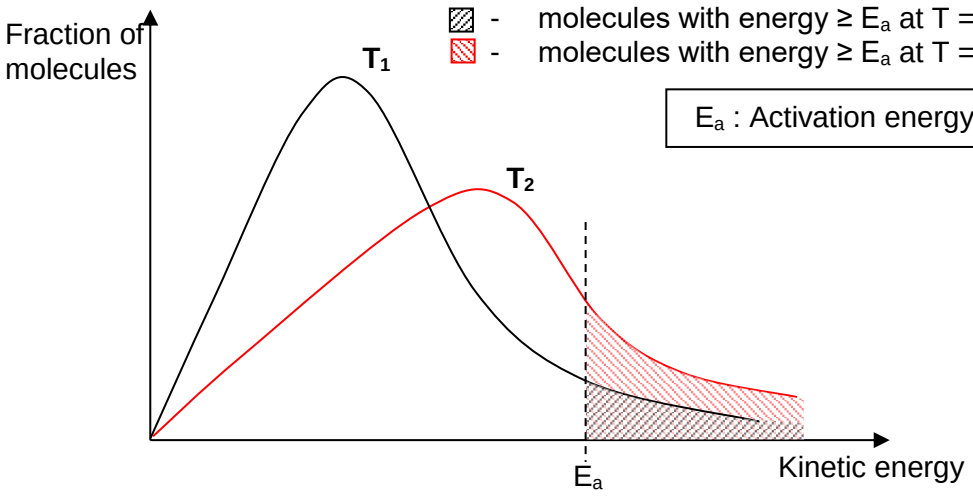
.....

.....

…… [3]



➔ When temperature is increased, average kinetic energy of particles increases.
➔ Proportion of particles with Energy ≥ Ea increases,
➔ Frequency of effective collision increases, leading to increase in rate of reaction.

For Examiners' Use

(c) **(i)** By considering the electronic configuration of the Cr^{3+} ion, determine the number of unpaired electrons for the Cr^{3+} ion in the ground state.

…… [1]

$(1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3)$ ➔ 3 unpaired electrons.

(ii) Suggest if the value of the dissociation constant of chromic acid, K_a, is larger or smaller than 1. Explain your answer.

……

……

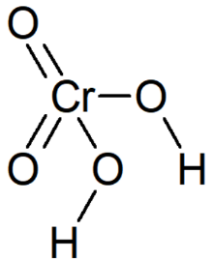
…… [1]

K_a is larger than 1 as chromic acid is a strong acid and hence dissociates completely / concentration of products is much larger than concentration of reactants in K_a expression / larger numerator and small denominator or OWTTE ;

(iii) Given that H_2CrO_4 is a simple molecule containing two Cr=O double bonds and two Cr–O single bonds, draw the displayed formula of H_2CrO_4 and state the predominant intermolecular interaction between two molecules of H_2CrO_4.

.....[2]

[Total: 18]



Hydrogen bonding ;

2 At a fixed temperature, nitrogen dioxide, $NO_2(g)$, was placed into a closed vessel of fixed volume and allowed to reach *dynamic equilibrium*. The equilibrium concentration of $NO_2(g)$ was found to be 0.800 mol dm^{-3} and the equilibrium constant, K_c, has a value of 0.400.

For Examiners' Use

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

(a) **(i)** Define the term *dynamic equilibrium*.

.....

.....

.....[1]

A dynamic equilibrium is a reversible reaction in which the forward and backward reaction rates are the same and the overall / net concentration of reactants and products remain unchanged.

(ii) Write an expression for the equilibrium constant, K_c, and state its units.

[2]

$K_c = \frac{[N_2O_4]}{[NO_2]^2}$ units: mol^{-1} dm^3

(iii) Calculate the equilibrium concentration of $N_2O_4(g)$.

[1]

$K_c = \frac{[N_2O_4]}{[NO_2]^2} = 0.400 = \frac{[N_2O_4]}{(0.800)^2}$

$[N_2O_4]_{eqm} = 0.400 \times (0.800)^2 = 0.256$ mol dm^{-3} ;

(iv) Using your answer in **(a)(iii)**, calculate the initial concentration of $NO_2(g)$ that was placed into the closed vessel.

[2]

	$2NO_2(g)$	→	$N_2O_4(g)$
Initial conc / mol dm^{-3}	x		0
Change in conc / mol dm^{-3}	–2 × (0.256)		+0.256
Eqm conc / mol dm^{-3}	x – 0.512 = 0.800		0.256 ;

(table not required)

x = 0.800 + 0.512 = 1.312 = 1.31 mol dm^{-3} (3 s.f.) ;

(v) Using your answer in **(a)(iii)**, calculate the average molecular mass, to **4 significant figures**, of all the gases in the mixture at equilibrium.

[2]

M_r of NO_2 = 14.0 + 2(16.0) = 46.0 M_r of N_2O_4 = 2(14.0) + 4(16.0) = 92.0 ;

Average molecular mass = [0.800 × 46.0 + 0.256 × 92.0] = 60.35 (4 s.f.) ;

(b) **(i)** Draw a 'dot-and-cross' diagram for the NO_2 molecule.

For Examiners' Use

[1]

;

(ii) Based on your answer in **(b)(i)** and using information from the *Data Booklet*, suggest a value for the enthalpy change for the dimerisation of nitrogen dioxide. Include the sign and units in your answer.

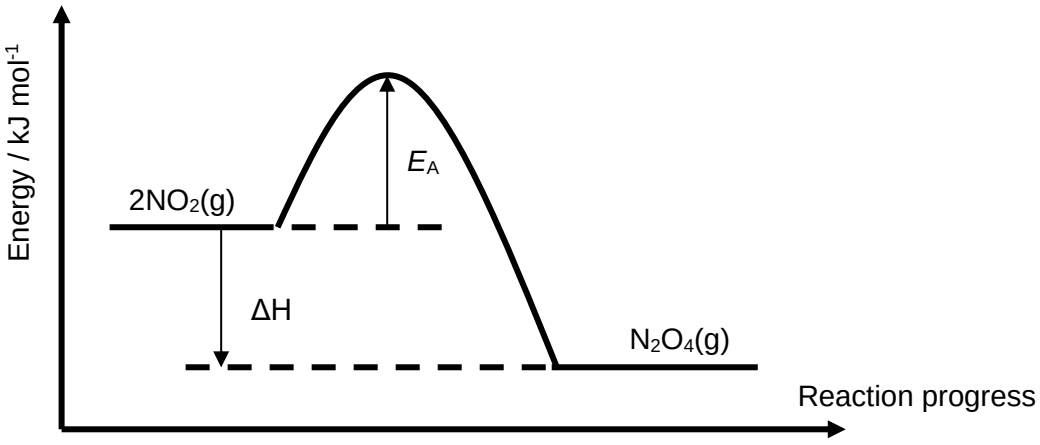
$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

[1]

1m – $\Delta H_{dimerisation}$ = – B.E. (N–N) = –160 kJ mol^{-1}

(iii) Hence, draw a well-labelled energy profile diagram for the reaction in **(b)(ii)**.

[2]



1m - Labels axes and reactants
1m – Correct Shape of graph + Draws and labels arrows for Ea and ΔH

(iv) Hence, or otherwise, explain how increasing the temperature will affect the position of equilibrium and suggest a value for the equilibrium constant.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

.....

.....

.....

.....

.....

..... [2]

(As the forward reaction is exothermic,)

When temperature is increased, the system will decrease the temperature by favouring the endothermic reaction (to oppose the change) ;

By shifting position of equilibrium to the left ;

(As the concentration of reactants would increase while the concentration of products will decrease after re-establishing equilibrium, the value of K_c will decrease.)

Accept any K_c value smaller than 0.4. e.g. 0.3 or 0.01 or even 10^{-6} ; (units not required)

(c) **(i)** Explain why the first ionisation energy of nitrogen is higher than that of oxygen.

For Examiners' Use

.....

.....

..... [1]

The valence electron of oxygen is **paired** and **experiences inter-electronic repulsion**, requiring less energy to remove than the unpaired valence electron in nitrogen.

(ii) Explain if the ionic radius of oxygen is smaller or larger than that of nitrogen.

.....

.....

.....

.....

…… [2]

[Total: 17]

Oxygen forms O^{2-} ion while nitrogen forms N^{3-}.

Across the isoelectronic series from nitrogen to oxygen, **nuclear charge increases** while the **increase in shielding effect is negligible (same number of electrons), effective nuclear charge increases**. ;

The **valence electron of O^{2-} ion** is more **strongly attracted to the nucleus** than the N^{3-} ion, resulting in **smaller ionic radius for O^{2-} ion**. ;

For Examiners' Use

3 **(a)** When magnesium chloride, $MgCl_2$, and phosphorus pentachloride, PCl_5, are separately placed in a beaker of hot water, they produce solutions of different pH values. Write balanced chemical equations, with state symbols, for the separate reactions of magnesium chloride and phosphorus pentachloride with hot water, and suggest the pH of the resulting solutions.

……

……

……

……

……

…… [4]

$MgCl_2$ (s) + $6H_2O$ (l) → $[Mg(H_2O)_6]^{2+}$ (aq) + $2Cl^-$ (aq) ;

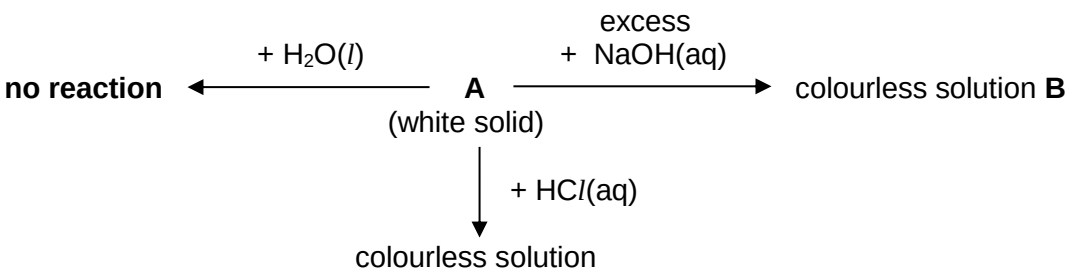
$[Mg(H_2O)_6]^{2+}$ (aq) ⇌ $[Mg(H_2O)_5(OH)]^+$ (aq) + H^+ (aq) ;

pH = 6.5 (6 to < 7 accepted)

PCl_5 (s) + 4 H_2O (l) → H_3PO_4 (aq) + 5HCl (aq) ;

pH = 2 (0-3 accepted) ; (both pH)

(b) A period 3 oxide, **A**, was subjected to the following reactions.



(i) Suggest the identities of **A** and **B**.

A: …… **B**: …….. [2]

A: aluminium oxide, Al_2O_3 ;

B: $Na[Al(OH)_4]$ or $[Al(OH)_4]^-$;

(ii) Explain why period 3 elements are able to accommodate more than 8 electrons in their valence shell.

……

…….. [1]

Period 3 elements have **energetically accessible vacant 3d orbitals** ;

For Examiners' Use

(c) The following table shows the observations when three group 17 elements, $\mathbf{D_2}$, $\mathbf{E_2}$, and $\mathbf{F_2}$, are reacted with their halide ions in aqueous solution.

	To a test tube containing 1 cm^3 of $\mathbf{D^-}$(aq)	To a test tube containing 1 cm^3 of $\mathbf{E^-}$(aq)	To a test tube containing 1 cm^3 of $\mathbf{F^-}$(aq)
Add 1 cm^3 of $\mathbf{D_2}$(aq)	-	Solution turns brown	No reaction
Add 1 cm^3 of $\mathbf{E_2}$(aq)	No reaction	-	No reaction
Add 1 cm^3 of $\mathbf{F_2}$(aq)	Solution turns orange	Solution turns brown	-

(i) Suggest the identities of elements **D**, **E**, and **F**.

D: …… **E**: …… **F**: …… [1]

D = Bromine / Br

E = Iodine / I

F = Chlorine / Cl

(ii) Rank bromine, chlorine and iodine in decreasing oxidising strength. Explain your answer.

……

……

……

…… [2]

Down the group, although nuclear charge and shielding effect both increases, the valence electron of iodine is in a quantum shell that is furthest from the nucleus, followed by bromine and then by chlorine. ;

Electronegativity OR the tendency to attract an electron (and thus oxidising another species) **decreases** from (most oxidising) **chlorine** to **bromine** to **iodine** (least oxidising) ;

(d) Recent technological advances have found that silicon nanoparticles (SiNPs) can be used as metal-free quantum dots exhibiting photoluminescence, i.e. SiNPs can emit light, such as in light-emitting diodes (LEDs) used in television screens. SiNPs are also researched as a reusable catalyst for the synthesis of sulfur-containing organic compounds.

For Examiners' Use

(i) Suggest a reason why SiNPs are corrosion-resistant compared to nanoparticles made from metals.

……

……[1]

Silicon has giant covalent structure and a large amount of energy required to break covalent bonds

OR metals tend to react in a redox reaction (to lose electrons) to form ions / ionic bonding.

(ii) Explain why silicon nanoparticles are preferred for use a catalyst over bulk silicon with dimensions of 1 cm x 1 cm.

……

……

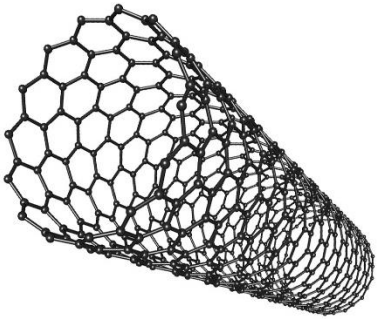
……

……[1]

Nanoparticles have a high surface area to volume ratio, hence
Less mass / amount of material required for the same surface area
OR Larger surface area for the same amount of material ;
Increasing the rate of reaction

(e) Another group 14 element, carbon, exists as several forms. One such form is called a carbon nanotube, which consists of a layer of graphene rolled into a cylindrical shape.

For Examiners' Use



carbon nanotube

Carbon nanotubes can be used as biosensors implanted in the human body due to its high electrical conductivity, high durability, low density, and absence of toxic metals.

(i) Explain whether a carbon nanotube is likely to be classified as a nanomaterial or nanoparticle.

……

……

……

……[1]

Nanomaterial as it has two dimensions ≤ 100 nm but the length of the nanotube can be longer than 100 nm, so it would not be classified as a nanoparticle.

(ii) Explain why a carbon nanotube is able to conduct electricity.

……

……

……

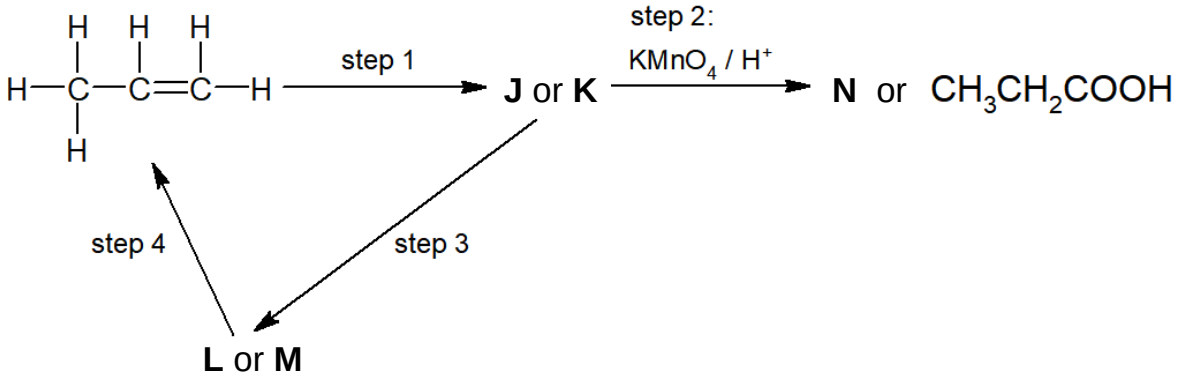
……[1]

[Total: 14]

Each carbon is covalently bonded to three other carbons,
One valence electron of each carbon atom is delocalised and act as mobile (electrical) charge carriers.

For Examiners' Use

4 **(a)** The following schematic shows reactions involving propene.



J, **K**, **L**, **M** and **N** are all organic compounds. **J** is a constitutional isomer of **K**, while **L** is a constitutional isomer of **M**.

J reacts via step 2 to form **N**, and **J** reacts via step 3 to form **L**.

(i) State the reagents and conditions for steps 1, 3 and 4.

step 1: .....

step 3: .....

step 4: ..... [3]

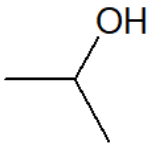
step 1: $H_2O(g)$, concentrated H_3PO_4 catalyst, high temperature and pressure ;

step 3: PCl_3, r.t. / PCl_5, r.t. / $SOCl_2$, r.t. / NaCl(s) in conc H_2SO_4 OR PBr_3 , r.t. ;

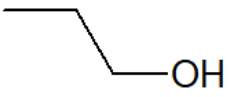
step 4: ethanolic NaOH, heat under reflux ;

(ii) Draw the structures of **J**, **K**, **L**, **M** and **N**.

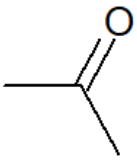
[5]



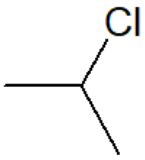
J:
$CH_3CH(OH)CH_3$



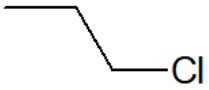
K:
$CH_3CH_2CH_2OH$



N:
CH_3COCH_3

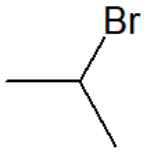


L:
$CH_3CHClCH_3$

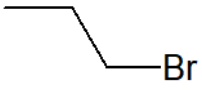


M:
$CH_3CH_2CH_2Cl$

If PBr_3 was given in step 3 in previous answer:



L:
$CH_3CHBrCH_3$



M:
$CH_3CH_2CH_2Br$

(b) The bond energies of C–C*l* and C–Br are 340 kJ mol^{-1} and 280 kJ mol^{-1} respectively. Explain the difference in bond energies.

For Examiners' Use

……

……

……

……

…… [2]

[Total: 10]

Br has a larger atomic radius than C*l*, causing the C-Br bond length to be longer than the C-C*l* bond ;
Lower extent of orbital overlap resulting in a weaker covalent bond in C-Br than in C-C*l* ;

Section B

Answer **one** question from this section in the spaces provided.

For Examiners' Use

5 (a) (i) Define what is meant by the terms *acid* and *base* using the Brønsted-Lowry theory of acids and bases.

……

……

…… [1]

A Brønsted-Lowry acid is a **proton donor** while a Brønsted-Lowry base is a **proton acceptor** ;

(ii) State the conjugate acid of $H_2PO_4^-$.

…… [1]

H_3PO_4

(iii) Write a balanced ionic equation which represents the ionic product of water, K_w.

…… [1]

$H_2O(l) \rightleftharpoons H^+(aq) + OH^- (aq)$
OR
$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^- (aq)$

(iv) Water has a K_w value of 5.13×10^{-13} at 100 °C.

Calculate the pH of pure water at 100 °C.

[2]

$K_w = [H^+][OH^-]$, since $[H^+] = [OH^-]$ for water,
$[H^+] = \sqrt{K_w} = 7.162 \times 10^{-7}$ mol dm^{-3} OR $pK_w = -\lg (5.13 \times 10^{-13}) = 12.29$;
pH = 6.14 (6.15 if intermediate 3sf) OR pH = ½ × pK_w = 6.145 = 6.15 ;

(v) Hence, explain if a solution with a pH of 6.3 is considered to be acidic or basic at 100 °C.

…… [1]

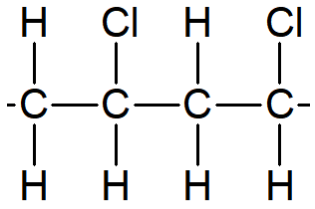
At pH 6.3 > 6.15 hence the solution is basic at 100 °C ;

(b) Chloroethene, C_2H_3Cl, polymerises to form poly(chloroethene), also known as polyvinyl chloride, PVC. The process can be considered as involving the breaking of a C=C bond and forming two C-C bonds per molecule of chloroethene.

For Examiners' Use

(i) Draw two repeat units for poly(chloroethene).

[1]



;

(ii) Using information from the *Data Booklet*, calculate the enthalpy change for the polymerisation of ethene into poly(ethene), in terms of kJ per mol of ethene.

[1]

ΔH = ΣB.E. (bonds broken) – ΣB.E. (bonds formed)
= 610 – 2(350)
= –90 kJ mol^{-1} of ethene

(iii) Suggest a reason why the value calculated in **(b)(ii)** is less exothermic than the actual enthalpy change for the polymerisation process.

……

……

…….. [1]

Bond energy values are quoted for particles in the gaseous state, but the polymer formed is in the solid state
OR

Enthalpy change for the change in phase from gaseous to solid is not accounted for the polymer formed.
OR
Bond energy values are only average values

(iv) Suggest an object that is made of PVC and describe a property of PVC that enables it to be used as a material for that object.

……

……

…….... [2]

PVC is used as a material for raincoats / water pipes / shoes / bags / signages as it is ;

Water resistant / chemical resistant / good tensile strength / can be made in low density flexible forms for raincoats, shoes and bags OR in high density rigid forms for water pipes and signages. ;

(v) It is possible to form chloroethene from ethene in a way similar to their alkane counterparts. However, the yield of chloroethene turns out to be very low.

State the reagent and conditions for the formation of chloroethane from ethane and suggest a reason why the same reagents and conditions results in a low yield when applied to ethene.

……

……

……

…….... [2]

Cl_2(g) or Cl_2 in CCl_4 , UV light or heat ;

The **addition of Cl_2 to ethene** to form 1,2-dichloroethane **would occur** more readily ; instead of substitution of Cl to form chloroethene.

(vi) State the shape and bond angle about the carbon atoms in chloroethene, C_2H_3Cl, and explain if the molecule is polar.

……

……

……

……

…….... [3]

Trigonal planar ;
120° ;
The molecule is polar as there is a dipole moment across the C-C*l* bond (or difference in electronegativity) which is not cancelled out (overall dipole moment) ;

(c) A sample of chlorine atoms were ionised. When a beam of $^{35}Cl^{+}$ ions are passed through an electric field, it was deflected by an angle of +5.25° relative to the horizontal axis. A detector plate was placed at that angle and counted 1036 of the $^{35}Cl^{+}$ ions hitting the plate.

For Examiners' Use

(i) Determine the angle and direction of deflection, relative to the horizontal axis, when $^{37}Cl^{2-}$ ions were passed through the same electric field.
Give your answer to 3 significant figures.

[1]

Angle = $+5.25 \times (\frac{-2}{37} \div \frac{+1}{35}) = -9.93°$ (or 9.93° towards the positive plate) ;

(ii) If another detector plate counted 258 of the $^{37}Cl^{2-}$ ions, calculate the relative atomic mass of chlorine in the sample. Give your answer to 2 decimal places.
(Assume that only $^{35}Cl^{+}$, $^{37}Cl^{2-}$ ions are formed from the ionisation of the sample.)

[1]

Relative atomic mass = $\frac{(1036 \times 35) + (258 \times 37)}{(1036+258)}$ = 35. 3987 = 35.40 (2 d.p.) ;

(d) Explain, in terms of oxidation number changes, why the following reaction is considered to be a disproportionation reaction.

For Examiners' Use

$$2Cl_2 + 2H_2O \rightarrow ClO_2^- + 3Cl^- + 4H^+$$

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…… [2]

[Total: 20]

Oxidation number of chlorine increases from 0 in Cl_2 to +3 in ClO_2^- ;

And decreases simultaneously for the same species Cl_2 from 0 to -1 in Cl^- , ;

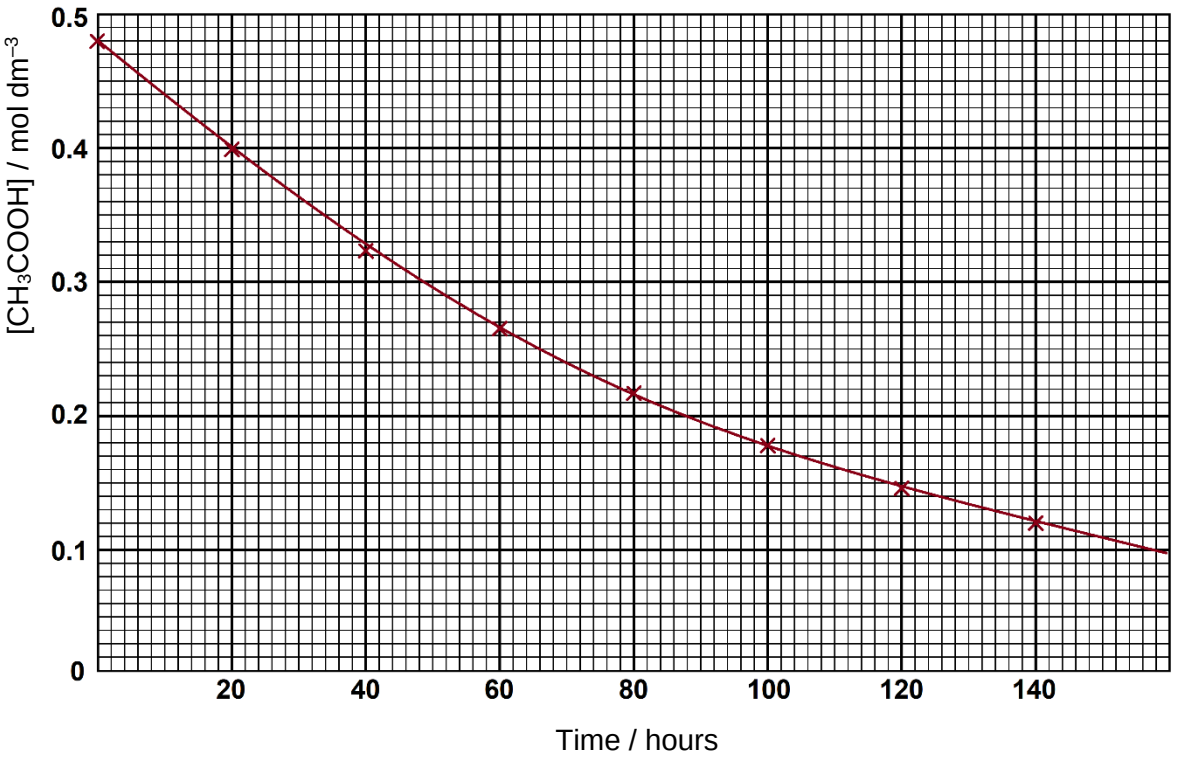
it is a disproportionation reaction.

6 (a) The following balanced equation shows the reaction between ethanoic acid and methanol.

For Examiners' Use

$$CH_3COOH(l) + CH_3OH(l) \rightleftharpoons CH_3COOCH_3(l) + H_2O(l)$$

The rate of reaction can be found by determining the remaining ethanoic acid concentration, through titration, against fixed time intervals (in hours) as seen in the graph below.



(i) Using the graph, determine the order of reaction with respect to $[CH_3COOH]$.

[2]

At t = 0, $[CH_3COOH] = 0.48$ mol dm^{-3}
When $[CH_3COOH] = 0.24$ mol dm^{-3}, t = 70 hours, 1st half life = 70 - 0 = 70 hours
When $[CH_3COOH] = 0.12$ mol dm^{-3}, t = 140 hours, 2nd half life = 140 - 70 = 70 hours ;
Since half-life is constant, order of reaction is 1 with respect to $[CH_3COOH]$;

(ii) Given that the overall order of reaction is 2, write the rate equation for the reaction.

……[1]

Rate = k $[CH_3COOH]$ $[CH_3OH]$;

(iii) Suggest a reagent that can be added to the reaction mixture to speed up the reaction.

…… [1]

Concentrated sulfuric acid

(iv) Explain how a catalyst speeds up the rate of a reaction.

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……[2]

- ➔ A catalyst provides an alternative pathway of lower activation energy ,
- ➔ proportion of particles wit energy ≥ Ea increases,
- ➔ frequency of effective collisions increases ; speeding up the reaction.

(v) Define the term *standard enthalpy change of formation*.

For Examiners' Use

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……[1]

The heat energy released when 1 mole of a substance is formed from its elements in their standard states under standard conditions of 298K and 1 bar.

(vi) Given the following values, calculate the standard enthalpy change of reaction between ethanoic acid and methanol in **(a)**.

Standard enthalpy change of formation of $CH_3COOH(l)$ / kJ mol^{-1}	– 483.52
Standard enthalpy change of formation of $CH_3OH(l)$ / kJ mol^{-1}	– 238.54
Standard enthalpy change of formation of $CH_3COOCH_3(l)$ / kJ mol^{-1}	– 445.66
Standard enthalpy change of formation of $H_2O(l)$ / kJ mol^{-1}	– 285.82

[2]

$\Delta H_r = \sum \Delta H_f$ (products) - $\sum \Delta H_r$ (reactants)
= (-445.66) + (-285.82) – (-483.52) + (-238.54); (correct substitution)
= –9.42 kJ mol^{-1} ; (minus one mark if no sign)

vii) The concentration of H^+ ions is 6.86 × 10^{-3} mol dm^{-3} in the ethanoic acid solution before reaction with methanol.

Calculate the acid dissociation constant, K_a, for ethanoic acid, stating its units.

[2]

$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]} = \frac{(0.00686)(0.00686)}{0.48} = 9.80 \times 10^{-5}$ mol dm^{-3}

OR

$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]} = \frac{(0.00686)(0.00686)}{0.48-0.00686} = 9.95 \times 10^{-5}$ mol dm^{-3}

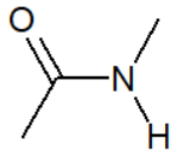
(b) Ethanoic acid can be reacted with CH_3NH_2 to form an amide. This reaction is difficult to occur without the presence of an activating agent.

For Examiners' Use

State the reagent needed for the reaction to occur more readily and draw the skeletal structure of the resulting amide.

…… [2]

Dicyclohexylcarbodiimide (DCC) ;



;

(c) The following are some properties of two period 3 elements **Q** and **R**.

	Q	**R**
Electrical conductivity in the solid state	Poor	Good
Melting point / °C	-101	660
Solubility in water	Poor	Insoluble

(i) Suggest the identities of **Q** and **R**. For each element, choose one property and explain your answer in terms of structure and bonding.

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…… [3]

Q = either Phosphorus, Sulfur or Chlorine are accepted (actual answer is Chlorine)

R = either Magnesium or Aluminium (actual answer is Aluminium. Do not accept sodium as sodium reacts vigorously with water) (both identities - 1m) ;

Q has simple molecular structure and either one of the following - 1m ;

- ➔ little energy is required to overcome weak instantaneous dipole-induced dipole forces of attraction between molecules → low solubility
- ➔ lack of delocalised electrons or mobile ions to act as mobile electrical charge carriers
- ➔ energy released from formation of id-id with water insufficient to overcome stronger hydrogen bonding between water molecules → poor solubility.

R has giant metallic lattice structure and either one of the following - 1m ;

- ➔ a lot of energy is required to overcome strong electrostatic forces of attraction between metal cations and delocalised electrons → high melting point

➔ delocalised electrons can act as mobile electrical charge carriers → good conductor of electricity

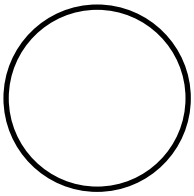
(For aluminium, a layer of insoluble Al_2O_3 coats the exterior of the metal. Energy released from the formation of ion-dipole interactions of Al^{3+} ions and O^{2-} ions with water is insufficient to overcome the stronger electrostatic forces of attraction between oppositely charged ions in Al_2O_3).

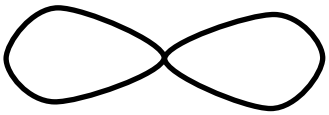
(ii) Draw and label the two different types of orbitals in the valence shell of a period 3 element.

For Examiners' Use

[2]

3s orbital ; 3p orbital ;





(iii) *Use of the Data Booklet is relevant to this question.*

In a certain reaction, a voltage was applied causing the reduction of nitrate ions, NO_3^-, to nitrogen gas, N_2, in acidic solution. Water is concurrently oxidised to oxygen gas.

Write the balanced ion-electron equations for the reduction and oxidation, and hence write the overall balanced ionic equation for the reaction.

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…… [2]

[Total: 20]

Reduction: $2NO_3^- + 12H^+ + 10e^- \rightarrow N_2 + 6H_2O$; x2

Oxidation: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ x 5 (no marks, obtainable from Data Booklet)

Overall: $4NO_3^- + 4H^+ \rightarrow 2N_2 + 2H_2O + 5O_2$;

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