Q1.

2 **(a)** Barium ions are poisonous. Patients with digestive tract problems are sometimes given an X-ray after they have swallowed a 'barium meal', consisting of a suspension of $BaSO_4$ in water. The $[Ba^{2+}(aq)]$ in a saturated solution of $BaSO_4$ is too low to cause problems of toxicity.

(i) Write an expression for the solubility product, K_{sp}, for $BaSO_4$, including its units.

.....

(ii) The numerical value of K_{sp} is 1.30×10^{-10}. Calculate $[Ba^{2+}(aq)]$ in a saturated solution of $BaSO_4$.

.....

.....

(iii) The numerical value of K_{sp} for $BaCO_3$ (5×10^{-10}) is not significantly higher than that for $BaSO_4$, but barium carbonate is **very** poisonous if ingested. Suggest a reason why this might be so.

.....

.....

[3]

(b) A useful commercial source of magnesium is sea water, where $[Mg^{2+}(aq)]$ is $0.054\ mol\ dm^{-3}$. The magnesium is precipitated from solution by adding calcium hydroxide.

$$Mg^{2+}(aq) + Ca(OH)_2(s) \longrightarrow Ca^{2+}(aq) + Mg(OH)_2(s)$$

(i) Write an expression for the K_{sp} of $Mg(OH)_2$, including its units.

.....

(ii) The numerical value for K_{sp} is 2.00×10^{-11}. Calculate $[Mg^{2+}(aq)]$ in a saturated solution of $Mg(OH)_2$.

.....

.....

Use

(iii) Hence calculate the maximum percentage of the original magnesium in the seawater that this method can extract.

.....

.....

[5]

(c) The magnesium ions in seawater are mainly associated with chloride ions.

(i) Use the following $\Delta H_f^{\ominus}$ values to calculate a value for the $\Delta H^{\ominus}$ of the following reaction.

$$MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq)$$

species	$\Delta H_f^{\ominus}$/kJ mol^{-1}
$MgCl_2$ (s)	–641
Mg^{2+}(aq)	–467
Cl^- (aq)	–167

.....

.....

.....

(ii) Use your answer to explain why $MgCl_2$ is very soluble in water.

.....

[2]

(d) All the chlorides of Group II elements are soluble in water. The same is not true of their sulphates. These become less soluble as the group is descended.

Explain qualitatively the variation in solubility of the sulphates of the elements in Group II down the Group from magnesium to barium.

.....

.....

.....[2]

[Total : 12]

Q2.

5 **(a)** Give an expression for K_a as applied to the weak acid RCO_2H.

.....

..... [1]

(b) The K_a values for three carboxylic acids are listed in the table below.

acid	K_a / mol dm^{-3}
CH_3CO_2H	1.8×10^{-5}
$ClCH_2CO_2H$	1.4×10^{-3}
Cl_2CHCO_2H	5.5×10^{-2}

(i) Describe and explain the trend in acid strength illustrated by these values.

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(ii) Calculate the pH of a 0.100 mol dm^{-3} solution of $ClCH_2CO_2H$.

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.....

(iii) Calculate the pK_a value for Cl_2CHCO_2H.

.....

.....

[5]

Q3.

2 Monuments made of marble or limestone, such as the Taj Mahal in India and the Mayan temples in Mexico, are suffering erosion by acid rain. The carbonate stone is converted by the acid rain into the relatively more soluble sulphate.

$$CaCO_3(s) + \underset{\text{acid rain}}{H_2SO_4(aq)} \rightarrow CaSO_4(s) + H_2O(l) + CO_2(g)$$

(a) (i) Write an expression for the solubility product, K_{sp}, of $CaSO_4$, stating its units.

.....

(ii) The K_{sp} of $CaSO_4$ has a numerical value of 3×10^{-5}. Use your expression in **(i)** to calculate $[CaSO_4]$ in a saturated solution.

.....

(iii) Hence calculate the maximum loss in mass of a small statue if 100 dm^3 of acid rain falls on it. Assume the statue is made of pure calcium carbonate, and that the acid rain becomes saturated with $CaSO_4$.

.....

.....

.....

[5]

(b) The life of such monuments is now being extended by treating them with a mixture of urea and barium hydroxide solutions. After soaking into the pores of the carbonate rock, the urea gradually decomposes to ammonia and carbon dioxide. The carbon dioxide then reacts with the barium hydroxide to form barium carbonate.

$$(NH_2)_2CO(aq) + H_2O(l) \longrightarrow 2NH_3(g) + CO_2(g)$$

$$Ba(OH)_2(aq) + CO_2(g) \longrightarrow BaCO_3(s) + H_2O(l)$$

Acid rain then converts the barium carbonate to its sulphate.

$$BaCO_3(s) + H_2SO_4(aq) \longrightarrow BaSO_4(s) + H_2O(l) + CO_2(g)$$

Barium sulphate is much less soluble than calcium sulphate. A saturated solution contains $[Ba^{2+}] = 9.0 \times 10^{-6}$ mol dm^{-3}.

(i) Explain why barium sulphate is less soluble than calcium sulphate.

.....

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.....

(ii) Write an expression for the K_{sp} of barium sulphate and use the data to calculate its value.

.....

.....

[4]

(c) (i) Explain what is meant by the term *lattice energy*.

.....

.....

(ii) Predict, with a reason, how the lattice energy of $BaSO_4$ might compare with that of $MgSO_4$.

.....

.....

.....

[3]

[Total: 12]

Q4.

2 This question is about the properties and reactions of the oxides of some elements in their +4 oxidation state.

(a) Chlorine dioxide, ClO_2, is an important industrial chemical, used to bleach wood pulp for making paper, and to kill bacteria in water supplies.

However, it is unstable and decomposes into its elements as follows.

$$2ClO_2(g) \rightarrow Cl_2(g) + 2O_2(g)$$

(i) The chlorine atom is in the middle of the ClO_2 molecule. Using the chlorine-oxygen bond energy as 278 kJ mol^{-1}, and other values from the *Data Booklet*, calculate ΔH for the above reaction.

ΔH = ... kJ mol^{-1}

(ii) Assuming the C*l*-O bonds in chlorine dioxide are double bonds, predict the shape of the ClO_2 molecule. Explain your answer.

.....

.....

(iii) ClO_2 can be made in the laboratory by reacting $KClO_3$ with concentrated H_2SO_4. Other products are K_2SO_4, $KClO_4$ and H_2O.

Construct a balanced equation for this reaction. You may find the use of oxidation numbers helpful.

.....

[5]

(b) Sulphur dioxide is an atmospheric pollutant.

(i) State **two** sources of atmospheric SO_2 that arise from human activity.

.....

.....

(ii) Explain why SO_2 is a pollutant, and state an environmental consequence of this pollution.

.....

.....

[3]

(c) All the oxides of the elements in Group IV in their +4 oxidation state are high melting point solids except CO_2.

(i) Explain this observation by describing the bonding in CO_2, SiO_2 and SnO_2.

.....

.....

.....

(ii) State the difference in the thermal stabilities of SnO_2 and PbO_2. Illustrate your answer with an equation.

.....

.....

CO_2 dissolves in water to form a weakly acidic solution containing the hydrogencarbonate ion.

(iii) Write an equation for the reaction of CO_2 with water, and write an expression for the equilibrium constant, K_c.

.....

.....

(iv) Explain the role of the hydrogencarbonate ion in controlling the pH of blood, illustrating your answer with relevant equations.

.....

.....

.....

[7]

[Total: 15]

Q5.

1 **(a)** Explain what is meant by the *Bronsted-Lowry* theory of acids and bases.

.....

.....

..... [2]

(b) The K_a values for some organic acids are listed below.

acid	K_a/mol dm^{-3}
CH_3CO_2H	1.7×10^{-5}
$Cl CH_2CO_2H$	1.3×10^{-3}
Cl_2CHCO_2H	5.0×10^{-2}

(i) Explain the trend in K_a values in terms of the structures of these acids.

.....

.....

.....

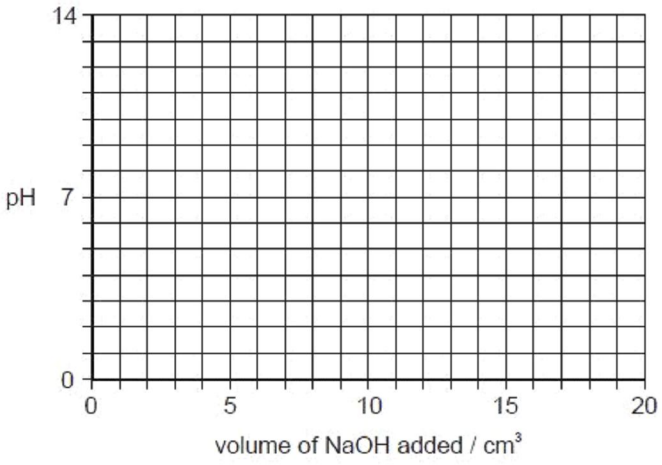
.....

(ii) Calculate the pH of a 0.10 mol dm^{-3} solution of $Cl CH_2CO_2H$.

pH = ...

(iii) Use the following axes to sketch the titration curve you would obtain when 20 cm^3 of 0.10 mol dm^{-3} NaOH is added gradually to 10 cm^3 of 0.10 mol dm^{-3} $ClCH_2CO_2H$.

For Examiner's Use



[8]

(c) **(i)** Write suitable equations to show how a mixture of ethanoic acid, CH_3CO_2H, and sodium ethanoate acts as a buffer solution to control the pH when either an acid or an alkali is added.

.....

.....

(ii) Calculate the pH of a buffer solution containing 0.10 mol dm^{-3} ethanoic acid and 0.20 mol dm^{-3} sodium ethanoate.

pH = ...

[4]

[Total: 14]

Q6.

2 **(a)** State briefly what is meant by the following terms.

For Examiner's Use

(i) reversible reaction

.....

(ii) dynamic equilibrium

.....

.....

[2]

(b) Water ionises to a small extent as follows.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad \Delta H = +58\,kJ\,mol^{-1}$$

(i) Write an expression for K_c for this reaction.

.....

(ii) Write down the expression for K_w, the ionic product of water, and explain how this can be derived from your K_c expression in **(i)**.

.....

.....

(iii) State and explain how the value of K_w for hot water will differ from its value for cold water.

.....

.....

[3]

(c) K_w can be used to calculate the pH of solutions of strong and weak bases.

(i) Use the value of K_w in the *Data Booklet* to calculate the pH of $0.050\,mol\,dm^{-3}$ NaOH.

pH = ...

Ammonia ionises slightly in water as follows.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

The following expression applies to this equilibrium.

$$[H_2O] \times K_c = [NH_4^+][OH^-]/[NH_3] = 1.8 \times 10^{-5}\,mol\,dm^{-3}$$

(ii) Calculate $[OH^-(aq)]$ in a $0.050\,mol\,dm^{-3}$ solution of NH_3. You may assume that only a small fraction of the NH_3 ionises, so that $[NH_3]$ at equilibrium remains at $0.050\,mol\,dm^{-3}$.

For Examiner's Use

$[OH^-(aq)]$ = ...

(iii) Use the value of K_w in the *Data Booklet*, and your answer in **(ii)**, to calculate $[H^+(aq)]$ in $0.050\,mol\,dm^{-3}$ $NH_3(aq)$.

$[H^+(aq)]$ = ...

(iv) Calculate the pH of this solution.

pH = ...

[6]

[Total: 11]

Q7.

1 **(a)** Hydrogen fluoride, HF, behaves as a weak acid in water, with $K_a = 5.6 \times 10^{-4}\,mol\,dm^{-3}$.

Calculate the pH of a $0.050\,mol\,dm^{-3}$ solution of HF.

pH = ...[2]

(b) Gaseous ammonia and hydrogen fluoride react together to give solid ionic ammonium fluoride.

$$NH_3(g) + HF(g) \rightleftharpoons NH_4F(s) \qquad \Delta H = -147\,kJ\,mol^{-1}$$

(i) What *type of reaction* is this?

.....

(ii) Draw dot-and-cross diagrams (outer shells only) describing the bonding in the three compounds involved in this reaction.

NH_3	HF	NH_4F

(iii) There are **three** types of bonding in NH_4F.
Give the names of each of the three types, and state where in the compound each type occurs.

.....

.....

.....

(iv) The reaction between NH_3 and HF is reversible. What conditions of temperature and pressure would favour the **reverse** reaction, i.e. the dissociation of NH_4F? Explain your answer.

For Examiner Use

.....

.....

.....

[9]

(c) Many commercial copper and brass polishes contain ammonia. The tarnish that forms on the surface of copper is often copper sulfide, CuS. In the presence of O_2 from the air, NH_3 can combine with this copper sulfide to produce the soluble cuprammonium sulfate, $[Cu(NH_3)_4]SO_4$.

(i) Construct an equation for this reaction.

.....

(ii) State the colour of cuprammonium sulfate solution.

.....

(iii) Describe what you would see if a solution of cuprammonium sulfate was diluted with water. Explain your answer.

.....

.....

[3]

(d) When sulfuric acid is added to $Cu^{2+}(aq)$, no colour change occurs, but when concentrated hydrochloric acid is added to $Cu^{2+}(aq)$, the solution turns yellow-green. The solution reverts to its original colour when it is diluted with water.

Suggest the type of reaction occurring with $HCl(aq)$, suggest what is formed during the reaction, and write an equation for the change.

.....

.....

.....

.....[3]

[Total: 17]

Q8.

1 **(a)** What is meant by the term *standard electrode potential*, SEP?

.....

.....

[2]

(b) Draw a fully labelled diagram of the apparatus you could use to measure the SEP of the Fe^{3+}/Fe^{2+} electrode.

[5]

(c) The reaction between Fe^{3+} ions and I^- ions is an equilibrium reaction.

$$2Fe^{3+}(aq) + 2I^-(aq) \rightleftharpoons 2Fe^{2+}(aq) + I_2(aq)$$

(i) Use the *Data Booklet* to calculate the $E^{\ominus}_{cell}$ for this reaction.

.....

(ii) Hence state, with a reason, whether there will be more products or more reactants at equilibrium.

.....

.....

(iii) Write the expression for K_c for this reaction, and state its units.

$K_c =$

units .....

For Examiner Use

An experiment was carried out using solutions of $Fe^{3+}(aq)$ and $I^-(aq)$ of equal concentrations. 100 cm^3 of each solution were mixed together, and allowed to reach equilibrium.

The concentrations at equilibrium of $Fe^{3+}(aq)$ and $I_2(aq)$ were as follows.

$[Fe^{3+}(aq)] = 2.0 \times 10^{-4}$ mol dm^{-3}

$[I_2(aq)] = 1.0 \times 10^{-2}$ mol dm^{-3}

(iv) Use these data, together with the equation given in **(c)**, to calculate the concentrations of $Fe^{2+}(aq)$ and $I^-(aq)$ at equilibrium.

$[Fe^{2+}(aq)]$ = ... mol dm^{-3}

$[I^-(aq)]$ = ... mol dm^{-3}

(v) Calculate the K_c for this reaction.

K_c = ...

[8]

[Total: 15]

Q9.

(b) A buffer solution is to be made using 1.00 mol dm^{-3} ethanoic acid, CH_3CO_2H, and 1.00 mol dm^{-3} sodium ethanoate, CH_3CO_2Na.
Calculate to the nearest 1 cm^3 the volumes of each solution that would be required to make 100 cm^3 of a buffer solution with pH 5.50.
Clearly show all steps in your working.
K_a (CH_3CO_2H) = 1.79×10^{-5} mol dm^{-3}

volume of 1.00 mol dm^{-3} CH_3CO_2H = ... cm^3

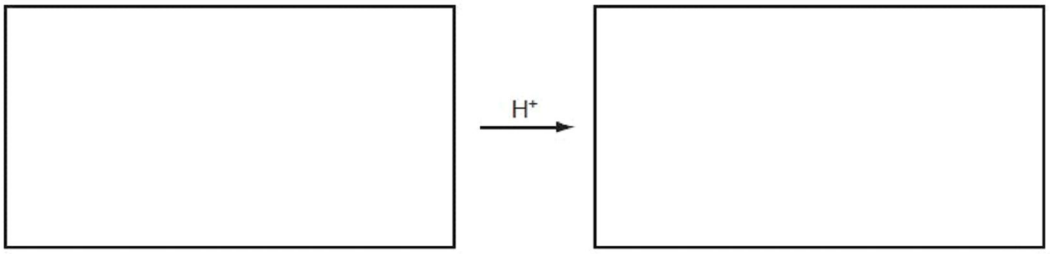
volume of 1.00 mol dm^{-3} CH_3CO_2Na = ... cm^3
[4]

(c) Write an equation to show the reaction of this buffer solution with each of the following.

(i) added HC*l* .....

(ii) added NaOH .....
[2]

(d) Choose **one** reaction in organic chemistry that is catalysed by an acid, and write the structural formulae of the reactants and products in the boxes below.



[3]

Q10.

2 **(a)** Methanoic acid, HCO_2H, is a weak acid, with $K_a = 1.77 \times 10^{-4}$ mol dm^{-3}.

(i) Write an expression for the K_a of methanoic acid.

.....

(ii) Use your expression to calculate the $[H^+]$ in a 0.0500 mol dm^{-3} solution of methanoic acid.

.....

(iii) Calculate the percentage of HCO_2H molecules that are ionised in this solution.

(iv) Calculate the pH of this solution.

.....

[4]

Use

(b) Calculate the pH of a 0.0500 mol dm^{-3} solution of the strong acid HCl.

.....[1]

(c) Both HCO_2H and HCl react with powdered magnesium metal, giving off hydrogen gas. For a fixed amount of magnesium, the rate equation for the reaction is as follows.

$$\text{rate} = k[H^+(aq)]$$

(i) Write an equation for the reaction between HCO_2H and Mg.

.....

When 20.0 cm^3 of a 0.0500 mol dm^{-3} solution of either acid is reacted with an excess of powdered magnesium, the same volume of hydrogen is given off, but the methanoic acid solution reacts much more slowly than the hydrochloric acid.

(ii) Calculate the volume of hydrogen given off.

.....

(iii) Explain why the hydrogen is evolved more slowly from the methanoic acid solution.

.....

.....

(iv) Explain why, eventually, the methanoic acid solution produces just as much hydrogen as the hydrochloric acid solution.

.....

.....

.....[5]

[Total : 10]

Q11.

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

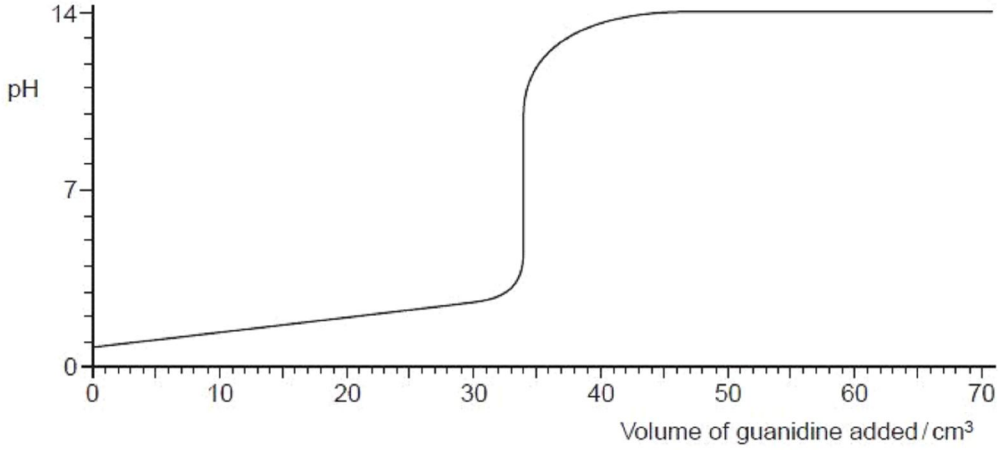
$$H_2SO_4(aq) \rightleftharpoons 2H^+(aq) + SO_4^{2-}(aq)$$

(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}.

.....

.....

.....

(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.

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

(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}]

.....

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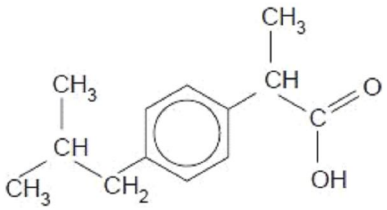
..... [3]

[Total: 13]

Q12.

2 Ibuprofen is one of the most commonly used non-steroidal anti-inflammatory drugs, used to treat chronic arthritic pain caused by inflammation of the joints.



ibuprofen

(a) **(i)** Draw a circle around any chiral centre(s) in the above structure.

(ii) Write down the molecular formula of ibuprofen.

.....

(iii) Calculate the M_r of ibuprofen and use it to calculate how many grams are needed to make 100 cm^3 of a 0.15 mol dm^{-3} solution.

.....

.....

.....

(iv) Vigorous oxidation of ibuprofen produces a dibasic acid **A**. A solution containing 0.10 g of **A** required 12.0 cm^3 of 0.10 mol dm^{-3} NaOH for neutralisation.

Suggest a structure for **A**, showing your working.

.....

[7]

(b) The K_a value for ibuprofen is 6.3×10^{-6} mol dm^{-3}.

(i) Write an expression for K_a.

.....

(ii) Use the K_a value to calculate the pH of a 0.15 mol dm^{-3} solution of ibuprofen.

.....

.....

[3]

Use

(c) To avoid problems with digestive irritation over a long period of use, research is being carried out into ways of administering ibuprofen using skin patches. For this use the compound is dissolved in a hydrophilic gel which acts as a buffer.

(i) What do you understand by the term *buffer*?

.....

.....

The buffer used in the pharmaceutical preparation is a solution containing Na_2HPO_4 and NaH_2PO_4. These salts contain the HPO_4^{2-} and $H_2PO_4^-$ ions respectively.

(ii) Write equations to show how this buffer reacts with

H^+ ions, ...

OH^- ions. .....

(iii) A buffer solution containing equal concentrations of the two sodium phosphate salts has a pH of 7.20.

Calculate the pH of a pharmaceutical preparation containing 0.002 mol dm^{-3} of Na_2HPO_4 and 0.005 mol dm^{-3} of NaH_2PO_4.

[5]

[Total: 15]

Q13.

1 **(a)** Use the general formula of a carboxylic acid, RCO_2H, to write equations to explain the following terms.

(i) K_a .....

(ii) pK_a .....

[2]

(b) The pK_a values of four carboxylic acids are listed in the table below.

acid	formula of acid	pK_a
1	$CH_3CH_2CO_2H$	4.9
2	$CH_3CHClCO_2H$	2.8
3	$CH_3CCl_2CO_2H$	1.4
4	$CH_2ClCH_2CO_2H$	4.1

(i) Describe and explain the trend in acid strength shown by acids 1, 2 and 3.

.....

.....

.....

.....

(ii) Suggest an explanation for the difference in the pK_a values for acids 2 and 4.

.....

.....

(iii) Calculate the pH of a 0.010 mol dm^{-3} solution of propanoic acid (acid 1).

.....

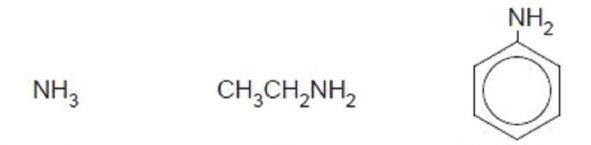
.....

.....

[6]

Q14.

2 **(a)** Describe and explain how the basicities of ammonia, ethylamine and phenylamine differ.



ammonia ethylamine phenylamine

.....

.....

.....

.....[3]

(b) Describe how the use of aqueous silver nitrate and aqueous ammonia can distinguish between aqueous solutions containing chloride, bromide or iodide ions by filling in the following table.

halide	observation when $AgNO_3(aq)$ is added	observation when dilute $NH_3(aq)$ is added	observation when concentrated $NH_3(aq)$ is added
chloride			
bromide			
iodide			

[3]

(c) Silver bromide is sparingly soluble in water.

$$AgBr(s) \rightleftharpoons Ag^+(aq) + Br^-(aq) \qquad K_{sp} = 5 \times 10^{-13}\ mol^2\ dm^{-6}$$

(i) Calculate $[Ag^+(aq)]$ in a saturated aqueous solution of AgBr.

$[Ag^+(aq)]$ = ... mol dm^{-3}

(ii) State and explain whether AgBr will be less or more soluble in 0.1 mol dm^{-3} KBr than it is in pure water.

.....

.....

[2]

(d) Silver ions form complexes with ammonia and with amines.

$$Ag^+(aq) + 2RNH_2(aq) \rightleftharpoons [Ag(RNH_2)_2]^+(aq)$$

(i) Write an expression for the K_c for this reaction, and state its units.

K_c = ... units .....

K_c has the numerical value of 1.7×10^7 when R = H.

(ii) Using your expression for K_c calculate the $[NH_3(aq)]$ needed to change the $[Ag^+(aq)]$ in a 0.10 mol dm^{-3} solution of silver nitrate to the value that you calculated in **(c)(i)**.

$[NH_3(aq)]$ = ... mol dm^{-3}

(iii) Explain whether you would expect the K_c for the reaction where R = C_2H_5 to be greater or less than that for the reaction where R = H.

.....

.....

[5]

[Total: 13]

Q15.

7 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.

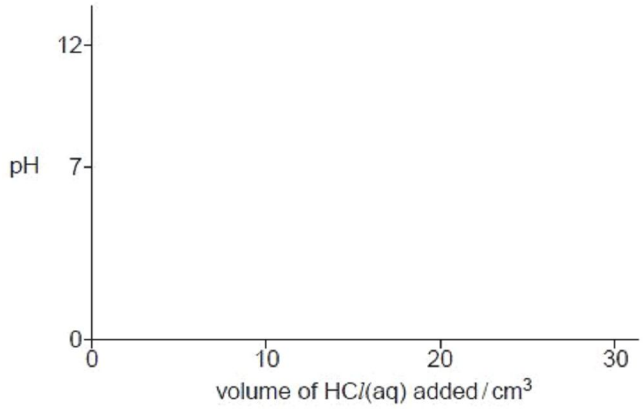
For Examiner's Use

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

.....

.....[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]

Q16.

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

For Examiner's Use

.....

(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.

.....

.....

.....

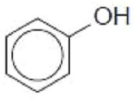
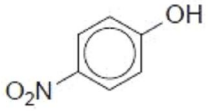
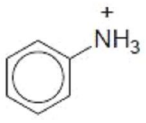
.....

[4]

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

.....

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.

.....

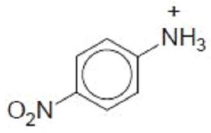
.....

.....

.....

(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.

For Examiner's Use



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)**.

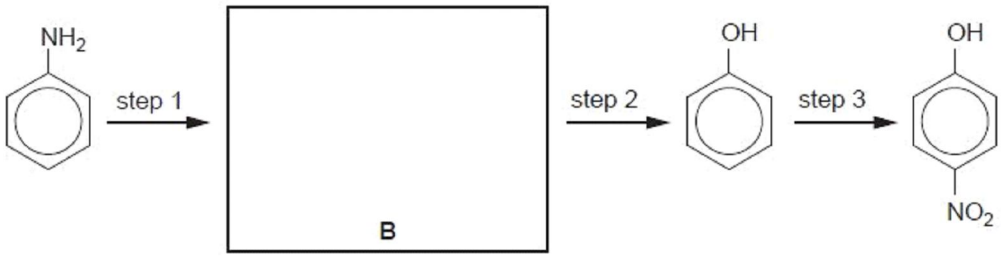
.....

.....

.....

[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]

Q17.

3 **(a)** **(i)** Using the symbol **HZ** to represent a Brønsted-Lowry acid, write equations which show the following substances acting as Brønsted-Lowry bases.

NH_3 + →

CH_3OH + →

(ii) Using the symbol B^- to represent a Brønsted-Lowry base, write equations which show the following substances acting as Brønsted-Lowry acids.

NH_3 + →

CH_3OH + →

[4]

(b) State briefly what is meant by the following terms.

(i) reversible reaction

.....

(ii) dynamic equilibrium

.....

.....

[2]

(c) **(i)** Explain what is meant by a *buffer solution*.

.....

.....

.....

(ii) Explain how the working of a buffer solution relies on a reversible reaction involving a Brønsted-Lowry acid such as **HZ** and a Brønsted-Lowry base such as Z^-.

.....

.....

.....

.....

[4]

(d) Propanoic acid, $CH_3CH_2CO_2H$, is a weak acid with $K_a = 1.34 \times 10^{-5}$ mol dm^{-3}.

(i) Calculate the pH of a 0.500 mol dm^{-3} solution of propanoic acid.

Buffer solution **F** was prepared by adding 0.0300 mol of sodium hydroxide to 100 cm^3 of a 0.500 mol dm^{-3} solution of propanoic acid.

(ii) Write an equation for the reaction between sodium hydroxide and propanoic acid.

.....

(iii) Calculate the concentrations of propanoic acid and sodium propanoate in buffer solution **F**.

[propanoic acid] = ... mol dm^{-3}

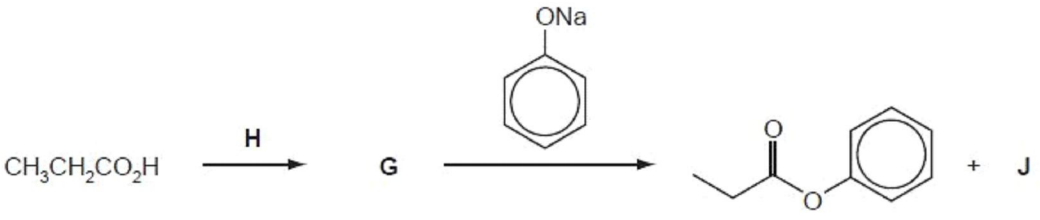
[sodium propanoate] = ... mol dm^{-3}

(iv) Calculate the pH of buffer solution **F**.

pH = ...

[6]

(e) Phenyl propanoate cannot be made directly from propanoic acid and phenol.
Suggest the identities of the intermediate **G**, the reagent **H** and the by-product **J** in the following reaction scheme.



G is .....

H is .....

J is .....

[2]

[Total: 18]

Q18.

For Examine Use

8 In a world with a rapidly increasing population, access to clean drinking water is critical. For many countries, groundwater sources, rather than stored rainwater or river-water, are vital. *Groundwater* is water that exists in the pore spaces and fractures in rock and sediment beneath the Earth's surface. The World Health Organisation (WHO) provides maximum recommended concentrations for different ions present in drinking water.

(a) The geological nature of the soil determines the chemical composition of the groundwater. The table shows some ions which may contaminate groundwater.

ion present	WHO maximum permitted concentration / mg dm^{-3}
Ba^{2+}	0.30
Cl^-	250.00
NO_3^-	50.00
Pb^{2+}	0.01
Na^+	20.00
SO_4^{2-}	500.00

(i) Nitrate, NO_3^-, ions are difficult to remove from groundwater. What is the reason for this?

.....

(ii) State which ions in the table above are likely to be removed from the water by treatment with powdered limestone, $CaCO_3$, giving reasons for each of your answers.

.....

.....

.....

[4]

(b) Nitrates and phosphates can enter water courses such as rivers or streams as a result of human activity. Both of these ions are nutrients for algae.

(i) What is the origin of these nitrates?

.....

(ii) Suggest an origin for the phosphates found in water courses.

.....

(iii) What effect do nitrates and phosphates have on water courses?

.....

.....

[3]

(c) Acid rain can have a major impact on natural waters, particularly lakes. In recent years there has been a worldwide effort to reduce the amount of acid rain produced.

(i) Write equations to show the production of acid rain from sulfur dioxide, SO_2.

.....

.....

(ii) The use of fossil fuels is one major source of sulfur dioxide.
Name another major industrial source.

.....

[2]

[Total: 9]

Q19.

2 **(a)** State **two** assumptions of the kinetic theory of gases, as applied to ideal gases.

Ex

.....

.....

[2]

(b) **(i)** State the conditions of temperature and pressure under which real gases behave **least** like an ideal gas.

.....

(ii) Explain why real gases do **not** behave ideally under these conditions.

.....

.....

[2]

(c) Gaseous aluminium chloride is dimeric at low temperatures, but the dimer dissociates on heating.

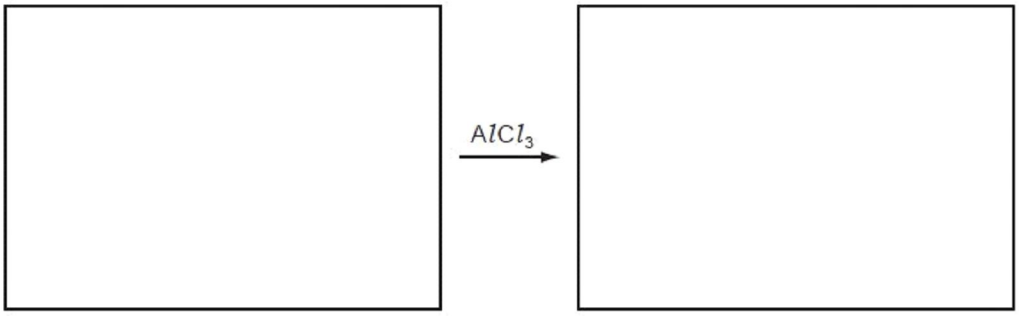
$$Al_2Cl_6(g) \rightleftharpoons 2AlCl_3(g)$$

(i) State whether this dissociation is endothermic or exothermic. Explain your answer.

.....

.....

(ii) Choose **one** reaction in organic chemistry that is catalysed by $AlCl_3$, and write the structural formulae of the reactants and products in the boxes below.



[3]

[Total: 7]