

OCR A-LEVEL CHEMISTRY B (SALTERS) • H433

CHEMISTRY



EXAM QUESTION PACK

OCEANS (O)

SCORE

/414

PERCENTAGE

%

STEMUP

These questions belong to OCR, not to us.

The examination questions, mark schemes and examiner comments in this pack were written and published by OCR. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with OCR and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. OCR has not endorsed, approved or been involved in the production of it. OCR and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

OCR publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at ocr.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

1(a) Research is being conducted into chemical reactions that can be used on other planets such as Mars.

One reaction being studied is shown below.



The atmosphere of Mars consists mainly of carbon dioxide. Hydrogen is initially brought from Earth.

Suggest, with reasons, what effect increasing temperature and pressure would have on the **equilibrium yield** of carbon monoxide and water in **equation 1.1**.



In your answer you should use appropriate technical terms, spelled correctly.

[4]

(b) A catalyst of iron and chromium is used.

State why a catalyst is used, giving its effect on K_c .

[2]



(c) At 500 K, the equilibrium constant for **equation 1.1** is 7.76×10^{-3} .

In an equilibrium mixture at 500 K, the concentrations of hydrogen and carbon dioxide are:

$$[\text{H}_2] = 1.00 \times 10^{-5} \text{ mol dm}^{-3}$$

$$[\text{CO}_2] = 3.46 \times 10^{-5} \text{ mol dm}^{-3}$$

Calculate the equilibrium concentrations of H_2O and CO at 500 K.

Assume the H_2O and CO come solely from this reaction.

Give your answers to an **appropriate** number of significant figures.

$$[\text{H}_2\text{O}(\text{g})] = \text{-----} \text{ mol dm}^{-3} \quad [\text{CO}(\text{g})] = \text{-----} \text{ mol dm}^{-3} \quad [4]$$

(d) The water is electrolysed to regenerate the hydrogen.

(i) Suggest a source of the energy needed to electrolyse water.

----- [1]

(ii) Suggest a reason why the electrolysis of water is beneficial to sustaining life on Mars.

----- [1]



(e) The entropies of the gases involved in **equation 1.1** are:

Gas	Entropy, $S/\text{J mol}^{-1} \text{K}^{-1}$
CO	+198
CO ₂	+214
H ₂ O	+189
H ₂	+131

(i) Calculate the entropy change, ΔS_{sys} , of the forward reaction in **equation 1.1**.

$$\Delta S_{\text{sys}} = \text{-----} \text{ J mol}^{-1} \text{K}^{-1} \text{ [1]}$$

(ii) Calculate the temperature at which $\Delta S_{\text{tot}} = 0$, giving the units.

$$T = \text{-----} \text{ units -----} \text{ [3]}$$

(iii) What can you conclude about the equilibrium when $\Delta S_{\text{tot}} = 0$?

----- [1]

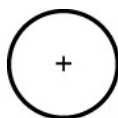
2(a) Scientists involved in the conservation of old leather books are concerned about the presence of acidic ammonium sulfate rotting the surface of the leather. This ammonium sulfate is formed by sulfuric acid from polluted air reacting with proteins in the leather.

The dissolving of ammonium sulfate in water is an endothermic process.

(i) The circle below represents an ammonium ion.

Complete the diagram to show how this ion is hydrated in aqueous solution and name the bonds formed between water and the ion.

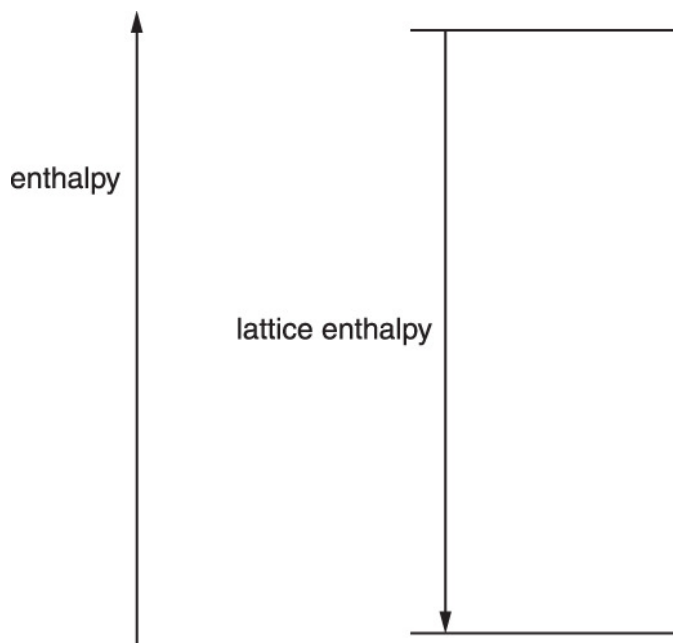
Include any relevant partial charges.



name of bonds _____

[3]

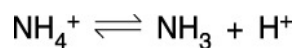
(ii) Part of the relevant enthalpy level diagram for the endothermic dissolving of ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$, is shown below.



- Complete the enthalpy level diagram to show the level for ammonium sulfate solution.
- Label the levels with the correct species including state symbols.
- Label the other enthalpy changes.

[5]

(b) The following equilibrium exists in an aqueous solution of ammonium ions.



(i) Indicate an acid-base pair on the equation above, labelling which is the acid and which the base.

[1]

(ii) Write the expression for K_a for the ammonium ion.

$K_a =$

[1]

(iii) The pH of a 0.10 mol dm^{-3} solution of ammonium ions is 5.13.

Calculate the value of K_a for the ammonium ion and give its units.

$K_a =$ _____ units _____ [3]

(iv) Ammonia is a weak base and it has an 'ionisation constant', K_b , given by:

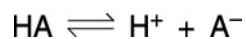
$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$$

Use the expressions for K_a , K_b and K_w and your value for K_a to calculate a value for K_b .

$$K_w = 1.0 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$$

$K_b =$ _____ mol dm^{-3} [2]

- (c) A buffer solution based on 'lactic acid' is sometimes used to buffer the acidic effects of the ammonium sulfate. Lactic acid is a weak acid and its ionisation can be represented by the equation below.

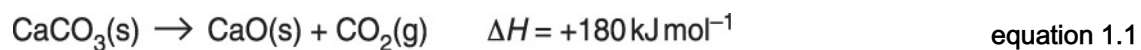


Explain, using the equation above, how a solution containing HA and A⁻ ions acts as a buffer solution when a small amount of acid is added.

[4]

3(a) Limestone, consisting mainly of calcium carbonate, CaCO_3 , is a major constituent of some rocks.

The action of heat on limestone forms calcium oxide that can be used for making cement.



State the bonding in $\text{CO}_2(\text{g})$ and the bonding and structure in $\text{CaO}(\text{s})$.

----- [2]

(b) Some entropy data for the compounds in **equation 1.1** are given below.

Compound	$S / \text{J mol}^{-1} \text{K}^{-1}$
$\text{CaCO}_3(\text{s})$	+93
$\text{CaO}(\text{s})$	+40
$\text{CO}_2(\text{g})$	+214

(i) Calculate a value of ΔS_{sys} for the reaction in **equation 1.1**.

$$\Delta S_{\text{sys}} = \text{-----} \text{ J mol}^{-1} \text{K}^{-1} \text{ [1]}$$

(ii) Calculate the value of ΔS_{tot} at 298 K.

$$\Delta S_{\text{tot}} = \text{-----} \text{ J mol}^{-1} \text{K}^{-1} \text{ [2]}$$

(iii) Calculate the temperature at which ΔS_{tot} for the reaction in **equation 1.1** is zero and comment on the significance of this temperature.

$$T = \text{-----} \text{ K}$$

comment -----

----- [2]

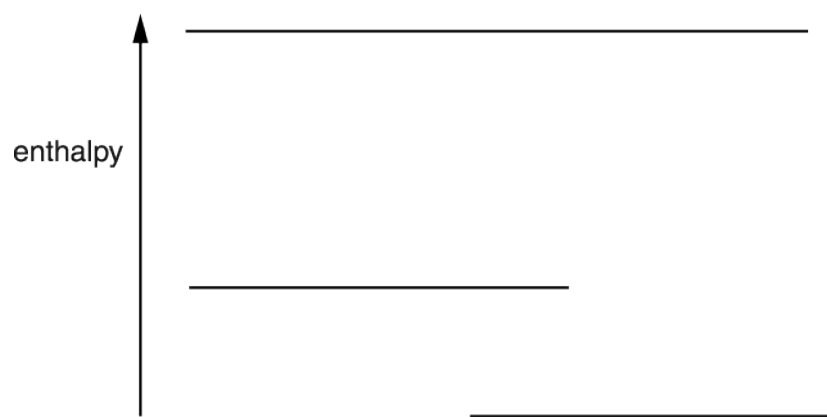
(c) Some data for the dissolving of calcium carbonate are given in the table below.

	Enthalpy change / kJ mol ⁻¹
Lattice enthalpy of CaCO ₃ (s)	-2800
Enthalpy change of solution of CaCO ₃ (s)	-12
Enthalpy change of hydration of Ca ²⁺ (g)	-1650

The enthalpy level diagram below is for the dissolving of calcium carbonate.

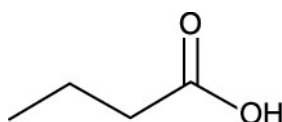
Label it with the species present on each energy level.

Use your diagram to calculate the enthalpy change of hydration of CO₃²⁻(g).



$\Delta H_{\text{hyd}}(\text{CO}_3^{2-}(\text{g})) = \text{-----} \text{ kJ mol}^{-1}$ [4]

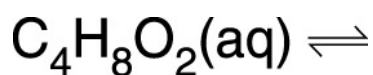
- 4(a) Butanoic acid (often called 'butyric acid') is a foul-smelling liquid that has been used by anti-whaling protesters to throw on board whaling ships.



butanoic acid

Butanoic acid is soluble in water and its K_a value is $1.51 \times 10^{-5} \text{ mol dm}^{-3}$.

- (i) Complete the equation for the ionisation of butanoic acid in water.



[1]

- (ii) Explain, in terms of a property of butanoic acid, why an equilibrium sign is used in the equation in (i).

----- [1]

- (iii) Pure butanoic acid does not react with solid calcium carbonate.

Suggest why pure butanoic acid does not react.

----- [2]

- (iv) When butanoic acid is partially neutralised by sodium hydroxide, a buffer solution is formed.

Explain how the particles in the solution account for its buffering action.

----- [4]

(b) In answering this part, you will need the following data.

$$K_a = 1.51 \times 10^{-5} \text{ mol dm}^{-3}$$

$$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$$

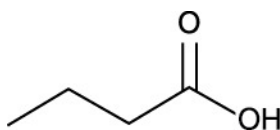
(i) Calculate the pH of a $0.0200 \text{ mol dm}^{-3}$ solution of butanoic acid.

pH = ----- [2]

(ii) 30.0 cm^3 of $0.0200 \text{ mol dm}^{-3}$ sodium hydroxide are added to 25.0 cm^3 of $0.0200 \text{ mol dm}^{-3}$ butanoic acid.

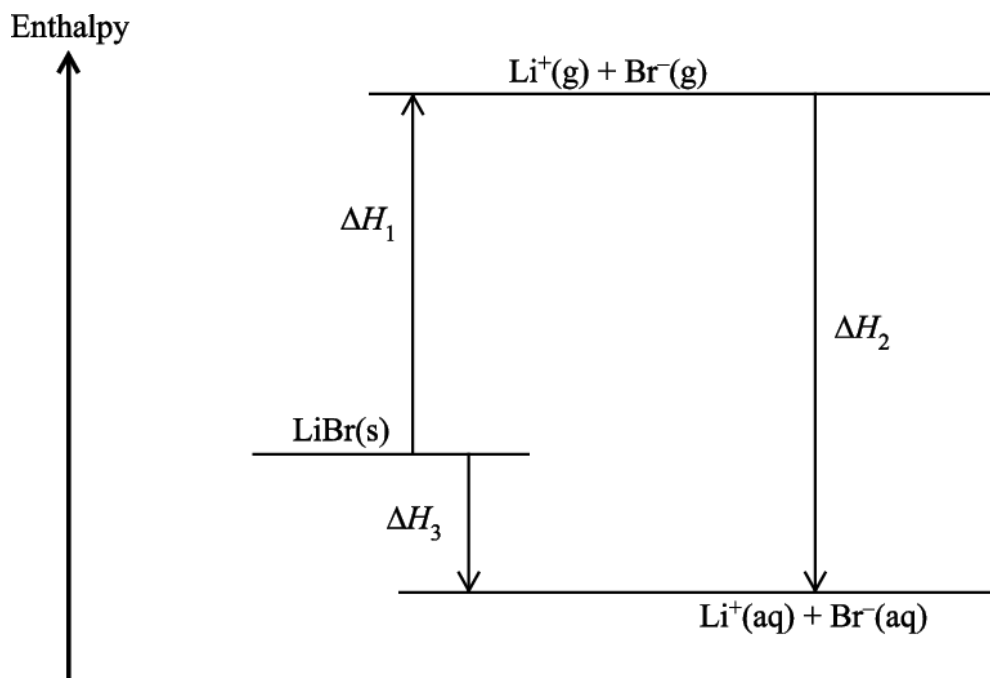
Calculate the pH of the resulting solution.

pH = ----- [3]



butanoic acid

5 Below is an enthalpy-level diagram for the solution of lithium bromide.



Which enthalpy change is represented by ΔH_2 ?

- A $\Delta_{\text{sol}}H(\text{Li}^+) + \Delta_{\text{sol}}H(\text{Br}^-)$
- B $\Delta_{\text{hyd}}H(\text{Li}^+) + \Delta_{\text{hyd}}H(\text{Br}^-)$
- C $\Delta_{\text{LE}}H(\text{LiBr})$
- D $\Delta_{\text{sol}}H(\text{LiBr})$

Your answer

[1]

6 Four changes W, X, Y and Z have the following signs for their ΔH and $\Delta_{\text{sys}}S$ values.

	W	X	Y	Z
ΔH	+	+	-	-
$\Delta_{\text{sys}}S$	+	-	+	-

Which of the following is a correct statement?

- A Change W never occurs.
- B Change X could be the reaction of a solid carbonate with an acid.
- C Change Y could be a precipitation reaction.
- D Change Z could be the condensation of a gas to a liquid.

Your answer

☐

[1]

7 Chemists use knowledge of bonding between molecules and ions to explain why different substances are soluble in water.

Which of the following statements is correct?

- A pentane is insoluble in water because pentane molecules are non-polar and **do not** form hydrogen bonds with water molecules
- B propanone is soluble in water even though water molecules **do not** form hydrogen bonds with propanone molecules
- C sodium chloride is soluble in water because water molecules are polar and form hydrogen bonds with Na^+ ions and Cl^- ions
- D carbon dioxide is insoluble in water because it is non-polar and **does not** form hydrogen bonds with water

Your answer

☐

[1]

- 8 The decomposition of calcium carbonate is a reaction that takes place in cement manufacture.



	CaCO ₃	CaO	CO ₂
$S / \text{J mol}^{-1} \text{K}^{-1}$	93	40	214

What is $\Delta_{\text{tot}} S$ for this reaction at 298 K?

- A $-436 \text{ J mol}^{-1} \text{K}^{-1}$
- B $+160 \text{ J mol}^{-1} \text{K}^{-1}$
- C $+161 \text{ J mol}^{-1} \text{K}^{-1}$
- D $+758 \text{ J mol}^{-1} \text{K}^{-1}$

Your answer

[1]

9 Which of the following quantities increase from left to right along the series:
 MgSO_4 ; CaSO_4 ; SrSO_4 ; BaSO_4 ?

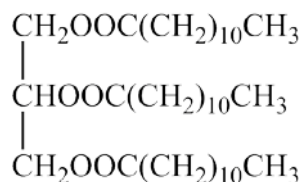
- 1: Size of the metal ions
- 2: The magnitude of enthalpy change of hydration of the metal ions
- 3: The magnitude of lattice enthalpy of the compounds

- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]

10(a) Coconut oil contains a large amount of compound **E**. The sodium salt, **F**, of compound **E** is used as a soap.



Compound E

After **F** is formed from **E**, **F** remains dissolved in the solution. **F** is precipitated out as a solid soap by adding NaCl.

- (i) Using Na^+L^- to represent the solid **F**, give the mathematical equation for the solubility product of **F**.

[1]

- (ii) Explain why adding NaCl to a solution of **F** causes the salt to precipitate out.

[2]

- (iii) The solubility in water of **F** is 24.0 g dm^{-3} at 24°C .

The molar mass of **F** is 222 g mol^{-1} .

Calculate the minimum mass (in g) of solid NaCl that is needed to form a precipitate when added to 500 cm^3 of a $1.00 \times 10^{-2} \text{ mol dm}^{-3}$ of **F** at 24°C .

Assume you can neglect the $[\text{Na}^+(\text{aq})]$ from salt **F** in comparison with the $[\text{Na}^+(\text{aq})]$ from NaCl.

Show **all** your working.

Give one **other** assumption you make in your calculation.

minimum mass of NaCl = _____ g

assumption:

[5]

- (b) Sodium ethanoate may be used in the production of ester G. It can also be used in buffer solutions.

Calculate the mass of solid sodium ethanoate (molar mass = 82 g mol^{-1}) that would need to be added to ethanoic acid (concentration 1.0 mol dm^{-3}) in order to make 250 cm^3 of buffer solution with a pH of 4.80.

K_a of ethanoic acid is $1.74 \times 10^{-5} \text{ mol dm}^{-3}$.

Show all your working.

mass of solid sodium ethanoate = _____ g [4]

11(a) Ammonium nitrate (NH_4NO_3) can be used in cold packs to treat sports injuries.

Ammonium nitrate dissolves in water in an endothermic process.

Some students carry out an experiment to measure the enthalpy change of solution of ammonium nitrate. The students have some powdered ammonium nitrate and normal laboratory equipment.

- (i) Describe what the students do and the measurements they make so that they can calculate the enthalpy change of solution.

You do not need to include details of how to carry out the calculation.

[3]

- (ii) The students use a thermometer that can be read to $\pm 0.5^\circ\text{C}$.

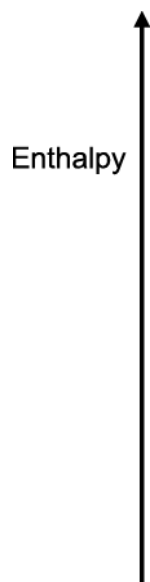
Give the percentage uncertainty in measuring a temperature **change** of 17°C .

percentage uncertainty = ----- % **[1]**

(b) Draw an enthalpy level diagram for dissolving ammonium nitrate.

Label the enthalpy levels and use the data below to calculate $\Delta_{\text{hydration}} H$ for the NO_3^- ion.

$\Delta_{\text{hydration}} H \text{ NH}_4^+$	-307 kJ mol^{-1}
$\Delta_{\text{LE}} H \text{ NH}_4\text{NO}_3$	-645 kJ mol^{-1}
$\Delta_{\text{solution}} H \text{ NH}_4\text{NO}_3$	$+25.0 \text{ kJ mol}^{-1}$



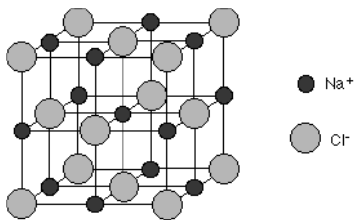
$\Delta_{\text{hydration}} H$ for $\text{NO}_3^- =$ _____ kJ mol^{-1} [4]

(c) State and explain how the lattice enthalpy of ammonium chloride would compare with the lattice enthalpy of ammonium nitrate.

----- [3]

(d)

- (i) Use the diagram of the sodium chloride lattice to draw diagrams of the hydrated ions in aqueous solution.

Sodium chloride lattice	Aqueous ions
	

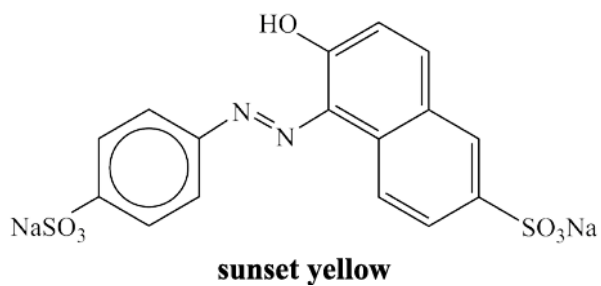
[2]

- (ii) List the types of bonds broken and made during dissolving.

Broken -----
Made -----

[2]

12(a) The azo dye 'sunset yellow' is a food colouring, though its use is being phased out.

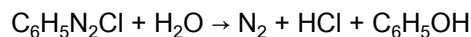


The groups shown as ' SO_3Na ' aid the solubility of the dye.

Explain how the SO_3Na groups do this, in terms of bonds broken and made.

[4]

- (b) A compound similar to compound **B** decomposes in dilute aqueous solution.



Some chemists investigate the rate of this decomposition. They collect the nitrogen gas in a graduated syringe at different initial concentrations of the $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$ solution. They time how long it takes for 50 cm^3 of nitrogen to be collected. The volume of solution used in each experiment is 100 cm^3 .

- (i) Two of the chemists' results are given in the table below.

Initial concentration / mol dm^{-3}	0.020	0.040
Initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$	8.70×10^{-7}	1.74×10^{-6}

Use these data to calculate the rate constant for the reaction. Include units in your answer.

Assume that the reaction is zero order with respect to water.

Show **all** your working.

rate = _____ units _____ [3]

- (ii) The chemists could have measured the time to produce a much larger volume of nitrogen.

Suggest why it would have been inappropriate to measure the time to collect larger volumes of gas, particularly in the experiments with lower concentrations of $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$.

----- [2]

- (iii) The progress of the reaction can also be followed with a pH meter.

What is the pH of the solution once 50 cm^3 of nitrogen have been collected?

Give your answer to **two** decimal places.

- (iv) Besides gas collection and measuring pH, suggest **one** other method with which the chemists could measure the progress of the reaction.

----- [1]

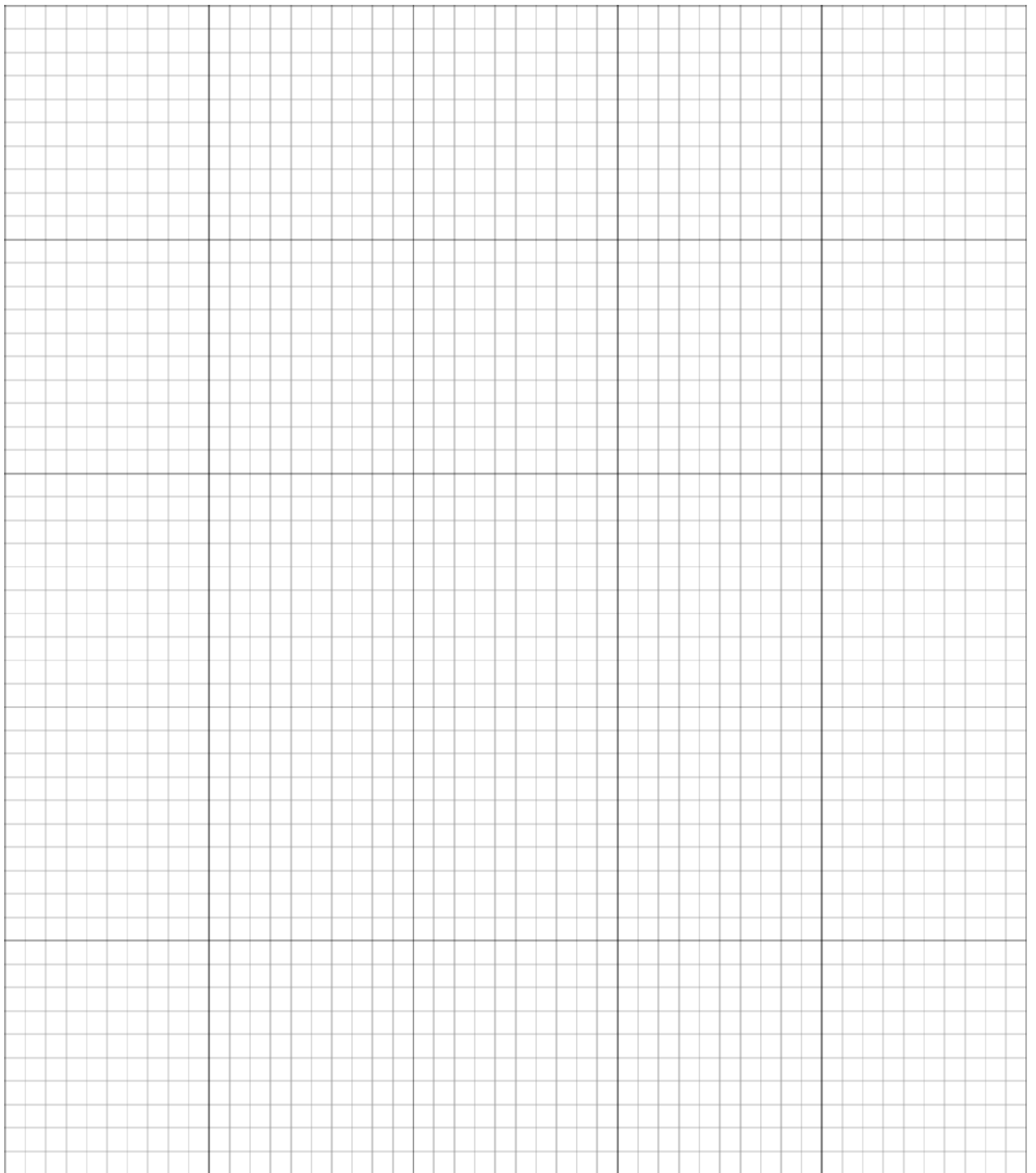
- (v) The chemists carried out the reaction at several temperatures and obtained the results in the left-hand two columns of **Table 1.1**.

Table 1.1

Temperature, T/K	rate constant, k/s^{-1}	$1/T/K^{-1}$	$\ln k$
278	1.5×10^{-6}	3.60×10^{-3}	-13.41
298	4.1×10^{-5}		-10.10
308	2.0×10^{-4}	3.25×10^{-3}	
323	1.4×10^{-3}	3.10×10^{-3}	-6.57

Calculate the missing values in **Table 1.1** and plot a graph of $\ln k$ against $1/T$ on the graph paper below.

Use your graph to calculate a value for the activation enthalpy of the reaction.



activation enthalpy = ... kJ mol^{-1}

13(a) Concrete contains calcium hydroxide, $\text{Ca}(\text{OH})_2$, and is alkaline when damp. The steel reinforcements in concrete do **not** corrode in an alkaline environment. When the calcium hydroxide reacts with carbon dioxide from the air to form calcium carbonate, 'carbonatation' occurs and the pH falls. The increased acidity can cause the steel to corrode.

(i) Write the equation for carbonatation.

[1]

(ii) Calculate the mass of calcium carbonate that is formed when 15 cm^3 of carbon dioxide (measured at room temperature and pressure) react with excess calcium hydroxide.

Give your answer to an **appropriate** number of significant figures.

mass = _____ g [2]

(b) Carbonatation produces calcium carbonate. The carbonate ion is alkaline in aqueous solution.

(i) Write an equation for the reaction that occurs between the carbonate ion and water.

[1]

(ii) Explain how the carbonatation reaction in (a)(i) accounts for the fall in pH.

[2]

(c)

- (i) Calculate the pH of a $0.0020 \text{ mol dm}^{-3}$ solution of calcium hydroxide.

Show all your working.

pH = _____ [3]

- (ii) Calculate the pH of a $0.0010 \text{ mol dm}^{-3}$ solution of carbon dioxide.

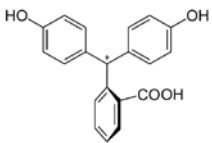
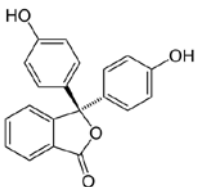
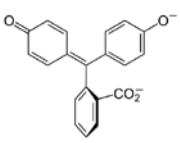
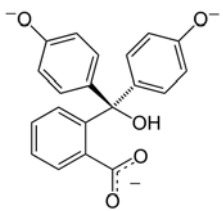
$$K_a = 4.5 \times 10^{-7} \text{ mol dm}^{-3}$$

pH = _____ [2]

- (iii) Explain the approximation that is made in performing the calculation in (ii) when $[\text{H}^+]$ is low.

----- [2]

- (d) The indicator phenolphthalein can be used to detect carbonatation in concrete.
Phenolphthalein has a variety of related structures, depending on the pH.

Species	C	D	E	F
Structure				
pH	<0	0–8.2	8.2–12.0	>12.0
Conditions	strongly acidic	acidic or near-neutral	alkaline	strongly alkaline
Colour	orange	colourless	pink	colourless

- (i) Give the colours of phenolphthalein for normal concrete and for concrete that has undergone carbonatation.

normal:

carbonatation: [1]

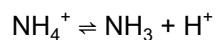
- (ii) An acid is titrated with a strong alkali using phenolphthalein until the pink colour just persists.
If the solution is then allowed to stand in the titration flask it slowly goes colourless.

Explain what is happening.

.....

 [2]

14(a) The following equilibrium exists in an aqueous solution of ammonium ions.



(i) On the equation above indicate an acid-base pair, labelling which is the acid and which the base.

[1]

(ii) Write the expression for K_a for the ammonium ion.

$$K_a =$$

[1]

(iii) The pH of a 0.10 mol dm^{-3} solution of ammonium ions is 5.13.

Calculate the value of K_a for the ammonium ion and give its units.

$$K_a = \text{----- units -----} [3]$$

(iv) Ammonia is a weak base and it has an 'ionisation constant', K_b , given by the following expression.

$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$$

Use the expressions for K_a , K_b and K_w to calculate a value for K_b .

$$K_b = \text{----- mol dm}^{-3} [2]$$

(b) A buffer solution based on 'lactic acid' is sometimes used to buffer the acidic effects of the ammonium sulfate.

Lactic acid is a weak acid with $K_a = 1.38 \times 10^{-4} \text{ mol dm}^{-3}$.

(i) A student sets out to make a buffer solution using lactic acid and its sodium salt.

Calculate the mass of salt ($M_r = 112$) that must be dissolved in 250 cm^3 of $0.0100 \text{ mol dm}^{-3}$ lactic acid ($M_r = 90$) to produce a buffer of pH 4.0.

mass of salt = _____ g [3]

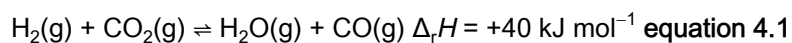
(ii) A student says that the salt must be added as a solid and not as a solution of the salt, otherwise the pH of the buffer will not be exactly 4.0.

Comment on this statement.

----- [1]

15(a) Research is being conducted into chemical reactions that can be used on other planets such as Mars.

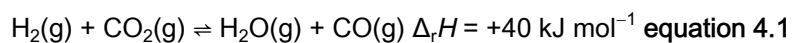
One reaction being studied is shown below.



The atmosphere of Mars consists mainly of carbon dioxide.

Hydrogen is initially brought from Earth.

The value of $\Delta_{\text{sys}} S$ for the forward reaction in equation 4.1 is $+42 \text{ J mol}^{-1} \text{ K}^{-1}$.



Gas	Entropy, $S/\text{J mol}^{-1} \text{ K}^{-1}$
CO	+198
CO ₂	+214
H ₂ O	+189

Use the data above to calculate the entropy of $\text{H}_2(\text{g})$.

entropy of $\text{H}_2(\text{g}) = \text{-----} \text{ J mol}^{-1} \text{ K}^{-1}$ [1]

(b)

(i) Calculate the value of $\Delta_{\text{tot}}S$ for the forward reaction in **equation 4.1** at 1000°C.

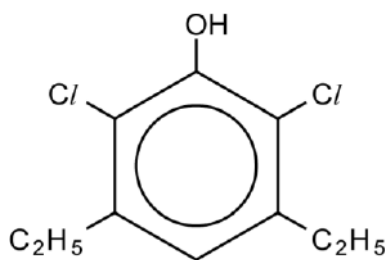
$$\Delta_{\text{tot}}S = \text{-----} \text{ J mol}^{-1} \text{ K}^{-1} \text{ [2]}$$

(ii) Explain what you can deduce about the forward reaction in **equation 4.1** at 1000°C.

----- [2]

16(a) This question refers to the Advance Notice Article *Dettol* which accompanies this paper.

A chemist suggests using compound C, shown below, as an ingredient in an antiseptic such as dettol.



Compound C

- (i) Give the systematic name of compound C.

----- [1]

- (ii) Suggest, with a reason, **one** way in which compound C might be a better ingredient in dettol than the compound PCMX.

----- [1]

- (iii) Suggest, with reasons, **two** ways in which compound C might be a worse ingredient in dettol than the compound PCMX.

----- [2]

- (b) Explain why compounds with an aromatic ring usually form substituted derivatives, rather than addition compounds.

[2]

- (c) Suggest how PCMX binds to proteins.

[1]

- (d) PCMX is slightly more acidic than phenol. Suggest why this is so.

[2]

- (e) PCMX can dissolve in water and in non-polar solvents.

Name the intermolecular forces broken in the solvent in each case.

water -----

non-polar solvents -----

[2]

- 17 A group of students set out to investigate the heating effect of volcanic lava on any carbonate rocks that it may flow over. They decide to devise an experiment to compare the thermal stability of magnesium carbonate and calcium carbonate.

The students have access to magnesium carbonate powder, lumps of calcium carbonate, calcium hydroxide powder, distilled water and whatever apparatus they need.

- (i) * Describe how the students could carry out their experiment.

You should include in your answer:

- a labelled diagram of the apparatus used to safely heat the carbonate compounds
- the main steps in the experimental procedure and the names of the key apparatus (not included in the labelled diagram)
- the observations and measurements that should be recorded
- how to ensure the comparison is fair and the results are as accurate as possible.

[6]

- (ii) The students find that the magnesium carbonate decomposes more readily than calcium carbonate and believe this can be explained by the difference in *charge density* of the magnesium and calcium ions.

What is meant by the term *charge density*?

-----[1]-----

- (iii) Explain, in terms of the charge densities of the cations, the relative thermal stabilities of magnesium carbonate and calcium carbonate.

- (iv) The enthalpy change of reaction, $\Delta_r H$, for the decomposition of magnesium carbonate is $+118 \text{ kJ mol}^{-1}$.

The entropies for the compounds in this reaction are given in the table below.

	MgCO_3	MgO	CO_2
$S / \text{J mol}^{-1} \text{K}^{-1}$	66	27	214

What is the minimum temperature to which the students must heat the magnesium carbonate powder for decomposition to occur?

Include units in your answer.

Show **all** your working.

minimum temperature = _____ [3]

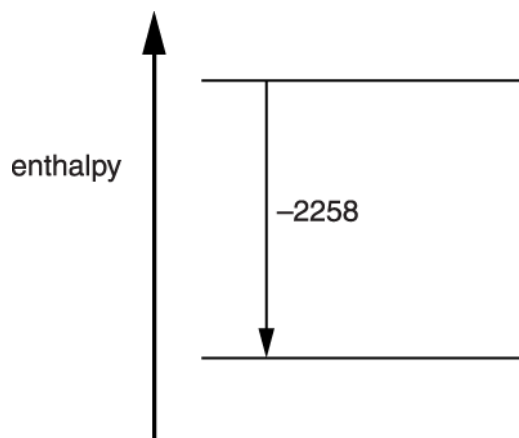
18(a) Calcium chloride, CaCl_2 , is used with sodium chloride to melt ice.

One reason calcium chloride helps to melt ice is that the dissolving process is exothermic. Some enthalpy changes for this process are given below.

Enthalpy change	$\Delta H/\text{kJ mol}^{-1}$
hydration of Ca^{2+}	-1650
hydration of Cl^-	-364
lattice enthalpy of CaCl_2	-2258

(i) Part of an enthalpy level diagram for the dissolving process is shown below.

- Draw another energy level to complete the diagram.
- Label the energy levels with the relevant species, including state symbols.
- Use the diagram to calculate a value for $\Delta H_{\text{solution}}$ of CaCl_2 .



$\Delta H_{\text{solution}} = \text{-----} \text{ kJ mol}^{-1}$ [5]

(ii) Suggest and explain why the enthalpy change of hydration for calcium ions is more exothermic than the enthalpy change of hydration for chloride ions.

----- [2]

(b) Draw a diagram to show a hydrated calcium ion in solution.

Show full and partial charges.

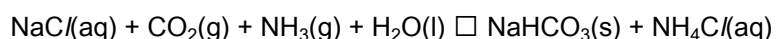
[2]

- (c) Calcium chloride is made by the Solvay process. This also produces another useful substance, sodium carbonate.

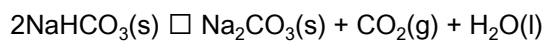
The Solvay process consists of the following reactions:



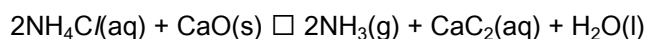
Equation 2.1



Equation 2.2



Equation 2.3



Equation 2.4

- (i) Write an equation in the box for the overall reaction that occurs to form just two products.

[2]

- (ii) State the atom economy of the Solvay process and explain why this is important for the environment.

----- [1]

- (d) Give the systematic names of NaHCO_3 and NH_4Cl .

NaHCO_3 -----

NH_4Cl ----- [2]

(e) The reaction in **Equation 2.1** has a positive ΔS_{sys} .

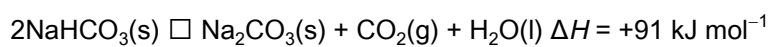


Equation 2.1

Explain the term *entropy* and give **one** reason why ΔS_{sys} is positive for this reaction.

[2]

(f) The standard entropies for the compounds in **Equation 2.3** are given below.



Equation 2.3

Compound	$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$
$\text{NaHCO}_3(\text{s})$	+102
$\text{Na}_2\text{CO}_3(\text{s})$	+135
$\text{CO}_2(\text{g})$	+214
$\text{H}_2\text{O}(\text{l})$	+70

Calculate the minimum temperature for the reaction in **Equation 2.3** to occur.

Show all your working.

minimum temperature = _____ K **[3]**

(g) $\text{NH}_3(\text{aq})$ and $\text{NH}_4\text{Cl}(\text{aq})$ can be used to make a buffer solution.

K_a for the NH_4^+ ion is $5.6 \times 10^{-10} \text{ mol dm}^{-3}$.

(i) Write the equilibrium for this K_a value.

[1]

(ii) Calculate the pH of a $0.010 \text{ mol dm}^{-3}$ solution of NH_4Cl .

pH = _____ [2]

(iii) A small amount of acid is added to a solution that contains approximately 0.01 mol dm^{-3} of $\text{NH}_3(\text{aq})$ and $0.01 \text{ mol dm}^{-3} \text{ NH}_4^+(\text{aq})$.

Explain how the solution is buffered, by reference to your answer to (h)(i).



In your answer you should indicate how the points you make link together.

[4]

(iv) Calculate the pH of a buffer solution where the concentration of $\text{NH}_3(\text{aq})$ is twice the concentration of $\text{NH}_4^+(\text{aq})$.

pH = ... [2]

19(a) Some students set out to make a sample of dry crystals of the soluble salt strontium chloride. They react excess strontium carbonate with hydrochloric acid.

They place the acid in a beaker and add spatula measures of strontium carbonate to the acid while stirring.

Describe the rest of their procedure.

[4]

(b)

- (i) Write an equation for the reaction that occurs in the previous question to form SrCl_2 .
Show state symbols.

[2]

- (ii) Calculate the mass of strontium carbonate that will react with 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid.

mass = _____ g [2]

(c) The strontium chloride formed is a hydrated salt with formula $\text{SrCl}_2 \cdot x\text{H}_2\text{O}$.

The students take 2.00 g of the dry salt, dissolve it in water and add an excess of silver nitrate solution so the total volume is 200 cm^3 . They filter off the precipitate of silver chloride, wash it and heat it to constant mass to remove all the water.

(i) Suggest how the students would 'heat the silver chloride to constant mass'.

----- [2]

(ii) 2.16 g of silver chloride, AgCl , is formed.

Calculate the value of x in $\text{SrCl}_2 \cdot x\text{H}_2\text{O}$.

$x =$ ----- [4]

(iii) A student says that the mass of silver chloride formed is not accurate because silver chloride is slightly soluble in water.

The solubility product of AgCl is $2.0 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$.

Use calculations to comment on the student's statement.

[2]

(iv) Another hydrated strontium chloride has formula $\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$.

Calculate the percentage loss in mass when all the water is driven off by heating.

loss in mass = ----- % [1]

20(a) Sodium chloride is used to melt ice on roads each winter.

(i) Some data for the dissolving of sodium chloride are given below.

	$\Delta H^\circ / \text{kJ mol}^{-1}$
lattice enthalpy of NaCl	-780
enthalpy change of solution of NaCl	+4
enthalpy change of hydration of Na^+	-406

Draw an enthalpy level diagram that connects these values and the enthalpy change of hydration of the chloride ion.

Label the energy levels.

Use the data to calculate the enthalpy change of hydration of the chloride ion.

$$\Delta_{\text{hyd}} H^\circ \text{Cl}^- = \text{-----} \text{ kJ mol}^{-1} \text{ [4]}$$

(ii) Draw a diagram of a hydrated sodium ion in solution.

Show full and partial charges.

(iii) A student says:

- there are ionic bonds in the lattice
- ionic bonds are formed between the water and the ions in solution
- the energy required to break bonds in the lattice is very similar to the energy given out when bonds are made.

Comment on these statements.

[3]

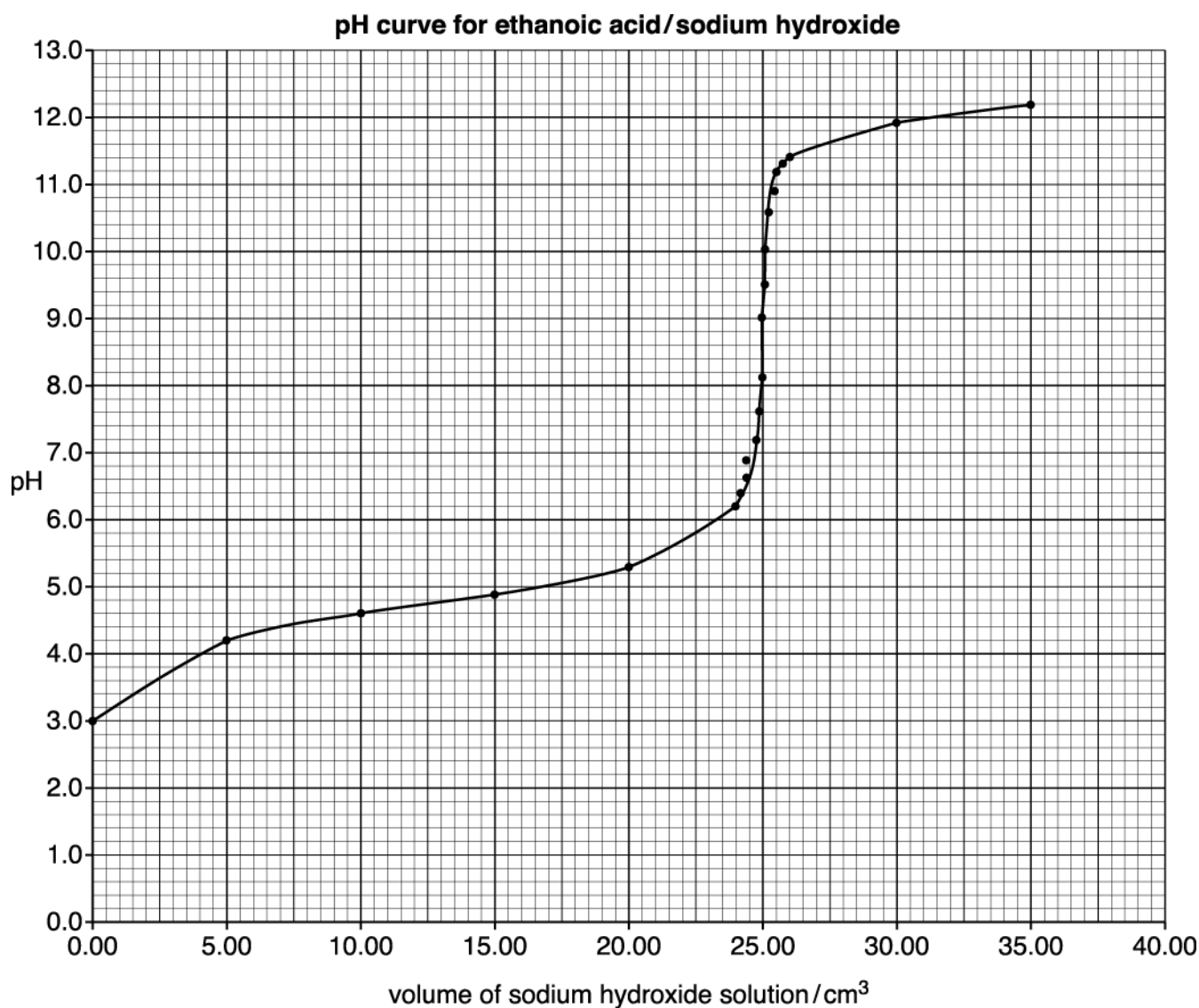
(b) 10.0 g of sodium chloride are dissolved in 200 cm³ of water.

Calculate the temperature change that would occur. Give the sign.

(Take the mass of solution as 210 g and its specific heat capacity to be the same as that of water.)

temperature change = _____ °C [2]

21(a) A student uses a pH meter to measure the pH of the solution when 0.10 mol dm^{-3} sodium hydroxide is added to a solution of ethanoic acid. The student's results are shown in the graph below.



- (i) Explain why the student decided to use a pH meter rather than universal indicator to determine the pH of the solution as the titration progressed.

----- [1]

- (ii) The pH meter should have been calibrated by the student before use.

Explain how a pH meter is calibrated.

----- [1]

(b)

(i) Ethanoic acid is a weak acid.

Give an equation for its ionisation in water.

[1]

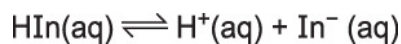
(ii) Use the graph to find the pH when $[\text{CH}_3\text{COOH}] = [\text{CH}_3\text{COO}^-]$ and from that the value of K_a for ethanoic acid.

$K_a =$ _____ mol dm^{-3} [4]

- (c) The student decides to repeat the experiment using two different indicators to see whether the colour change matches the equivalence point shown by pH titration.

The indicators are weak acids and can be represented by the formula HIn.

Indicators partially ionise in solution where the HIn molecule has a different colour to the In⁻ anion.



The table below gives some information on two possible indicators that could be used in the experiment.

Indicator	Colour of HIn	Colour of In ⁻	pH range over which indicator changes colour
phenolphthalein	colourless	pink	8.2–10
methyl orange	red	yellow	3.2–4.4

- (i) Suggest, with reference to the pH curve on page 4, and the information in the table above, which indicator would be suitable for this titration.

----- [2]

- (ii) Use the information in the table above to predict which indicator ionises more when dissolved in distilled water.

Explain your prediction.

----- [2]

(d) A solution of sodium ethanoate and ethanoic acid forms a buffer solution.

(i) What is a buffer solution?

Explain how a sodium ethanoate/ethanoic acid solution acts as a buffer solution.

[4]

(ii) A student measures the pH of a sodium ethanoate/ethanoic acid buffer solution before and after adding a small amount of distilled water to the buffer.

Describe and explain any change in the pH after the addition of the water.

[2]

22 What is correct for **all** ionic solids dissolving in water?

- A The sum of the enthalpy changes of hydration of the ions is more exothermic than the lattice enthalpy.
- B The entropy of the water increases.
- C $\Delta_{\text{sol}}H$ is exothermic.
- D The formation of ion-dipole bonds between water and ions is exothermic.

Your answer

☐

[1]

23 Which statement(s) about the greenhouse effect is/are correct?

- 1 Carbon dioxide, methane and water vapour all absorb the same frequencies of infrared radiation.
- 2 Energy from visible and ultra violet light is absorbed by the Earth.
- 3 The Earth emits infrared radiation from its surface.

- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]

24(a) Esters have many uses in organic chemistry, including in polymers.

Some students want to determine the equilibrium constant for the esterification reaction in **equation 33.1** in acidic conditions.



They set up their experiment with known masses of ethanol, ethanoic acid and concentrated sulfuric acid catalyst.

They place the reactants in a stoppered bottle and wait a week for equilibrium to be established.

Suggest how the students could find the amount of ethanoic acid in the bottle at equilibrium.

----- [2]

- (b) By using the method from (a), the students find that the amount of ethanoic acid present at equilibrium is 0.123 mol.

They produce the table below.

Substance	Mass present at the start / g	Amount present at the start / mol	Amount present at equilibrium / mol
ethanol	15.8		
ethanoic acid	21.0		0.123
ethyl ethanoate	0	0	
water	0	0	

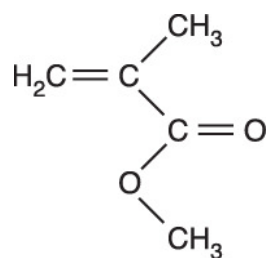
Carry out appropriate calculations to fill in the blanks in the table.

Use figures from the table to work out a value for the equilibrium constant, K_c , of the reaction in equation 33.1.

$K_c =$ [4]

- (c) Another ester is the monomer for the polymer polymethyl methacrylate or PMMA. PMMA is often used to make lightweight transparent materials as a replacement for glass.

The monomer has the structure shown below.



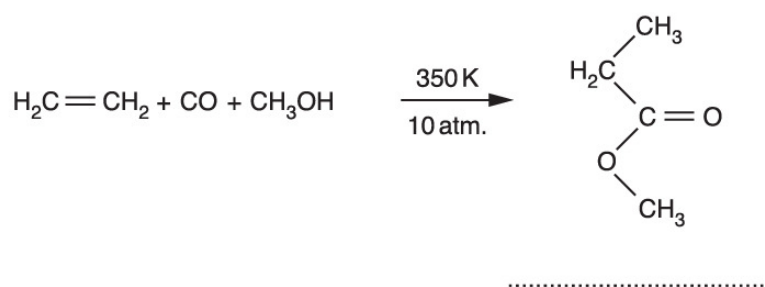
Draw the structural formula for **one** repeating unit of the polymer.

[1]

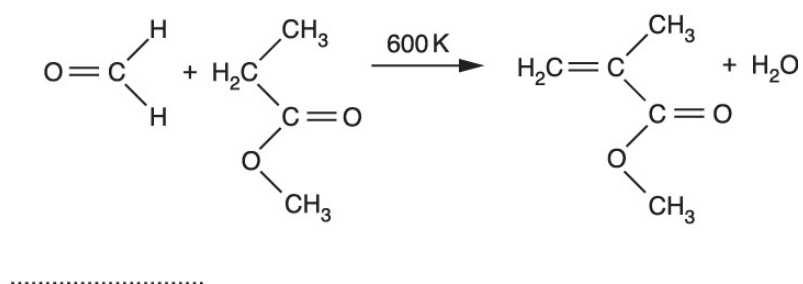
(d) The monomer can be made in the following reaction sequence.

Give the systematic names of two of the compounds on the dotted lines below their structures.

Stage 1:



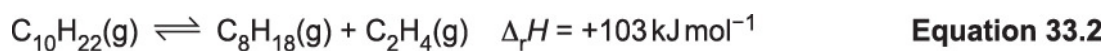
Stage 2:



[1]

- (e) The ethene used in **stage 1** comes from thermal cracking of long chain alkanes from crude oil in the presence of steam.

One such reaction is shown below.



Substance	Entropy / $\text{J mol}^{-1} \text{K}^{-1}$
$\text{C}_{10}\text{H}_{22}$	+425.9
C_8H_{18}	+361.1
C_2H_4	+219.5

Use the entropy values given to find the minimum temperature needed for the forward reaction to be feasible.
Give your answer to an **appropriate** number of significant figures.

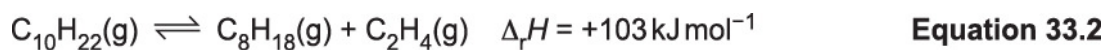
minimum temperature = _____ K [3]

- (f) Give the effects that the following changes have on the value of K_c for the reaction in **equation 33.2**.

Change	Increased temperature	Increased pressure	Use of a catalyst
Effect on K_c			

[2]

(g) The yield of the reaction in **equation 33.2** is typically 50%.



Calculate the volume (in dm^3) of ethene produced when 25.0 kg of decane are cracked at 900 K and a pressure of 150 kPa.

volume of ethene = _____ dm^3 [3]

(h) An alternative method of obtaining ethene is catalytic cracking using zeolite catalysts.

Explain the advantage to the environment of this method over steam cracking.

----- [1]

25(a) Students decide to investigate the solubility of calcium hydroxide by shaking solid calcium hydroxide with deionised water and filtering the mixture to remove undissolved solid. They then titrate the dissolved hydroxide ions with hydrochloric acid.

(i) They titrate 25.0 cm^3 of their saturated solution of calcium hydroxide with $0.0400 \text{ mol dm}^{-3} \text{ HCl}$.

Their results are shown below.

	Trial	Repeat 1	Repeat 2	Repeat 3	Repeat 4
Titre/ cm^3	15.00	13.80	13.90	14.00	14.60

Use their results to find the solubility product of calcium hydroxide.

solubility product of calcium hydroxide = _____

units _____ [4]

(ii) Describe and explain what difference they would see in their titre if they repeated their titration with saturated magnesium hydroxide solution.

 _____ [1]

(b) 15.0 g of calcium chloride are dissolved in water.

Use the information below to find the temperature rise of the solution.

You may assume the mass of the solution is 100 g and its specific heat capacity is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$.

	Enthalpy change/ kJ mol^{-1}
$\Delta_{\text{LE}} H \text{ CaCl}_2$	-2258
$\Delta_{\text{hyd}} H \text{ Cl}^-$	-364
$\Delta_{\text{hyd}} H \text{ Ca}^{2+}$	-1650

temperature rise = _____ $^{\circ}\text{C}$ [3]

26 The maximum solubility of magnesium hydroxide is $1.71 \times 10^{-4} \text{ mol dm}^{-3}$.

What is the value of the solubility product?

- A 5.00×10^{-12}
- B 2.00×10^{-11}
- C 2.92×10^{-8}
- D 5.13×10^{-4}

Your answer

[1]

27 Which statement(s) connected with the greenhouse effect is/are correct?

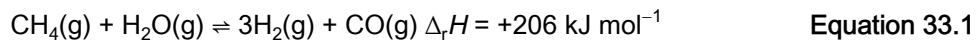
- 1 The Earth radiates infrared radiation.
- 2 Solar energy heats the surface of the Earth.
- 3 Greenhouse gases absorb ultra violet radiation causing their bonds to vibrate more.

- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]

28(a) An important source of hydrogen is from the steam reforming reaction shown below.



The entropy change for the forward reaction in **equation 33.1**, $\Delta_{\text{sys}} S = +214.5 \text{ J K}^{-1} \text{ mol}^{-1}$.

(i) How does the sign of $\Delta_{\text{sys}} S$ relate to the equation for the reaction?

----- [1]

(ii) The entropy values for some of the gases in **equation 33.1** are shown below.

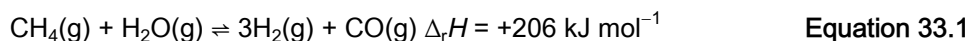
Gas	Entropy, $S / \text{J K}^{-1} \text{ mol}^{-1}$
CH_4	+186.3
H_2O	+188.7
CO	+197.7

Use the value of $\Delta_{\text{sys}} S$ and the entropy values in the table to calculate the entropy of $\text{H}_2(\text{g})$.

entropy of $\text{H}_2(\text{g}) = \text{-----} \text{ J K}^{-1} \text{ mol}^{-1}$ [2]

(b) Calculate whether the forward reaction in **equation 33.1** is feasible at 1000 K.

----- [2]



29(a) Sodium ethanoate is used as an 'acidity regulator' in foods.

Sodium ethanoate, CH_3COONa , can be made by reacting solutions of ethanoic acid, CH_3COOH , and sodium carbonate, Na_2CO_3 , in the laboratory.

(i) Write an equation for this reaction.

[2]

(ii) Calculate the volume (in cm^3) of $0.500 \text{ mol dm}^{-3}$ Na_2CO_3 that would react with 25.0 cm^3 of $0.450 \text{ mol dm}^{-3}$ CH_3COOH .

volume of $\text{Na}_2\text{CO}_3 = \text{-----} \text{ cm}^3$ [2]

(b) The ethanoate ion forms an alkaline solution in water.
Write an equation to show this.

[1]

(c) Ethanoic acid is a weak acid. $K_a = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$.

(i) Write an equation for the reaction of ethanoic acid in water. [1]

(ii) Calculate the pH of a $0.030 \text{ mol dm}^{-3}$ solution of ethanoic acid.

pH = _____ [2]

(d) When sodium ethanoate is acting as an acidity regulator in food, a buffer solution is set up. This buffer involves sodium ethanoate, CH_3COONa , and ethanoic acid, CH_3COOH .

Explain, with the help of an appropriate equation, how this buffer solution works when acid is added.

----- [3]

(e) Some students investigate buffers involving sodium ethanoate and ethanoic acid.

- (i) They make a solution containing equal amounts of ethanoic acid and sodium ethanoate.
Calculate the pH of this solution.

$$K_a = 1.7 \times 10^{-5} \text{ mol dm}^{-3} \text{ for ethanoic acid.}$$

pH = _____ [1]

- (ii) The students then set out to make a buffer solution of a known pH. They have 25.0 cm^3 of a $0.100 \text{ mol dm}^{-3}$ solution of ethanoic acid.

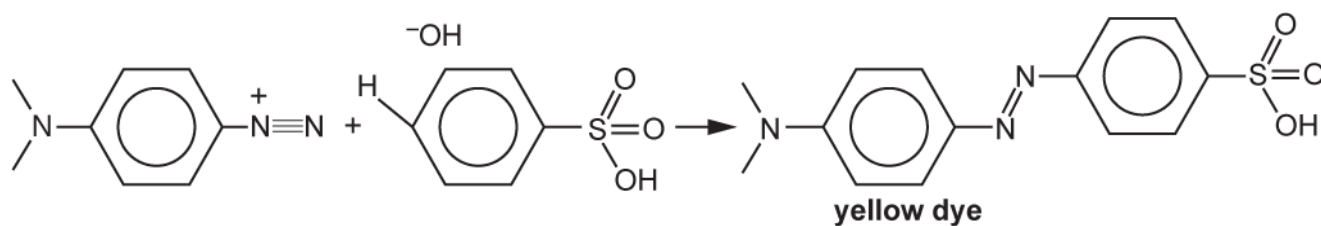
Calculate the mass of sodium ethanoate they need to add to the acid solution to make a solution of pH = 5.00.

mass of sodium ethanoate = _____ g [4]

30(a) A dye is used as an acid-base indicator. It is red in acidic conditions and yellow in neutral or alkaline conditions.

The equation for the reaction producing the yellow form of the dye is shown below. It is carried out in alkaline conditions.

Add curly arrows to the equation to show the mechanism of the reaction forming the dye.



[3]

(b) The indicator dye is a weak acid and may be described as HIn.

For the reaction shown below, $K_a = 1.6 \times 10^{-4} \text{ mol dm}^{-3}$.



This indicator changes colour at pH 3.7.

Find the ratio $[\text{In}^-] / [\text{HIn}]$ when it changes colour.

$[\text{In}^-] / [\text{HIn}] = \text{-----}$ [2]

31(a) The student looks up the enthalpy change of solution for anhydrous magnesium sulfate and finds it is $-84.00 \text{ kJ mol}^{-1}$.

The student measures the enthalpy change of solution of $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ by adding it to water and measuring the temperature change.

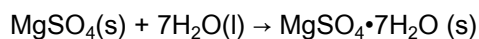
The student's results are shown in the table.

Solute	Mass of solute dissolved / g	Mass of solution / g	Initial temperature of water/ °C	Final temperature of water/ °C
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}(\text{s})$	9.7	50.0	18.0	15.0

Calculate $\Delta_{\text{sol}}H$ for $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ in kJ mol^{-1} .

Assume the specific heat capacity of the solution is the same as that of water.

Use your answer, with the $\Delta_{\text{sol}}H$ for the anhydrous salt and draw an appropriate cycle to find a value for Δ_rH for the reaction shown below.

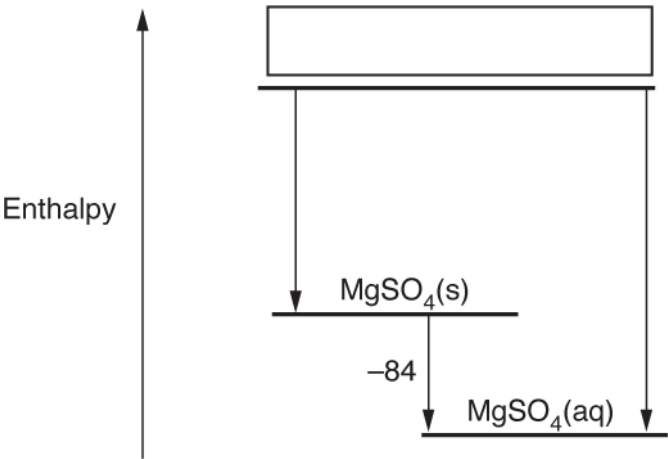


$\Delta_rH =$ _____ kJ mol^{-1} [4]

(b) $\Delta_{\text{hyd}}H$ values for the ions in magnesium sulfate are given in the table below.

Ion	$\Delta_{\text{hyd}}H / \text{kJ mol}^{-1}$
Mg^{2+}	-1922
SO_4^{2-}	-1099

Fill in the missing species in the box and use the diagram to calculate $\Delta_{\text{LE}}H$ for magnesium sulfate.



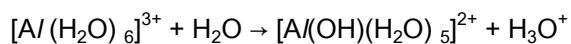
$\Delta_{\text{LE}}H = \text{-----} \text{ kJ mol}^{-1}$ [2]

(c) Strontium sulfate is much less soluble than magnesium sulfate.

Use ideas of hydration enthalpy to suggest an explanation.

----- [2]

(i) What is acting as the acid in the equation shown below?



-----[1]

(ii) Draw a diagram to illustrate the shape of the $[\text{Al}(\text{OH})(\text{H}_2\text{O})_5]^{2+}$ ion, naming the shape.

name of shape-----[2]

33 Which statement about a strong base at 298 K is correct?

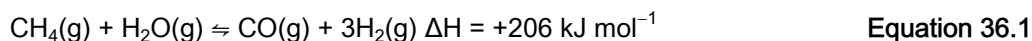
- A It is partially ionised.
- B Its pH is given by $\text{pH} = 14 + \log[\text{OH}^-]$.
- C It will not react with weak acids.
- D It has the same pH as a weak base of the same concentration.

Your answer

[1]

34(a)

The hydrogen needed to manufacture ammonia can be produced from steam and methane as shown in **equation 36.1** below.



- (i) Use the entropy values in the table below to calculate $\Delta_{\text{sys}}S$ for the forward reaction in **equation 36.1**.

Substance	Entropy $S / \text{J K}^{-1} \text{ mol}^{-1}$
$\text{CH}_4(\text{g})$	186.2
$\text{H}_2\text{O}(\text{g})$	189.0
$\text{CO}(\text{g})$	197.6
$\text{H}_2(\text{g})$	130.6

$$\Delta_{\text{sys}}S = \text{-----} \text{ J K}^{-1} \text{ mol}^{-1} \quad [1]$$

- (ii) Explain how the sign of your answer to (i) is predicted by **equation 36.1**.

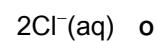
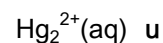
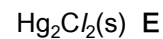
 ----- [1]

- (b) Calculate the minimum temperature required for the forward reaction in **equation 36.1** to be feasible.

Give your answer to an **appropriate** number of significant figures.

$$\text{temperature} = \text{-----} \text{ K} \quad [2]$$

An equilibrium, represented by equation 2.1, exists between the solid Hg_2Cl_2 and its ions in solution.



n

2.

1

The

solubility of the solid Hg_2Cl_2 in a saturated solution at 298 K is $3.5 \times 10^{-4} \text{ g dm}^{-3}$.

Calculate the solubility product, K_{sp} , for Hg_2Cl_2 at 298 K. Include the units.

Give your answer to an **appropriate** number of significant figures.

solubility product, $K_{\text{sp}} =$ ----- units ----- [5]

- 36 'Morton's salt'TM contains a mixture of sodium chloride with magnesium carbonate. It is advertised using the slogan 'When it rains it pours' indicating that the table salt is free-flowing in humid weather.

Magnesium carbonate is hygroscopic (absorbs water) and forms hydrated salts, eg $\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$, but does not dissolve. This stops the sodium chloride absorbing water.

- (i) Some data for the dissolving of NaCl is given below.

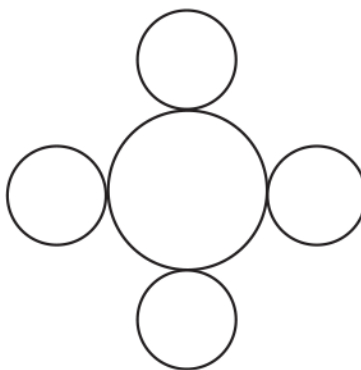
Enthalpy change	Value / kJ mol^{-1}
$\Delta_{\text{LE}} H \text{ NaCl}$	-780
$\Delta_{\text{hyd}} H \text{ Na}^+$	-402
$\Delta_{\text{hyd}} H \text{ Cl}^-$	-374

Calculate a value for the enthalpy change of solution of NaCl.

enthalpy change of solution of NaCl = ... [1]

- (ii) The diagram below shows the pattern of ions in **one face** of a NaCl lattice.
Extend the diagram to show the repeating pattern by adding **three** more suitable ions.

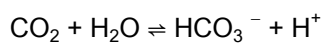
Label one Na^+ ion and one Cl^- on the diagram.



[2]

37(a) The pH of human blood needs to be held within strict limits for good health.

The pH is controlled using buffer systems. One buffer system is based on the equilibrium in **equation 4.1**.



Equation 4.1

(i) Give the **systematic** name for HCO_3^- .

-----[1]

(ii) HCO_3^- can act as either an acid or a base.

Give the **formula** of the conjugate **base** of HCO_3^- .

-----[1]

(b) For the equilibrium in **equation 4.1**:

$$K_a = \frac{[\text{HCO}_3^-] [\text{H}^+]}{[\text{CO}_2(\text{aq})]} = 7.9 \times 10^{-7} \text{ mol dm}^{-3}$$

(i) A saturated solution of CO_2 at 298 K has a concentration of $3.3 \times 10^{-2} \text{ mol dm}^{-3}$.

Calculate the pH of this solution.

pH = ----- [2]

(ii) Calculate the concentration of a solution of HC/ that has the same pH as the solution in (i).

concentration = ----- mol dm^{-3} [1]

(c)

- (i) The pH of healthy human blood is 7.4.

Calculate the ratio of $\frac{[\text{HCO}_3^-]}{[\text{CO}_2]}$ in healthy human blood.

$$\frac{[\text{HCO}_3^-]}{[\text{CO}_2]} = \text{.....} \quad [2]$$

- (ii) A patient's blood has a pH below 7.4. A student says that HCO_3^- needs to be added to the patient's blood.

Say, with reasons, whether the student is correct.

.....

.....

.....

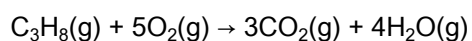
..... [2]

(d) Some students mix 20 cm³ of 5.0 × 10⁻³ mol dm⁻³ HCl with 20 cm³ of 1.0 × 10⁻² mol dm⁻³ NaOH.

Calculate the pH of the resulting solution.

pH = ----- [3]

38 Entropy values for the combustion of propane are shown below.



Substance	Entropy / J K ⁻¹ mol ⁻¹
C ₃ H ₈ (g)	+269.9
O ₂ (g)	+205.0
CO ₂ (g)	+213.6
H ₂ O(g)	+188.7

What is the entropy change for the combustion of propane?

- A -829.6
- B -72.6
- C +100.7
- D +1125.7

Your answer

[1]

39 A vinegar contains 5.0 g of ethanoic acid in each 100 cm³ of solution and no other acids.

What is the pH of this vinegar?

For ethanoic acid $K_a = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$, $M_r = 60$

A 2.42

B 2.92

C 5.85

D 6.73

Your answer

[1]

40 Which statement about the greenhouse effect is correct?

A UV radiation from the Sun increases the vibrational energy of greenhouse gases.

B The Earth absorbs UV radiation and emits IR radiation.

C Greenhouse gases absorb UV radiation from the Earth.

D All gases in the atmosphere contribute to the greenhouse effect.

Your answer

[1]

41 The solubility product of magnesium hydroxide, $\text{Mg}(\text{OH})_2$, is $2.00 \times 10^{-11} \text{ mol}^3 \text{ dm}^{-9}$.

What is the solubility of magnesium hydroxide, in mol dm^{-3} ?

A 3.16×10^{-6}

B 4.47×10^{-6}

C 1.71×10^{-4}

D 2.71×10^{-4}

Your answer

[1]

42(a) A group of students are investigating the properties of weak acids and buffer solutions.

They take measurements of the pH of some solutions before and after adding an equal volume of 0.01 mol dm^{-3} sodium hydroxide solution.

Some of the students' results are shown in the table below.

Experiment	Original solution	pH before addition	pH after addition
A	0.01 mol dm^{-3} ethanoic acid	3.4	8.2
B	0.1 mol dm^{-3} ethanoic acid plus an equal volume of 0.1 mol dm^{-3} sodium ethanoate	4.8	4.9
C	0.1 mol dm^{-3} sodium ethanoate	8.9	11.7
D	Distilled water	7.0	

The solution in experiment B is behaving as a buffer solution.

Explain the meaning of the term **buffer solution**.

[2]

(b) K_a for ethanoic acid is $1.7 \times 10^{-5} \text{ mol dm}^{-3}$.

Show by calculation that the initial pH in experiment B is 4.8.

[2]

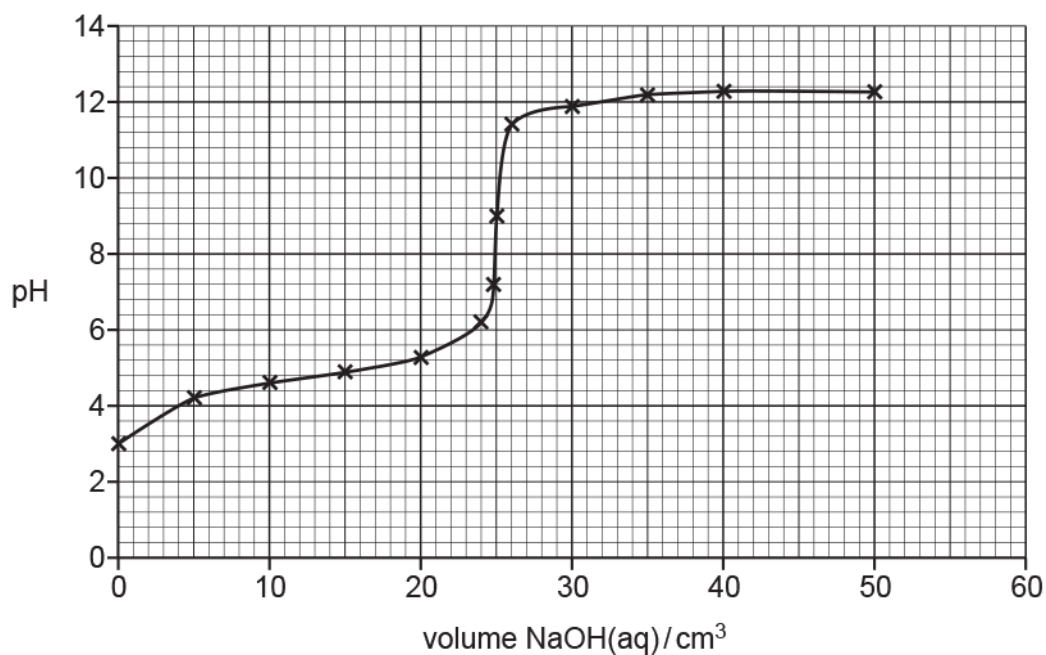
- (c) Explain why the pH of sodium ethanoate in experiment C is alkaline.
Include an equation in your answer.

----- [2]

- (d) Calculate the pH of the solution formed after the addition of sodium hydroxide solution in experiment D.

pH = ...[3]

- (e) In a follow-up experiment, 25.0 cm^3 of the ethanoic acid solution is titrated with a solution of sodium hydroxide of unknown concentration and the following graph is obtained.



Suggest a suitable practical procedure that would enable this graph to be obtained.

[3]

- (i) Write the equation for the equilibrium that occurs between solid strontium hydroxide and its ions in solution.

Use your equation to write the expression for the solubility product of strontium hydroxide.

Equation with state symbols:

$K_{sp} =$

[2]

- (ii) At 0 °C, the solubility of strontium hydroxide in water is $3.4 \times 10^{-2} \text{ mol dm}^{-3}$.

Calculate the solubility product of strontium hydroxide at this temperature.

Give the units in your answer.

solubility product = ... units[3]

- (iii) Explain how the solubility of strontium hydroxide in aqueous NaOH at 0 °C compares with $3.4 \times 10^{-2} \text{ mol dm}^{-3}$.

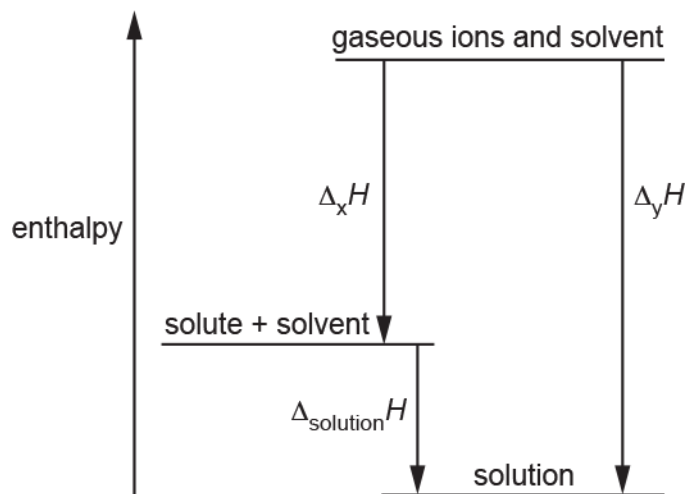
Use the idea of solubility product in your answer.

-----[2]

44(a) A student is investigating the properties of some s-block metals and their compounds.

Some Group 2 salts are soluble in water.

The enthalpy cycle below shows the key enthalpy changes involved in dissolving ionic solids in water.



Name the enthalpy change(s) represented by $\Delta_x H$ and $\Delta_y H$.

$\Delta_x H$

$\Delta_y H$

[2]

- (b) The enthalpy change of hydration is less negative for barium ions than for calcium ions.

Student **A** says this is because barium is more reactive than calcium.

Student **B** says it is due to the differences between Ca^{2+} and Ba^{2+} ions.

Comment on the students' statements giving the correct chemistry.

[4]

- 45 What causes an enhanced greenhouse effect?

- A Less ozone in the ozone layer
- B Less UV from the Sun
- C More methane in the troposphere
- D More ozone in the troposphere

Your answer

[1]

- 46 What is the pH of a $0.005 \text{ mol dm}^{-3}$ solution of NaOH?

- A 1.3
- B 2.3
- C 11.7
- D 12.7

Your answer

[1]

47 Mg^{2+} has a higher charge density than Ca^{2+} .

Which statement is correct?

- A MgCO_3 is more thermally stable than CaCO_3 .
- B The Mg^{2+} ion has a less exothermic enthalpy change of hydration than that of Ca^{2+} .
- C The ionic radius of Mg^{2+} is greater than that of Ca^{2+} .
- D The lattice enthalpy of MgCl_2 is more exothermic than that of CaCl_2 .

Your answer

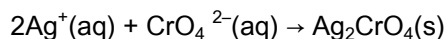
[1]

48 Some students want to find the concentration of chloride ions in seawater. They look up a method in a textbook.

They dilute the seawater and then titrate with standard silver nitrate, AgNO_3 , solution.

1.0 cm^3 0.25 mol dm^{-3} potassium chromate(VI), K_2CrO_4 , is added as an indicator.

At the end-point, all the silver chloride has been precipitated in the 52.5 cm^3 solution. A slight excess of silver ions causes a red-brown precipitate of silver chromate(VI) to form.



(i) The solubility product of silver chloride is:

$$K_{\text{sp}} = 2.0 \times 10^{-10} \text{ mol}^2\text{dm}^{-6}$$

Use this value to explain why $[\text{Ag}^+] = 1.41 \times 10^{-5} \text{ mol dm}^{-3}$ at the end-point.

----- [2]

(ii) The solubility product of silver chromate(VI) is:

$$K_{\text{sp}} = [\text{Ag}^+]^2 [\text{CrO}_4^{2-}] = 3.0 \times 10^{-12} \text{ mol}^3\text{dm}^{-9}$$

Perform a calculation to show whether a precipitate of silver chromate(VI) would form before all the Cl^- ions have reacted with the Ag^+ ions.

[3]

(i) Name the shape of a satraplatin molecule around the Pt atom.

-----[1]

(ii) Give the co-ordination number of Pt in satraplatin.

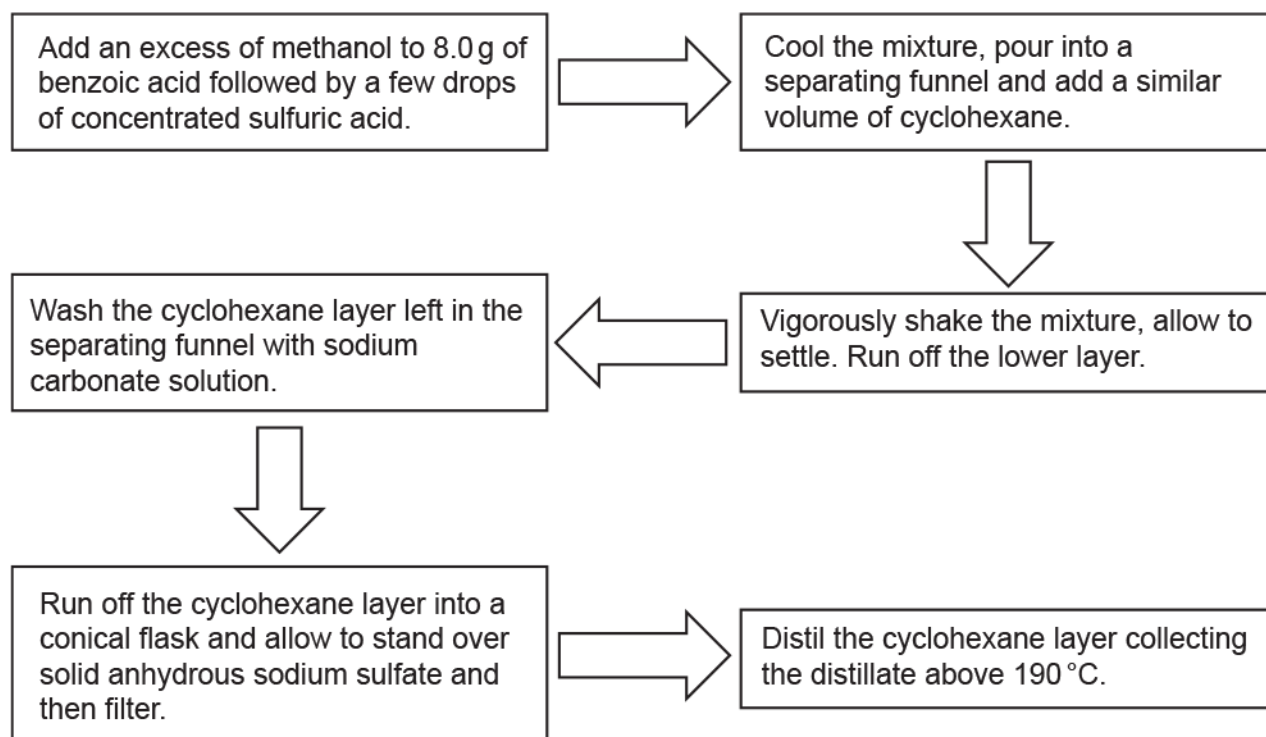
-----[1]

(iii) Suggest, in terms of intermolecular bonds, why satraplatin is soluble whereas cisplatin is not.

-----[3]

50(a) Methyl benzoate is a liquid at room temperature and has a boiling point of 200 °C.

The steps in a procedure for preparing and purifying the simple ester, methyl benzoate, are shown in the flow chart.



Give the reasons for the following experimental procedures in the flow chart:

(i) adding cyclohexane

----- [1]

(ii) adding sodium carbonate solution

----- [1]

(iii) standing the cyclohexane layer over solid anhydrous sodium sulfate

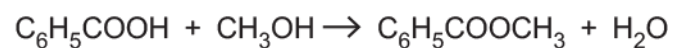
----- [1]

(iv) collecting the distillate above 190 °C

----- [1]

(b) A student followed the procedure in the flow chart and obtained 5.46 g of methyl benzoate.

The equation for the preparation is:



benzoic acid methanol methyl benzoate

Calculate the percentage yield of methyl benzoate.

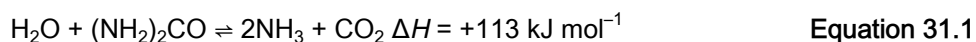
Give your answer to an **appropriate** number of significant figures.

percentage yield = ... % [4]

51(a) There is a high air concentration in the air-fuel mix of diesel engines. This makes the formation of oxides of nitrogen more likely.

Urea, $(\text{NH}_2)_2\text{CO}$, is used in the exhaust system to remove oxides of nitrogen.

The urea reacts in the exhaust system as shown in **equation 31.1**.



(i) The forward reaction in **equation 31.1** is only feasible above a certain temperature.

Use the entropy values in the table to calculate this temperature.

Substance	Entropy, $\text{S/J mol}^{-1} \text{K}^{-1}$
H_2O	+ 69.9
$(\text{NH}_2)_2\text{CO}$	+ 173.9
NH_3	+ 192.3
CO_2	+ 213.6

temperature = ... K [3]

(ii) **Equation 31.1** is repeated again below.



The ammonia produced in **equation 31.1** reacts with oxygen and NO in the presence of a catalyst. Water and nitrogen are formed.

Construct the equation for this reaction.

- (b) It has been stated that cars cause the most pollution on short journeys.

Evaluate this statement in terms of the rate and equilibrium position of the reaction shown in **equation 31.1**.

[4]

52(a) 'Monopotassium phosphate', KH_2PO_4 , is added to fertilisers.

KH_2PO_4 acts as a buffer and supplies phosphorus.

The H_2PO_4^- ion has two OH groups.

Draw a 'dot-and-cross' diagram for this ion.

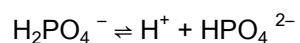
[2]

(b) KH_2PO_4 when used in fertilisers is said to be equivalent to 52% P_2O_5 and 34% K_2O by mass.

Show that the mole ratio of potassium to phosphorus in 52% P_2O_5 and 34% K_2O is the same as in KH_2PO_4 .

[2]

(c) In a solution of KH_2PO_4 , the equilibrium in **equation 3.1** occurs:



$$K_a = 6.2 \times 10^{-8} \text{ mol dm}^{-3}$$

Equation 3.1

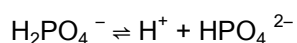
(i) Identify the base in this reaction and explain your choice.

----- [1]

(ii) Calculate the $\text{p}K_a$ for the equilibrium in **equation 3.1**.

$\text{p}K_a = \dots\dots\dots$ [1]

Equation 3.1 is repeated again.



$$K_a = 6.2 \times 10^{-8} \text{ mol dm}^{-3}$$

Equation 3.1

(iii) Calculate the pH of a $1.0 \times 10^{-3} \text{ mol dm}^{-3}$ solution of KH_2PO_4 .

$\text{pH} = \dots\dots\dots$ [2]

(d) The acidity of KH_2PO_4 reduces the loss of ammonia from ammonium ions (NH_4^+) in a fertiliser.

Explain how this happens when the fertiliser is in solution.

----- [2]

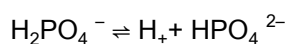
(e) A mixture of HPO_4^{2-} and H_2PO_4^- ions in solution makes a 'phosphate buffer'.

Calculate the mass of KH_2PO_4 that must be added to 1.0 dm^3 of a 0.10 mol dm^{-3} solution of HPO_4^{2-} to make a solution with a pH of 6.50.

The volume of the solution does not change when the solid is added.

mass of KH_2PO_4 = ... g [4]

Equation 3.1 is repeated again.



$$K_a = 6.2 \times 10^{-8} \text{ mol dm}^{-3}$$

Equation 3.1

(f)

- (i) A student says that a solution of HPO_4^{2-} alone will act as a buffer when acid is added.
The student says that this is because the position of equilibrium in **equation 3.1** moves to the left to remove H^+ ions.

Discuss the student's statements.

----- [2]

- (ii) A student is doing calculations involving solutions of hydrochloric acid.

The student says that the concentration of hydrogen ions can be taken as the concentration of the acid.

Discuss this statement.

----- [1]

- (iii) Calculate the **change** in pH when 1 drop (0.05 cm^3) of $0.01 \text{ mol dm}^{-3} \text{ HCl}$ is added to 1.0 dm^3 of water at pH 7.0.

pH change = ... [2]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a		temp: increased yield / more products ✓ forward reaction [stated or implied] is endothermic (ora) ✓ pressure: no effect on yield AW ✓ same number of (gaseous) moles / molecules on each side (of equation) AW✓	4	ALLOW 'it increases' IGNORE 'equilibrium (position) moves to right' QWC: endothermic (or exothermic for ora) must be used and spelled correctly to score second mark ALLOW 'no effect on position of equilibrium' ALLOW 'no change of yield' / 'no increase of yield' NOT 'little effect on yield' etc No ecf but mark separately within each pair. Examiner's Comments This was a nice gentle start. Most candidates realised that temperature increased the yield and that pressure had no effect and were able to explain these in terms of the endothermic reaction and the same number of moles on each side.
	b		speeds up achievement of equilibrium OR speeds up both (forward and back) reactions ✓ no effect on K_c (AW) ✓	2	Can score this alternative for the first marking point while explaining effect on K_c Examiner's Comments Most candidates knew that a catalyst had no effect on K_c and some were able to extend their knowledge that catalysts speed up reactions to say that equilibrium would be reached faster.

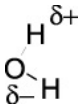
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		$(K_c = [\text{H}_2\text{O}] [\text{CO}] / [\text{H}_2] [\text{CO}_2])$ 1. $[\text{H}_2\text{O}] [\text{CO}] = 2.68496 \times 10^{-12}$ (3 or more sf) ✓ 2. either concentration = $1.63858 \dots \times 10^{-6}$ (2 or more sf) ✓ 3. both concentrations to 3 sf (1.64×10^{-6}) ✓ 4. concentrations equal ✓	4	award 1. if later answers correct 3. award for any numbers to 3sf 1.64×10^{-6} twice on the answer lines scores 4 marks without reference to working. Examiner's Comments This calculation was often done well, especially if candidates wrote out their method carefully. The main error was halving the product of the H_2O and CO concentrations, rather than taking the square root.
	d	i	the sun OR burning CO ✓	1	ALLOW 'uv' Examiner's Comments Some candidates were able to envisage the situation on Mars and suggest the Sun, rather than burning fossil fuels, the commonest wrong answer.
		ii	oxygen (is formed) ✓	1	any mention of oxygen that makes sense IGNORE references to CO_2 and / or hydrogen Examiner's Comments Again, some candidates realised that oxygen was also produced, though many talked about hydrogen removing carbon dioxide.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e	i	+42 ✓	1	plus sign essential Examiner's Comments Most candidates correctly gave +42 as the answer and the commonest error was omitting the plus sign.
		ii	1. $42 = 40000/T$ ✓ 2. $T = 950$ ✓ 3. K / Kelvin ✓	3	ALLOW ecf from a positive (or no sign) value from (i) for 1. and 2. ($T = 40000/\text{ans to (i)}$). award both marks 1. and 2. if correct answer for T given ALLOW two sf up to calculator value (952.38...)(correctly rounded) 0.95/0.95238 etc scores 1 mark for 2. (but not 1.) no other ecf from 1. to 2. 3. mark separately • ALLOW 'k' • IGNORE + sign for temperature (– is CON) • NOT degree sign before K Examiner's Comments There was a good success rate on this question and most candidates realised that the enthalpy change was in kJ.
		iii	equilibrium const / $K_c = 1$ OR reaction (equally) balanced / in the middle OR no tendency to go in either direction AW ✓	1	ALLOW rate of forward reaction = rate of back reaction Examiner's Comments Only a few realised that the equilibrium was exactly balanced at this point.
			Total	17	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
2	a	i	  (one of these needed for second mark)   (three of either of these acceptable for first mark) At least three water molecules around ion (can be shown as  or Δ with points towards ion) ✓ correct formula for at least one water molecule, with bent shapes, $\delta+$ on at least one hydrogen, $\delta-$ on at least one oxygen, with oxygen pointing towards ion ✓ ion-(permanent) dipole ✓	3	Mark separately detail of water molecule can be shown as separate diagram. Ignore wrong water molecules ALLOW 'ion dipole' (no hyphen) Examiner's Comments Many could draw this diagram correctly and name 'ion-dipole' bonds. There were some omissions in labelling the water molecules and some did not know the name of the bonds.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	1. $2\text{NH}_4^+(\text{g}) + \text{SO}_4^{2-}(\text{g})$ ✓ 2. enthalpy (change) of hydration of ions ✓ 3. $2\text{NH}_4^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) / (\text{NH}_4)_2\text{SO}_4(\text{aq})$ ✓ 5. $(\text{NH}_4)_2\text{SO}_4(\text{s})$ ✓ 4. enthalpy (change) of solution ✓ State symbols must be shown correctly	5	Scale is not important Mark separately, but... ALLOW ecf between 1. and 3. if wrong species or numbers shown consistently in both ALLOW missing '+' sign between ions in 1. and 3. 2. ALLOW 'solvation' for 'hydration' ALLOW $\Delta H_{\text{hyd}(\text{ration})}$ for 'enthalpy (change) of hydration' (or $\Delta H_{\text{solv}(\text{ation})}$) It must be clear that both ions are referred to and arrow must be present. ALLOW 'enthalpy(change) of hydration of cation(s)* + (enthalpy (change) of hydration of) anion*' *ALLOW if a cation and an anion are shown using wrong formulae 4. To award mark for 'enthalpy (change) of solution', it must be endothermic and upward arrow must be shown ALLOW ΔH_{sol} / $\Delta H_{\text{solution}}$ Examiner's Comments This was a test of understanding, which many had, and also of careful attention to detail. Some were able to label the lines correctly, to describe the enthalpy change of hydration of both ions and label an endothermic enthalpy change of solution. There were many pitfalls; just talking about 'hydration enthalpy' was the most common, but omitting the '2' before the sign in SO_4^{2-} or failing to show two ammonium ions were also quite common.
	b	i	$\text{NH}_4^+ \rightleftharpoons \text{NH}_3 + \text{H}^+$ acid base ✓	1	IGNORE 'conjugate' Examiner's Comments Most candidates had no trouble here but there were some who labelled the H^+ as the acid.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$\frac{[\text{NH}_3][\text{H}^+]}{[\text{NH}_4^+]} \checkmark$	1	ALLOW multiplication signs State symbols not required, but any other than 'aq' [ignore absence of brackets] are CON. Examiner's Comments Most candidates were correct here.
		iii	$[\text{H}^+](\text{or } \text{H}^+) = 7.4(13102\dots) \times 10^{-6} \checkmark$ $K_a (= (7.41 \times 10^{-6})^2 / 0.1) = 5.5 \times 10^{-10} \checkmark$ $\text{mol dm}^{-3} \checkmark$	3	ALLOW 2 or more sf for first marking point. first mark is automatically scored if correct answer is given to K_a value ALLOW ecf from first marking point, provided 'H⁺ =' or '[H⁺] =' is shown and [H⁺] is smaller than 1×10^{-4} ALLOW any answer rounding to 5.5×10^{-10} mark last marking point separately Examiner's Comments Again, most could do this, though some had trouble with the powers of ten.
		iv	$K_a \times K_b = K_w \text{ OR } K_b = K_w / K_a \checkmark$ $K_b = 1.0 \times 10^{-14} / (\text{answer to (c)(iii)})$ calculated $(1.8 \times 10^{-5} \text{ if (c)(iii) correct}) \checkmark$	2	ALLOW expressions with numbers substituted correct answer (with ecf from (c)(iii)) scores 2 without reference to working no ecf from first marking point ALLOW any answer rounding to 1.8×10^{-5} Examiner's Comments This was a harder question but some managed to realise the relationship between K_a, K_b and K_w and solve the problem.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		H^+ added / more H^+ ✓ equilibrium position moves to left ✓ large concentration / large amount of A^- ✓ pH remains (virtually) unchanged / resists change in pH ✓	4	IGNORE 'acid added' ALLOW change in A^- concentration is very small compared to the initial A^- concentration IGNORE 'large concentration of HA' Examiner's Comments This is a frequently-asked question, so accuracy of expression was required to score the marks. Most managed to state that adding acid meant more H_+ ions, which moved the position of equilibrium to the left. The large concentration of A_- meant that the pH was hardly affected. Most scored the last part and each of the first three marks were lost about equally.
			Total	19	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3	a		CO₂ covalent ✓ CaO giant ionic ✓	2	IGNORE 'molecular', small molecules, etc but any suggestion of a giant structure is CON The words 'giant' and 'ionic' must be there, but other correct chemical words (eg 'lattice' can be ignored) If compounds are not identified, assume order of answers is that of question. Examiner's Comments Most knew that the bonding was covalent in CO₂ and ionic in CaO. Fewer realised that the crucial term for the structure of CaO was 'giant'.
	b	i	+161	1	plus sign must be present
		ii	$\Delta S_{\text{tot}} = 161 - 180000/298$ ✓ = - 443 ✓	2	<i>Award the following without consulting working:</i> 2 marks for -443 (to 3 or more sf) 1 mark for +160(.395...) (failure to multiply by 1000) 1 mark for +765 (not 765) (adding not subtracting) ALLOW ecf from 1bi NB Zone for (i) is shown above answer

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$T (= 180000/161) = 1118 \text{ K} \checkmark$ (Temperature) above which / at which reaction is feasible ora AW OR temperature at which the system / reaction is at equilibrium $\checkmark$	2	ALLOW ecf on 161 from 1(b)(i) and on non-use of 1000 from (b)(ii) (i.e. 1.1 K scores the first mark if (+)160 given in 1 (b)(ii)) IGNORE + sign. ALLOW 2 or more sig figs ALLOW 'spontaneous' or 'favourable' or 'viable' or 'occurs' etc for 'feasible' ALLOW $K_c = 1$ Mark separately NB the zones for (i) and (ii) are shown below answer. Examiner's Comments The calculations, were often correct. The need to convert from kJ to Joules was usually understood. Some still have difficulty realising that signs are needed for positive entropy values. There were many good comments on the significance of the temperature where ΔS_{tot} is zero.
	c		$\text{Ca}^{2+}(\text{g}) \text{ (+) } \text{CO}_3^{2-}(\text{g}) \checkmark$ $\text{CaCO}_3(\text{s}) \checkmark$ $\text{Ca}^{2+}(\text{aq}) \text{ (+) } \text{CO}_3^{2-}(\text{aq}) / \text{CaCO}_3(\text{aq}) \checkmark$ $\Delta H_{\text{hyd}} \text{CO}_3^{2-}(\text{aq}) = - (2800 + 12 - 1650) = -1162 \checkmark$	4	ALLOW ecf on bottom line from wrong charges on top line IGNORE arrows between levels mark is for final answer (with sign) not working Examiner's Comments Was often well done with relatively few technical errors. The commonest mistake in the calculation was to use the wrong sign for the enthalpy change of solution.
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a	i	$\text{C}_4\text{H}_8\text{O}_2 (\text{aq}) \rightleftharpoons \text{C}_4\text{H}_7\text{O}_2^- (\text{aq}) + \text{H}^+ (\text{aq})$ ✓	1	State symbols required ALLOW $\text{H}_2\text{O} + \text{C}_4\text{H}_8\text{O}_2 \rightleftharpoons \text{C}_4\text{H}_7\text{O}_2^- + \text{H}_3\text{O}^+$ ALLOW $\text{C}_3\text{H}_7\text{COO}^-$ or $\text{C}_3\text{H}_7\text{CO}_2^-$ for $\text{C}_4\text{H}_7\text{O}_2^-$ Examiner's Comments There were again a lot of correct answers but the commonest error was to omit the state symbols (needed to 'complete the equation' since a state symbol was given for the acid).
		ii	Weak acid / incompletely ionised / incompletely dissociated ✓	1	Examiner's Comments Was usually correct but.
		iii	No / not enough... H^+ / H_3O^+ ions / protons ✓ (H^+) react (with carbonate) ✓	2	ALLOW 'needs water to ionise' for first mark Second mark depends on first Examiner's Comments Caused more problems and the crucial idea of lack of H^+ ions was often missing.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	1. (added) H^+ / acid... ...reacts with (AW) $\text{C}_4\text{H}_7\text{O}_2^-$ OR moves equilibrium to left and forms acid ✓ 2. (added) OH^- / alkali / (sodium)hydroxide... ...reacts with (AW) $\text{C}_4\text{H}_8\text{O}_2$ / H^+ OR moves equilibrium to right to replace H^+ / butanoic acid dissociates / ionises ✓ 3. $\text{C}_4\text{H}_7\text{O}_2^-$ (concentration) and $\text{C}_4\text{H}_8\text{O}_2$ (concentration) large / reservoir / in excess AW ✓ 4. pH does not change (much) ✓	4	ALLOW A^- or 'salt' or 'anion' or 'butanoate' or '(conjugate) base' or ecf from (i) [*] for $\text{C}_4\text{H}_7\text{O}_2^-$ throughout ALLOW HA or '(butanoic) acid' or ecf from (i) [*] for $\text{C}_4\text{H}_8\text{O}_2$ throughout IGNORE 'base' for 'alkali' (added) References to large amounts / reserves of H^+ or OH^- are CON [*]NB the zone for (i) is given below the answer if needed. Examiner's Comments Candidates had to realise that the question was slightly different from previous buffer questions in that the <i>particles</i> involved needed to be discussed. Hence the movement of the equilibrium alone was insufficient to score and expressions like 'added H^+ moves the equilibrium to the left and forms the acid' were required. Many candidates mentioned that a large concentration of salt was required but fewer mentioned a large concentration of acid also being necessary. Almost all scored for saying that the pH did not change much when small amounts of acid or alkali were added.
	b	i	$[\text{H}^+] = (\sqrt{1.51 \times 10^{-5} \times 0.02}) = 5.5(0) \times 10^{-4}$ ✓ pH = 3.26 ✓	2	Any pH value rounding to 3.3 scores 2 ALLOW ecf for second mark if $[\text{H}^+] < 0.02$ To score either mark alone, first mark must include '$[\text{H}^+] =$' or '$\text{H}^+ =$' Examiner's Comments Was usually correct but.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	1. calculation of $[\text{OH}^-]$ $[\text{OH}^-] = 5 \times 0.02/55 = 1.82 \times 10^{-3}$ ✓ 2. calculation of $[\text{H}^+]$ from $[\text{OH}^-]$ $[\text{H}^+] = 1 \times 10^{-14} / \text{'calculated } [\text{OH}^-]\text{'}$ eg $1 \times 10^{-14} / 1.82 \times 10^{-3} = 5.49 \times 10^{-12}$ ✓ 3. calculation of pH from $[\text{H}^+]$ pH = 11.3 ✓	3	Allow the following answers (to 1dp) without reference to working: 3 marks: 11.3 2 marks: 12.0 (just dilution of NaOH) 2 marks: 12.3 (pH of 0.02M NaOH) Either working or values score first two marks ALLOW ecf for second mark provided $[\text{OH}^-] / \text{OH}^- = \text{'shown } \mathbf{ALLOW}$ ecf for third mark if $[\text{H}^+] / \text{H}^+ = \text{'}$ shown and value is $< 1 \times 10^{-10}$ Examiner's Comments Was seldom so. Candidates had to realise that much of the OH^- was used up <i>and it was also diluted</i>. Marks were given for error carried forward wherever possible, but the layout of many answers made it impossible to see where the mistakes had been made.
			Total	13	
5			B	1	
			Total	1	
6			D	1	
			Total	1	
7			A	1	
			Total	1	
8			A	1	
			Total	1	
9			D	1	
			Total	1	

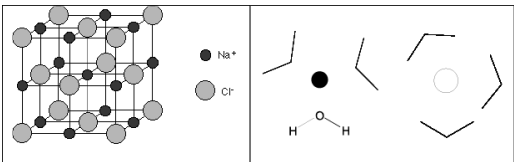
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10	a	i	$K_{sp} = [Na^+(aq)] \times [L^-(aq)]$ ✓	1	State symbols required ALLOW $K_{sp} = [Na^+(aq)] [L^-(aq)]$
		ii	$[Na^+]$ increases but K_{sp} remains constant ✓ so NaL precipitates to make $[L^-]$ smaller / to move equilibrium left ✓	2	
		iii	FIRST CHECK ANSWER ON ANSWER LINE minimum mass of NaC/ = 34.2 g award 4 marks Solubility of F = $24.0/222 = 0.108 \text{ mol dm}^{-3}$ $K_{sp} = (\text{solubility})^2 = 0.0117$ ✓ $0.0117 = [Na^+(aq)] \times 1.0 \times 10^{-2}$ ✓ [NaC/] to exceed $K_{sp} = 0.0117 / 1.0 \times 10^{-2}$ = $1.17 \text{ (mol dm}^{-3})$ ✓ Min mass of NaC/ to add to 500 cm^3 to form ppt of F = $(1.17/2) \times 58.5 = 34.2 \text{ g}$ ✓ Assumption: volume of solution does not change when NaC/ added ✓	5	IGNORE units

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		FIRST CHECK ANSWER ON ANSWER LINE Answer = 22.5 g award 4 marks $[H^+] = 10^{-4.8} = 1.585 \times 10^{-5} \text{ mol dm}^{-3} \checkmark$ $K_a = \frac{[H^+][\text{salt}]}{[\text{acid}]} \text{ AND } \frac{[\text{salt}]}{[\text{acid}]} = \frac{K_a}{[H^+]} \checkmark$ $= \frac{1.74 \times 10^{-5}}{1.585 \times 10^{-5}} = 1.0979 \checkmark$ Therefore amount of ethanoate required $= 1.0979 \times n(\text{ethanoic acid})$ $= 1.0979 \times 0.250 = 0.274 \text{ (mol)}$ $0.274 \times 82.0 = 22.5 \text{ (g)} \checkmark$	4	ALLOW ECF from first marking point ALLOW ECF from third marking point
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
11	a	i	Place known volume / mass of water in a (polystyrene) beaker ✓ Weigh out (a suitable / calculated mass) / add a known mass of ammonium nitrate and add to water with stirring ✓ Measure temperature of water before and after ✓	3	
		ii	$(100/17) = 6(\%)$ ✓	1	ALLOW any sf rounding to 6
	b		$\text{NH}_4^+(\text{g}) + \text{NO}_3^-(\text{g})$ ✓ $\text{NH}_4^+(\text{aq}) + \text{NO}_3^-(\text{aq})/\text{NH}_4\text{NO}_3(\text{aq})$ ✓ $\text{NH}_4\text{NO}_3(\text{s})$ ✓ $\Delta_{\text{hydration}} H \text{NO}_3^- (= 25 - (645 + ^-307) =) - 313$ ✓	4	IGNORE axes and labels line must be above the $\text{NH}_4\text{NO}_3(\text{s})$ line to score this mark must have negative sign to score
	c		More exothermic / more negative ✓ C/ smaller / greater charge density ✓ more strongly attracted to the ammonium ion ✓	3	Not just 'larger'
	d	i	 Each ion surrounded by at least 3 water molecules (minimum as shown) ✓ one with O and H labelled and correct atoms pointing to correct ion ✓	2	Dipoles not required but, if they are wrong they are CON to second mark
		ii	Bonds broken: ionic bonds AND hydrogen bonds ✓ Bonds made: ion dipole bonds ✓	2	NOT ionic dipole
			Total	15	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
12	a		-SO_3^- groups (formed by dissociation of NaSO_3) ✓ form ion-dipole bonds with water ✓ energy released by bond formation greater than required for bonds broken (AW) ✓ (these are) hydrogen bonds between water molecules OR ionic bonds between ions ✓	4	
	b	i	FIRST CHECK THE ANSWER ON THE ANSWER LINE rate = 4.35×10^{-5} award 2 marks rate = 4.35×10^{-5} AND units = s^{-1} award 3 marks rate doubles with concentration so reaction 1st order to $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$ rate = $k[\text{C}_6\text{H}_5\text{N}_2\text{Cl}]$ ✓ $k = \text{rate} / [\text{C}_6\text{H}_5\text{N}_2\text{Cl}] = 4.35 \times 10^{-5} \text{ s}^{-1}$ ✓	3	Answer can be calculated using either data set.
		ii	only know concentration at start / initial concentration ✓ (therefore) collecting larger volumes would not give initial rate ✓	2	IGNORE references to actual percentages
		iii	FIRST CHECK THE ANSWER ON THE ANSWER LINE pH = 1.68 (2 d.p.) award 2 marks $n(\text{N}_2) = 0.050 / 24.0 = 0.00208 \text{ mol}$ concentration $\text{HCl} = 0.00208 \times 10 = 0.0208 \text{ mol dm}^{-3}$ ✓ pH = 1.68 (2 d.p.) ✓	2	
		iv	One from ✓ (Measure) loss of mass Titrate HCl	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		v	two missing values: 3.36×10^{-3} and -8.52 ✓ axes drawn, labels correct x-axis: $1/T / K^{-1}$ y-axis: $\ln k$ scales that use over half of each axis ✓ all points plotted correctly with best straight line drawn through points ✓ measurement of slope ($1.33 \pm 0.05 \times 10^4$) ✓ multiplication by 8.314, division by 10^3 and change of sign to give E_a in kJ units [$+111 \text{ (kJ mol}^{-1}\text{)}$] ✓	5	units of $1/T$ can be missing ALLOW no sign but not minus sign for last mark ALLOW 2 or more sig figs ALLOW any answer rounding to 106–115 (calculated correctly from slope)
			Total	17	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13	a	i	$\text{CO}_2 + \text{Ca(OH)}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$ ✓	1	IGNORE state symbols
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE mass = 0.0625 award 1 mark mass = 0.063 g to 2 sig figs award 2 marks moles $\text{CO}_2 = 15/24000$ OR 6.25×10^{-4} ✓ mass $\text{CaCO}_3 = (6.25 \times 10^{-4} \times 100) = 0.063$ g to 2 sig figs ✓	2	ALLOW ECF from first marking point
	b	i	$\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{OH}^-$ OR $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + 2\text{OH}^-$ ✓	1	ALLOW equilibrium signs IGNORE state symbols
		ii	CaCO_3 is less soluble / weaker base than Ca(OH)_2 ✓ so fewer OH^- (aq) ions are present (as Ca(OH)_2 reacts / CaCO_3 forms) ✓	2	
	c	i	FIRST CHECK THE ANSWER ON THE ANSWER LINE pH = 11.6 award 3 marks $[\text{OH}^-] = 2 \times 0.002 = 0.004 \text{ (mol dm}^{-3}\text{)}$ ✓ $[\text{H}^+] = (1 \times 10^{-14} / 4 \times 10^{-3}) = 2.5 \times 10^{-12} \text{ (mol dm}^{-3}\text{)}$ ✓ pH = 11.6 ✓	3	ALLOW ECF on third marking point from a given $[\text{H}^+]$, provided pH is between 10 and 13
		ii	$[\text{H}^+] = 2.1 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ ✓ pH = 4.7 ✓	2	
		iii	contribution of $[\text{H}^+]$ from water ✓ 1×10^{-7} insignificant compared to (AW) 2×10^{-5} ✓	2	
	d	i	(normal) pink; (after carbonatation) colourless ✓	1	both answers required for mark
		ii	CO_2 from air is reacting with water to form H^+ ✓ turning (the structure of phenolphthalein) from E to D ✓	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	16	
14	a	i	$\text{NH}_4^+ \rightleftharpoons \text{NH}_3 + \text{H}^+$ acid base	1	IGNORE 'conjugate'
		ii	$[\text{NH}_3][\text{H}^+] / [\text{NH}_4^+]$	1	ALLOW dot or multiplication sign on top IGNORE correct state symbols. Incorrect ones are CON
		iii	FIRST CHECK ANSWER ON ANSWER LINE IF $K_a = 5.5 \times 10^{-10} \text{ mol dm}^{-3}$ award 3 marks IF $K_a = 5.5 \times 10^{-10}$ with incorrect or missing units, award 2 marks $[\text{H}^+]$ (or $\text{H}^+ = 7.4(13102) \times 10^{-6}$ ✓ $K_a = (7.41 \times 10^{-6})^2 / 0.1 = 5.5 \times 10^{-10}$ ✓ mol dm^{-3} ✓	3	ALLOW ECF from first marking point, provided ' $[\text{H}^+] =$ ' or ' $\text{H}^+ =$ ' is shown and value is smaller than 1×10^{-4} ALLOW 2 or more sf
		iv	FIRST CHECK ANSWER ON ANSWER LINE IF $K_b = 1.8 \times 10^{-5} (\text{mol dm}^{-3})$ award 2 marks $K_a \times K_b = K_w$ OR $K_b = K_w / K_a$ ✓ $K_b (= 1.0 \times 10^{-14} / 5.5 \times 10^{-10}) = 1.8 \times 10^{-5} (\text{mol dm}^{-3})$ ✓	2	ALLOW ECF from (iii) ALLOW 2 or more sf
	b	i	FIRST CHECK ANSWER ON ANSWER LINE IF answer = 0.386(g) award 3 marks $[\text{lactate}] = 1.38 \times 10^{-4} \times 0.01 / 1 \times 10^{-4}$ OR 0.0138 ✓ amount lactate = $0.0138 / 4$ OR $3.45 \times 10^{-3} (\text{mol})$ ✓ mass sodium lactate = $(3.45 \times 10^{-3} \times 112 =) 0.386 (\text{g})$ ✓	3	ALLOW 2 or more sf.
		ii	Incorrect, because the ratio of the concentrations will remain the same (whatever the volume)	1	DO NOT ALLOW 'incorrect' without an explanation
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a		$S_{H_2} = (198 + 189 - 214 - 42) = +131 \text{ (J mol}^{-1} \text{ K}^{-1})$ ✓	1	
	b	i	FIRST CHECK ANSWER ON ANSWER LINE IF $\Delta_{tot}S = +10.6 \text{ (J mol}^{-1} \text{ K}^{-1})$ award 2 marks $T = 1273 \text{ K}$ ✓ $\Delta_{tot}S = (42 - 40000/1273) = +10.6 \text{ (J mol}^{-1} \text{ K}^{-1})$ ✓	2	ALLOW two or more sf.(common rounding +11)
		ii	Reaction is feasible ✓ Sign is positive for $\Delta_{tot}S$ ✓	2	ALLOW 'spontaneous' or 'goes' or 'possible'
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16	a	i	2,6-dichloro-3,5-diethylphenol	1	Ignore, commas, dashes and gaps
		ii	greater activity since longer alkyl groups OR less toxic (when taken by mouth) since more substitution	1	must have reason as well as effect to score
		iii	activity decreases since no halogen in 4 position ✓ less soluble since more substituted ✓	2	must have reason as well as effect to score two correct effects alone score 1 mark
	b		(aromatic compounds have) delocalised electrons that are lost on addition AND retained on substitution ✓ (loss of delocalisation causes) less stability AW ✓	2	
	c		-OH hydrogen bonds to N/N-H/O on protein	1	
	d		anion is more stable ✓ overlap of p-orbital on chlorine with delocalised / π electrons of ring ✓	2	Answers can be in either order Idea of negative charge of anion being spread over the delocalised system and Cl side group
	e		(water) hydrogen bonds ✓ (non-polar) instantaneous dipole-induced dipole ✓	2	must be spelled correctly, no abbreviations
	f		FIRST CHECK ANSWER ON ANSWER LINE IF pH = 6.19 award 3 marks conc of PCMX = $0.330/156.6$ OR 2.1073×10^{-3} (mol dm ⁻³) ✓ [H ⁺] = $\sqrt{(1.99 \times 10^{-10} \times 2.1073 \times 10^{-3})}$ OR 6.4757×10^{-7} (mol dm ⁻³) ✓ pH = 6.19 ✓	3	ALLOW ECF from each stage ALLOW 6.2 ALLOW 2 or more sf

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	g		<i>First please read point 10 of the instructions for marking 'Level of Response' mark-schemes on page 4</i> Level 3 (5–6 marks) Learners show comprehension of information from the article to produce a full response containing most of the scientific points. <i>The explanation is relevant and logically structured and contains no errors.</i> Level 2 (3–4 marks) Learners show some comprehension of information from the article to produce a partial response containing some of the scientific points <i>The explanation is generally relevant and logically structured and contains few errors.</i> Level 1 (1–2 marks) Learners show partial comprehension of information from the article to produce a response containing a few of the scientific points <i>A partial explanation is attempted and has some structure.</i> Level 0 (no marks) No response or no response worthy of credit.	6	Indicative scientific points may include Soap • Soap formed by reaction of ricinoleic acid with NaOH • ionic head • (largely) non-polar tail • structure (eg sodium ricinoleate) Solubility • PCMX low solubility in water because only the OH group can form hydrogen bonds • PCMX held in micelles / description of micelles (by soap molecules) ALLOW 'held in pine oil droplets that are made soluble(AW) by soap molecules' as an alternative held by id-id bonds in micelles • ionic heads allow solubility in water / forms hydrogen bonds with the water molecules • equilibrium with free PCMX in water • idea of reservoir
			Total	20	

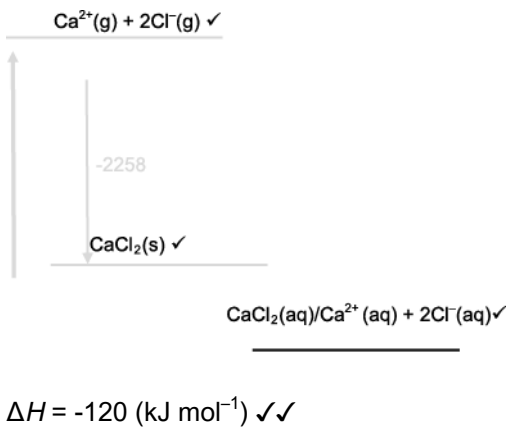
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
17	i <i>* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Develops a safe, fully detailed and accurate method that correctly includes apparatus. The full accurately labelled diagram reflects the method. The accurate observations / measurements recorded allow for a fair and accurate comparison between MgCO_3 and CaCO_3. <i>The method is detailed, clear and logically structured. Accuracy is discussed in terms of the apparatus chosen. Observations / measurements are detailed and allows for a full comparison.</i> Level 2 (3–4 marks) Develops a safe, detailed method that includes relevant apparatus. The diagram reflects this method and is labelled correctly. Details refer to accurate measurements. The observations / measurements recorded allow for a fair comparison between MgCO_3 and CaCO_3. <i>The method is detailed and logical. Relevant apparatus is identified and there is reference to the accuracy of the measurements to be taken. The observations / measurements are relevant and supply evidence to allow a fair comparison.</i> Level 1 (1–2 marks) Develops a basic safe method that includes relevant apparatus either in a correctly labelled diagram or named in the method. Suggests which observation(s) / measurement(s) need to be recorded to allow some comparison between MgCO_3 and CaCO_3. <i>The method is basic and unstructured. Although relevant apparatus is labelled / referred to it lacks detail and accuracy. The observations / measurements are relevant</i>	6	Indicative scientific points may include Method with details - Crush lumps of calcium carbonate to a powder using a pestle and mortar - Add calcium hydroxide to distilled water and filter - Glass test tube / boiling tube to contain the solid fitted with a bung carrying a delivery tube which dips into a solution of calcium hydroxide in a test tube / boiling tube. - Tube is heated and is approximately horizontal, - solid (metal carbonate) and solution (calcium hydroxide) are clearly labelled in diagram. Measurements - Measure time for cloudiness to first appear. - Measure time taken to obscure a cross on paper OR alternative way of measuring relative thickness of ppt (of calcium carbonate) Fair comparison - Equal mass of MgCO_3 and CaCO_3 - Same volume and concentration of calcium hydroxide solution

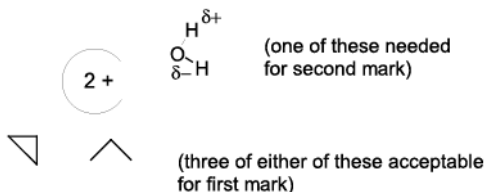
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>but do not supply sufficient evidence to ensure a fair comparison.</i> 0 marks No response or no response worthy of credit.		
		ii	The ratio of charge on ion to its volume ✓	1	ALLOW charge / volume ALLOW size instead of volume
		iii	Magnesium carbonate is less thermally stable than calcium carbonate (because) the smaller magnesium (Mg^{2+}) ion ✓ distorts the (large) carbonate (CO_3^{2-}) ion ✓	2	ORA
		iv	FIRST CHECK THE ANSWER ON THE ANSWER LINE minimum temperature = 674 K award 3 marks $\Delta_{\text{sys}}S = 27 + 214 - 66 = +175 \text{ J mol K}^{-1}$ ✓ Minimum temperature is where $\Delta_{\text{sys}}S = \Delta_{\text{surr}}S$ $- \frac{118000}{T} = 175 \Delta$ $T = 11800 / 175 = 674 \text{ K}$ ✓	3	ALLOW ECF from first marking point Correct unit required for mark. ALLOW 401 °C
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
18	a	i	 $\Delta H = -120 \text{ (kJ mol}^{-1}\text{)} \checkmark\checkmark$	5	allow ecf for omission of '2' on both energy levels IGNORE extra energy level for hydration in two steps ALLOW lack of plus signs between ions solution level need not be below solid level to score 120 scores 1 mark; +120 does not score; +244 (only one hydration of Cl^-) scores 1 mark if solution level is above solid level. Examiner's Comments This was well done with many candidates labelling all the energy levels correctly and working out the correct value for the enthalpy change of solution.
		ii	greater charge (density) (of Ca^{2+}) ✓ stronger attraction/bonds to water molecules (ora for chloride) OR more water molecules attracted OR stronger/more ion-dipole bonds formed ✓	2	Mark separately IGNORE 'hydration' or 'hydrated' Examiner's Comments Most recognised that the crucial factor was the greater charge on the calcium ion. The rest was a matter of careful expression, avoiding imprecise answers like 'more bonds to water'.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		 (one of these needed for second mark) (three of either of these acceptable for first mark) At least three water molecules around ion with 2+ charge (can be shown as  or Δ with points towards ion) ✓ correct formula for at least one water molecule, with bent shapes, $\delta+$ on at least one hydrogen, $\delta-$ on at least one oxygen, with oxygen pointing towards ion ✓	2	ALLOW Ca^{2+} as ion label, circle not necessary Examiner's Comments This question was well done with almost all candidates scoring one mark and most scoring two (for showing the partial polarisations of the atoms in water). The previous error, HO_2 was hardly ever seen.
	c	i	$\text{CaCO}_3 + 2\text{NaCl} \rightarrow \text{Na}_2\text{CO}_3 + \text{CaCl}_2$ ✓✓	2	Unbalanced equation with just these species OR <i>Balanced</i> equation involving CaO, CO_2 instead of CaCO_3 scores 1 mark IGNORE state symbols IGNORE omission of plus signs or arrow if meaning is clear Examiner's Comments Most managed to unravel the equations given to get the overall equation for the reaction between calcium carbonate and sodium chloride to give sodium carbonate and calcium chloride.
		ii	Atom economy 100% AND No waste or both products useful✓	1	Examiner's Comments This was another high-scoring question with most candidates spotting that it was 100% atom economy and that this resulted in no waste. Comments like 'little waste' did not score.
	d		sodium hydrogencarbonate ✓ ammonium chloride ✓	2	allow 'sodium hydrogen carbonate' and (l) after sodium (but not ammonium) Examiner's Comments A gratifyingly large number of candidates could name sodium hydrogencarbonate and ammonium chloride. Occasional errors were to put oxidation states after the carbonate or the ammonium.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e		Entropy is a measure of disorder or number of ways of arrangement/distribution of molecules/particles/energy quanta ✓ (more) gas formed has more/higher entropy/disorder/ways of arrangement ✓	2	ALLOW 'disorder' or 'ways of arrangement' for 'entropy' NOT arrangement of a molecule IGNORE 'more molecules formed' needs to be mention of gas formed and it having higher/more entropy Examiner's Comments Defining entropy presented few problems. Many spotted that a gas was evolved but fewer clearly stated that gases had higher entropy than solids.
	f		$\Delta S_{\text{sys}} = (+) 215 \text{ (J K}^{-1} \text{ mol}^{-1})$ ✓ $T = \Delta H / \Delta S_{\text{sys}}$ OR $T = 91000 / 215$ ✓ $T = (+)423 \text{ (K)}$ ✓	3	ALLOW ecf from each step Second marking point can subsume first ALLOW two or more significant figures Negative answers do not score the third marking point even if they follow by ecf. If 423 shows in working but 424 given, mark can be awarded. Correct answer on answer line scores 3 marks Examiner's Comments This calculation was often done correctly. Negative answers scored few marks.
	g	i	$\text{NH}_4^+ \rightleftharpoons \text{NH}_3 + \text{H}^+$ OR $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$	1	If ss are present they must be (aq) [or (l) for water] Examiner's Comments Some candidates realised that they were to answer the question and gave the equilibrium for the ionisation of NH_4^+. Others gave an alternative equilibrium or the expression for K_a.

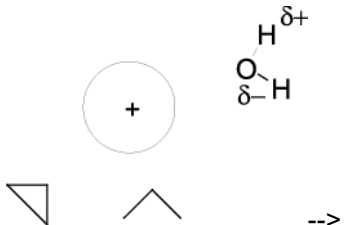
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$[H^+] = \sqrt{(5.6 \times 10^{-10} \times 0.01)}$ or 2.37×10^{-6} (mol dm ⁻³) ✓ pH = 5.6(3) ✓	2	ALLOW 'H⁺ = 'for '[H⁺] = ' Ecf for second mark for a [H⁺] (or H⁺) value larger than 1×10^{-7} and smaller than 1×10^{-3}. Must be to at least one decimal place Correct answer scores both marks without working Examiner's Comments Often in spite of wrong answers to part (i), many candidates got back on track here and correctly calculated this pH.
		iii	1. H ⁺ added ✓ 2. eqm <u>position</u> moves to left ✓ 3. large NH ₃ (concentration) ✓ 4. pH constant/little change ✓	4	1. IGNORE 'acid added' 2. This mark cannot be scored if it does not match the equation in (i) – allow ecf from equation in (i) but it must contain H⁺. QWC only allow 2nd mpt if 1st scored or it says 'acid added' 3. and 4. mark separately Examiner's Comments Some gave good answers based on their understanding of buffer solutions. Adding H⁺ caused the equilibrium position of the (correct) equilibrium in (i) to move to the left so the pH remained virtually unchanged because the concentration of NH₃ was high.
		iv	Use of $[H^+] = K_a \times [NH_4^+]/[NH_3]$ or pH = pK _a – log [NH ₄ ⁺]/[NH ₃] or $[H^+] = 2.8 \times 10^{-10}$ (mol dm ⁻³) ✓ pH = 9.55/ 9.6 ✓	2	Mark this part without reference to h(i). Correct answer scores 2 marks without reference to working; 8.95/ 9.0 (ratio wrong way up) scores 1 mark without reference to working; no other ecf. must be at least one decimal place Examiner's Comments Many got the correct answer by using $[H^+] = K_a \times [NH_4^+]/[NH_3]$. The main cause of error was to get the ratio up the wrong way. <i>Numerical answers: 2a(i) –120 kJ mol⁻¹; 2c –2.9°C; 2g 423 K; 2h(ii) 5.63; 2h(iv) 9.55.</i>

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	28	
19	a		add until no more fizzing ✓ filter ✓ evaporate and allow to crystallise ✓ filter (or pick out crystals) and dry ✓	4	ALLOW until no more dissolves
	b	i	$\text{SrCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{SrCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$ equation ✓ state symbols ✓	2	ALLOW state symbol mark if formulae or balancing wrong but no species is missing or extra.
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 7.4 (g) award 2 marks amount HCl = $2 \times 50/1000$ OR $0.1(0)$ ✓ mass $\text{SrCO}_3 = (0.1 \times 147.6 \times 0.5) = 7.4$ (g) ✓	2	ALLOW ecf from first mark to second or from wrong formula for SrCO_3 in (b)(i) ALLOW 2 or more sf
	c	i	Heat, cool (in desiccator), weigh, ✓ Repeat until mass constant ✓	2	
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 6 award 4 marks amount AgCl = $2.16/143.4$ OR 1.506×10^{-2} ✓ amount $\text{SrCl}_2 = 0.5 \times 2.16/143.4$ OR 7.531×10^{-3} ✓ $M_r \text{SrCl}_2 \cdot x\text{H}_2\text{O} = (2/7.531 \times 10^{-3}) = 266$ ✓ $x = ((266 - 158.6)/18) = 6$	4	ALLOW ecf Second mark subsumes first OR mass $\text{SrCl}_2 = 7.531 \times 10^{-3} \times 158.6$ (or 1.19g) and mass $\text{H}_2\text{O} = 2 - 1.19 = 0.81$ g ✓ $(0.81/18) = 0.045 / (1.19/158.6) = 0.0075 = 6$ ✓
		iii	Solubility of silver chloride = $\sqrt{K_{sp}} = 1.4 \times 10$ (mol dm ⁻³) ✓ Moles in 200 cm ³ 3×10^{-6} which is negligible compared with 1.5×10^{-2} ✓	2	OR compare masses 4×10^{-4} g with 1.19g
		iv	$(36 \times 100/194.6) = 18.5$ or 18(%) ✓	1	ALLOW more sf
			Total	17	

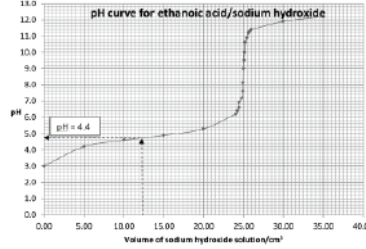
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20	a	i	$\text{Na}^+(\text{g}) + \text{Cl}^-(\text{g}) \checkmark$ $\text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})/\text{NaCl}(\text{aq}) \checkmark$ $\text{NaCl}(\text{s}) \checkmark$ -370 $\checkmark$	4	IGNORE ΔH labels ALLOW two steps to this level Level must be above NaCl(s) line to score. Minus sign required for last marking point
		ii	 (one of these needed for second mark) (three of either of these acceptable for first mark) Na^+ surrounded by at least three water molecules (minimum as shown) $\checkmark$ at least one water molecule shown with atoms and dipole $\checkmark$	2	
		iii	(yes) ionic bonds in lattice $\checkmark$ (no) bonds (between water and ions) are ion-dipole $\checkmark$ (yes) bonds broken and made are very similar OR because sum of enthalpies of hydration of ions similar to LE $\checkmark$ OR ion dipole bonds have similar strength to ionic bonding OR enthalpy change of solution is small	3	must clearly state or imply error to score second mark.
	b		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = -0.7789 ($^{\circ}\text{C}$), to any sf, award 2 marks $\Delta T = 4000 \times 10 / (210 \times 4.18 \times 58.5) = -0.8$ ($^{\circ}\text{C}$) $\checkmark\checkmark$	2	ALLOW any sf (1 is most correct) Answers scoring 1 mark: • acceptable number with plus (or no) sign • -4.56 (no moles) • -0.000779 (no unit conversion) correct expression with wrong evaluation.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
21	a	i	difficult to match colour with exact pH value using UI soln.✓	1	ALLOW AW
		ii	use two (buffer) solutions of known pH✓	1	IGNORE refs to temperature adjustment IGNORE specific pH values quoted
	b	i	$\text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}^+(\text{aq})$	1	ALLOW $\text{CH}_3\text{COOH}(\text{aq/l}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = $1.58 - 1.78 \times 10^{-5} (\text{mol dm}^{-3})$ and some signs of working/lines on graph award four marks Just correct evaluation without apparent use of graph award three marks. volume at half-neutralisation using graph = 12.5cm^3✓ value of pH from graph at half neutralisation $\text{pH} = \text{pK}_a = 4.75 - 4.8$ ✓ convert pK_a to $\text{K}_a = \text{K}_a (10^{-4.8}) = 1.58 - 1.78 \times 10^{-5} (\text{mol dm}^{-3})$ ✓	4	#If there are no signs of working on graph allow only a maximum of 3 marks.  (first calculation mark – taking line up at 12.5cm^3 and second for crossing horizontally to pH 4.4). ALLOW range of $1.6 - 2.0 \times 10^{-5}$ ALLOW 2sig figs or more
	c	i	phenolphthalein as equivalence point in alkaline conditions ✓ Methyl orange would already have changed colour ✓	2	
		ii	Methyl orange dissociates more because water at pH 7 ✓ Yellow at this pH so In- in excess ✓	2	ALLOW answers in terms of pK_a and pH. Methyl orange, lower pK_a , so higher K_a more dissociated.
	d	i	Solution that resists change in pH on addition of (small quantities) acid or alkali ✓ Addition of salt means high concn. of base and acid species✓ addition of acid results in H^+ removed by reaction with CH_3COO^- ✓ addition of alkali results in OH^- removed by reaction with H^+ ions and CH_3COOH further ionises to replace them ✓	4	
		ii	No (pH) change ✓ ratio of concentration of acid to salt remains the same ✓	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	17	
22			D	1	
			Total	1	
23			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																				
24	a		Titrate the equilibrium mixture with alkali/NaOH of known concentration (to find total moles of acid) ✓ Subtract moles of (H ₂ SO ₄) catalyst ✓	2																					
	b		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 3.61 award 4 marks <table><tr><th>Sub-stance</th><th>Mass at start</th><th>Amount present at the start</th><th>Amount present at equilibrium</th></tr><tr><td>ethanol</td><td>15.8</td><td>15.8/46 (= 0.343)</td><td>(0.343 – [0.35 – 0.123]) = 0.116</td></tr><tr><td>ethanoic acid</td><td>21.0</td><td>21.0/60 (= 0.35(0))</td><td>0.123</td></tr><tr><td>ethyl ethan- oate</td><td>0</td><td>0</td><td>[0.35–0.123 =] 0.227</td></tr><tr><td>Water</td><td>0</td><td>0</td><td>0.227</td></tr></table> One mark for both amounts at start ✓ One mark for amount of ethanol at equilibrium ✓ One mark for amounts of ester and water at equilibrium ✓ $K_c = 0.227^2 / (0.123 \times 0.116) = 3.61$ ✓	Sub-stance	Mass at start	Amount present at the start	Amount present at equilibrium	ethanol	15.8	15.8/46 (= 0.343)	(0.343 – [0.35 – 0.123]) = 0.116	ethanoic acid	21.0	21.0/60 (= 0.35(0))	0.123	ethyl ethan- oate	0	0	[0.35–0.123 =] 0.227	Water	0	0	0.227	4	ALLOW ecf throughout ALLOW other answers (to 2 or more sf) by using various rounding during calculation.
Sub-stance	Mass at start	Amount present at the start	Amount present at equilibrium																						
ethanol	15.8	15.8/46 (= 0.343)	(0.343 – [0.35 – 0.123]) = 0.116																						
ethanoic acid	21.0	21.0/60 (= 0.35(0))	0.123																						
ethyl ethan- oate	0	0	[0.35–0.123 =] 0.227																						
Water	0	0	0.227																						
	c		$\begin{array}{c} \text{H} \quad \text{CH}_3 \\ \quad \\ \text{---C---C---} \\ \quad \\ \text{H} \quad \text{CO} \\ \quad \\ \quad \text{OCH}_3 \end{array} \checkmark$	1	ALLOW any unambiguous structure IGNORE brackets or 'n'																				
	d		Methyl propanoate AND methanal ✓	1																					

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance								
	e		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = (+)666(K) award 3 marks $\Delta S_{\text{sys}} = (+) 154.7 \text{ (J K}^{-1} \text{ mol}^{-1})$ ✓ $T = \Delta H/\Delta S_{\text{sys}}$ OR $T = 103000/154.7$ ✓ $T = (+)666 \text{ (K)}$ ✓	3									
	f		<table border="1"><tr><td>Change</td><td>Increase d temper ature</td><td>Increase d pressure</td><td>Use of a catalyst</td></tr><tr><td>Effect on K_c</td><td>Increase</td><td>No change</td><td>No change</td></tr></table> ✓✓	Change	Increase d temper ature	Increase d pressure	Use of a catalyst	Effect on K_c	Increase	No change	No change	2	All 3 correct 2 2 correct 1
Change	Increase d temper ature	Increase d pressure	Use of a catalyst										
Effect on K_c	Increase	No change	No change										
	g		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 4390(dm ³) award 3 marks Unit conversion, $n = 25000/142$, $p = 150000$, ✓ Use of $pV = nRT$ and 50% yield, $V = 0.5 \times 25000 \times 8.314 \times 900/142 \times 150000$ ✓ Evaluation and conversion to dm ³ 4390 ✓	3	ALLOW 2 or more sf								
	h		Allows reaction to occur at lower temp AND less energy used ✓	1									
			Total	17									

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25	a	i	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $5.47 \times 10^{-6} \text{ mol}^3 \text{ dm}^{-9}$ award 4 marks Mean titre = 13.90 (exclude trial and anomaly)✓ Concentration of OH^- = $13.90 \times 0.04/25 = 0.02224 \text{ mol dm}^{-3}$ ✓ Concentration of Ca^{2+} is therefore $0.02224/2 = 0.01112 \text{ mol dm}^{-3}$ ✓ $K_{\text{sp}} = 0.0111 \times 0.0222^2 = 5.47 \times 10^{-6}$ AND units $\text{mol}^3 \text{ dm}^{-9}$ ✓	4	ALLOW answers that round to 5.5×10^{-5}
		ii	Titre would be (much) lower as magnesium hydroxide is less soluble ✓	1	
	b		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = (+)38.8 (°C) award 3 marks $\Delta_{\text{sol}} H \text{ CaCl}_2 = 2258 - 1650 - (2 \times -364) = -120 \text{ kJ mol}^{-1}$ ✓ Energy given out by 15.00 g = $15 \times 120000/111.1 = 16202 \text{ J}$ ✓ Temp rise $16202/(100 \times 4.18) = (+)38.8(^\circ\text{C})$ ✓	3	ALLOW 2 or more sf
			Total	8	
26			B	1	
			Total	1	
27			B	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
28	a	i	(Entropy increase because) more moles of products / on right-hand side / more moles produced ✓	1	ALLOW particles / molecule as an alternative to moles NOT just ways of arrangement Examiner Comments The answers to this question were general and did not relate the increased entropy to the fact there were more moles of gas in the products.
		ii	FIRST CHECK ANSWER ON ANSWER LINE If answer = +130.6 or any number rounding to +131 award 2 $3S_{H_2} = \Delta_{sys}S + S_{H_2O} + S_{CH_4} - S_{CO}$ OR: $3S_{H_2} = 214.5 + 186.3 + 188.7 - 197.7$ ✓ Evaluation with sign = +130.6/131 ✓	2	No ecf from first point' 130.6/131 without sign scores 1 mark Examiner Comments This question was well done, although a significant number of correct numerical answers did not have the sign, despite all the entropy values in the data having positive signs.
	b		$(\Delta_{total}S = +214.5 - 206000/1000) = (+)8.5$ ✓ feasible (since positive)✓	2	ALLOW ecf from negative answer to first mpt and from wrong positive answer Second mark must be consistent with the (implied) sign of the answer to the first point Examiner Comments This question was well done. Many correctly calculated the correct positive entropy, although a few forgot to multiply the ΔH value by 1000. A few candidates used the alternative approach of calculating the minimum temperature at which the reaction is feasible and finding it was below 1000 K. This was equally creditworthy.
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
29	a	i	$2\text{CH}_3\text{COOH} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{CH}_3\text{COONa} + \text{CO}_2 + \text{H}_2\text{O}$ formulae ✓ balancing of correct formulae ✓	2	ALLOW any unambiguous formulae (including molecular formulae) ALLOW H_2CO_3 as a product in a balanced equation for 1 mark IGNORE state symbols Examiner's Comment: (i) Most candidates were able to score both marks here, when only 1 mark was awarded this was usually for identifying H_2CO_3 incorrectly as a product of the reaction.
		ii	FIRST CHECK ANSWER LINE If answer = 11.25 or 11.3 (cm³) award 2 marks amount $\text{CH}_3\text{COOH} = 25 \times 0.450/1000$ OR 0.01125(mol) ✓ volume $\text{Na}_2\text{CO}_3 (= 0.5 \times 0.01125 \times 1000/0.500) = 11.25 \text{ (cm}^3\text{)} \checkmark$	2	ALLOW ecf from 1:1 ratio in a(i) ALLOW 3 or more sf Examiner's Comment: In this calculation candidates used the appropriate equation to determine the number of moles of ethanoic acid, and then to determine the volume of sodium carbonate required (11.25cm³). Where candidates had not given the correct equation in a(i) credit was allowed for correctly calculating a volume based upon their answer, usually calculating a value of 22.5cm³ from an equation with a 1:1 ratio of reactants.
	b		$\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH} + \text{OH}^-$	1	IGNORE state symbols ALLOW arrow for equilibrium sign Examiner's Comment: Most candidates scored this mark successfully.
	c	i	$\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+$	1	ALLOW: $\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_3\text{O}^+$ Equilibrium sign required IGNORE state symbols Examiner's Comment: This equation was a bit more challenging for candidates, where the most common error was the use of an arrow between reactants and products rather than the equilibrium symbol.

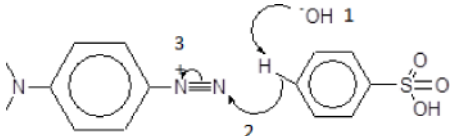
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST CHECK ANSWER LINE If answer = 3.1(462) award 2 marks $[H^+] = \sqrt{(1.7 \times 10^{-5} \times 0.030)}$ OR $7.14(\dots) \times 10^{-4} \checkmark$ $pH (= -\log 7.14 \times 10^{-4}) = 3.1(462) \checkmark$	2	ALLOW 'H⁺' for '[H⁺]' ALLOW ecf for second mark provided value for [H⁺] is quoted and it is smaller than 3×10^{-2} and greater than 1.1×10^{-7}. Examiner's Comment: This calculation was not as well answered as might have been expected. More able candidates used the information provided to correctly calculate the [H⁺] and hence the pH value of 3.15, but many weaker candidates used the figure of 0.03 in the calculation as this is the value given for the concentration of ethanoic acid in the question. Where this was used without any reference to the value of K_a no marks were awarded. However, if candidates had used this and multiplied it by K_a and subsequently calculated the pH then a mark was awarded. One mark was allowed for any answer derived from $3 \times 10^{-2} < [H^+] < 1.1 \times 10^{-7}$.
	d		acid / H⁺ moves equilibrium to left / reactants $\checkmark$s idea of restoring / maintaining <u>pH</u> $\checkmark$ large concentrations / amounts / excess of salt / CH₃COO⁻ $\checkmark$	3	Equilibrium must be written out (either for ethanoic acid or HA) to score first mark (or they could refer back to (c)(i)) ALLOW idea of "ethanoate ions react with H⁺ ions to restore equilibrium" to score first mark Examiner's Comment: Most candidates scored 1 mark here for correctly recalling that buffer solutions act to maintain pH levels when small quantities of acid or alkali are added to the reaction. More able candidates also included an appropriate equilibrium equation in their answer and made reference to it in trying to explain how this occurred. Very few candidates identified that this was made possible where there was a large concentration of salt(ethanoate) anions.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e	i	$([H^+] = K_a \times [CH_3COOH]/[MCH_3COO^-])$ gives pH = 4.77/4.8 ✓	1	Examiner's Comment: This question was generally well answered, the most common reason for candidates not scoring this mark was failing to recognise that when the concentrations of ethanoic acid and sodium ethanoate were equal that the $[H^+]$ is equal to the value of K_a for this system, and instead often used a value of 0.03mol / dm ³ from earlier in the question.
		ii	FIRST CHECK ANSWER LINE If answer = 0.35(g) award 4 marks $[CH_3COO^-] = K_a \times [CH_3COOH]/[H^+] \checkmark$ $= 1.7 \times 10^{-5} \times 0.1/10^{-5} \text{ OR } 0.17 \text{ (mol dm}^{-3}\text{)} \checkmark$ mass CH ₃ COONa per dm ³ = 82 × 0.17 OR 13.94 g ✓ mass per 25 cm ³ = 13.94/40 = 0.35 g ✓ OR moles in 25cm ³ = 0.17/40 = 4.25 × 10 ⁻³ ✓ mass per 25 cm ³ = 4.25 × 10 ⁻³ × 82 = 0.35g ✓	4	Accept 0.349g / 0.3485g ALLOW 2 or more sf ALLOW ecf throughout ALLOW correct expression for K_a Examiner's Comment: This was a multi-stage calculation which required candidates to be able to structure their response clearly. Those candidates who had spent time practising this type of calculation were clearly at an advantage as they set out their calculation in a clear and organised manner. They understood the need to rearrange the equation for K_a to make [ethanoate] the subject and then calculated the required $[H^+]$ using the pH value given in the question. From here many candidates correctly calculated the concentration as 0.17mol / dm ³ but then either failed to appreciate that the volume of buffer solution required was 25cm ³ rather than 1dm ³ and so failed to scale down their calculated value, or used a figure of 60g / mol (ethanoic acid) for the formula mass rather than the correct value for sodium ethanoate of 82g / mol. In either case marks were subsequently lost. Centres should ensure that candidates have sufficient time to practise this type of calculation, and should try to ensure that they are aware of the need to attempt to structure their calculations in an appropriate manner.
			Total	16	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
30	a	✓ ✓ ✓ 1 for each arrow 	3	ALLOW arrows that, if continued in the same direction, would start and finish in the correct places, (anywhere on appropriate atom or bond). ALLOW arrow from H into the ring AND an arrow from the ring to the right-hand N as alternative for arrow 2 Examiner Comments There were a significant number of candidates who overlooked this question. Of those who did it, points 1 and 3 were the easiest to see where electrons were moving to and from.
	b	FIRST CHECK ANSWER ON ANSWER LINE If answer = 0.8(0) award 2 marks $[H^+] = 10^{-3.7}$ evaluated = 2.0×10^{-4} ✓ $K_a / [H^+] = [In^-] / [HIn]$ evaluated = 0.80 ✓	2	Must have 'H⁺ =' to score the first point ALLOW 1: 1.25, 4: 5 etc NOT 1: 0.8 Examiner Comments This question was well done, although the ratio was the wrong way round in some cases. If full marks were not scored then the clarity of the working out was an important factor. If the pH had been used to find $[H^+]$, it needed to be clearly stated to score.
		Total	5	

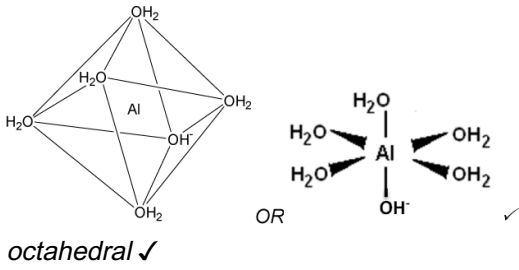
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
31	a	FIRST CHECK ANSWER ON ANSWER LINE If answer = -99.9 or -100 award 4 marks (+) 99.9 or -68.1 scores 3 (1 of the last 2) 1 Use of $Q=mc\Delta T$: $50 \times 3.0 \times 4.18 (= 627 \text{ J or } 0.627 \text{ kJ}) \checkmark$ 2 moles $\text{MgSO}_4 \cdot 7\text{H}_2\text{O} = 9.7 / 246.4 = 0.0394$ AND Scale up for 1 mole: $\Delta H = 0.627 / 0.0394 = (+)15.9 \text{ kJ mol}^{-1} \checkmark$ 3 $\Delta H = (-84.0 - (+15.9)) \checkmark$ OR Cycle (or enthalpy level diagram) labelled with species $\checkmark$ 4 Evaluated with sign = $-99.9 \text{ kJ mol}^{-1} \checkmark$	2	ALLOW ecf throughout. IGNORE sign for first point. A common mistake is to take the mass as 59.7. NOT -15.9 as temp of water falls. IGNORE (7)H_2O in bottom box. Examiner Comments There were a number of perfectly correct answers but there were many opportunities for making errors. These were the mass of the solution being 9.7 instead of 50, or 50 + or - 9.7. Candidates did not always realise the need to scale up for 1 mole of solute, or if they did, they used an incorrect molecular mass and had a negative enthalpy change despite the temperature falling.
	b	Top box: $\text{Mg}^{2+} (\text{g})$ AND $\text{SO}_4^{2-} (\text{g}) \checkmark$ $\Delta_{\text{LE}} H (= -1922 - 1099 + 84) = -2937 \checkmark$	2	Examiner Comments This question was well done.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		Strontium (ions) are larger / have a lower charge density ✓ so forces between water and strontium / ion-dipole forces less strong OR fewer water molecules surround it OR Not enough energy released in making ion-dipole bonds OR $\Delta_{\text{hyd}}H$ is less exothermic / releases less energy ✓	2	1 Charge density / radius. 2 Correct statement on the interactions between strontium ions and water. IGNORE smaller / larger in relation to $\Delta_{\text{hyd}}H$. ORA throughout Examiner Comments Many candidates lost marks by using inappropriate language such as 'atomic' or 'molecular' when describing ionic species. Candidates also focused on ΔH_{hyd} being 'smaller' or 'larger' rather than more or less exothermic or on the strength of ion-dipole forces.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32		i	$[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ / H_2O <u>ligand</u> / <u>in complex</u> ✓	1	Allow water / aqua for H_2O . Examiner's Comment: This question was generally well answered with $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ being the most common correct answer given.
		ii	 octahedral ✓ OR	2	IGNORE charges Allow diagrams that are unambiguous in showing adjacent equatorial ligands with two coming out of the plane, and two going into the plane of the paper Do Not allow bonds to H atoms, must be to O as bonding is to the lone pair of electrons Mark independently Examiner's Comment: Common errors here included incorrect bonding to the water molecules in the diagram, or not clearly showing the 3D nature of the bonds in the equatorial region of the molecule resulting in a diagram that gave the impression of all of the equatorial ligands being in the same plane as the polar ligands. Most candidates, however, did give the correct description for the shape of the complex ion.
			Total	3	
33			B	1	<u>Examiner's Comments</u> The unfamiliar way the pH of an alkali was expressed made this question difficult, but the other options are relatively easy to eliminate.
			Total	1	

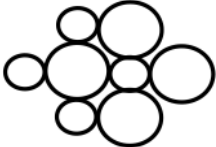
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
34	a	i	$\Delta S = (3 \times 130.6) + 197.6 - (186.2 + 189.0)$ Correct Expression evaluated with sign = +214.2 ✓	1	Sign must be included <u>Examiner's Comments</u> Quite a few candidates lost the mark as they omitted the sign.
		ii	Increase in entropy/positive as there are more molecules of products/gas ✓	1	NOT comments inconsistent with sign of ΔS calculated <u>Examiner's Comments</u> The answer was simply the number of moles on each side of the equation. Some candidates commented on feasibility of reaction.
	b		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 962 (K) award 2 marks $T = 206000/214.2$ ✓ Evaluated to 3sf = 962 (K) ✓	2	ALLOW ECF from (b)(i) ALLOW 963 (early rounding of 214.2) for 1 mark <u>Examiner's Comments</u> The ability to answer this type of question has greatly improved over the years and teachers are to be congratulated on it. Marks were lost due to an incorrect number of significant figures in some cases.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35			FIRST CHECK THE ANSWER ON ANSWER LINE If answer = $1.6 \times 10^{-18} \text{ mol dm}^{-3}$ award 5 marks Molar mass of $\text{Hg}_2\text{Cl}_2 = 472.2 \checkmark$ Solubility Hg_2Cl_2 in $\text{mol dm}^{-3} = 3.5 \times 10^{-4} \div 472.2 \times 7.41 \times 10^{-7} \checkmark$ $K_{\text{sp}} = (7.41 \times 10^{-7}) \times (2 \times 7.41 \times 10^{-7})^2 \checkmark$ $= 1.6 \times 10^{-18} \checkmark$ Units = $\text{mol}^3\text{dm}^{-9} \checkmark$ irrespective of answer BUT if MASS concentration is used in the calculation the ecf on the units must be in terms of grammes see Guidance	5	Figure of 7.41×10^{-7} is worth 2 marks alone The $\times 2$ is commonly missed giving an answer of 4.1×10^{-19} and with correct units this answer should be awarded 4 marks. Calculations must be carried out on number of moles and NOT mass, but can allow sig fig mark and units mark if units are $\text{g}^3 \text{dm}^{-9}$. Look for ecf on units off K_{sp} equation. Must be 2 sig figs to score this mark (ecf off last marking point e.g. from above) <u>Examiner's Comments</u> There were a good number of fully correct answers, although some candidates used mass rather than moles. Units were generally correct even when mass was used. This question in particular showed good discrimination.
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
36		i	+4 (kJmol ⁻¹)	1	ALLOW '4' but NOT -4, if units are evident they must be correct
		ii	At least one large ion labelled 'Cl⁻' and one small ion labelled 'Na⁺' ✓ three ions added that continue to demonstrate the ordered arrangement of ions ✓ 	2	DO NOT ALLOW if two large ions are touching or if two small ions are touching IGNORE extra correct ions added ALLOW other correct diagrams eg as shown <u>Examiner's Comments</u> Q1a(i) and (ii) were generally well answered by candidates. The majority of candidates scored full marks. However, there were a few examples where candidates had carried out their calculation incorrectly and arrived at a final answer of -4kJ/mol in part a(i). Others had identified the ions incorrectly in a(ii) such that the smaller ion was labelled as Cl⁻ and the larger ion as Na⁺. The numbers of candidates making these errors was small and most scored at least 2 marks across these introductory questions.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
37	a	i	hydrogen carbonate	1	ALLOW 'hydrogencarbonate'/hydrogen carbonate(IV) but no other oxidation states IGNORE bicarbonate
		ii	CO_3^{2-}	1	IGNORE 'carbonate' <u>Examiner's Comments</u> This question produced mixed responses. A variety of (incorrect) oxidation states were quoted for the hydrogen carbonate ion in part (i) which negated the mark. In part (ii) common incorrect responses included H_2O , CO_2 and CO_3^- .
	b	i	FIRST CHECK ANSWER ON ANSWER LINE If answer = 3.79 award 2 marks $[\text{H}^+] = \sqrt{(3.3 \times 10^{-2} \times 7.9 \times 10^{-7})}$ OR $1.6(1..) \times 10^{-4}$ ✓ pH = 3.79(19....) ✓	2	An answer rounding to 3.8 scores 2 ALLOW ecf from incorrect $[\text{H}^+]$

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$([H^+] = [HCl] =) 1.6(14..) \times 10^{-4} \checkmark$	1	ALLOW ecf from any value from pH 3 – 6 in 4d(i) eg pH3.8 gives $[H^+] = 1.58 \times 10^{-4}$ <u>Examiner's Comments</u> In general, this section of questions (4d(i) – 4f), were well answered, clearly showing that candidates and teachers had spent an appropriate amount of time working through many examples of these calculations. In many cases the answers were very clearly laid out and it was easy to see where marks could be credited. This was especially helpful where candidates had made some slips, as it allowed examiners to award credit for use of the appropriate methodology, even if the final answer did not match that expected on the mark scheme. In 4d(i), most candidates used the data provided to arrive at the correct answer and scored 2 marks. There were a small number of candidates who used an incorrect value for the concentration of H^+ ions (usually either 3.3×10^{-2} or 7.9×10^{-7}), but used this correctly to calculate a pH value. Where candidates did not arrive at the correct pH value in part (i), they could still gain the mark in part (ii) but only if their suggested pH was in the range pH 3 – 6. The rationale behind this was that candidates were told in the stem of the question that they were using a solution of hydrochloric acid, which they should realise is a strong acid, and so the pH value definitely should not exceed pH 7.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	FIRST CHECK ANSWER ON ANSWER LINE If answer = 19.8 award 2 marks $[H^+] = 3.98 \times 10^{-8} \checkmark$ $[HCO_3^-]/[CO_2] = (7.9 \times 10^{-7} / 3.98 \times 10^{-8}) = 19.8(5) \checkmark$	2	ALLOW answer rounding to 20 for 2 marks ALLOW ecf from incorrect $[H^+]$ <u>Examiner's Comments</u> Many candidates scored at least one mark here as they correctly converted the pH value for the blood into a concentration value for H^+ ions to then use. Once this was arrived at some stumbled and did not realise that they needed to use the K_a value from part d(i) to work out the ratio. However, there was clear evidence that candidates had worked through this type of question in their preparation for the examination, and many scored both marks. Again as with all other parts of this question, where candidates had incorrectly calculated a value for the H^+ concentration, or had used an incorrect value for K_a, credit was given for showing their working. Exemplar 10 when $pH = 7.4$ $[CO_2]$ $[H^+] = 3.98 \times 10^{-8}$ $K_a = \frac{[HCO_3^-][6.1125 \times 10^{-4}]}{[CO_2]}$ $[H^+] = 6.1125 \times 10^{-4}$ $\frac{K_a}{[H^+]} = \frac{[HCO_3^-]}{[CO_2]}$ $\frac{6.1125 \times 10^{-4}}{6.1125 \times 10^{-4}} = \frac{7.9}{6.1125}$ $\frac{[HCO_3^-]}{[CO_2]} = \frac{7.9}{6.1125}$ $\frac{[HCO_3^-]}{[CO_2]} = 1.29 \times 10^{-4}$ $[2]$ This candidate has calculated an incorrect value for $[H^+]$ from the pH value, but has then used this appropriately to calculate the ratio. As their working is shown clearly, they have received partial credit for this question through error carried forward.
		ii	Student is correct since blood contains too much H^+ / is too acidic $\checkmark$ Adding HCO_3^- will move equilibrium (position in 4.1) to left / increases pH $\checkmark$	2	<u>Examiner's Comments</u> Most candidates scored 1 mark for correctly stating that the addition of HCO_3^- would move the equilibrium to the left, or, that it would increase the pH. However, they did not identify that the patient's blood was too acidic, or contained too many H^+ ions, and consequently many candidates only scored 1 mark here.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		FIRST CHECK ANSWER ON ANSWER LINE If answer = 11.4 award 3 marks amount NaOH (remaining) = 1×10^{-4} mol ✓ in 40 cm³, so $[\text{OH}^-] = 1 \times 10^{-4} \times 1000/40$ OR 2.5×10^{-3} ✓ pH (= 14 – pOH = 14 ✓ 2.6) = 11.4 ✓	3	ALLOW ecf Final answer must be to at least 1dp Examiner's Comments Very few candidates scored more than 1 mark here. Many did calculate that the NaOH was in excess, and that once the reaction was complete there were 1×10^{-4} moles of NaOH remaining, scoring 1 mark. At this stage a variety of approaches were taken that did not involve calculating the new concentration of OH⁻ ions. Candidates did not appreciate that the total volume of the solution was 40cm³, and so used their value of 1×10^{-4} to calculate a pH value of 10. However, the convention is for pH values to be quoted to 1 decimal place and this was stated in the mark scheme. Therefore an answer of pH = 10 did not score a second mark. Some candidates had not realised that the NaOH was in excess, and had simply calculated the number of moles of NaOH initially present. This did not gain any credit. If they did then recognise that the total volume of solution was 40cm³, and used this appropriately, they could still score marking points 2 and 3.
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
38			C	1 AO 2.2	<u>Examiner's Comments</u> This was very well done with the majority of candidates getting the mark. Again, there was evidence of working at the side. It should have been possible to eliminate the negative values straight away as there were more moles of gas in the products. There were some candidates who confused entropy with enthalpy and selected the negative values as it is an exothermic reaction.
			Total	1	
39			A	1 AO 2.6	<u>Examiner's Comments</u> This question required close reading to include all the information and candidates generally managed very well. There were some candidates who forgot to find the square root or forgot that the ethanoic acid was dissolved in 100 cm³ water (or forgot both).
			Total	1	
40			B	1 AO 1.1	<u>Examiner's Comments</u> More than half the answers were correct, but a significant number of responses of A and C were seen, focusing on the greenhouse gases but the not noticing that the incorrect type of radiation was indicated.
			Total	1	
41			C	1 AO 2.2	<u>Examiner's Comments</u> This was another stretch and challenge question and proved the most difficult on the paper. Many had obviously learnt a technique for solving this type of question successfully.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
42	a		solution that resists/opposes/prevents changes in pH / maintains / minimizes pH change ✓ on addition of <u>small</u> amounts of acid or alkali ✓	2(AO 1.1)	Allow <i>and</i> instead of or
	b		$[H^+] = K_a \times [HA]/[A^-]$, $K_a = [H^+][A^-]/[HA]$ ✓ ($[HA] = [A^-]$) to gain the second marking point this has to be shown, words or numbers pH = pK_a = 4.8 ✓	2(AO 2.8)	Mark independently can be shown with same numbers i.e. 0.1 for both N.B. do not give 2 marks for just seeing 4.8 <u>Examiner's Comments</u> Examiners were looking for students to realise that [ethanoate ion] = [acid] and that following on from that $K_a = [H]$ and $pK = pH$ ($-\log 1.7 \times 10^{-5}$). Candidate responses just stating $-\log 1.7 \times 10^{-5} = 4.8$ were not credited.
	c		$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$ ✓ $CH_3COO^- + H^+ \rightleftharpoons CH_3COOH$ ✓ excess OH^- means solution alkaline AW ✓	2(AO 2.5)	DO NOT ALLOW 'irrelevant' equations including $NaCH_3COO \rightarrow Na^+ + CH_3COO^-$ IGNORE state symbols ALLOW arrow in equation Needs to imply concentration of $OH^- > H^+$ <u>Examiner's Comments</u> This question proved one of the most difficult on the paper. Very few appropriate equations were seen, with a common equation being the ionisation of sodium ethanoate in water. This was not credited. The idea of a solution being alkaline because the concentration of hydroxide ions is higher than the concentration of hydrogen ions was often missing.

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	d	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 11.7 award 3 marks / 12 award 2 marks unless 12 is rounded from 11.7 in which case still 3 marks $[H^+] = \frac{K_w}{[OH^-]} \checkmark / [H^+] = \frac{10^{-14}}{[OH^-]} \checkmark$ $= \frac{1.00 \times 10^{-14}}{0.005} (= 2.00 \times 10^{-12}) \checkmark$ pH = -log(2.00 x 10⁻¹²) = 11.7 ✓	3(AO 2.4)	ALLOW ecf ALLOW one or more decimal places but see below <u>Examiner's Comments</u> Higher ability candidates tended to score 2 or 3 marks on this question - the third mark often dropped because the concentration of hydroxide ion used in the K_w expression had not been halved.
	e	• NaOH in burette • <u>Pipette</u> 25 cm³ ethanoic into beaker/conical flask • measure pH with a pH meter • run in 5cm³ volumes at a time • smaller / 1 cm³ volumes when pH starts to change rapidly Any four scores three marks (✓✓✓) Any three scores two marks (✓✓) Any two scores one mark (✓)	3(AO 3.3)(AO 3.4 x2)	<u>Examiner's Comments</u> This question proved challenging. Many responses involved a standard titration using indicators which does not relate to the procedure used in this question. Only a few candidates realised the addition of much smaller volumes of NaOH was required near the 'end point' where the pH starts to rapidly change.  AfL The extra emphasis on practical in this paper does require students to have hands on experience of practical techniques and procedures to be able to fully answer questions like the one above. Helpful written material on various practical procedures can be found in both the specification and in endorsed course textbooks, but these are no substitute for the experience of carrying out and writing up these procedures.
		Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
43		i	$\text{Sr}(\text{OH})_2(\text{s}) \rightleftharpoons \text{Sr}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \checkmark$ $K_{sp} = [\text{Sr}^{2+}] [\text{OH}^{-}]^2 \checkmark$	2(AO2.2) (AO1.1)	Equilibrium can be either way round. Penalise incorrect charge on Sr ions once only Examiner's Comments In this part, most candidates scored the mark for the expression required for the solubility product, but a number of candidates did this without first of all writing an equation for the equilibrium. There were a significant number of others who did write out the expression but either did not give the appropriate state symbols or gave an incorrect state symbol for the strontium hydroxide ((aq) rather than (s)).
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = $1.6 \times 10^{-4} \text{ mol}^3 \text{ dm}^{-9}$ award 3 marks $[\text{Sr}^{2+}] = 3.4 \times 10^{-2}$ AND $[\text{OH}^{-}] = 6.8 \times 10^{-2} \checkmark$ $K_{sp} = 3.4 \times 10^{-2} \times (6.8 \times 10^{-2})^2 = 1.6 \times 10^{-4}$ $\checkmark$ units $\text{mol}^3 \text{ dm}^{-9} \checkmark$	3(AO2.6 x 3)	If final answer does not = $1.6 \times 10^{-4} \text{ mol}^3 \text{ dm}^{-9}$ ALLOW ECF from (i) provided only Sr and OH ions are involved ALLOW ECF from incorrect concentrations of Sr or OH ions, including units as appropriate ALLOW 2 or more sf ALLOW units derived from an attempt at a worked calculation Examiner's Comments In this part, provided that candidates used their expression from (i) and realised that the concentration of hydroxide ions would be twice that of the strontium ions, they should have scored all three marks. The most commonly seen error was where this had not happened, and so 3.4×10^{-2} was used for both the strontium and hydroxide ion concentrations. This results in a value of $3.93 \times 10^{-5} \text{ mol}^3 \text{ dm}^{-9}$ which would score two marks, as the single error was only penalised once. Where a candidate had an incorrect expression for the solubility product in (i) and had used this, it was possible for them to score one mark for correctly derived units from their expression.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	larger/increased concentration of OH^- ✓ concentration of Sr^{2+} reduces in order for K_{sp} to remain constant AND solubility is lower ✓	2(AO3.2 x 2)	ALLOW more hydroxide ions ALLOW moves equilibrium to left AND solubility is lower Any reference to K_{sp} changing is CON <u>Examiner's Comments</u> This question proved to be a good question to differentiate between candidates. It needed the candidate to recognise that K_{sp} is a constant value and so whatever happens in the reaction mixture this has to remain unchanged. Using the sodium hydroxide solution would result in a larger concentration of hydroxide ions being present, and so for K_{sp} to remain constant the concentration of the strontium ions had to reduce, which would result in the solubility of the strontium hydroxide decreasing. A second acceptable route through this question was if a candidate recognised that the increase in hydroxide ions meant that the equilibrium established would act to counter the change by moving to the left, and that this would result in the solubility of the strontium hydroxide decreasing.
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
44	a		$\Delta_x H$ Lattice enthalpy ✓ $\Delta_y H$ hydration enthalpies of cation + anion / ions in the solvent ✓	2 (AO1.2×2)	ALLOW LE and Hyd as abbreviations ALLOW solvation energy must be for both cation and anion OR ions
	b		More reactive is correct but not reason / reactivities have nothing to do with it ✓ (Student B is correct): barium has lower charge density(ora) / Ba^{2+} is larger than Ca^{2+} ✓ attracts water molecules less (ora) ✓ less energy released (AW) (ora) ✓	4 (AO3.1) (AO3.2) (AO3.2) (AO2.1)	Look for "it isn't the reason / not reason"
			Total	6	
45			C	1 (AO1.1)	
			Total	1	
46			C	1 (AO2.6)	
			Total	1	
47			D	1 (AO2.5)	
			Total	1	
48		i	At end point $[Ag^+] = [Cl^-]$, stated or implied ✓ $[Ag^+] = \sqrt{K_{sp}}$ ✓	2 (AO2.7) (AO2.8)	Second mark depends on first
		ii	$[CrO_4^{2-}] = 2.5 \times 10^{-4} \times 1000/53.50$ $= 4.67 \times 10^{-3}$ ✓ $[Ag^+]^2 [CrO_4^{2-}] = 2 \times 10^{-10} \times 4.67 \times 10^{-3}$ $= 9.35 \times 10^{-13}$ ✓ This is less than the solubility product of silver chromate so no precipitate (of silver chromate) forms (before all the Cl^- ions have reacted). ✓	3 (AO3.1 × 3)	Alternative method: $[CrO_4^{2-}]$ when ppt forms $= 3 \times 10^{-12} / [Ag^+]^2$ $= 0.015$ ✓ $[CrO_4^{2-}]$ in the solution is $2.5 \times 10^{-4} \times 1000/53.50$ $= 4.67 \times 10^{-3}$ ✓ This less than the 0.015 needed for a precipitate so no ppt forms ✓ ALLOW MP3 if a correct conclusion from incorrect calculated numbers
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
49		i	octahedral ✓	1 (AO2.1)	
		ii	6 ✓	1 (AO2.1)	
		iii	Satraplatin also has ethanoate / ester/C=O groups/(4) O atoms (in addition to NH ₃ groups that cisplatin also has) ✓ (These form more) H-bonds with water(ORA for cisplatin) ✓ and (more than) compensate for 'insoluble' (AW) ring OR H-bonds broken in water ✓	3 (AO3.1 × 3)	Oxygen MOLECULES is CON <u>Examiner's Comments</u> In (iii) most candidates recognised that satraplatin formed more hydrogen bonds with water than cisplatin, but some did not state why this was happening, and very few candidates could explain why this resulted in greater solubility compared to cisplatin.
			Total	5	
50	a	i	solvent for ester/(organic) product formed ✓	1 (AO2.3)	
		ii	Removes / neutralises acid (impurity) ✓	1 (AO1.2)	ALLOW reacts with acid
		iii	removes water / dries/dehydrates the mixture ✓	1 (AO1.2)	
		iv	(about) boiling point of ester / cyclohexane boils off before ester ✓	1 (AO2.7)	So methyl benzoate is the only product / substance collected.. ALLOW only pure product.
	b		FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 61(%) award 4 marks 8.0g of benzoic acid is $8.00/122 = 0.066$ moles ✓ 100% conversion gives $0.066 \times 136 = 8.976$ g ✓ % yield is $5.46/8.92 \times 100 = 61.2 / 60.8$ ✓ two sf = 61(%) ✓	4 (AO2.6 × 2)(AO2.8 × 2)	ecf on values actual values depend on when rounding done OR mol ester = $5.46/136 = 0.04$ OR % = $0.04 \times 100 / 0.066 = 60.6$
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
51	a	i	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 319 (K) award 3 marks $\Delta S_{\text{sys}} = \text{products} - \text{reactants} \checkmark$ $= 213.6 + (2 \times 192.3) - 69.9 - 173.9$ $= (+) 354.4 \checkmark$ temp = $113000/354.4$ $318.8 \text{ K} \checkmark$	3 (AO2.6 × 3)	ALLOW 2 or more sf ALLOW ecf on incorrect ΔS_{sys} Second mark subsumes first 354.4 gains 2 marks
		ii	$4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}$ OR $2\text{NH}_3 + \text{NO} + \text{O}_2 \rightarrow 1\frac{1}{2} \text{N}_2 + 3\text{H}_2\text{O} \checkmark$	1 (AO2.1)	ALLOW halves / multiples IGNORE state symbols
	b		On short journeys the engine has not yet reached high temperature $\checkmark$ (Equation 31.1 is) <u>endothermic</u> so (position of) eqm will be on the left $\checkmark$ Less ammonia available to remove oxides of nitrogen $\checkmark$ At lower temp the <u>rate</u> of formation of <u>ammonia</u> will be slower $\checkmark$	4 (AO3.1) (AO2.5) (AO3.1) (AO2.5)	ORA
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
52	a		ten electrons around P atom / eight electrons around P atom if clear that lone pair from P are used to form a dative covalent bond to one O atom ✓ rest correct ✓	2 (AO2.5 × 2)	IGNORE minus sign ALLOW 'extra' electron on single bonded O to be the same symbol or different from the rest of the electrons on that O. Must be clear that only five electrons are from P atom. Examiner's Comments Most candidates scored at least 1 mark in this part as they correctly identified the 8 or 10 electrons surrounding the P atom, but then did not complete the diagram fully as they did not make ensure that each oxygen atom had a full outer shell of electrons.
	b		mol P = $52 \times 2/142 = 0.73$ AND mol K = $34 \times 2/94.2 = 0.72$ ✓ Ratio is about 1:1 as in KH_2PO_4 ✓	2 (AO2.6 × 2)	ALLOW $52/142 = 0.365$ AND $34/94.2 = 0.36$ for MP1
	c	i	HPO_4^{2-} AND proton acceptor ✓	1 (AO1.1)	Examiner's Comments This question was then developed to test candidates' knowledge and understanding of buffers. In (i), while most candidates could state that a base is defined as a proton acceptor, they often did not identify the correct species from the equation given. In parts (ii) and (iii) these candidates carried out the required calculations successfully, often scoring full marks.
		ii	7.2..... ✓	1 (AO1.2)	
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 5.1 award 2 marks $[\text{H}^+] (= \sqrt{6.2 \times 10^{-8} \times 1.0 \times 10^{-3}}) = 7.87 \times 10^{-6} \text{ (mol dm}^{-3}\text{)} \checkmark$ pH = 5.1 ✓	2 (AO2.2 × 2)	ALLOW ecf provided '$[\text{H}^+] =$' or '$\text{H}^+ =$' is shown AND value is $> 10^{-7}$ and $< 10^{-4}$

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		$\text{NH}_4^+ \rightleftharpoons \text{NH}_3 + \text{H}^+$ OR $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$ ✓ Acid / H^+ / H_3O^+ (from KH_2PO_4) moves equilibrium (position) to left ✓	2 (AO2.7 × 2)	ALLOW equilibrium the other way round (and the corresponding 'right' in MP2) <u>Examiner's Comments</u> However, in this part, where the concept of buffers and equilibria was tested, many candidates did not score many marks. The most common omissions were not giving an appropriate equilibrium equation.
	e		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 69 (g) award 4 marks Value of $[\text{H}^+]$: 3.16×10^{-7} ✓ Rearrangement of eqn: $[\text{H}_2\text{PO}_4^-] = [\text{H}^+][\text{HPO}_4^{2-}] / K_a$ ✓ $[\text{H}_2\text{PO}_4^-] = 3.16 \times 10^{-7} \times 0.1 / 6.2 \times 10^{-8}$ OR 0.51 ✓ mass $\text{KH}_2\text{PO}_4 = (0.51 \times 136) = 69$ (g) ✓	4 (AO2.8 × 4)	ALLOW 2 or more sf ALLOW ecf throughout
	f	i	Equilibrium will move to left (AW) ✓ $[\text{H}^+]$ only restored / unchanged (AW) if $[\text{H}_2\text{PO}_4^-]$ is large ✓	2 (AO3.1 × 2)	<u>Examiner's Comments</u> However, in this part, where the concept of buffers and equilibria was tested, many candidates did not score many marks. The most common omissions were failing to explain why the equilibrium moves to the left in (i).
		ii	(Student is correct (AW) AND) HCl strong (acid) so all reacts / dissociates/ionises ✓	1 (AO3.1)	
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 0.7 award 2 marks $[\text{H}^+] (= 0.05 \times 0.01/1000) = 5 \times 10^{-7}$ ✓ pH change = $7 - 6.3 = 0.7$ ✓	2 (AO2.8 × 2)	ALLOW ecf
			Total	19	