Candidate Name	Centre Number					Candidate Number				
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GCE A LEVEL CHEMISTRY

A2 UNIT 3

Physical and Inorganic Chemistry

SPECIMEN PAPER

1 hour 45 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 8.**	**10**	
Section B	**9.**	**17**	
	10.	**14**	
	11.	**8**	
	12.	**12**	
	13.	**19**	
	Total	**80**	

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a data sheet and a calculator.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

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

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question 10.

SECTION A

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

1. Circle all the acids in the following equation.

$$CH_3COOH + NH_3 \rightleftharpoons CH_3COO^- + NH_4^+$$ [1]

2. The table shows some enthalpy change values for three compounds.

	Standard enthalpy change of hydration / kJ mol^{-1}	Standard enthalpy change of lattice breaking / kJ mol^{-1}
lithium fluoride	–1005	1032
potassium fluoride	–792	776
rubidium fluoride	–819	813

State which compound(s) you would expect to be soluble in water. [1]

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3. *(a)* Balance the equation for the reaction of sodium hydroxide with chlorine. [1]

…….. Cl_2 + …… NaOH → ……. NaCl + ……. $NaClO_3$ + …… H_2O

(b) Use oxidation states to show that this is a disproportionation reaction. [1]

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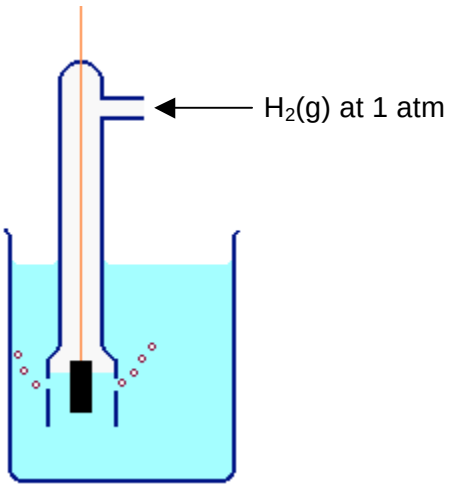
4. The standard electrode potential for a half-cell can be measured by connecting it to the standard hydrogen electrode shown below.



Name the solution in the beaker and state its concentration. [1]

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5. Put the following species in order of increasing entropy. [1]

Br_2(l) Kr(g) Se(s)

lowest .... *highest*

6. Acidified potassium dichromate may be used to oxidize iron(II) ions. The two relevant half equations are shown below.

$$Cr_2O_7^{2-} + 14H^+ + 6e \rightleftharpoons 2Cr^{3+} + 7H_2O$$

$$Fe^{3+} + e \rightleftharpoons Fe^{2+}$$

Write the overall ionic equation for this reaction. [1]

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7. Carbon tetrachloride does not react with cold water, however silicon(IV) chloride reacts violently. Explain why the reactivity of these compounds is so different. [1]

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8. Chromyl chloride is a compound containing chromium, oxygen and chlorine only. It contains 33.5 % chromium and 45.8 % chlorine by mass.

Calculate the empirical formula of chromyl chloride. [2]

Empirical formula .....

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SECTION B

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

9. *(a)* (i) The boron in boron chloride, BCl_3, is described as electron deficient. State what is meant by the term *electron deficient*. [1]

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(ii) When BCl_3 is mixed with ammonia a new species is formed. Identify the new species and explain how it forms. [2]

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(b) Heating the species formed in *(a)*(ii) can be used to produce films of hexagonal boron nitride, BN.

(i) This form of BN has many similarities to the structure of graphite. Describe the **differences** between the structures of hexagonal boron nitride and graphite. [2]

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(ii) Graphite is commonly used as a lubricant as the layers slip over each other. It has been suggested that a significant factor in this softness is the presence of absorbed molecules such as O_2, H_2O and CO_2.

A sample of graphite was repeatedly exposed to a vacuum and then an atmosphere of pure $H_2O(g)$ to remove all traces of absorbed molecules other than H_2O, leaving a sample of mass 3.645g. This was then heated under vacuum until constant mass was reached, leaving a mass of 3.592 g.

I. Explain why the sample was heated to constant mass. [1]

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II. Calculate the ratio of carbon atoms to water molecules in the graphite. [3]

Ratio carbon : *water* .....

(c) Phosphorus(III) chloride, PCl_3, can be produced in the equilibrium below:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

(i) A sample of PCl_5 is introduced into a sealed vessel with an initial pressure of 12.4×10^3 Pa, and the system is allowed to reach equilibrium where the partial pressure of Cl_2 is 6.0×10^3 Pa.

Calculate the value of K_p under these conditions, giving its units. [4]

K_p = ...

Units .....

(ii) When the temperature is increased by 50 °C, the value of the equilibrium constant K_p doubles. State and explain whether this reaction is endothermic or exothermic. [2]

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(iii) Explain why phosphorus can form PCl_5 and PCl_3 but nitrogen can only form one chloride. [2]

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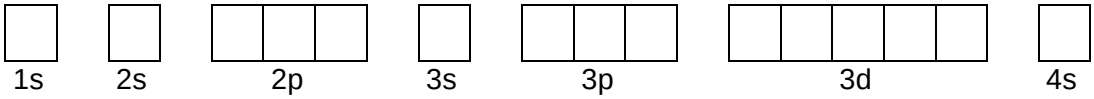
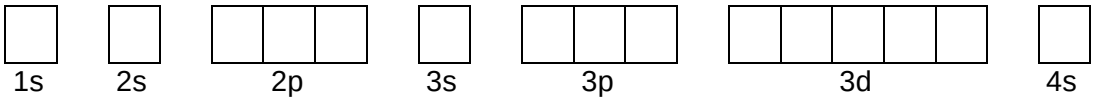
10. Cobalt, nickel and copper are metals which lie adjacent to each other in the Periodic Table.

(a) Use arrows in boxes to show the electronic structures of the copper atom and the Cu^{2+} ion. [2]

Copper atom, Cu



Copper(II) ion, Cu^{2+}



(b) Cobalt (II) compounds are often pink in aqueous solution as they contain the $[Co(H_2O)_6]^{2+}$ complex ion.

Addition of concentrated hydrochloric acid to a solution containing $[Co(H_2O)_6]^{2+}$ causes a colour change as a new species is formed. Give the colour and formula of the species formed and explain the origin of the colour in the complex $[Co(H_2O)_6]^{2+}$. [6QER]

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(c) Addition of ammonia solution to a pink solution of $[Co(H_2O)_6]^{2+}$ forms a yellow-brown solution of $[Co(NH_3)_6]^{2+}$, due to the reversible reaction:

$$[Co(H_2O)_6]^{2+} + 6NH_3 \rightleftharpoons [Co(NH_3)_6]^{2+} + 6H_2O$$

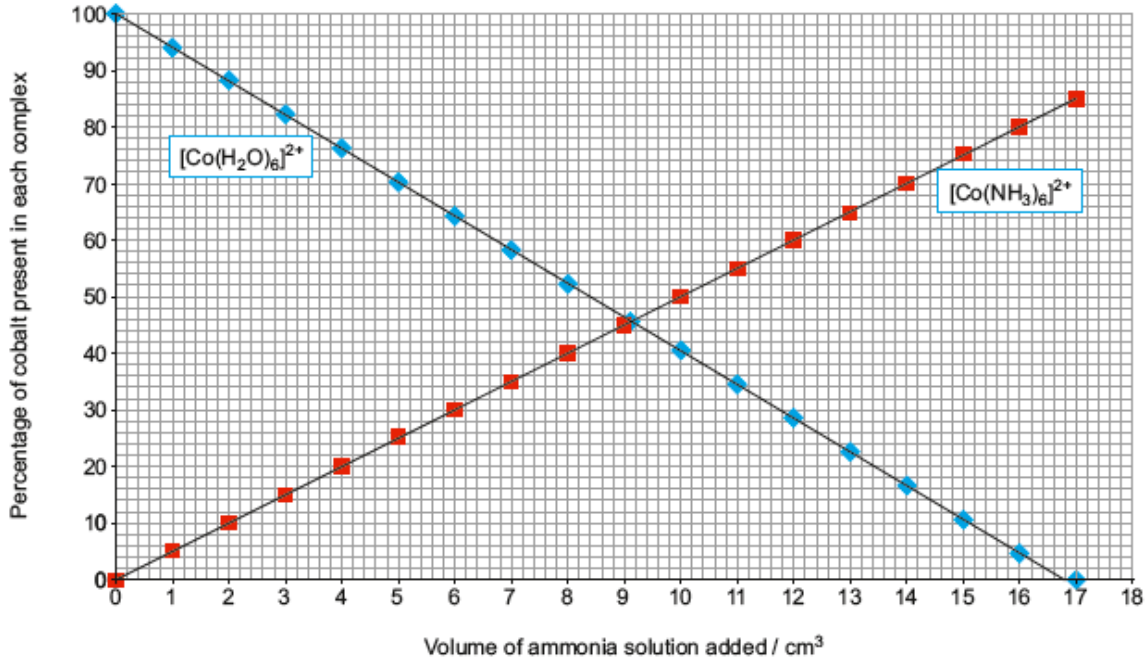
A student chose to study this change using colorimetry.

(i) The pink solution of $[Co(H_2O)_6]^{2+}$ absorbs light of wavelength 515 nm. Calculate the energy of the electron transition taking place, giving your answer in kJ mol^{-1}. [3]

$h = 6.63 \times 10^{-34}$ J s $\quad c = 3.00 \times 10^{8}$ m s^{-1} $\quad N_A = 6.02 \times 10^{23}$

Energy = ... kJ mol^{-1}

(ii) The results of the experiment are shown on the graph below.



Following the experiment the student decided that the reversible reaction shown did not fully reflect what was occurring during the experiment.

$$[Co(H_2O)_6]^{2+} + 6NH_3 \rightleftharpoons [Co(NH_3)_6]^{2+} + 6H_2O$$

State whether you agree with her conclusion and explain your reasoning. [3]

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11. Some students are provided with five solutions labelled **A**–**E**.

(a) Flame tests were undertaken on all the solutions and a range of colours were seen, including lilac for one solution and apple green for another.

State what information is provided by these observations. [1]

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The five solutions contain only common cations and anions that the students have met during their A-level studies. No two solutions contain the same cations or the same anions. One of the solutions is known to be aqueous sodium hydroxide, while another contains nitrate ions.

The students mixed each pair of solutions and recorded the following observations.

	Solution **A**	Solution **B**	Solution **C**	Solution **D**
Solution **E**	pale blue precipitate	no visible change	white precipitate formed that dissolves when extra solution **E** is added	no visible change
Solution **D**	thick white precipitate	no visible change	white precipitate	
Solution **C**	white precipitate	bright yellow precipitate		
Solution **B**	brown solution with a white solid formed			

(b) Use **all** the information given to find the identities of solutions **A**–**E**.
Explain your reasoning for identification of the metal ion present in solution **C**.
[7]

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Solution **A**	
Solution **B**	
Solution **C**	
Solution **D**	
Solution **E**	

8

12. A 25.00 cm^3 sample of sodium hydroxide solution was exactly neutralised by 24.25 cm^3 of sulfuric acid of concentration 0.176 mol dm^{-3}.

(a) Calculate the concentration of the sodium hydroxide solution, giving your answer to the appropriate number of significant figures. [3]

Concentration of sodium hydroxide = ... mol dm^{-3}

(b) An alternative method to calculate the concentration of the sodium hydroxide solution is to use its pH.

A student measures the pH of the same sodium hydroxide solution as being 13.5. Calculate the concentration of this sodium hydroxide solution. Show your working. [3]

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

Concentration of sodium hydroxide = ... mol dm^{-3}

(c) The two values calculated in *(a)* and *(b)* are consistent with each other. State and explain which method gives the more precise value. [1]

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(d) The titration was repeated using 25.00 cm^3 of the weak acid ethanoic acid with a concentration equal to that of the sodium hydroxide.

(i) Choose an appropriate indicator for this titration from the list below, giving a reason for your answer. [1]

Indicator	pH range
methyl red	4.2 - 6.3
methyl yellow	2.9 - 4.0
phenolphthalein	8.2 - 10.0

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(ii) Give the expected pH of the solution when 12.50 cm^3 of sodium hydroxide had been added to 25.00 cm^3 of ethanoic acid. [2]

[K_a for ethanoic acid = 1.8×10^{-5} mol dm^{-3}]

pH = ...

(e) The reaction of aqueous sulfuric acid with the weak base ammonia produces ammonium sulfate solution. State and explain the pH you would expect for a solution of ammonium sulfate. [2]

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13. When a new substance is identified as having beneficial effects, chemists need to devise an appropriate route to synthesise the desired substance. They need to consider many factors, including the feasibility and rate of different routes.

(a) There are different ways to identify the feasibility of a chemical reaction. Two methods are the use of electrochemical data and the calculation of Gibbs' free energy.

(i) Use the data below to identify whether the reaction given is feasible at 298 K. Show your working in each case. [6]

$2KMnO_4 + 5H_2O_2 + 6HCl \rightarrow 2MnCl_2 + 8H_2O + 5O_2 + 2KCl \quad \Delta S^\theta = 9 \text{ J K}^{-1} \text{ mol}^{-1}$

Standard enthalpy changes of formation

Substance	Standard enthalpy change of formation, $\Delta_f H^\theta$ / kJ mol^{-1}
$KMnO_4(s)$	–813
$H_2O_2(l)$	–188
$HCl(g)$	–92
$MnCl_2(s)$	–482
$H_2O(l)$	–286
$O_2(g)$	0
$KCl(s)$	–436

Standard electrode potentials

Half-equation	E^θ / V
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.52
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+0.68

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(ii) In a laboratory the reaction is attempted by mixing a solution of acidified potassium manganate(VII) of concentration 0.5 mol dm^{-3} and hydrogen peroxide solution of the same concentration at 350 K.

State and explain which of the approaches in part (i) is most suitable for working out whether the reaction is feasible in this case and suggest how the experiment could be changed to ensure the feasibility calculation is valid. [3]

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(b) Reactions that are feasible are not always economically useful as the product may be formed too slowly. This can be helped by using a catalyst to increase the rate of the reaction.

(i) The table below gives data on the initial rates of reaction for an acid-catalysed bromination of propanone.

$$Br_2(aq) + CH_3COCH_3(aq) \rightarrow HBr(aq) + CH_3COCH_2Br(aq)$$

$[Br_2]$ / mol dm^{-3}	$[CH_3COCH_3]$ / mol dm^{-3}	pH	Initial rate of reaction / mol dm^{-3} min^{-1}
0.10	0.80	0	1.36×10^{-3}
0.10	0.80	1	1.36×10^{-4}
0.10	0.40	1	6.80×10^{-5}
0.10	0.80	2	1.36×10^{-5}
0.20	0.40	2	6.80×10^{-6}

I. Show that the reaction is first order with respect to $[H^+(aq)]$. [2]

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II. Deduce a rate equation for this catalysed reaction, giving the value and units of the rate constant. [4]

k = ...

Units .....

III. A suggested mechanism for the process is given below.

$CH_3COCH_3 + Br_2 \rightarrow [CH_3COBrCH_3]^+ + Br^-$

$[CH_3COBrCH_3]^+ \rightarrow [CH_3COCH_2]^+ + HBr$

$[CH_3COCH_2]^+ + Br^- \rightarrow CH_3COCH_2Br$

State and explain whether this proposed mechanism is correct. [2]

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(ii) Explain why the use of homogeneous catalysts can be an environmental advantage but a problem in the isolation of the final product. [2]

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