Please check the examination details	s below before ent	ering your candidate information			
Candidate surname		Other names			
Pearson Edexcel Level 3 GCE	Centre Number	Candidate Number			
Tuesday 2 Jun	e 202	0			
Afternoon (Time: 1 hour 45 minutes) Paper Reference 9CH0/01					
Chemistry Advanced Paper 1: Advanced Inorganic and Physical Chemistry					
Candidates must have: Scientific Data Boo Ruler		Total Marks			

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer all questions.
- Answer the questions in the spaces provided
 - there may be more space than you need.

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
 - use this as a guide as to how much time to spend on each question.
- For the question marked with an asterisk (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶







Answer ALL questions.

Some questions must be answered with a cross in a box \boxtimes . If you change your mind about an answer, put a line through the box \boxtimes and then mark your new answer with a cross \boxtimes .

1 (a) Which equation shows the third ionisation energy of aluminium?

(1)

- \blacksquare A Al(g) \rightarrow Al³⁺(g) + 3e⁻¹
- \square **B** Al²⁺(g) \rightarrow Al³⁺(g) + e⁻
- \square **C** Al³⁺(g) + 3e⁻ \rightarrow Al(g)
- \square **D** $Al^{3+}(g) + e^- \rightarrow Al^{2+}(g)$
- (b) Which element in this table is in Group 2?

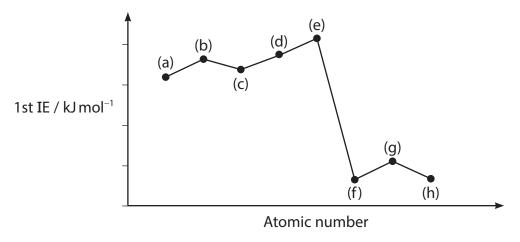
	Ionisation energy / kJ mol ⁻¹				
Element	First	Second	Third	Fourth	
W	1086	2353	4621	6223	
X	653	1592	2987	4740	
Y	590	1145	4912	6474	
Z	496	4563	6913	9544	

- \square A W
- \square **B** X
- \boxtimes **D** Z



(c) The graph shows the first ionisation energies (IE) of eight successive elements from the first 20 elements in the Periodic Table.

Which letter represents the first ionisation energy of oxygen?



(1)

- **A** (a)
- B (b)
- **∠** (c)
- (d) Give the formula of a stable **ion** that is isoelectronic with the magnesium ion, Mg²⁺.

(e) A student stated that 'the elements are not transition metals'.	s scandium and zinc are d-block elements but	
Discuss this statement, using appro your answer.	opriate electronic configurations to support	
·	(4)	
	(Total for Question 1 = 8 marks)	

- **2** This question is about acids and bases.
 - (a) What is the order of **decreasing** pH for 0.100 mol dm⁻³ solutions of these three acids?

(1)

- \square A CH₃COOH > CH₂ClCOOH > HCl
- B HCl > CH₃COOH > CH₂ClCOOH
- \square **D** HCl > CH₂ClCOOH > CH₃COOH
- (b) A solution of methanoic acid, HCOOH, has a concentration of 0.240 mol dm⁻³ and a pH of 2.20.

Calculate the value of pK_a for methanoic acid.

(3)

(c) Which of these mixtures would form a buffer solution with a pH **below** 7?

- ☑ A NaOH(aq) and excess HCl(aq)
- B NaOH(aq) and excess CH₃COOH(aq)
- D excess NaOH(aq) and CH₃COOH(aq)



(d) Bromothymol blue, methyl orange and phenolphthalein are indicators used in titrations.

Which, if any, of these indicators could be used for a titration of ammonia, NH₃(aq), with ethanoic acid, CH₃COOH(aq)?

(1)

- X bromothymol blue
- X methyl orange
- X phenolphthalein C
- X none of these three indicators

(Total for Question 2 = 6 marks)

1	This question is about transition metals and transition metal complexes.	
	(a) Describe the bonding in the element chromium and use your answer to justify why it has such a high melting temperature.	
	You may find it helpful to draw a labelled diagram.	
		(4)
	(b) When chromium(III) sulfate dissolves in water, a green solution containing the	
	[Cr(H2O)6]3+ ion forms.	
		(1)
	[Cr(H2O)6]3+ ion forms.	(1)
	[Cr(H ₂ O) ₆] ³⁺ ion forms. (i) Give the shape of this complex ion.	(1)
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(3)

(c) The ligand ethylenediaminetetraacetate, EDTA⁴⁻, has the structure shown.

When a solution of EDTA $^{\!4-}$ is added to a solution of $[Cr(H_2O)_6]^{3+}$ ions, a new complex ion is formed.

$$[Cr(H_2O)_6]^{3+} + EDTA^{4-} \rightleftharpoons [Cr(EDTA)]^- + 6H_2O$$

The equilibrium constant for this equilibrium is 2.51×10^{23} dm³ mol⁻¹.

By considering the equilibrium for this reaction and changes in entropy, comment on the value of the equilibrium constant. No calculations are required.

(d) Aqueous vanadium(II) chloride, $VCl_2(aq)$, can be oxidised by bubbling gaseous chlorine, $Cl_2(g)$, through the solution in the absence of air.

 $40.0\,\mathrm{cm^3}$ of $0.100\,\mathrm{mol}$ dm⁻³ VCl₂ solution was oxidised by $144\,\mathrm{cm^3}$ of chlorine gas, at room temperature and pressure (r.t.p.).

The chlorine was reduced to chloride ions, according to the half-equation

$$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$$

[Molar volume of a gas at r.t.p. = $24.0 \text{ dm}^3 \text{ mol}^{-1}$]

(i) Use these data to calculate the final oxidation state of vanadium. You **must** show your working.

(5)

(ii) State the initial and final colours you would see as the chlorine bubbles through the aqueous vanadium(II) chloride, VCl₂(aq).

(2)

(Total for Question 3 = 18 marks)

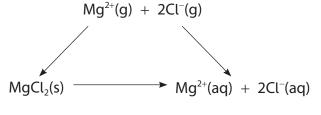


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- **4** This question is about dissolving different compounds.
 - (a) Which of these compounds is the most soluble in water?

(1)

- A barium sulfate
- **B** calcium sulfate
- **D** strontium sulfate
- (b) What is the value, in kJ mol⁻¹, for the standard enthalpy change of solution of magnesium chloride?



Lattice energy $MgCl_2(s) = -2526 \text{ kJ mol}^{-1}$

Hydration enthalpy of $Cl^{-}(g) = -381 \text{ kJ mol}^{-1}$

Hydration enthalpy of $Mg^{2+}(g) = -1921 \text{ kJ mol}^{-1}$

- **B** −157

*(c) The solubility of two compounds in different solvents was investigated. A summary of the findings is shown.

Compound	Soluble in water	Soluble in hexane
2-methylpentane	X	✓
potassium bromide	✓	X

Explain the findings of the investigation by considering the interactions between the compounds and each of the solvents.	
	(6)

(Total for Question 4 = 8 marks)



5	This question is about the chemistry of hydrated magnesium nitrate, $Mg(NO_3)_2.xH_2O$.	
	(a) Group 2 nitrates decompose when heated.	
	(i) State two observations you would see when hydrated magnesium nitrate is h	eated. (2)
	(ii) Explain the trend in thermal stability of Group 2 nitrates.	(3)
	(b) In an experiment, a sample of hydrated magnesium nitrate, Mg(NO ₃) ₂ .xH ₂ O, with a mass of 0.765 g, was dissolved in water and reacted with an excess of sodium hydroxide solution, NaOH(aq). The precipitate of magnesium hydroxide, Mg(OH) ₂ , produced was removed and dried. The mass of the dried sample was 0.174 g.	
	(i) Draw dot-and-cross diagrams for the ions in magnesium hydroxide. Show the outer electrons only.	(2)



(ii) Use the experimental data to calculate the value for x in the formula $Mg(NO_3)_2.xH_2O$. You **must** show all your working.

(5)

(Total for Question 5 = 12 marks)



6 Prop-2-en-1-ol is an unsaturated alcohol with the structure shown.

- (a) A student planned to use bond enthalpy data to calculate a value for the enthalpy change of combustion of prop-2-en-1-ol.
 - (i) When researching the bond enthalpy data, the student claimed that it was not necessary to find the value for the C=C bond as they could use the value for a C-C bond and multiply it by two.
 Explain why the student is **incorrect**.

(ii) Calculate a value for the enthalpy of combustion of prop-2-en-1-ol using the data shown.

$$C_{3}H_{6}O(g) + 4O_{2}(g) \ \to \ 3CO_{2}(g) + 3H_{2}O(g)$$

Bond	C–C	C=C	C-O	C=O	O–H	C–H	0=0
Bond enthalpy / kJ mol ⁻¹	347	612	358	805	464	413	498

(3)

(2)

(iii) Explain, in terms of entropy, why the combustion of prop-2-en-1-ol is always feasible in the gaseous state.

(2)

(b) Chemists are researching a process to make ethanol and ethene directly from carbon dioxide and water.

$$4CO_{2}(g) + 5H_{2}O(I) \ \rightarrow \ CH_{3}CH_{2}OH(I) + C_{2}H_{4}(g) + 6O_{2}(g) \ \Delta H^{\Theta} = +2778 \ kJ \ mol^{-1}$$

	CO ₂ (g)	H ₂ O(I)	CH ₃ CH ₂ OH(I)	C ₂ H ₄ (g)	O ₂ (g)
S [⊕] / J K ⁻¹ mol ⁻¹	213.6	69.9	160.7	219.5	205.0

Calculate $\Delta S^{\Theta}_{total}$ for the reaction and hence determine whether the reaction is feasible under standard conditions.

(5)

(Total for Question 6 = 12 marks)

7 A mixture of ethanoic acid, ethanol and a catalyst was left for several days to reach equilibrium.

$$CH_3COOH(I) + CH_3CH_2OH(I) \implies CH_3COOCH_2CH_3(I) + H_2O(I)$$

The equilibrium constant, K_c , under these conditions, was 0.28.

(a) (i) Write the expression for the equilibrium constant, K_c .

(1)

(ii) The initial amounts of ethanol and ethanoic acid used were 1.2 mol of each reactant.

Use this information, your expression for the equilibrium constant, K_c , and the value for K_c , to find the amounts of each product at equilibrium, in moles.

(3)

Amount of CH₃COOCH₂CH₃ =

Amount of H_2O =

(b) Another ester, methyl methanoate, can be formed by the reaction between methanol and carbon monoxide in the gaseous phase.

$$CO(g) + CH3OH(g) \longrightarrow H \underbrace{ \begin{matrix} O & H \\ \parallel & - \end{matrix} }_{X} C \underbrace{ \begin{matrix} - \end{matrix} }_{Y} O \underbrace{ \begin{matrix} - \end{matrix} }_{Y} C \underbrace{ \begin{matrix} - \end{matrix} }_{Y} H$$

(i) The two O–C–H bond angles, x and y, in the ester are approximately

(1)

- A 180° and 90°
- B 120° and 90°
- **C** 120° and 109.5°
- **D** 109.5° and 109.5°
- (ii) The reaction often forms an equilibrium mixture.

Which could be the units for the equilibrium constant, $K_{\rm D}$?

(1)

- lacktriangle A mol dm⁻³
- lacksquare **B** dm³ mol⁻¹
- C atm
- \square **D** atm⁻¹
- (iii) Describe what effect, if any, increasing the pressure would have on the equilibrium constant, K_p . Justify your answer.

(2)

(Total for Question 7 = 8 marks)

8 Tablets containing potassium manganate(VII), KMnO₄, are dissolved in water forming an antiseptic solution to treat skin conditions. The manufacturers claim that each tablet contains 400 mg of KMnO₄.

To check the claim, the titration procedure outlined was carried out.

- Five tablets were dissolved in distilled water to make 100.0 cm³ of solution.
- Some of the KMnO₄ solution was used to fill a burette.
- 25.0 cm³ of sodium ethanedioate solution, Na₂C₂O₄(aq), of concentration 0.200 mol dm⁻³, was added to a conical flask and warmed.
- Sulfuric acid, of concentration 2 mol dm⁻³, was also added to the conical flask.
- The KMnO₄ solution was added to the flask from the burette, until the end-point.

The equation for the reaction between MnO_4^- ions from the $KMnO_4$ and $C_2O_4^{2-}$ ions from the sodium ethanedioate solution is shown.

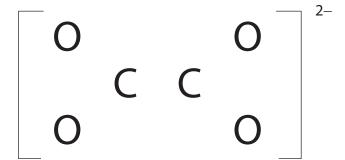
$$16H^{+}(aq) + 2MnO_{4}^{-}(aq) + 5C_{2}O_{4}^{2-}(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_{2}(g) + 8H_{2}O(l)$$

(a) Give the colour **change** at the end-point of the titration.

(1)

(b) (i) Complete the dot-and-cross diagram for the ethanedioate ion. Show the outer electrons only.

(2)



(ii) Determine the oxidation number of carbon in the ethanedioate ion, $C_2O_4^{2-}$.

(c) Give the reason why sulfuric acid was also added to the conical flask.

(1)

(d) This redox reaction could be used in an electrochemical cell.

The cell half-equations are

$$2CO_2(g) + 2e^- \rightleftharpoons C_2O_4^{2-}(aq)$$

$$8H^{\scriptscriptstyle +}(aq) + MnO_4^{\scriptscriptstyle -}(aq) + 5e^{\scriptscriptstyle -} \implies Mn^{2\scriptscriptstyle +}(aq) + 4H_2O(I)$$

Write a cell diagram for this cell using the conventional representation.

(2)



(e) The results of the titration are shown.

Run	Trial	1	2	3
Final volume / cm ³	17.50	34.10	17.20	34.10
Initial volume / cm³	0.00	17.30	0.00	17.20
Titre / cm³	17.50		17.20	
Concordant titres (✓)				
Mean titre / cm³				

(i) Complete the table.

(2)

(ii) The equation for the reaction between MnO_4^- ions from the $KMnO_4$ and $C_2O_4^{2-}$ ions from the sodium ethanedioate solution is shown.

$$16H^{+}(aq) + 2MnO_{4}^{-}(aq) + 5C_{2}O_{4}^{2-}(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_{2}(g) + 8H_{2}O(I)$$

Use this equation and your mean titre from (e)(i) to calculate the mass, in mg, of $KMnO_4$ in **one** tablet.

Give your answer to an appropriate number of significant figures.

(5)

(iii) A textbook suggested the conical flask should be heated during the titration, as the reaction between the MnO_4^- ions and the $C_2O_4^{2-}$ ions is slow.

Use these electrode potentials and your knowledge of homogeneous catalysis to deduce why the heating is very important at the start of the titration, but less important as the titration proceeds. Justify your answer. You may include equations in your justification.

Electrode system	E [⊕] /V
$2CO_2(g) + 2e^- \rightleftharpoons C_2O_4^{2-}(aq)$	+0.64
$Mn^{3+}(aq) + e^{-} \rightleftharpoons Mn^{2+}(aq)$	+1.49
$MnO_{4}^{-}(aq) + 8H^{+}(aq) + 5e^{-} \implies Mn^{2+}(aq) + 4H_{2}O(I)$	+1.51

(4)

(Total for Question 8 = 18 marks)
(Total for Question 9 - 19 marks)

TOTAL FOR PAPER = 90 MARKS



The Periodic Table of Elements

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						1.0										4.0
						hydrogen										Helium helium
			Key		_	-				•	(13)	(14)	(15)	(16)	(17)	2
		relati	relative atomic mass	mass							10.8	12.0	14.0	16.0	19.0	20.2
		ato	atomic symbol	poq							മ	U	z	0	L	Ne
beryllium			name	Ñ							boron	carbon	nitrogen	oxygen	fluorine	neon
		atomic	atomic (proton) number	numper							5	9	7	8	6	10
24.3											27.0	28.1	31.0	32.1	35.5	39.9
Wg											¥	Si	۵	S	ರ	Ar
magnesium 12	(3)	(4)	(5)	(9)	(7)	(8)	(6)	(10)	(11)	(12)	aluminium 13	silicon 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
	45.0	47.9	50.9	52.0	54.9	55.8	58.9	58.7	63.5	65.4	2.69	72.6	74.9	79.0	6.62	83.8
S	S	ï	>	ъ	Wn	Fe	ပိ	Æ	J	Zn	Ga	g	As	Se	В	궃
calcium	scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton
	21	22	23	23 24 25	25	56	27	28	29	30	31	32	33	34	35	36
87.6	88.9	91.2	92.9	6.36	[86]	101.1	102.9	106.4	107.9	112.4	114.8	118.7	121.8	127.6	126.9	131.3
	>	Zr		Wo	2	Ru	묎	Pd	Ag	В	I	Sn	Sb	Тe	Ι	×
strontium	>	zirconium	E	molybdenum technetium		ruthenium	£	palladium	silver	cadmium	indium	ti	antimony	tellurium	iodine	xenon
	39	40	41	42	43	4	45	46	47	48	49	20	51	52	53	24
137.3	138.9	178.5	180.9	183.8	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	[506]	[210]	[222]
Ba	La*	Ŧ	Ta	>	Re	S	<u>_</u>	T	Αu	Η̈́	F	Ъ	Bi	8	At	윤
barium	lanthanum	μ	Ē	tungsten	rhenium	osmium	iridium	platinum	plog	mercury	thallium	lead	bismuth	polonium	astatine	radon
- 1	22	72	73	74	75	76	14	78	79	80	81	82	83	84	85	98
[226]	[227]	[261]		[592]	[564]		[368]	[271]	[272]							
Ra	Ac*	₹	9	Sg	絽	Ŧ	Мŧ	Mt Ds Rg	Rg	Elen	Elements with atomic numbers 112-116 have been reported	atomic nur	nbers 112.	116 have t	een repor	per
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_ !	89	104	2	100		108	109	011	-							

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175	Γn	lutetium	71	[257]	۲	lawrencium	103
173	χ	ytterbium	70	[254]	2 N	nobelium	102
169	E	thulium	69	[256]	ΡW	mendelevium	101
167	Д	erbium	68	[253]	Fa	fermium	100
165	운	holmium	67	[254]	Es	einsteinium	66
163	ò	dysprosium	99	[251]	ᠸ	californium	98
	1			[245]	쑮	berkelium	26
157	В	gadotinium	49	[247]	Ę	aurium	96
152	Eu	europium	63	[243]	Am	americium	95
150	Sm	samarium	62	[242]	Pu	plutonium	94
[147]	Pm	promethium	61	[237]	å	neptunium	93
144	P	neodymium	09	238	¬	uranium	92
141	P	praseodymium	29	[231]	Pa	protactinium	91
140	S	cerium	28	232	£	thorium	06