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Pearson Edexcel
International
Advanced Level

Centre Number	Candidate Number
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Chemistry
Advanced
Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Tuesday 7 November 2017 – Morning Time: 1 hour 40 minutes	Paper Reference WCH05/01
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Candidates must have: Data Booklet Scientific calculator	Total Marks
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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.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
– *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

Advice

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

Turn over ►

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SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box . If you change your mind, put a line through the box and then mark your new answer with a cross .

1 Which species contains an element with the same oxidation number that sulfur has in NaHSO_4 ?

- A $\text{K}_4\text{Fe}(\text{CN})_6$
 B NH_4VO_3
 C K_2MnO_4
 D $[\text{CoCl}_4]^{2-}$

(Total for Question 1 = 1 mark)

2 Which species contains a bond angle of 90° ?

- A $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$
 B $[\text{CuCl}_2]^-$
 C $[\text{CrCl}_4]^-$
 D SiCl_4

(Total for Question 2 = 1 mark)

3 Which equation can only be described as a ligand exchange reaction?

- A $[\text{Zn}(\text{OH})_2](\text{s}) + 2\text{OH}^-(\text{aq}) \rightarrow [\text{Zn}(\text{OH})_4]^{2-}(\text{aq})$
 B $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow [\text{Fe}(\text{H}_2\text{O})_5(\text{OH})]^{2+}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
 C $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq}) + 2\text{NH}_3(\text{aq}) \rightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2(\text{s}) + 2\text{NH}_4^+(\text{aq})$
 D $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + 6\text{NH}_3(\text{aq}) \rightarrow [\text{Cr}(\text{NH}_3)_6]^{3+}(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$

(Total for Question 3 = 1 mark)

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4 A metal ion, M^+ , disproportionates spontaneously:



The table below gives the standard electrode potentials of four systems.

System	E^\ominus / V
$Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$	+0.15
$Cu^+(aq) + e^- \rightarrow Cu(s)$	+0.52
$Ag^{2+}(aq) + e^- \rightarrow Ag^+(aq)$	+1.98
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80

Use the data to predict which statement is true under standard conditions.

- A Both Cu^+ and Ag^+ can disproportionate.
- B Only Cu^+ can disproportionate.
- C Only Ag^+ can disproportionate.
- D Neither Cu^+ nor Ag^+ can disproportionate.

(Total for Question 4 = 1 mark)

5 In a reaction of dichromate(VI) ions, $Cr_2O_7^{2-}$, with a metal ion M^{2+} , the oxidation number of each Cr atom changes from +6 to +3.

Each dichromate(VI) ion reacts with three M^{2+} ions.

What is the oxidation number of M after the reaction?

(1)

- A +2
- B +3
- C +4
- D +5

(Total for Question 5 = 1 mark)

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- 6 A ligand exchange reaction occurs when EDTA is added to a solution containing the ion $[\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+}$.

What is the **best** explanation for this?

- A A complex forms with copper and EDTA which is more soluble than the original.
- B A complex forms with copper and EDTA which is less soluble than the original.
- C $\Delta H_{\text{reaction}}$ is positive for the reaction of $[\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+}$ with EDTA.
- D ΔS_{system} is positive for the reaction of $[\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+}$ with EDTA.

(Total for Question 6 = 1 mark)

- 7 The repeat units of four polymers are shown:

Polymer	Repeat unit
P	$-\text{CH}_2\text{CH}(\text{CONH}_2)-$
Q	$-\text{HN}(\text{CH}_2)_5\text{NHOC}(\text{CH}_2)_3\text{CO}-$
R	$-\text{HNCH}_2\text{CONHCH}(\text{CH}_3)\text{CO}-$
S	$-\text{CH}_2\text{CH}(\text{CN})-$

- (a) Which formula shows the repeat unit of the polymer poly(propenamide)?

(1)

- A P
- B Q
- C R
- D S

- (b) Which formula shows the repeat unit of a polymer which could be made using a diamine and a dioic acid as the monomers?

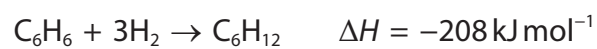
(1)

- A P
- B Q
- C R
- D S

(Total for Question 7 = 2 marks)



8 The enthalpy changes for the hydrogenation of cyclohexene and of benzene are shown:



The delocalised structure of benzene is more stable than a molecule with three C=C double bonds by

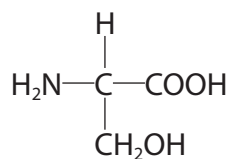
- A 504 kJ mol⁻¹
- B 328 kJ mol⁻¹
- C 152 kJ mol⁻¹
- D 88 kJ mol⁻¹

(Total for Question 8 = 1 mark)

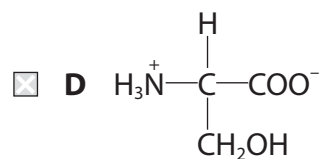
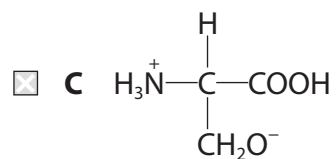
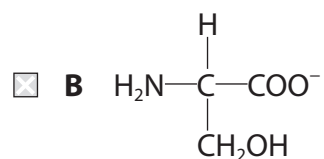
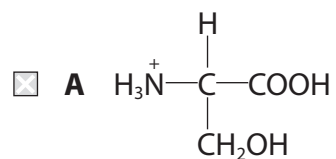
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9 The formula of the amino acid serine is shown:



The formula of the zwitterion of serine is



(Total for Question 9 = 1 mark)

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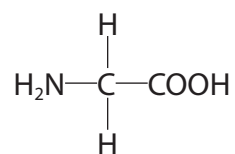
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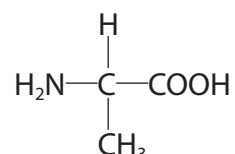
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10 This question is about the amino acids, glycine and alanine.



glycine



alanine

What is the total number of different dipeptides which can be made by reacting each of the optical isomers (enantiomers) of alanine with glycine?

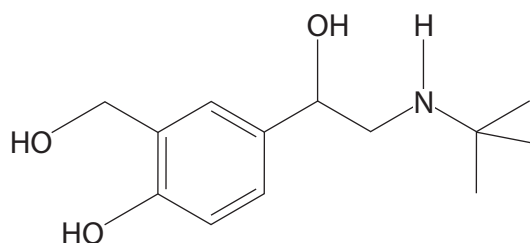
- A 2
- B 3
- C 4
- D 8

(Total for Question 10 = 1 mark)

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11 The structure of the asthma medication salbutamol is



(a) Which functional group is **not** present in salbutamol?

(1)

- A Alcohol
- B Amide
- C Amine
- D Phenol

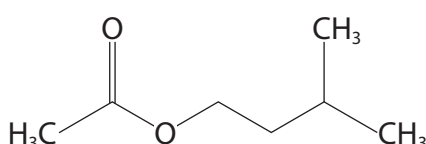
(b) What is the molecular formula of salbutamol?

(1)

- A $C_{13}H_{22}NO_3$
- B $C_{13}H_{21}NO_3$
- C $C_{13}H_{20}NO_3$
- D $C_{13}H_{19}NO_3$

(Total for Question 11 = 2 marks)

12 The compound **X** with molecular formula $C_7H_{14}O_2$ shown is responsible for some of the flavour of bananas.



compound **X**

(a) The number of peaks in the **low** resolution proton nmr spectrum of **X** is

(1)

- A 4
- B 5
- C 6
- D 14



(b) The number of singlets in the **high** resolution proton nmr spectrum of **X** is

(1)

- A 1
- B 2
- C 3
- D 5

(c) A sample of **X** is hydrolysed with dilute acid. Which of these peaks is present in the infrared spectrum of **X** but is **not** present in the spectra of its hydrolysis products?

Refer to the correlation table on page 6 of the Data Booklet.

(1)

- A 2962–2853 cm^{-1}
- B 1750–1735 cm^{-1}
- C 1725–1700 cm^{-1}
- D 1485–1365 cm^{-1}

(d) In the mass spectrum of **X**, which m/e peak would you expect **not** to be present?

(1)

- A 29
- B 43
- C 87
- D 129

(Total for Question 12 = 4 marks)

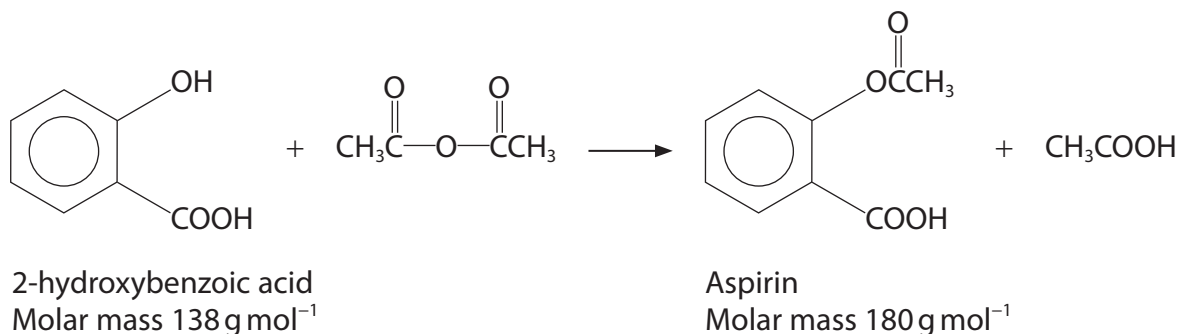
13 A sample of 0.25 mol of a cyclic hydrocarbon produced 66 g of carbon dioxide and 22.5 g of water on combustion. The hydrocarbon is

- A cyclohexane.
- B cyclohexene.
- C benzene.
- D ethylbenzene.

(Total for Question 13 = 1 mark)



- 14 A sample of aspirin is made by the reaction of 2-hydroxybenzoic acid with excess ethanoic anhydride.



- (a) In the preparation, 2.00 g of 2-hydroxybenzoic acid produced 1.65 g of aspirin.

The percentage yield was

(1)

- A 92.9
- B 82.5
- C 76.7
- D 63.3

- (b) The aspirin is purified by recrystallisation using water as the solvent. Which of the following statements is true?

(1)

- A The aspirin should be dissolved in an excess of water.
- B The solution should be heated to above the melting temperature of aspirin.
- C Soluble impurities are removed by filtering the mixture after cooling.
- D Only water soluble impurities in the aspirin can be removed.

(Total for Question 14 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS



SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

15 This question is about successive elements in Period 4.

	Potassium	Calcium	Scandium	Titanium
Atomic radius / nm	0.235	0.197	0.164	0.147
Sum of first and second ionisation energies / kJ mol^{-1}	3470	1735	1866	1968

*(a) There is a decrease in atomic radius between potassium and calcium, and also between scandium and titanium. Explain why the atomic radius decreases in both cases, and why the decrease between potassium and calcium is greater.

(2)

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*(b) Explain why the sums of the first two ionisation energies of Ca, Sc and Ti are all similar but less than the sum of the first two ionisation energies of potassium.

(2)

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(c) Explain why scandium and titanium are placed in the same block of the Periodic Table, but scandium is not a transition element.

(2)

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(d) Aqueous solutions of Ti(II) compounds contain the ion $[\text{Ti}(\text{H}_2\text{O})_6]^{2+}$.

Draw a diagram of this ion.

Name its shape, state the bond angle between adjacent water molecules and the type of bond between the ligand and the titanium.

(2)

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(Total for Question 15 = 8 marks)

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16 This question is about manganese and its ions.

(a) (i) Complete the electronic configuration of Mn and Mn²⁺.

(1)

Mn [Ar]

Mn²⁺ [Ar]

(ii) Suggest why the oxidation number +2 is very stable for manganese.

(1)

(b) Consider the data below.

Electrode system	Standard electrode potential (E^\ominus) / V
$\text{Mn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mn}(\text{s})$	-1.19
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51

(i) Draw a labelled diagram showing how to set up a cell with the two electrode systems in the table above, in order to measure E_{cell}^\ominus .

State the standard conditions required for the cell.

(4)



(ii) Calculate the value of $E_{\text{cell}}^{\ominus}$. (1)

(iii) Write the equation for the overall reaction that occurs in this cell.
State symbols are not required. (2)

(c) A student investigated the redox chemistry of manganese by adding manganese powder to a solution containing vanadium(III) ions, $\text{V}^{3+}(\text{aq})$. Deduce what products are formed in this reaction.

Justify your answer by using the data in (b), and by considering items 11, 26 and 42 in the table of Standard Electrode Potentials on pages 14 and 15 in the Data Booklet.

You should calculate $E_{\text{cell}}^{\ominus}$ for any feasible reactions. (4)

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(d) A solution containing $\text{Mn}^{2+}(\text{aq})$ reacts with aqueous sodium hydroxide to form a precipitate.

(i) Write the **ionic** equation for the formation of the precipitate. Include state symbols.

(1)

(ii) State the colour of the precipitate.

(1)

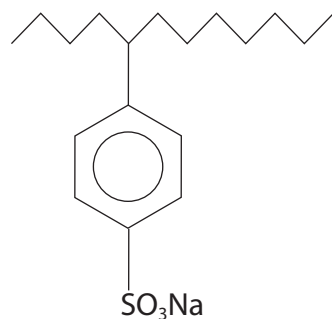
(iii) The precipitate darkens if it is left standing in air. Identify, by name or formula, the new manganese compound responsible for this darkening.

(1)

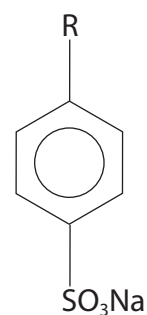
(Total for Question 16 = 16 marks)



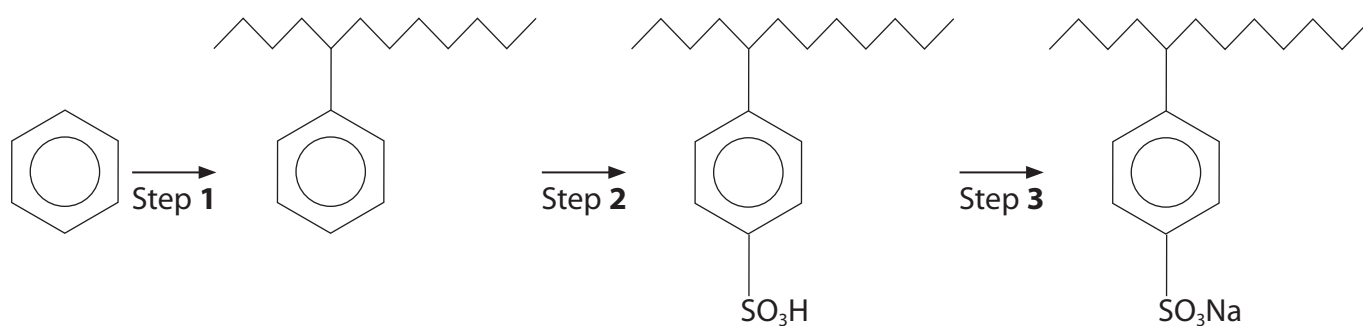
- 17 The structure of a detergent is shown. In simplified form, the symbol R can be used to represent the alkyl group.



OR



The detergent can be synthesised from benzene by the following route:



- (a) (i) Give the number of carbon atoms and the number of hydrogen atoms in the alkyl group R.

(1)

- (ii) Draw the structural formula of the **compound** which could be used to react with benzene in Step 1 and identify the catalyst required for this reaction.

(2)

Compound:

Catalyst:



(iii) Write a mechanism for the alkylation of benzene in Step 1, using the symbol R for the alkyl group. You should include an equation showing the formation of the electrophile.

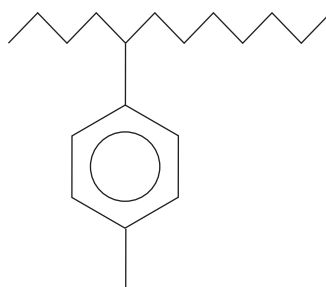
(3)

(iv) **Name** the reagent which is used to sulfonate the benzene ring in Step 2.

(1)

(v) Complete the diagram to show the **displayed** formula of the $\text{—SO}_3\text{H}$ group in the product formed in Step 2.

(1)



(vi) Identify a suitable reagent for use in Step 3.

(1)

* (b) (i) The product of Step 1, C_6H_5R , is not soluble in water. Explain this fact by identifying the intermolecular forces involved and comparing their relative strengths.

(2)

(ii) The detergent, $RC_6H_4SO_3Na$, is soluble in water. Explain how the bonding in this compound allows it to dissolve in water.

(2)

(Total for Question 17 = 13 marks)

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18 This question is about the chemistry of benzene, phenol and phenylamine.

(a) Both benzene and phenol can be brominated in **substitution** reactions under suitable conditions.

(i) Give the equation for the reaction of benzene with bromine.
Include state symbols.

(2)

(ii) Give the equation for the reaction of phenol with bromine water, showing the structure of the organic product.
State symbols are not required.

(1)

*(iii) Explain the effect the -OH group has on the bromination of the benzene ring.

(2)

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(b) (i) Phenol reacts with dilute nitric acid.

Give the formula of **one** organic product of this reaction and state the type and mechanism of the reaction which is occurring.

(2)

Formula:

Type and mechanism:

(ii) Phenylamine also reacts with dilute nitric acid but the reaction does not involve the benzene ring.

Give the formula of the organic product in this reaction and state the type of reaction which is occurring.

(2)

Formula:

Type of reaction:

(c) Write the equation for the reaction of phenylamine with ethanoyl chloride, giving the **displayed** formula of the organic product.

(2)

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(d) Phenylamine is the starting material for making certain dyes.

Write equations to show how a dye could be made in two steps, using phenylamine and phenol as the only organic compounds. State the conditions needed for the first step.

(3)

First step:

Conditions

Second step:

(Total for Question 18 = 14 marks)

TOTAL FOR SECTION B = 51 MARKS



SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

19

The element chromium occurs in the Earth's crust at a concentration of about 1.02×10^2 ppm. The name of the element comes from the Greek word for colour, and compounds of the three main oxidation states (+2, +3 and +6) are brightly coloured.

The element and its compounds have many uses, such as the manufacture of important alloys, pigments for paint and inks, colouring glass and tanning leather.

Chromium is an essential mineral for physiological functions but, above a certain level, its compounds are toxic. The target in many states of the USA is for a concentration in drinking water below 0.10 parts per billion. The maximum permissible level of Cr(VI) allowed to be released into waterways is 50 parts per billion. Chromium concentrations in drinking water can be measured by a colorimetric method.

- *(a) Solutions containing $\text{Cr}^{2+}(\text{aq})$ and $\text{Cr}^{3+}(\text{aq})$ are coloured due to electron transitions between d orbitals.

Explain why $\text{Cr}^{2+}(\text{aq})$ and $\text{Cr}^{3+}(\text{aq})$ **differ** in colour.

(2)

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* (b) (i) The oxide CrO_3 contains chromium in the oxidation state +6.

Suggest **two** reasons why CrO_3 is unlikely to contain Cr^{6+} ions.

(2)

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(ii) Predict, by writing an equation, how CrO_3 would react with water.

(1)

(iii) Write the equation for the reaction of dichromate(VI) ions with alkali in which chromate(VI) ions are formed. State symbols are not required.

(1)



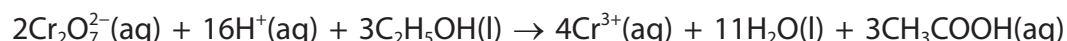
(c) The concentration of ethanol in white wine can be measured using potassium dichromate(VI) titrations. A suitable method is:

Step 1 A standard solution of ammonium iron(II) sulfate was used to measure the concentration of a potassium dichromate(VI) solution. The reactions are



The concentration of the potassium dichromate(VI) solution was found to be $0.0210 \text{ mol dm}^{-3}$.

Step 2 A mixture of 1.00 cm^3 of wine, 100 cm^3 of the potassium dichromate(VI) solution (an excess) and about 25 cm^3 of dilute sulfuric acid were reacted until all the ethanol in the wine had been oxidised by the dichromate(VI) ions.



Step 3 The reaction mixture from Step 2 was made up to a volume of 200.0 cm^3 and a portion was used to fill a burette. It was titrated with 25.00 cm^3 portions of acidified ammonium iron(II) sulfate with concentration $0.015 \text{ mol dm}^{-3}$. The mean titre was 18.60 cm^3 .

(i) An indicator of sodium diphenylamine and phosphoric acid was used to detect the end-point of the titrations.

If the titrations were carried out without an indicator, the colour change at the end-point would be difficult to detect. Explain, by reference to the ions involved and their colours, why this is the case.

(2)

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(ii) Name the experimental procedure which would be used in the oxidation of ethanol to ethanoic acid in Step 2.

(1)

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(iii) How many moles of dichromate(VI) ions were present at the start of Step 2? (1)

(iv) Use the results from Step 3 to calculate the number of moles of potassium dichromate(VI) solution present after it has oxidised the ethanol, and hence the number of moles used in the reaction. (4)

(v) Calculate the number of moles of ethanol which were present in the 1.00 cm³ of wine. (1)



(vi) The concentration of ethanol in wine is usually quoted as the percentage of "Alcohol by Volume" (ABV).

The volume of 1 mole of ethanol is 58.3 cm^3 .

Calculate the percentage of "Alcohol by Volume" in the wine.

(2)

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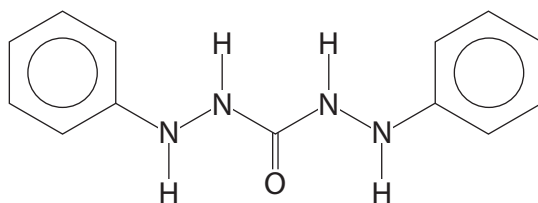
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- (d) The concentration of dichromate(VI) ions in drinking water can be measured by reacting them with a compound called diphenylcarbazide. This produces a complex with a reddish-purple colour. The concentration of this product is measured using a colorimeter.

The structure of diphenylcarbazide is shown.



The complex, which is thought to be octahedral, contains one chromium(III) ion formed by reduction.

Draw a circle round the atoms which are most likely to bond with the chromium ion. Hence predict the number of moles of diphenylcarbazide per mole of complex. Justify your answer.

(2)

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(Total for Question 19 = 19 marks)

TOTAL FOR SECTION C = 19 MARKS
TOTAL FOR PAPER = 90 MARKS



The Periodic Table of Elements

1	2	3	4	5	6	7	0 (8)
6.9 Li lithium 3	9.0 Be beryllium 4	10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	104 Rf rutherfordium 104	105 Db dubnium 105	106 Sg seaborgium 106	107 Bh bohrium 107	108 Hs hassium 108	109 Mt meitnerium 109
[227] Ac* actinium 89	[227] La* lanthanum 89	108 Hs hassium 108	109 Mt meitnerium 109	110 Ds darmstadtium 110	111 Rg roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated	
140 Ce cerium 58	141 Pr praseodymium 59	142 Nd neodymium 60	143 Pm promethium 61	144 Nd neodymium 60	145 Eu europium 63	146 Gd gadolinium 64	147 Tb terbium 65
148 Er erbium 68	149 Tm thulium 69	150 Yb ytterbium 70	151 Lu lutetium 71	152 Eu europium 63	153 Dy dysprosium 66	154 Ho holmium 67	155 Er erbium 68
157 Gd gadolinium 64	158 Tb terbium 65	159 Dy dysprosium 66	160 Ho holmium 67	161 Er erbium 68	162 Tm thulium 69	163 Yb ytterbium 70	164 Lu lutetium 71
168 Os osmium 76	169 Ir iridium 77	170 Pt platinum 78	171 Au gold 79	172 Hg mercury 80	173 Tl thallium 81	174 Pb lead 82	175 Bi bismuth 83
176 Pd palladium 46	177 Ag silver 47	178 Cd cadmium 48	179 In indium 49	180 Sn tin 50	181 Sb antimony 51	182 Te tellurium 52	183 I iodine 53
184 Cu copper 29	185 Zn zinc 30	186 Ga gallium 31	187 Ge germanium 32	188 As arsenic 33	189 Se selenium 34	190 Br bromine 35	191 Kr krypton 36
192 Ni nickel 28	193 Cu copper 29	194 Zn zinc 30	195 Ga gallium 31	196 Ge germanium 32	197 As arsenic 33	198 Se selenium 34	199 Br bromine 35
200 Co cobalt 27	201 Ni nickel 28	202 Cu copper 29	203 Zn zinc 30	204 Ga gallium 31	205 Ge germanium 32	206 As arsenic 33	207 Se selenium 34
208 Fe iron 26	209 Co cobalt 27	210 Ni nickel 28	211 Cu copper 29	212 Zn zinc 30	213 Ga gallium 31	214 Ge germanium 32	215 As arsenic 33
216 Mn manganese 25	217 Fe iron 26	218 Co cobalt 27	219 Ni nickel 28	220 Cu copper 29	221 Zn zinc 30	222 Ga gallium 31	223 Ge germanium 32
224 Cr chromium 24	225 Mn manganese 25	226 Fe iron 26	227 Co cobalt 27	228 Ni nickel 28	229 Cu copper 29	230 Zn zinc 30	231 Ga gallium 31
232 V vanadium 23	233 Cr chromium 24	234 Mn manganese 25	235 Fe iron 26	236 Co cobalt 27	237 Ni nickel 28	238 Cu copper 29	239 Zn zinc 30
240 Ti titanium 22	241 V vanadium 23	242 Cr chromium 24	243 Mn manganese 25	244 Fe iron 26	245 Co cobalt 27	246 Ni nickel 28	247 Cu copper 29
248 Zr zirconium 40	249 Nb niobium 41	250 Mo molybdenum 42	251 Tc technetium 43	252 Ru ruthenium 44	253 Rh rhodium 45	254 Pd palladium 46	255 Ag silver 47
256 Hf hafnium 72	257 Ta tantalum 73	258 W tungsten 74	259 Re rhenium 75	260 Os osmium 76	261 Ir iridium 77	262 Pt platinum 78	263 Au gold 79
264 Rf rutherfordium 104	265 Db dubnium 105	266 Sg seaborgium 106	267 Bh bohrium 107	268 Hs hassium 108	269 Mt meitnerium 109	270 Ds darmstadtium 110	271 Rg roentgenium 111
272 La* lanthanum 57	273 Ce* cerium 58	274 Pr* praseodymium 59	275 Nd* neodymium 60	276 Pm* promethium 61	277 Sm* samarium 62	278 Eu* europium 63	279 Gd* gadolinium 64
280 Er* erbium 68	281 Tm* thulium 69	282 Yb* ytterbium 70	283 Lu* lutetium 71	284 Ho* holmium 67	285 Dy* dysprosium 66	286 Ho* holmium 67	287 Er* erbium 68
288 Os* osmium 76	289 Ir* iridium 77	290 Pt* platinum 78	291 Au* gold 79	292 Hg* mercury 80	293 Tl* thallium 81	294 Pb* lead 82	295 Bi* bismuth 83
296 Pd* palladium 46	297 Ag* silver 47	298 Cd* cadmium 48	299 In* indium 49	300 Sn* tin 50	301 Sb* antimony 51	302 Te* tellurium 52	303 I* iodine 53
304 Cu* copper 29	305 Zn* zinc 30	306 Ga* gallium 31	307 Ge* germanium 32	308 As* arsenic 33	309 Se* selenium 34	310 Br* bromine 35	311 Kr* krypton 36
312 Ni* nickel 28	313 Cu* copper 29	314 Zn* zinc 30	315 Ga* gallium 31	316 Ge* germanium 32	317 As* arsenic 33	318 Se* selenium 34	319 Br* bromine 35
320 Co* cobalt 27	321 Ni* nickel 28	322 Cu* copper 29	323 Zn* zinc 30	324 Ga* gallium 31	325 Ge* germanium 32	326 As* arsenic 33	327 Se* selenium 34
328 Fe* iron 26	329 Co* cobalt 27	330 Ni* nickel 28	331 Cu* copper 29	332 Zn* zinc 30	333 Ga* gallium 31	334 Ge* germanium 32	335 As* arsenic 33
336 Mn* manganese 25	337 Fe* iron 26	338 Co* cobalt 27	339 Ni* nickel 28	340 Cu* copper 29	341 Zn* zinc 30	342 Ga* gallium 31	343 Ge* germanium 32
344 Cr* chromium 24	345 Mn* manganese 25	346 Fe* iron 26	347 Co* cobalt 27	348 Ni* nickel 28	349 Cu* copper 29	350 Zn* zinc 30	351 Ga* gallium 31
352 Ti* titanium 22	353 V* vanadium 23	354 Cr* chromium 24	355 Mn* manganese 25	356 Fe* iron 26	357 Co* cobalt 27	358 Ni* nickel 28	359 Cu* copper 29
360 Zr* zirconium 40	361 Nb* niobium 41	362 Mo* molybdenum 42	363 Tc* technetium 43	364 Ru* ruthenium 44	365 Rh* rhodium 45	366 Pd* palladium 46	367 Ag* silver 47
368 Hf* hafnium 72	369 Ta* tantalum 73	370 W* tungsten 74	371 Re* rhenium 75	372 Os* osmium 76	373 Ir* iridium 77	374 Pt* platinum 78	375 Au* gold 79
376 Rf* rutherfordium 104	377 Db* dubnium 105	378 Sg* seaborgium 106	379 Bh* bohrium 107	380 Hs* hassium 108	381 Mt* meitnerium 109	382 Ds* darmstadtium 110	383 Rg* roentgenium 111
384 La* lanthanum 57	385 Ce* cerium 58	386 Pr* praseodymium 59	387 Nd* neodymium 60	388 Pm* promethium 61	389 Sm* samarium 62	390 Eu* europium 63	391 Gd* gadolinium 64
392 Er* erbium 68	393 Tm* thulium 69	394 Yb* ytterbium 70	395 Lu* lutetium 71	396 Ho* holmium 67	397 Dy* dysprosium 66	398 Ho* holmium 67	399 Er* erbium 68
400 Os* osmium 76	401 Ir* iridium 77	402 Pt* platinum 78	403 Au* gold 79	404 Hg* mercury 80	405 Tl* thallium 81	406 Pb* lead 82	407 Bi* bismuth 83
408 Pd* palladium 46	409 Ag* silver 47	410 Cd* cadmium 48	411 In* indium 49	412 Sn* tin 50	413 Sb* antimony 51	414 Te* tellurium 52	415 I* iodine 53
416 Cu* copper 29	417 Zn* zinc 30	418 Ga* gallium 31	419 Ge* germanium 32	420 As* arsenic 33	421 Se* selenium 34	422 Br* bromine 35	423 Kr* krypton 36
424 Ni* nickel 28	425 Cu* copper 29	426 Zn* zinc 30	427 Ga* gallium 31	428 Ge* germanium 32	429 As* arsenic 33	430 Se* selenium 34	431 Br* bromine 35
432 Co* cobalt 27	433 Ni* nickel 28	434 Cu* copper 29	435 Zn* zinc 30	436 Ga* gallium 31	437 Ge* germanium 32	438 As* arsenic 33	439 Se* selenium 34
440 Co* cobalt 27	441 Ni* nickel 28	442 Cu* copper 29	443 Zn* zinc 30	444 Ga* gallium 31	445 Ge* germanium 32	446 As* arsenic 33	447 Se* selenium 34
448 Fe* iron 26	449 Co* cobalt 27	450 Ni* nickel 28	451 Cu* copper 29	452 Zn* zinc 30	453 Ga* gallium 31	454 Ge* germanium 32	455 As* arsenic 33
456 Mn* manganese 25	457 Fe* iron 26	458 Co* cobalt 27	459 Ni* nickel 28	460 Cu* copper 29	461 Zn* zinc 30	462 Ga* gallium 31	463 Ge* germanium 32
464 Cr* chromium 24	465 Mn* manganese 25	466 Fe* iron 26	467 Co* cobalt 27	468 Ni* nickel 28	469 Cu* copper 29	470 Zn* zinc 30	471 Ga* gallium 31
472 Ti* titanium 22	473 V* vanadium 23	474 Cr* chromium 24	475 Mn* manganese 25	476 Fe* iron 26	477 Co* cobalt 27	478 Ni* nickel 28	479 Cu* copper 29
480 Zr* zirconium 40	481 Nb* niobium 41	482 Mo* molybdenum 42	483 Tc* technetium 43	484 Ru* ruthenium 44	485 Rh* rhodium 45	486 Pd* palladium 46	487 Ag* silver 47
488 Hf* hafnium 72	489 Ta* tantalum 73	490 W* tungsten 74	491 Re* rhenium 75	492 Os* osmium 76	493 Ir* iridium 77	494 Pt* platinum 78	495 Au* gold 79
496 Rf* rutherfordium 104	497 Db* dubnium 105	498 Sg* seaborgium 106	499 Bh* bohrium 107	500 Hs* hassium 108	501 Mt* meitnerium 109	502 Ds* darmstadtium 110	503 Rg* roentgenium 111
504 La* lanthanum 57	505 Ce* cerium 58	506 Pr* praseodymium 59	507 Nd* neodymium 60	508 Pm* promethium 61	509 Sm* samarium 62	510 Eu* europium 63	511 Gd* gadolinium 64
512 Er* erbium 68	513 Tm* thulium 69	514 Yb* ytterbium 70	515 Lu* lutetium 71	516 Ho* holmium 67	517 Dy* dysprosium 66	518 Ho* holmium 67	519 Er* erbium 68
520 Os* osmium 76	521 Ir* iridium 77	522 Pt* platinum 78	523 Au* gold 79	524 Hg* mercury 80	525 Tl* thallium 81	526 Pb* lead 82	527 Bi* bismuth 83
528 Pd* palladium 46	529 Ag* silver 47	530 Cd* cadmium 48	531 In* indium 49	532 Sn* tin 50	533 Sb* antimony 51	534 Te* tellurium 52	535 I* iodine 53
536 Cu* copper 29	537 Zn* zinc 30	538 Ga* gallium 31	539 Ge* germanium 32	540 As* arsenic 33	541 Se* selenium 34	542 Br* bromine 35	543 Kr* krypton 36
544 Ni* nickel 28	545 Cu* copper 29	546 Zn* zinc 30	547 Ga* gallium 31	548 Ge* germanium 32	549 As* arsenic 33	550 Se* selenium 34	551 Br* bromine 35