Write your name here

Surname	Other names

Pearson Edexcel
International Advanced Level

Centre Number	Candidate Number

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

Candidates must have: Data Booklet
Scientific calculator

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.*
- 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 ▶

P50789A

6/5/5/5/5/1/

P 5 0 7 8 9 A 0 1 2 8

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** $K_4Fe(CN)_6$

☐ **B** NH_4VO_3

☐ **C** K_2MnO_4

☐ **D** $[CoCl_4]^{2-}$

(Total for Question 1 = 1 mark)

---

2 Which species contains a bond angle of 90°?

☐ **A** $[Pt(NH_3)_2Cl_2]$

☐ **B** $[CuCl_2]^-$

☐ **C** $[CrCl_4]^-$

☐ **D** $SiCl_4$

(Total for Question 2 = 1 mark)

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

☐ **A** $[Zn(OH)_2](s) + 2OH^-(aq) \rightarrow [Zn(OH)_4]^{2-}(aq)$

☐ **B** $[Fe(H_2O)_6]^{3+}(aq) + H_2O(l) \rightarrow [Fe(H_2O)_5(OH)]^{2+}(aq) + H_3O^+(aq)$

☐ **C** $[Cu(H_2O)_6]^{2+}(aq) + 2NH_3(aq) \rightarrow Cu(H_2O)_4(OH)_2(s) + 2NH_4^+(aq)$

☐ **D** $[Cr(H_2O)_6]^{3+}(aq) + 6NH_3(aq) \rightarrow [Cr(NH_3)_6]^{3+}(aq) + 6H_2O(l)$

(Total for Question 3 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

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

$$2M^+(aq) \rightarrow M(s) + M^{2+}(aq)$$

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)

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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)

Use this space for any rough working. Anything you write in this space will gain no credit.

6 A ligand exchange reaction occurs when EDTA is added to a solution containing the ion $[Cu(H_2O)_2(NH_3)_4]^{2+}$.

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** $\Delta H_{reaction}$ is positive for the reaction of $[Cu(H_2O)_2(NH_3)_4]^{2+}$ with EDTA.

☒ **D** ΔS_{system} is positive for the reaction of $[Cu(H_2O)_2(NH_3)_4]^{2+}$ with EDTA.

(Total for Question 6 = 1 mark)

7 The repeat units of four polymers are shown:

Polymer	Repeat unit
P	— $CH_2CH(CONH_2)$ —
Q	— $HN(CH_2)_5NHOC(CH_2)_3CO$ —
R	— $HNCH_2CONHCH(CH_3)CO$ —
S	— $CH_2CH(CN)$ —

(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)

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

$$C_6H_{10} + H_2 \rightarrow C_6H_{12} \qquad \Delta H = -120\,kJ\,mol^{-1}$$

$$C_6H_6 + 3H_2 \rightarrow C_6H_{12} \qquad \Delta H = -208\,kJ\,mol^{-1}$$

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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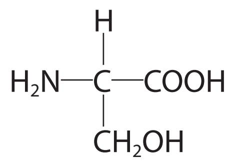
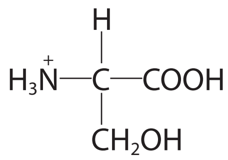
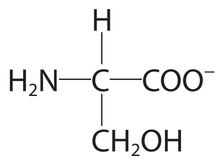
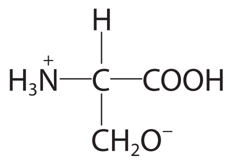
9 The formula of the amino acid serine is shown:

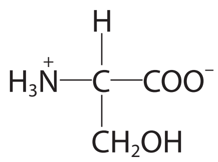


The formula of the zwitterion of serine is

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 9 = 1 mark)

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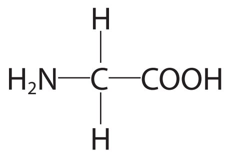
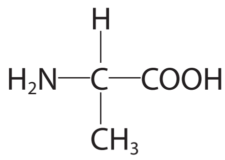
10 This question is about the amino acids, glycine and alanine.



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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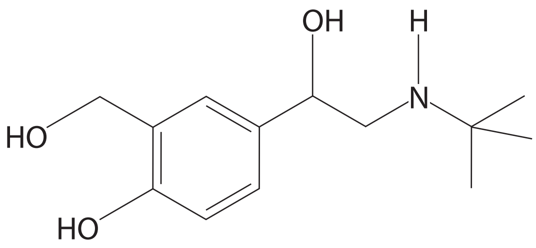
11 The structure of the asthma medication salbutamol is



(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)

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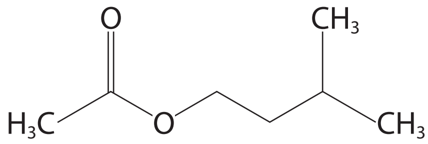
12 The compound **X** with molecular formula $C_7H_{14}O_2$ shown is responsible for some of the flavour of bananas.



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.

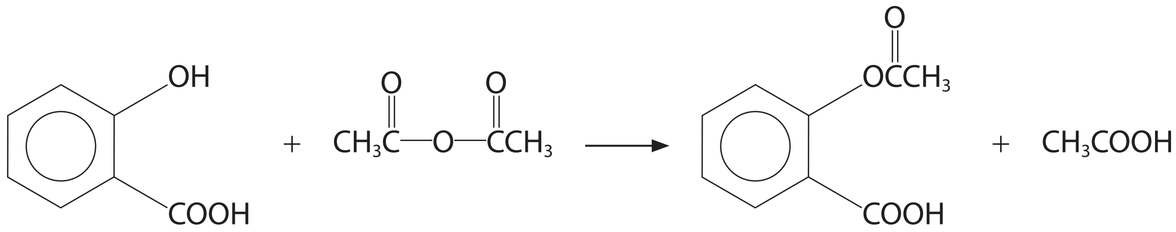
☒ **B** cyclohexene.

☒ **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.



2-hydroxybenzoic acid
Molar mass 138 g mol^{-1}

Aspirin
Molar mass 180 g mol^{-1}

(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 $[Ti(H_2O)_6]^{2+}$.

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)

....

....

(Total for Question 15 = 8 marks)

16 This question is about manganese and its ions.

(a) (i) Complete the electronic configuration of Mn and Mn^{2+}.

(1)

Mn [Ar] ....

Mn^{2+} [Ar] ....

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

(1)

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(b) Consider the data below.

Electrode system	Standard electrode potential ($E^{\ominus}$) / V
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	−1.19
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+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 $E^{\ominus}_{cell}$.

State the standard conditions required for the cell.

(4)

(ii) Calculate the value of $E^{\ominus}_{cell}$.

(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, V^{3+}(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 $E^{\ominus}_{cell}$ for any feasible reactions.

(4)

(d) A solution containing $Mn^{2+}(aq)$ 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)

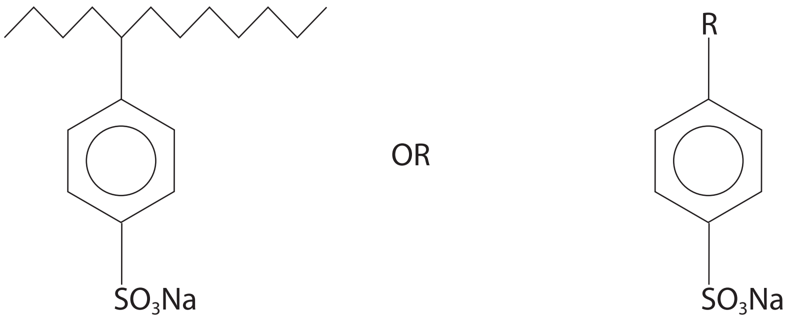
(iii) The precipitate darkens if it is left standing in air. Identify, by name or formula, the new manganese compound responsible for this darkening.

(1)

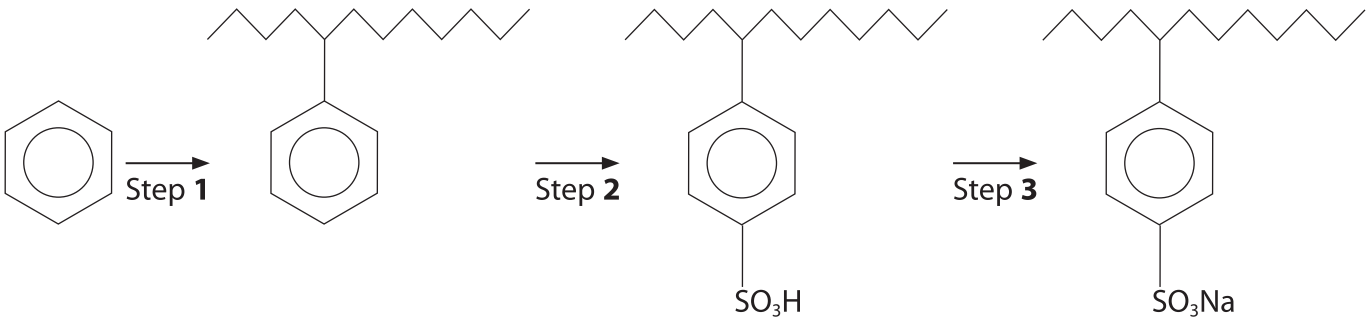
(Total for Question 16 = 16 marks)

P 5 0 7 8 9 A 0 1 5 2 8

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



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)

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(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:

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P 5 0 7 8 9 A 0 1 6 2 8

(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)

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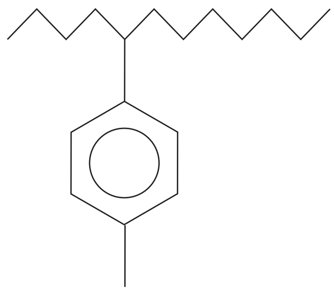
(v) Complete the diagram to show the **displayed** formula of the —SO_3H group in the product formed in Step **2**.

(1)



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

(1)

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*(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)

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(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)

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(Total for Question 17 = 13 marks)

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)

(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 Cr^{2+}(aq) and Cr^{3+}(aq) are coloured due to electron transitions between d orbitals.

Explain why Cr^{2+}(aq) and Cr^{3+}(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)

(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

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$$

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

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

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.

$$2Cr_2O_7^{2-}(aq) + 16H^+(aq) + 3C_2H_5OH(l) \rightarrow 4Cr^{3+}(aq) + 11H_2O(l) + 3CH_3COOH(aq)$$

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 $0.015\,mol\,dm^{-3}$. 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)

....

(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 $1.00\,cm^3$ of wine.

(1)

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

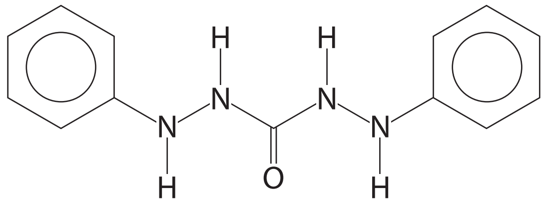
The volume of 1 mole of ethanol is 58.3 cm^3.

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

(2)

(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

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
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	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	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	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	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	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	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	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103