Write your name here

Surname	Other names

Centre Number	Candidate Number

Edexcel GCE

Chemistry

Advanced

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

Tuesday 22 January 2013 – Afternoon
Time: 1 hour 40 minutes

Paper Reference
6CH05/01

You must have: Data Booklet

Candidates may use a calculator.

Total Marks

Instructions

- Use **black** ink or 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.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

PEARSON

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 The reaction between iron and nickel(II) sulfate may be represented by the ionic equation

$$\mathrm{Ni^{2+}(aq) + Fe(s) \rightarrow Ni(s) + Fe^{2+}(aq)}$$

(a) This reaction is classified as a redox reaction because

(1)

☒ **A** the nickel(II) ions are oxidized and iron acts as an oxidizing agent.

☒ **B** the nickel(II) ions are oxidized and iron acts as a reducing agent.

☒ **C** the nickel(II) ions are reduced and iron acts as a reducing agent.

☒ **D** the nickel(II) ions are reduced and iron acts as an oxidizing agent.

(b) This reaction proceeds spontaneously, therefore

(1)

☒ **A** E_{cell} and ΔS_{total} for this reaction must both be positive.

☒ **B** E_{cell} and ΔS_{total} for this reaction must both be negative.

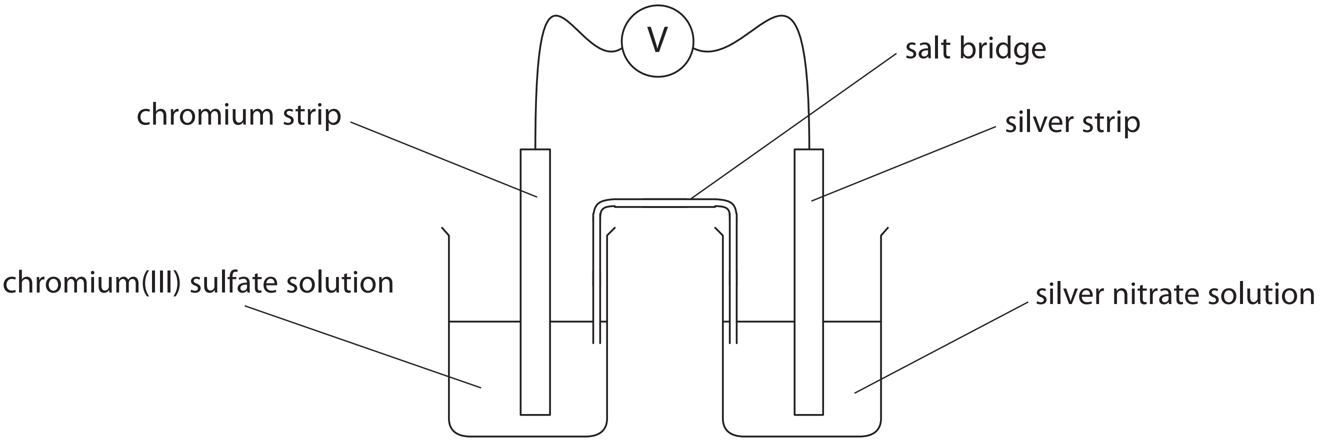
☒ **C** E_{cell} for this reaction must be positive and ΔS_{total} negative.

☒ **D** E_{cell} for this reaction must be negative and ΔS_{total} positive.

(Total for Question 1 = 2 marks)

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

2 The diagram below shows an electrochemical cell.



(a) The salt bridge in this cell is **best** prepared by soaking filter paper in a

(1)

☒ **A** 1 mol dm^{-3} solution of potassium bromide.

☒ **B** 1 mol dm^{-3} solution of potassium chloride.

☒ **C** saturated solution of potassium nitrate.

☒ **D** saturated solution of potassium iodide.

(b) The relevant standard electrode potentials for this cell are shown below.

$$Cr^{3+}(aq) + 3e^- \rightleftharpoons Cr(s) \quad E^\ominus = -0.74\ V$$

$$Ag^+(aq) + e^- \rightleftharpoons Ag(s) \quad E^\ominus = +0.80\ V$$

The emf of the cell shown in the diagram is

(1)

☒ **A** +1.54 V

☒ **B** −1.54 V

☒ **C** +0.06 V

☒ **D** −0.06 V

(c) The mass of 1 mol of chromium(III) sulfate ($Cr_2(SO_4)_3$) is 392 g. Hence, for the cell in the diagram to measure the **standard** electrode potential, 1 dm^3 of the chromium(III) sulfate solution used must contain

(1)

☒ **A** 104 g of chromium(III) sulfate.

☒ **B** 196 g of chromium(III) sulfate.

☒ **C** 392 g of chromium(III) sulfate.

☒ **D** 784 g of chromium(III) sulfate.

(Total for Question 2 = 3 marks)

3 Vanadium is classified as a transition metal. This is because vanadium

☒ **A** is a d-block element.

☒ **B** has incompletely filled d orbitals.

☒ **C** forms stable ions with incompletely filled d orbitals.

☒ **D** forms stable ions in which it has different oxidation states.

(Total for Question 3 = 1 mark)

4 Copper(II) sulfate solution is blue. This is because

☒ **A** excited electrons emit light in the blue region of the spectrum as they drop back to the ground state.

☒ **B** excited electrons emit light in the red region of the spectrum as they drop back to the ground state.

☒ **C** electrons absorb light in the red region of the spectrum and the residual frequencies are observed.

☒ **D** electrons absorb light in the blue region of the spectrum and the residual frequencies are observed.

(Total for Question 4 = 1 mark)

5 One method of manufacturing hydrazine (N_2H_4) involves the action of sodium chlorate(I) on excess ammonia at 443 K and 50 atm. The yield is normally around 80% but, if just 1 part per million of copper(II) ions is present, the yield drops to 30%.

The most likely explanation for this is the ability of copper(II) ions to

☒ **A** form complex ions with ammonia.

☒ **B** catalyse reactions producing other nitrogen compounds.

☒ **C** reduce the hydrazine as it is formed.

☒ **D** reduce the sodium chlorate(I).

(Total for Question 5 = 1 mark)

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

6 Platinum forms a complex with the formula $Pt(NH_3)_2Cl_2$ and chromium forms a complex ion with the formula $CrCl_4^-$.

(a) Considering the shapes of these complexes,

(1)

☒ **A** both complexes are square planar.

☒ **B** both complexes are tetrahedral.

☒ **C** $Pt(NH_3)_2Cl_2$ is tetrahedral and $CrCl_4^-$ is square planar.

☒ **D** $Pt(NH_3)_2Cl_2$ is square planar and $CrCl_4^-$ is tetrahedral.

(b) Considering the structures of these complexes,

(1)

☒ **A** both complexes form stereoisomers.

☒ **B** neither complex forms a stereoisomer.

☒ **C** $Pt(NH_3)_2Cl_2$ forms a stereoisomer but $CrCl_4^-$ does not.

☒ **D** $CrCl_4^-$ forms a stereoisomer but $Pt(NH_3)_2Cl_2$ does not.

(c) Considering the bonding between the central atom and the ligands in these complexes,

(1)

☒ **A** the bonding in both complexes is dative covalent.

☒ **B** the bonding in both complexes is ionic.

☒ **C** the bonding in $Pt(NH_3)_2Cl_2$ is dative covalent and in $CrCl_4^-$ is ionic.

☒ **D** the bonding in $Pt(NH_3)_2Cl_2$ is ionic and in $CrCl_4^-$ is dative covalent.

(Total for Question 6 = 3 marks)

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

7 When concentrated ammonia solution is added to a green solution of chromium(III) sulfate, a green precipitate is formed which slowly dissolves in excess of the concentrated ammonia solution.

The chromium-containing species formed in these reactions are

	Green precipitate	Resulting solution
☒ **A**	$Cr(OH)_3$	$[Cr(OH)_6]^{3-}$
☒ **B**	$Cr(OH)_3$	$[Cr(NH_3)_6]^{3+}$
☒ **C**	$(NH_4)_2CrO_4$	$[Cr(OH)_6]^{3-}$
☒ **D**	$(NH_4)_2CrO_4$	$[Cr(NH_3)_6]^{3+}$

(Total for Question 7 = 1 mark)

8 Bromine reacts much faster with phenylamine than with benzene. This is because

☒ **A** N—H bonds are weaker than C—H bonds.

☒ **B** nitrogen is very electronegative.

☒ **C** the benzene ring has greater electron density in phenylamine than in benzene.

☒ **D** phenylamine reacts by addition whereas benzene reacts by substitution.

(Total for Question 8 = 1 mark)

9 X-ray diffraction provides evidence that benzene molecules have

☒ **A** delocalized π electrons.

☒ **B** carbon–carbon bonds that are all the same length.

☒ **C** lower thermodynamic stability than molecules of 1,3,5-cyclohexatriene.

☒ **D** greater thermodynamic stability than molecules of 1,3,5-cyclohexatriene.

(Total for Question 9 = 1 mark)

10 Benzene is nitrated using a mixture of concentrated nitric and sulfuric acids. The sulfuric acid

☒ **A** acts as a solvent for the benzene and the nitric acid.

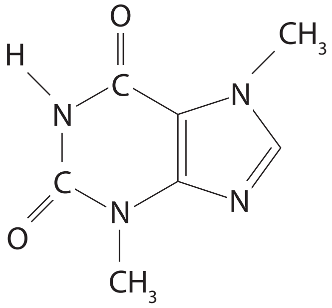
☒ **B** protonates the benzene to speed up the reaction.

☒ **C** protonates the nitric acid which acts as a base.

☒ **D** reacts with the benzene to form a benzenesulfonic acid intermediate.

(Total for Question 10 = 1 mark)

11 The compound shown below is found in cocoa beans and in chocolate. Which of the groups listed is **not** present in its structure?



☒ **A** Alkyl

☒ **B** Amide

☒ **C** Amine

☒ **D** Ketone

(Total for Question 11 = 1 mark)

12 The **distinguishing** characteristic of combinatorial chemistry is that it involves the

☒ **A** simultaneous synthesis of many products.

☒ **B** interaction of starting materials to form a unique product.

☒ **C** use of catalysts.

☒ **D** use of polymer supports.

(Total for Question 12 = 1 mark)

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

13 Phenylamine (aniline), $C_6H_5NH_2$, may be prepared from nitrobenzene, $C_6H_5NO_2$.

(a) The reagent normally used for this reaction is

(1)

☒ **A** lithium tetrahydridoaluminate(III) (lithium aluminium hydride) in ether.

☒ **B** concentrated ammonia in ethanol.

☒ **C** potassium dichromate(VI) in sulfuric acid.

☒ **D** tin in concentrated hydrochloric acid.

(b) The phenylamine is separated from the reaction mixture by

(1)

☒ **A** paper chromatography.

☒ **B** steam distillation.

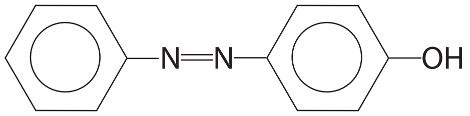
☒ **C** filtration.

☒ **D** recrystallization.

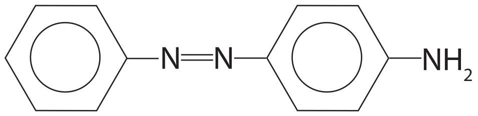
(c) One test for phenylamine is to convert it into a diazonium ion which is then reacted with phenol to form an azo dye. The structure of this dye is

(1)

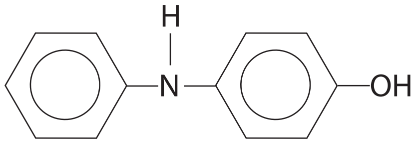
☒ **A**



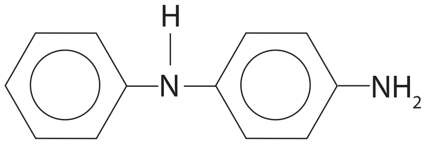
☒ **B**



☒ **C**



☒ **D**



(Total for Question 13 = 3 marks)

TOTAL FOR SECTION A = 20 MARKS

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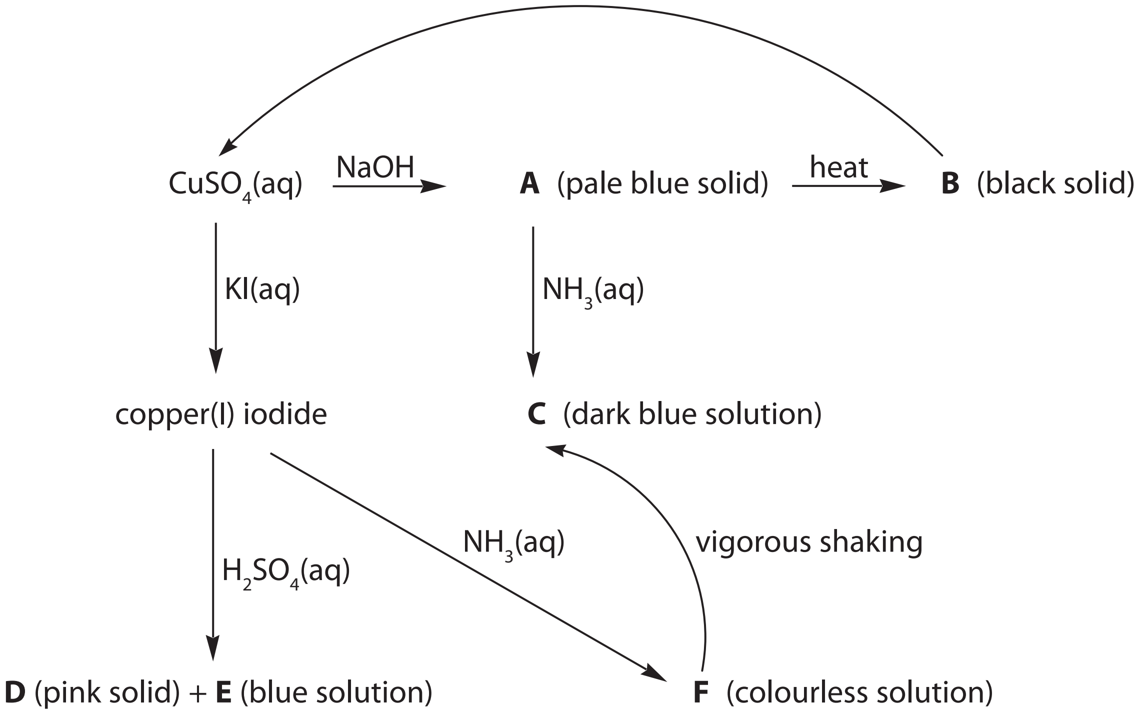
SECTION B

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

14 This question concerns the chemistry of copper. In the sequence below, **A**, **B**, **C**, **D**, **E** and **F** all contain copper in various oxidation states.



(a) Identify, by name (including the oxidation state where appropriate) or formula, the copper-containing species in the sequence.

(6)

A ....

B ....

C ....

D ....

E ....

F ....

(b) Identify, by name or formula, the reagent that would be used to convert **B** into $CuSO_4(aq)$.

(1)

....

(c) (i) **C** and **F** are the same type of chemical species. Name this type.

(1)

....

(ii) Explain why **C** is coloured but **F** is colourless.

(3)

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*(iii) Explain why **F** changes into **C** on shaking.

(2)

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(d) The reaction of copper(I) iodide to form **D** and **E** is a disproportionation.

(i) Explain the term disproportionation.

(2)

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....

(ii) Write an ionic equation for this reaction. State symbols are **not** required.

(1)

(iii) Use the relevant standard reduction (electrode) potentials, from the table on page 17 of your data booklet, to calculate the $E^{\ominus}_{\text{cell}}$ value for this reaction, giving your answer with the appropriate sign.

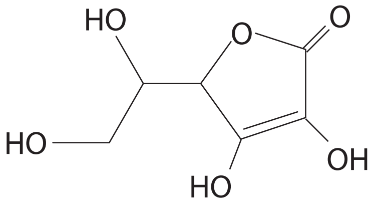
(2)

*(iv) If copper(I) iodide is treated with nitric acid, rather than sulfuric acid, a blue solution is still formed but no pink solid. Use the standard electrode potentials on page 15 of your data booklet to explain this. Quote any data that you use.

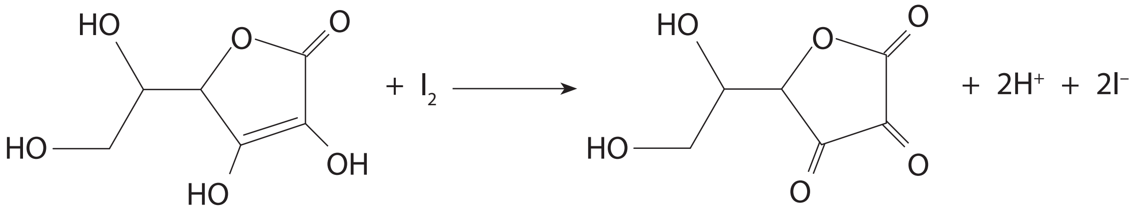
(4)

(Total for Question 14 = 22 marks)

15 Vitamin C (L-ascorbic acid) is present in fresh fruit and vegetables although prolonged cooking destroys it. The structure of ascorbic acid, $C_6H_8O_6$, is shown below.



(a) The amount of ascorbic acid present in a sample is determined by reacting it with a known amount of iodine. The excess iodine is then measured by titration with a solution of sodium thiosulfate, using a starch indicator. The equations for the reactions are given below.



$$2S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2I^-$$

Four 500 mg vitamin C tablets were dissolved in distilled water and the solution made up to 250 cm^3 in a volumetric flask. A 25.0 cm^3 portion of this solution was added to an iodine solution containing 2.00×10^{-3} moles of iodine. The resulting mixture was titrated with sodium thiosulfate solution of concentration 0.0631 mol dm^{-3}. The titration was repeated and the mean (average) titre was 27.85 cm^3.

(i) State the type of chemical change undergone by ascorbic acid when it reacts with iodine.

(1)

(ii) State the colour of the solution in the flask just before the starch is added to the titration mixture and state the colour change at the end-point of the titration.

(2)

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....

(iii) Calculate the percentage by mass of ascorbic acid in the tablets. The molar mass of ascorbic acid is 176 g mol^{-1}.

(5)

(iv) Explain why using four tablets in 250 cm^3 of solution gives a more accurate result than two tablets in 250 cm^3.

(1)

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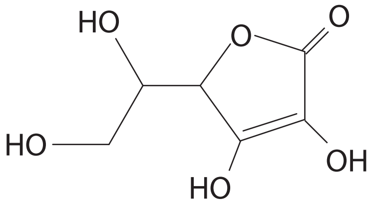
....

(b) The structure of ascorbic acid is shown again below. Vitamin C is one of the optical isomers of this structure.



(i) Mark on this diagram the two chiral centres of this molecule.

(2)

(ii) How might you show that vitamin C is a single optical isomer and not a racemic mixture of the optical isomers of ascorbic acid?

(2)

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....

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....

(iii) Despite its name, ascorbic acid is not a carboxylic acid but it does contain an ester group. Suggest what happens to destroy vitamin C on prolonged cooking.

(1)

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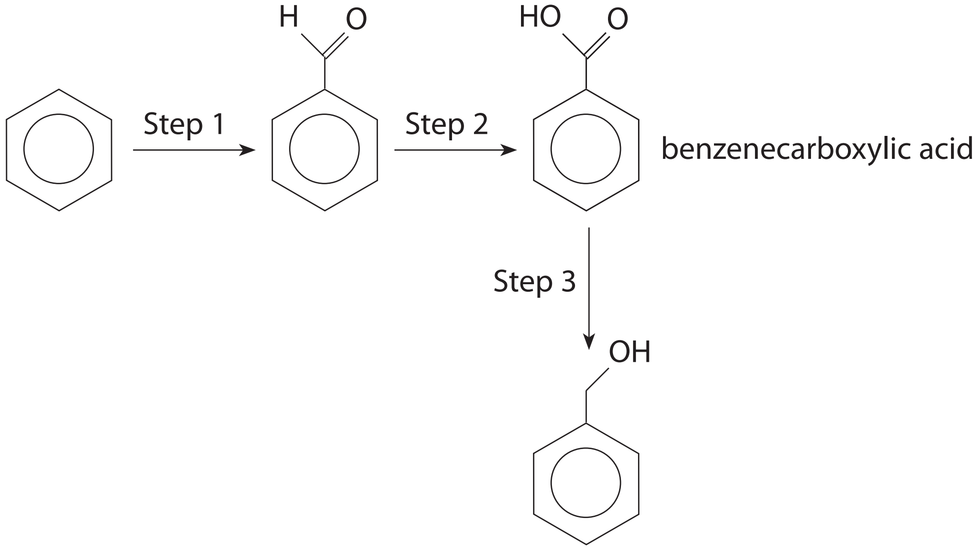
....

(Total for Question 15 = 14 marks)

16 Benzenecarboxylic acid (benzoic acid) and phenylmethanol (benzyl alcohol) are compounds which occur naturally and have a wide range of uses. For example, benzenecarboxylic acid is used as a food preservative and phenylmethanol is used as a solvent.

A laboratory sequence for the preparation of these two compounds is shown below.



phenylmethanol

(a) In the first step of the synthesis, benzene reacts with hydrogen chloride and carbon monoxide in the presence of aluminium chloride in an electrophilic substitution called the Gattermann-Koch reaction. The hydrogen chloride and carbon monoxide together behave as if they form the unstable species methanoyl chloride (HCOCl).

(i) Explain why benzene undergoes substitution rather than addition reactions. A detailed description of the bonding in benzene is **not** required.

(2)

....

....

....

....

(ii) Give the mechanism for step 1, including the formation of the electrophile.

(4)

(iii) Identify the reagents and essential conditions used in the remaining steps of the sequence. You may assume that the correct reaction temperatures are being used.

(4)

Step 2 ....

....

....

Step 3 ....

....

....

*(b) Phenol reacts faster than phenylmethanol in electrophilic substitution reactions. Suggest why this is so.

(4)

(Total for Question 16 =14 marks)

TOTAL FOR SECTION B = 50 MARKS

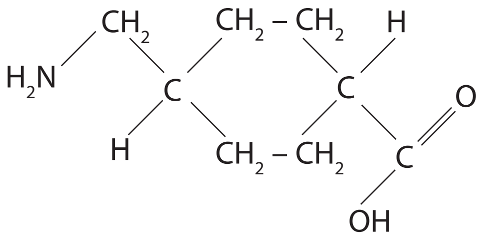
SECTION C

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

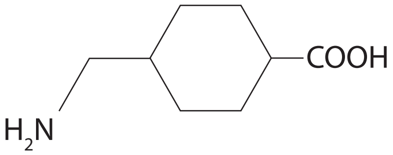
17

Tranexamic acid

Tranexamic acid is an amino acid. It is a white crystalline solid which melts at 300 °C. It is used to reduce bleeding during surgery and dental procedures and is especially useful where patients suffer from deficiencies in blood-clotting factors. The structure of tranexamic acid can be drawn as shown below.



or



As the name suggests, tranexamic acid is the *trans* form of a compound that forms geometric (or *cis-trans* or *E-Z*) isomers.

(a) (i) Explain why some molecules which contain a C═C double bond show geometric isomerism.

(2)

....

....

....

....

(ii) Suggest how tranexamic acid can form geometric isomers although it does not have a C═C double bond.

(1)

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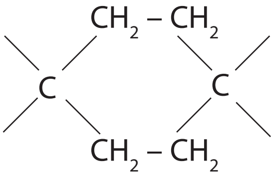
(iii) Complete the diagram to show the structure of the *cis* isomer.

(1)



(iv) Explain why tranexamic acid melts at 300 °C while the alkane, undecane ($C_{11}H_{24}$) which has almost the same number of electrons, melts at –26 °C. A detailed description of the forces involved is **not** required.

(3)

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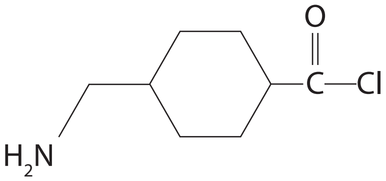
(b) The diagram below shows a compound, **K**, which is a derivative of tranexamic acid.



(i) Identify by name or formula a compound that might react with tranexamic acid to form **K**.

(1)

....

(ii) Under suitable conditions, molecules of **K** react together forming a polymer, **L**. Draw the structure of **L**, showing two repeat units.

(2)

(iii) Name the type of polymerization that results in the formation of **L**.

....

(1)

(iv) State the type of naturally occurring substance which contains the same type of linkage as in the polymer **L**.

(1)

....

(c) If the sequence of reactions, that produces polymer **L** from tranexamic acid, is carried out starting with the *cis* isomer of tranexamic acid, an organic compound, **M**, is formed.

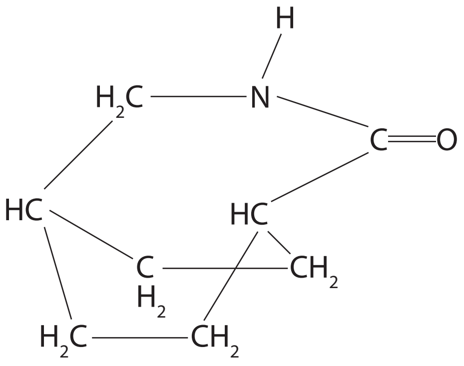
The low resolution nuclear magnetic resonance (nmr) spectrum of **M** has six peaks with relative heights 4:4:2:1:1:1.

The infrared (IR) spectrum of **M** has peaks in the region 1700–1630 cm^{-1} and 3500–3140 cm^{-1}.

(i) The structure of **M** is shown below.

The nmr spectrum shows that the molecule, **M**, has six different hydrogen environments. Use the letters **a** to **f** to label the H atoms of **M** showing the six hydrogen environments. All thirteen hydrogen atoms should be labelled.

(4)



(ii) Explain how the IR data are consistent with the structure of **M**.

(2)

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....

....

(iii) Suggest why **M** is formed from the *cis* isomer but not from the *trans* isomer.

(2)

....

....

....

(Total for Question 17 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
							1.0 **H** hydrogen 1										*(18)*
(1)	*(2)*											*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	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	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(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