Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Time 1 hour 45 minutes

Paper reference **WCH15/01**

Chemistry

International Advanced Level
UNIT 5: Transition Metals and Organic Nitrogen Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

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.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how 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.
- 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 This question is about catalysts.

(a) Some standard electrode potentials are shown.

Right-hand electrode system	$E^{\ominus}$/V
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+0.15
$I_2 + 2e^- \rightleftharpoons 2I^-$	+0.54
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+0.77
$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$	+1.36
$S_2O_8^{2-} + 2e^- \rightleftharpoons 2SO_4^{2-}$	+2.01

Which of these ions is most likely to catalyse the reaction between $S_2O_8^{2-}$ and I^-?

$$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$$

(1)

☒ **A** Cl^-

☒ **B** Fe^{2+}

☒ **C** Cu^{2+}

☒ **D** Cu^+

(b) Which term best describes the type of catalyst for the reaction in (a)?

(1)

☒ **A** autocatalyst

☒ **B** biocatalyst

☒ **C** heterogeneous

☒ **D** homogeneous

(c) Which substance is manufactured in a process involving a reaction catalysed by vanadium(V) oxide?

(1)

☒ **A** ammonia

☒ **B** nitric acid

☒ **C** sodium hydroxide

☒ **D** sulfuric acid

(Total for Question 1 = 3 marks)

2 This question is about alkaline hydrogen-oxygen fuel cells.

(a) What is the half-equation at the **negative** electrode?

(1)

☒ **A** $H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$

☒ **B** $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

☒ **C** $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

☒ **D** $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$

(b) Which statement is correct for an alkaline hydrogen-oxygen fuel cell when compared with an acidic hydrogen-oxygen fuel cell?

(1)

☒ **A** $E^{\ominus}_{cell}$ is greater

☒ **B** $\Delta S^{\ominus}_{total}$ is greater

☒ **C** the catalyst is more efficient

☒ **D** K_c is greater

(Total for Question 2 = 2 marks)

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

3 Excess aqueous sodium thiosulfate is added to an aqueous solution of ammonium vanadate(V).

What colour is the mixture when the reaction is complete?

Refer to page 10 of the Data Booklet.

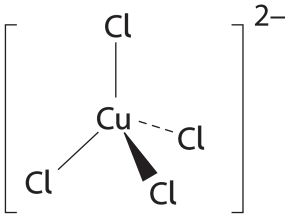
- ☒ **A** yellow
- ☒ **B** blue
- ☒ **C** green
- ☒ **D** violet

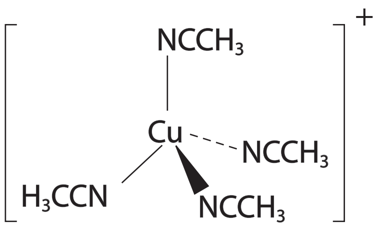
(Total for Question 3 = 1 mark)

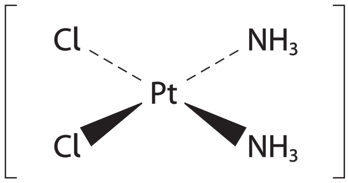
Use this space for rough working. Anything you write in this space will gain no credit.

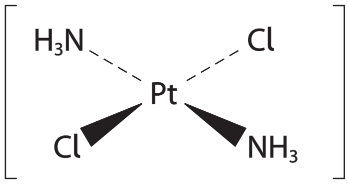
P 7 0 9 5 6 A 0 4 3 2

4 Which transition metal complex is commonly used as a treatment for cancer?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 4 = 1 mark)

5 Which reagent, when added to aqueous sodium dichromate(VI), $Na_2Cr_2O_7(aq)$, causes a shift in equilibrium resulting in the formation of a yellow solution?

☒ **A** $NaOH(aq)$

☒ **B** $HCl(aq)$

☒ **C** $Zn(s)$

☒ **D** $H_2O_2(aq)$

(Total for Question 5 = 1 mark)

6 A titre has an uncertainty of 0.32 %.
The uncertainty of each burette reading is ±0.05 cm^3.

What is the most likely value of the titre in cm^3?

☒ **A** 6.40

☒ **B** 15.60

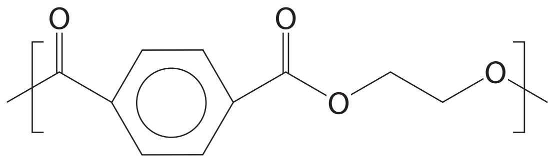
☒ **C** 31.25

☒ **D** 32.00

(Total for Question 6 = 1 mark)

7 This question is about polymers.

(a) A repeat unit of the polymer PET has the structure shown.



What is the percentage by mass of carbon in the repeat unit?

(1)

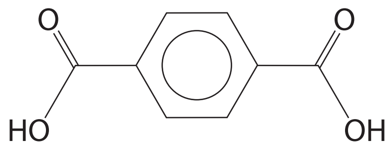
☒ **A** 57.1 %

☒ **B** 62.5 %

☒ **C** 65.2 %

☒ **D** 66.7 %

(b) One of the monomers used to make PET is benzene-1,4-dicarboxylic acid.



How many peaks are there in the ^{13}C NMR spectrum of benzene-1,4-dicarboxylic acid?

(1)

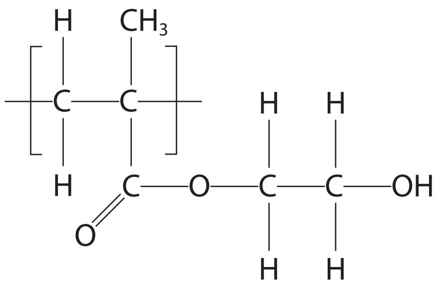
☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 6

(c) The repeat unit of another polymer has the structure shown.



This polymer is formed from

(1)

☒ **A** a single type of monomer by an addition reaction

☒ **B** a single type of monomer by a condensation reaction

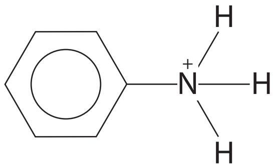
☒ **C** two different types of monomer by an addition reaction

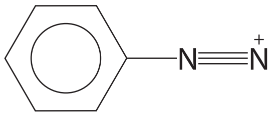
☒ **D** two different types of monomer by a condensation reaction

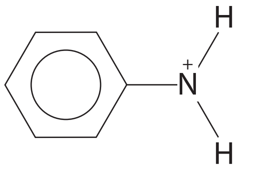
(Total for Question 7 = 3 marks)

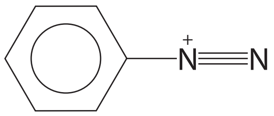
Use this space for rough working. Anything you write in this space will gain no credit.

8 Which ion is formed when a mixture of sodium nitrite, $NaNO_2$, and dilute hydrochloric acid reacts with phenylamine at a temperature of 5°C?

☒ **A** 

☒ **B** 

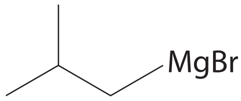
☒ **C** 

☒ **D** 

(Total for Question 8 = 1 mark)

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

9 This question is about a Grignard reagent, 2-methylpropylmagnesium bromide.



This Grignard reagent can be prepared by refluxing 1-bromo-2-methylpropane with magnesium in a flask containing a dry solvent and anti-bumping granules.

(a) Which solvent is used in this preparation?

(1)

☒ **A** ethanol

☒ **B** ether

☒ **C** pentane

☒ **D** propanone

(b) Why are anti-bumping granules added to the flask?

(1)

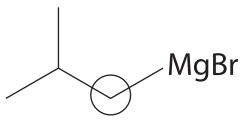
☒ **A** to lower the boiling temperature of the solvent

☒ **B** to prevent the solvent evaporating

☒ **C** because the solvent is highly flammable

☒ **D** to ensure the solvent boils smoothly

(c) The structure of 2-methylpropylmagnesium bromide is shown.



Which statement best describes the circled carbon atom?

(1)

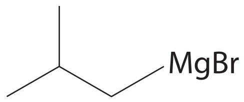
☒ **A** positive and electrophilic

☒ **B** positive and nucleophilic

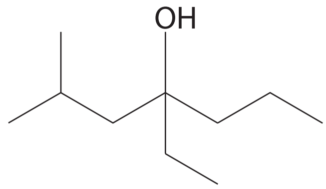
☒ **C** negative and electrophilic

☒ **D** negative and nucleophilic

(d) Which compound reacts with 2-methylpropylmagnesium bromide to form 4-ethyl-2-methylheptan-4-ol?



2-methylpropylmagnesium bromide



4-ethyl-2-methylheptan-4-ol

(1)

☒ **A** hexan-3-one

☒ **B** hexan-2-one

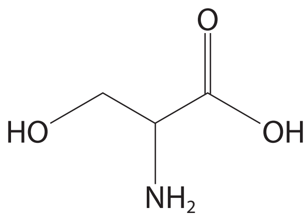
☒ **C** hexan-3-ol

☒ **D** hexan-2-ol

(Total for Question 9 = 4 marks)

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

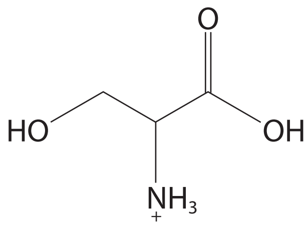
10 This question is about the amino acid serine.

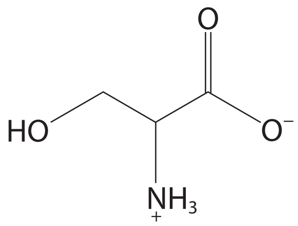


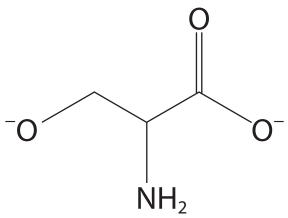
serine

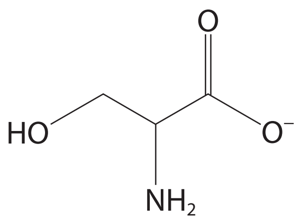
(a) Which ion is most likely to form if serine is dissolved in sodium carbonate solution?

(1)

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(b) Serine has a melting temperature in the region of 200–300 °C.

This high melting temperature is mainly due to the formation of

(1)

☒ **A** hydrogen bonds

☒ **B** ionic bonds

☒ **C** London forces

☒ **D** peptide bonds

(Total for Question 10 = 2 marks)

11 Which is correct for the reaction of bromine with phenol when compared with benzene?

		Reactivity of phenol	Electron density of the ring in phenol
☒	**A**	more reactive	higher electron density
☒	**B**	more reactive	lower electron density
☒	**C**	less reactive	higher electron density
☒	**D**	less reactive	lower electron density

(Total for Question 11 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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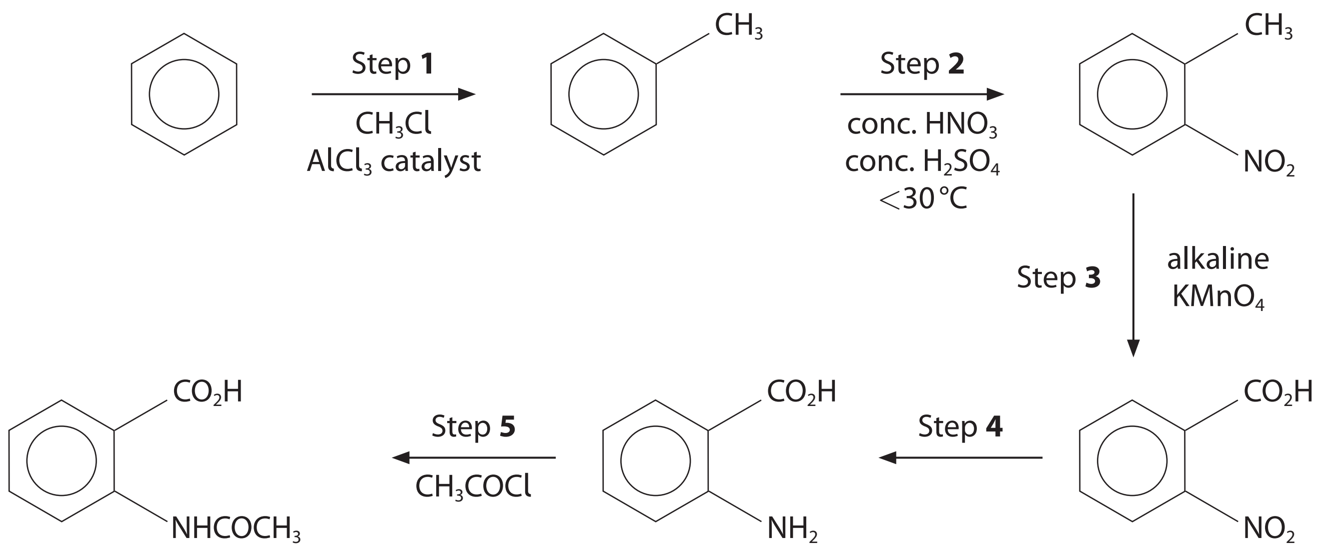
SECTION B

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

12 This question is about 2-ethanoylaminobenzoic acid.
Crystals of this compound emit flashes of light when crushed.

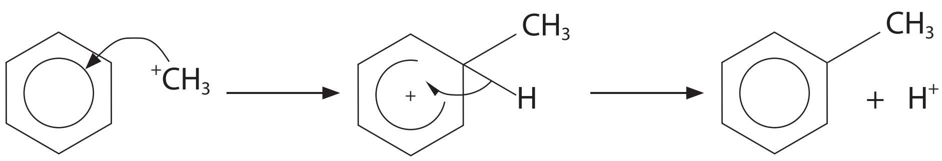
2-ethanoylaminobenzoic acid can be synthesised using benzene as a starting material.



2-ethanoylaminobenzoic acid compound **A**

(a) A student proposed a mechanism for Step **1**.

$$CH_3Cl + AlCl_3 \longrightarrow {}^{+}CH_3 + AlCl_4^-$$



$$H^+ + AlCl_4^- \longrightarrow HCl + AlCl_3$$

(i) Identify **two** errors in the mechanism by circling them.

(2)

(ii) State how the errors identified in (a)(i) should be corrected.
Justify your answer in terms of the structures involved.

(2)

(b) Give a reason why it is important to keep the temperature below 30 °C in Step **2**.

(1)

(c) State the type of reaction in Step **3**.

(1)

(d) Identify, by name or formula, the reagents needed for Step **4**.

(1)

(e) Explain how the structures of ethanoyl chloride, CH_3COCl, and compound **A** enable them to react forming 2-ethanoylaminobenzoic acid in Step **5**.

(3)

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(f) Calculate the volume of benzene required to form 5.92 g of 2-ethanoylaminobenzoic acid, assuming the overall yield for the synthesis is 28.2 %.

Give your answer to an appropriate number of significant figures.

[Density of benzene = 0.879 g cm^{-3}]

(4)

(Total for Question 12 = 14 marks)

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***13** Compare and contrast the reactions in aqueous solution of nickel(II) sulfate with sodium hydroxide and with ammonia.

For each reaction include

- what would be seen
- the equation (state symbols are not required)
- the type of reaction.

(6)

(Total for Question 13 = 6 marks)

14 A compound, **Q**, is a pale yellow liquid that is the main constituent of cinnamon oil. **Q** contains the elements carbon, hydrogen and oxygen only.

(a) Complete combustion of 6.02 g of **Q** produces 18.07 g of carbon dioxide and 3.30 g of water.

Determine the empirical formula of **Q**.

(4)

(b) Tests on samples of **Q** show that it

- burns in air with a very sooty flame
- forms an orange precipitate with Brady's reagent (2,4-dinitrophenylhydrazine solution)
- forms a silver precipitate with Tollens' reagent
- decolourises bromine water
- exists as a pair of geometric isomers.

Deduce a structure for **Q**, explaining how each piece of information supports your answer.

(6)

(Total for Question 14 = 10 marks)

15 This question is about transition metal compounds and their quantitative analysis.

(a) Potassium dichromate(VI), $K_2Cr_2O_7$, is present in very small amounts in cement, to help increase the time for the cement to set.

A 50.0 g sample of cement was washed with portions of deionised water to dissolve the potassium dichromate(VI). Any insoluble residues were removed by filtration and the filtrate was transferred to a volumetric flask. The volume was made up to 100.0 cm^3, using 2 mol dm^{-3} sulfuric acid.

50.0 cm^3 of this solution was transferred to a conical flask and titrated with a solution of ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2(aq)$, of concentration 3.24×10^{-4} mol dm^{-3}.

The indicator *N*-phenylanthranilic acid was used, which gave an intense red-violet colour at the end-point.

The mean titre of ammonium iron(II) sulfate was 10.90 cm^3.

The ionic equation for the redox reaction in the titration is shown.

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

(i) State the colour of each chromium species in the reaction.

(1)

$Cr_2O_7^{2-}$ ....

Cr^{3+} ....

(ii) Suggest a reason why an indicator is needed in this titration.

(1)

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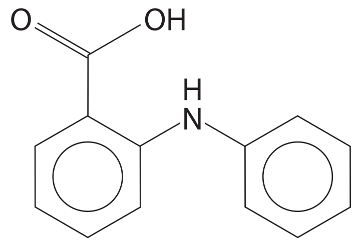
....

(iii) Calculate the percentage by mass of potassium dichromate(VI) in the cement sample.

(5)

(b) *N*-phenylanthranilic acid has the structure shown.



The solution used as an indicator was prepared by mixing 100 mg of this acid in 5 cm^3 of sodium hydroxide solution, NaOH(aq).
The mixture was then diluted to 100 cm^3 with deionised water.

Explain why the *N*-phenylanthranilic acid is added to the sodium hydroxide solution before it is mixed with water in the preparation of this solution.

(2)

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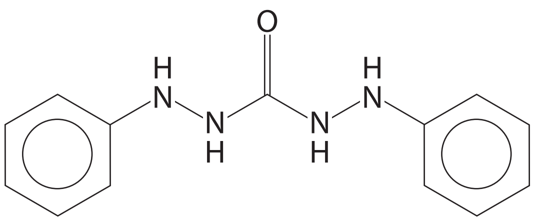
(c) The concentration of chromium(VI) in aqueous solution may also be determined using a colorimeter.

On adding 1,5-diphenylcarbazide, DPC, to a solution of chromium(VI) ions, an intensely coloured octahedral complex forms.
The formula of the complex is $Cr(DPC)_3^{6+}$.

(i) The structure of DPC is shown.



Describe how DPC is able to act as a bidentate ligand, using your diagram to show the atoms involved.

(3)

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DO NOT WRITE IN THIS AREA

(ii) The intense colour of this complex is due to the transfer of electrons from the ligand to the chromium(VI) ion.

Suggest a possible reason why the colour is **not** due to the transfer of electrons between split d-orbitals in the ion.
Refer to the electronic configuration of the chromium(VI) ion.

(1)

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....

....

(d) The concentration of nickel(II) ions, $Ni^{2+}(aq)$, can be determined by forming a complex with the ligand dimethylglyoxime, $C_4H_8N_2O_2$.

$$[Ni(H_2O)_6]^{2+} + 2C_4H_8N_2O_2 + 2OH^- \rightarrow [Ni(C_4H_7N_2O_2)_2(H_2O)_2] + 6H_2O$$

Explain why the formation of the dimethylglyoxime complex is favoured, in terms of entropy.

(2)

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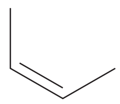
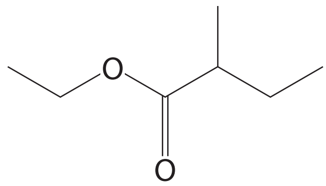
(Total for Question 15 = 15 marks)

16 The ester ethyl 2-methylbutanoate is found in wild berries such as bilberries.

Devise a synthesis to convert but-2-ene into ethyl 2-methylbutanoate in **four** steps.



but-2-ene



ethyl 2-methylbutanoate

Include the reagents and essential conditions for each step and the name or structure of each of the intermediate compounds.

Details of practical procedures are not required.

(Total for Question 16 = 6 marks)

TOTAL FOR SECTION B = 51 MARKS

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SECTION C

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

17

Gilding Metal

Gilding metal is a type of brass alloy that consists of copper and a small amount of zinc, ranging from 5% to 11% by mass. Copper is very malleable and is hardened by the addition of zinc.

Gilding metal is much less susceptible to cracking due to corrosion than brasses with a higher percentage of zinc.

It has a warm, golden colour and can be used to coat materials using electrolysis. It is also used to make test pieces in jewellery manufacture because it has similar properties to silver but is less expensive.

The proportions of copper and zinc determine the exact properties of the gilding metal and can be determined by chemical analysis.

(a) 2.72 g of a type of brass is dissolved in excess concentrated nitric acid, forming a solution containing both Cu^{2+} and Zn^{2+} ions.
A solution containing hydrogensulfate(IV) ions, HSO_3^-, is then added.

$$2Cu^{2+}(aq) + HSO_3^-(aq) + H_2O(l) \rightarrow 2Cu^+(aq) + HSO_4^-(aq) + 2H^+(aq)$$

The addition of ammonium thiocyanate, NH_4SCN, gives a precipitate of copper(I) thiocyanate, CuSCN.

$$Cu^+(aq) + SCN^-(aq) \rightarrow CuSCN(s)$$

The precipitate of copper(I) thiocyanate is collected, dried and found to have a mass of 4.69 g.

(i) Determine whether or not this type of brass is a gilding metal, by calculating its percentage by mass of copper.

(4)

(ii) Explain, by considering both thermodynamic and kinetic factors, why HSO_3^- reduces Cu^{2+} to Cu^+ but does **not** then reduce Cu^+ to Cu.
Use the data in the table.

(3)

Right-hand electrode system	$E^\ominus$/V
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+0.15
$HSO_4^- + 2H^+ + 2e^- \rightleftharpoons HSO_3^- + H_2O$	+0.17
$Cu^+ + e^- \rightleftharpoons Cu$	+0.52

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DO NOT WRITE IN THIS AREA

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(b) After the copper(I) thiocyanate is precipitated, Zn^{2+} ions remain in solution.

A student suggested that these Zn^{2+} ions can be precipitated by adding a large **excess** of aqueous sodium hydroxide.

Comment on this suggestion by describing the reactions that take place as a large **excess** of aqueous sodium hydroxide is **gradually** added.

(4)

(c) Suggest why gilding metals are less malleable than pure copper, by considering their structure.

(2)

(d) Zinc and copper are also used in electrochemical cells.

(i) Draw a labelled diagram of the apparatus used to measure the emf of a cell with copper and zinc electrodes under standard conditions.

(3)

(ii) The Nernst equation describes the relationship between the concentration of metal ions in a half-cell and its electrode potential.

$$E = E^{\ominus} + \frac{0.0260}{z} \times \ln[\text{ion}]$$

E = electrode potential under non-standard concentrations

z = the number of positive charges on the metal ion

A cell is set up with Cu^{2+} ions of concentration 1.00 mol dm^{-3} and Zn^{2+} ions of unknown concentration. The emf of the cell is +1.09 V.

Calculate the concentration of the zinc ions.

Use the data on page 10 of the Data Booklet.

(3)

(Total for Question 17 = 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