Past-paper walk-through

General physical and chemical properties of the first row of transition ▪ 28.1

eXercise

Questions in this set

- 9701/31 N25 Q3 ▪ 15 marks
- 9701/41 N25 Q2 ▪ 8 marks
- 9701/41 N25 Q5 ▪ 14 marks
- 9701/42 N25 Q5 ▪ 15 marks
- 9701/42 N25 Q6 ▪ 7 marks
- 9701/44 N25 Q1 ▪ 19 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 3

9701/31 N25 ▪ Q3 ▪ 15 marks

3 **(a)** A bottle labelled **FA 5** is thought to contain hydrated zinc sulfate. It would therefore contain zinc ions and sulfate ions as well as water of crystallisation.

(i) Devise and carry out tests to investigate whether zinc ions, sulfate ions and water of crystallisation are present.

Record the tests you carry out and the observations you see in the space provided.

Question 3

[5]

(ii) Use your observations in **(a)(i)** to complete Table 3.1 to show whether each species is present in **FA 5**.

Use a tick (✓) if the species is present.

Use a cross (✗) if the species is **not** present.

Table 3.1

Zn^{2+}	
SO_4^{2-}	
H_2O	

[1]

(b) You are provided with solid **FA 6**.

Question 3

Question 3

(i) Heat a few crystals of **FA 6** in a hard-glass test-tube until no further gas is evolved. Record all your observations.

Leave the test-tube until it is cool.

Keep the cooled residue for use in (b)(ii).

Question 3

(ii) To the cooled residue from **(b)(i)**, add approximately 3 cm depth of distilled water and stir. Filter the solution formed into a test-tube.

Question 3

(c) You are provided with aqueous solutions **FA 7** and **FA 8** and with solid **FA 9**.

FA 7 is an aqueous solution of **FA 6**.
FA 7, **FA 8** and **FA 9** contain compounds which all have one metal that is the same but which may be in different oxidation states.

(i) Carry out the following tests on **FA 7**, **FA 8** and **FA 9** and record your observations in Table 3.2. For each test use a 1 cm depth of a solution or a spatula measure of solid.

Table 3.2

test	*observations*		
	FA 7	**FA 8**	**FA 9**
Test 1 Add hydrogen			

Question 3

peroxide.

Question 3

Test 2 Add aqueous sodium hydroxide, then			
leave to stand.			
Test 3 Add aqueous iron(II) sulfate.			

Question 3

Question 3

[1]

(ii) Suggest the identity of the metal in **FA 6**/**FA 7**, **FA 8** and **FA 9**.

The metal is ..... . [1]

(iii) Complete Table 3.3 to suggest the oxidation state of the metal in **FA 6**/**FA 7** and **FA 8**.

Table 3.3

	FA 6/**FA 7**	**FA 8**
oxidation state		

[1]

[Total: 15]

Qualitative analysis notes

Question 3

Question 3

1 Reactions of cations

cation	reaction with	
	NaOH(aq)	**NH_3(aq)**
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	no ppt. ammonia produced on warming	–
barium, Ba^{2+}(aq)	faint white ppt. is observed unless $[Ba^{2+}(aq)]$ is very low	no ppt.
calcium, Ca^{2+}(aq)	white ppt. unless $[Ca^{2+}(aq)]$ is very low	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution

Question 3

giving dark blue solution

Question 3

iron(II), $Fe^{2+}(aq)$	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), $Fe^{3+}(aq)$	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, $Mg^{2+}(aq)$	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), $Mn^{2+}(aq)$	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, $Zn^{2+}(aq)$	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $Cl^-(aq)$	gives white ppt. with $Ag^+(aq)$ (soluble in $NH_3(aq)$)

Question 3

chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives cream / off-white ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives pale yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; decolourises acidified aqueous $KMnO_4$
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca^{2+}(aq)]
sulfite, SO_3^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids); decolourises acidified aqueous $KMnO_4$
thiosulfate, $S_2O_3^{2-}$(aq)	gives off-white / pale yellow ppt. slowly with H^+

3 Tests for gases

gas	test and test result

Question 3

ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	‘pops’ with a lighted splint
oxygen, O_2	relights a glowing splint

Solution 3

(a)(i) Mark scheme

- M1 Heat (solid FA 5)
- AND
- observe condensation, droplets, steam, water vapour M2
- Make an aqueous solution of FA 5 / dissolve in water to use for tests M3
- (To portion of the solution) add aqueous NH3
- AND
- white ppt AND insoluble in excess NH3 M4
- (To portion of the solution) add aqueous barium chloride or barium nitrate

Solution 3

- AND
- white precipitate **M5**
- to distinguish sulfate / sulfite
- (white precipitate from M4) insoluble in hydrochloric OR nitric acid
- OR
- KMnO4 is not decolourised / remains purple (added after M4 or directly to FA 5 (aq))
- 5

Solution 3

(a)(ii) Mark scheme

- Zn^{2+}
- X
- SO_4^{2-}
-
- H_2O
-
- 1

Solution 3

(b)(i) Mark scheme

- ▪
- (FA 6) starting colour purple
- ▪
- solid jumps / moves around
- ▪
- black residue
- ▪
- test with glowing splint

Solution 3

- ▪
- splint relights / glows more brightly
- 2

Solution 3

(b)(ii)

Mark scheme

- (dark) Green
- 1
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Solution 3

(c)(i) Mark scheme

- 'No change' 2 correct = *, 3 correct = **
- 2* = 1 mark
- Max mark = 4
- test
- observations
- FA 7
- FA 8
- FA 9

Solution 3

- Test 1
- Add
- hydrogen peroxide
- Bubbles/ effervescence *
- Purple / FA 7 (solution) to
- colourless (solution) *
- (Gas / oxygen) relights
- glowing splint *
- No change
- Bubbles / effervescence *

Solution 3

- (Gas/ oxygen) relights
- glowing splint *
- Test 2
- Add
- sodium hydroxide,
- then
- Off-white ppt*
- No change
- leave to stand
- brown ppt on standing*

Solution 3

- Test 3
- Add aqueous
- iron(II) sulfate
- Turns colourless / yellow
- OR colourless / yellow
- solution formed*
- No change
- 4

Solution 3

(c)(ii)

Mark scheme

- manganese / Mn
- 1
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Solution 3

(c)(iii) Mark scheme

- FA 6 / FA 7
- FA 8
- oxidation
- state
- (+)7
- (+)2
- 1

Question 2

9701/41 N25 ▪ Q2 ▪ 8 marks

2 **(a)** Iron can form stable ions in the +2 and +3 oxidation states.

Explain why transition elements have variable oxidation states.

Question 2

(b) Aqueous solutions of iron(II) salts contain the complex ion $[Fe(H_2O)_6]^{2+}$.

Define complex ion.

Question 2

(c) $[Fe(H_2O)_6]^{2+}$ can be converted into $[Fe(H_2O)_4(OH)_2]$.

(i) Suggest a suitable reagent for this conversion. State the type of reaction.

Question 2

Question 2

[1]

(ii) $[Fe(H_2O)_4(OH)_2]$ is a green precipitate that turns brown on standing in air.

Table 2.1 shows electrode potentials for some electrode reactions.

Table 2.1

electrode reaction	$E^{\ominus}$ / V
$Fe(H_2O)_3(OH)_3 + H_2O + e^- \rightleftharpoons Fe(H_2O)_4(OH)_2 + OH^-$	–0.56
$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$	+0.40

Use the information in Table 2.1 to explain why $[Fe(H_2O)_4(OH)_2]$ turns brown on standing in air.
Include an equation for this reaction.

Question 2

(d) The complex $[Co(NH_3)_6]^{2+}$ reacts with hydrogen peroxide as shown.

reaction 1 $2[Co(NH_3)_6]^{2+} + H_2O_2 \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$ $E^{\ominus}_{cell} = +1.67\,V$

Calculate $\Delta G^{\ominus}$, in $kJ\,mol^{-1}$, for reaction 1.

Question 2

[Total: 8]

Solution 2

(a)

Mark scheme

- the (3)d and (4)s sub-shells / orbitals / electrons are close / similar in energy
- 1

Solution 2

(b)

Mark scheme

- species or ion formed by a central metal atom/ion AND surrounded by/bonded to (one or more) ligands
- 1

Solution 2

(c)(i)

Mark scheme

- NaOH / OH–(aq) AND precipitation / ligand exchange / deprotonation / acid–base
- 1

Solution 2

(c)(ii)

Mark scheme

- M1: $Fe(H_2O)_4(OH)_2$ is oxidised (from + 2 to + 3 on standing)
- M2: Eo of $Fe(H_2O)_3(OH)_3$ is more negative than Eo of O_2
- OR Eocell = 0.40 – (–0.56) = (+)0.96 V
- M3: $4Fe(H_2O)_4(OH)_2 + O_2 \rightarrow 4Fe(H_2O)_3(OH)_3 + 2H_2O$
- 3

Solution 2

(d) Mark scheme

- $G^o = -2 \times 1.67 \times 96\,500 = -322\,310$ J mol–1
- M1: $G^o = -nE^o_{cell}$ IF AND $n = 2$
- OR $-2 \times 1.67 \times 96\,500$
- M2: $G^o = -322.3$ kJ mol–1
- 2
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Question 5

9701/41 N25 ▪ Q5 ▪ 14 marks

5 **(a)** Copper shows typical properties of transition elements, including its behaviour as a catalyst.

Complete Table 5.1 to show the total number of **unpaired** electrons in the 3d and 4s orbitals of an isolated gaseous Cu atom and a Cu^{2+} ion.

Table 5.1

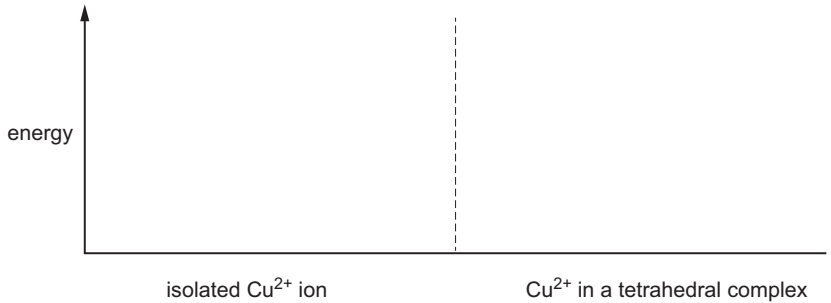
species	number of **unpaired** electrons	
	3d	4s
Cu		
Cu^{2+}		

[1]

(b) The 3d orbitals in an isolated Cu^{2+} ion are degenerate.

Question 5

Complete the diagram to show the relative energies of the 3d orbitals in an isolated Cu^{2+} ion and in Cu^{2+} in a tetrahedral complex.



[2]

(c) Explain why transition elements behave as catalysts.

(d) CN^- is a monodentate ligand.

Table 5.2 shows information about two complex ions that contain only CN^- ions as ligands.

Complete Table 5.2.

Table 5.2

metal ion	coordination number	formula of complex ion	charge of complex ion
Ag^+	2		
Fe^{2+}			4–

[2]

(e) The complex ion $[Au(CN)_2Br_2]^-$ displays geometrical (cis/trans) isomerism.

Draw the structure of *trans*-$[Au(CN)_2Br_2]^-$. State its shape and the Br-Au-Br bond angle.

Question 5

Draw the structure of *trans*-$[Au(CN)_2Br_2]^-$. State its shape and the Br–Au–Br bond angle.

Question 5

Question 5

[2]

(f) An impure sample of a vanadium(V) compound of mass 0.250 g is dissolved in aqueous acid. This solution contains VO_3^- ions.

An excess of zinc is added to this solution. All the VO_3^- ions are reduced to V^{2+} ions and Zn atoms are oxidised to Zn^{2+} ions.

The unreacted zinc is removed and the resulting solution is titrated with acidified MnO_4^-.

The end-point is reached when 22.5 cm^3 of 0.0750 mol dm^{-3} MnO_4^- is added.

A redox reaction takes place and all the V^{2+} reacts forming VO_3^-.

$$3MnO_4^- + 5V^{2+} + 3H_2O \rightarrow 3Mn^{2+} + 5VO_3^- + 6H^+$$

(i) Calculate the percentage by mass of vanadium in the 0.250 g of impure sample.

Assume the impurities do not contain any vanadium ions.

Question 5

Question 5

Show your working.

Question 5

(ii) Complete the equation for the reaction between acidified VO_3^- ions and Zn metal.

Question 5

[2]

[Total: 14]

Solution 5

(a)

Mark scheme

- 1

Solution 5

(b) Mark scheme

- ▪
- five 3d orbitals (lines, boxes) in the isolated Cu2+ ion of the same energy
- ▪
- splitting: three higher and two lower d orbitals
- ▪
- energy of all five d orbitals in complex higher than all d orbitals in isolated ion
- any two [1], all three [2]
- 2

Solution 5

(c)

Mark scheme

- M1: more than one (stable) oxidation state / exist in variable oxidation states
- M2: vacant / empty (d) orbitals are energetically accessible
- OR vacant / empty (d) orbitals can form dative bonds with ligands
- 2

Solution 5

(d)

Mark scheme

- each row [1]
- 2
- 9701/41
- October/November 2025

Solution 5

(e)

Mark scheme

- M1:
- M2: (shape) square planar AND (bond angle) 180o
- 2

Solution 5

(f)(i)

Mark scheme

- M1: moles $MnO4- = 0.075 \times 0.0225 = 1.6875 \times 10–3$
- M2: moles $V2+ = 5 / 3 \times 1.6875 \times 10–3 = 2.8125 \times 10–3$
- M3: mass $V = 50.9 \times 2.8125 \times 10–3 = 0.143\,g$
- % of $V = 0.143 / 0.250 \times 100 = 57.3$ min 2sf
- 3

Solution 5

(f)(ii)

Mark scheme

- $2VO3- + 3Zn + 12H+ \rightarrow 2V2+ + 3Zn2+ + 6H2O$
- M1: 2 : 3 ratio on both sides
- M2: rest of the equation correct
- 2

Question 5

9701/42 N25 ▪ Q5 ▪ 15 marks

5 Cobalt is a transition element which forms compounds containing Co^{2+} and Co^{3+} ions. Cobalt(II) sulfate dissolves in water to form a solution containing the $[Co(H_2O)_6]^{2+}$ complex ion.

(a) (i) Complete the electronic configurations of a Co^{2+} ion and a Co^{3+} ion.

Question 5

Question 5

[1]

(ii) Explain why transition elements can form complex ions.

Question 5

(iii) An excess of concentrated HC*l* is added to a solution containing $[Co(H_2O)_6]^{2+}$.

Describe the colour change observed and the state of the cobalt-containing product.

Question 5

Question 5

[2]

(iv) Write an equation for the reaction occurring in **(a)(iii)**.

Question 5

(v) Name the type of reaction occurring in **(a)(iii)**.

Question 5

(vi) Write an equation for the reaction that occurs when an excess of NaOH(aq) is added to a solution containing $[Co(H_2O)_6]^{2+}$.

Question 5

(b) Cobalt metal can be oxidised by acidified $K_2Cr_2O_7$. The relevant half-equations, and their $E^\ominus$ values, are shown.

$$Co^{2+} + 2e^- \rightleftharpoons Co \qquad E^\ominus = -0.28\,V$$
$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O \qquad E^\ominus = +1.33\,V$$

(i) A Co^{2+}/Co electrode is constructed in which $[Co^{2+}]$ is $0.020\,mol\,dm^{-3}$ at 298 K.

Use the Nernst equation to show that the E value for this Co^{2+}/Co electrode is –0.33 V.

Question 5

[2]

(ii) An electrochemical cell is constructed using the Co^{2+}/Co electrode described in **(b)(i)** and a $Cr_2O_7^{2-}/Cr^{3+}$ electrode in which all conditions are standard.

Calculate the value of E_{cell}.

Question 5

(iii) A current is drawn from the electrochemical cell described in **(b)(ii)**.

Write an equation for the reaction taking place in the cell.

Question 5

(iv) Complete the sentences to identify the negative electrode and the direction of electron flow when a current is drawn from the cell described in **(b)(ii)**.

Question 5

[1]

(c) A molten Co^{2+} salt is electrolysed using a current of 0.500 A.

0.547 g of cobalt metal forms at the cathode. Under the conditions used no other reduction reaction occurs at the cathode.

Calculate the time in minutes for which the current flows to produce this mass of cobalt.

Give your answer to **three** significant figures.

Question 5

[Total: 15]

Solution 5

(a)(i)

Mark scheme

- Co2+ = [Ar] 3d7 AND Co3+ = [Ar] 3d6
- 1

(a)(ii)

Mark scheme

- has vacant d orbitals that are energetically accessible
- 1

Solution 5

(a)(iii) Mark scheme

- ▪
- pink
- ▪
- blue
- ▪
- aqueous
- Any two [1], all three [2]
- 2

Solution 5

(a)(iv)

Mark scheme

Co(H2O)6 2+ + 4HCl → [CoCl4]2– + 6H2O + 4H+ OR [Co(H2O)6]2+ + 4Cl– → [CoCl4]2– + 6H2O

- 1
- 9701/42
- October/November 2025

Solution 5

(a)(v)

Mark scheme

- ligand exchange
- 1

Solution 5

(a)(vi)

Mark scheme

$Co(H_2O)_6^{2+} + 2OH^- \rightarrow Co(OH)_2(H_2O)_4 + 2H_2O$ OR

$Co(H_2O)_6^{2+} + 2OH^- \rightarrow Co(OH)_2 + 6H_2O$

- 1

Solution 5

(b)(i)

Mark scheme

- M1: Nernst equation $E = Eo + (0.059 / z) \times \log(\frac{[\text{oxidised}]}{[\text{reduced}]})$
- M2: $E = -0.28 + (0.059 / 2) \times \log(0.02)$
- 2

Solution 5

(b)(ii)

Mark scheme

- 1.66 V
- 1

(b)(iii)

Mark scheme

- $3Co + Cr2O72- + 14H+ \rightarrow 3Co2+ + 2Cr3+ + 7H2O$
- 1

Solution 5

(b)(iv)

Mark scheme

- Co^{2+} / Co, Co^{2+} / Co, $Cr_2O_7^{2-}$ / Cr^{3+}
- 1

Solution 5

(c)

Mark scheme

- M1: moles of cobalt $= 0.547 / 58.9 = 0.00929$
- M2: coulombs required $= 0.00929 \times 96500 \times 2 = 1792$
- M3: time required $= 1792 / 0.50 = 3584.8\,\text{s} = 59.7$ minutes 3sf
- 3

Question 6

9701/42 N25 ▪ Q6 ▪ 7 marks

6 **(a)** Nickel forms complexes.

(i) Give the formula and charge of the tetrahedral complex formed by Ni atoms with carbon monoxide molecules. Carbon monoxide is a monodentate ligand. This is complex **E**.

Question 6

(ii) Give the formula and charge of the octahedral complex formed by Ni^{2+} ions with ethanedioate ions. This is complex **F**.

Question 6

(iii) Identify which complex, **E** or **F**, exists as a mixture of two stereoisomers and the type of stereoisomerism involved.

Question 6

Question 6

[1]

(b) Cadmium forms complexes with methylamine, CH_3NH_2, and 1,2-diaminoethane, *en*. The values of the stability constants, K_{stab}, of these complex ions are given in Table 6.1.

Table 6.1

complex	K_{stab}
$[Cd(CH_3NH_2)_4]^{2+}$	3.5×10^6
$[Cd(en)_2]^{2+}$	4.0×10^{10}

(i) Explain, by reference to its structure, why CH_3NH_2 acts as a monodentate ligand.

Question 6

(ii) Some $Cd^{2+}(aq)$ is added to a solution containing equal concentrations of CH_3NH_2 and *en*.

Predict which of the two complexes in Table 6.1 forms at the higher concentration.

Explain your answer.

Question 6

[1]

(iii) Complete the expression for the K_{stab} of $[Cd(CH_3NH_2)_4]^{2+}$.

K_{stab} =

[1]

[Total: 7]

Solution 6

(a)(i)

Mark scheme

- $Ni(CO)4$
- 1

Solution 6

(a)(ii) Mark scheme

- ▪
- ethanedioate given as C2O4
- ▪
- formula shows one Ni and three ligands
- ▪
- charge = 4–
- any two [1], all three [2]
- Ni(C2O4)34– scores [2]

Solution 6

- 2
- 9701/42
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Solution 6

(a)(iii)

Mark scheme

- F AND optical
- 1

Solution 6

(b)(i)

Mark scheme

- N atom can donate one lone pair of electrons
- 1

(b)(ii)

Mark scheme

$Cd(en)_2^{2+}$ AND has a larger Kstab / is more stable

- 1

Solution 6

(b)(iii)

Mark scheme

(CH3NH2)4 2+]

Cd2+ [CH3NH2]4

- 1

Question 1

9701/44 N25 ▪ Q1 ▪ 19 marks

1 **(a)** Define a transition element.

Question 1

(b) The 3d orbitals in an isolated gaseous Cu^{2+} ion are degenerate.

(i) Define the term degenerate.

Question 1

(ii) Complete the electronic configuration of Cu^{2+}.

Question 1

(c) **(i)** State the colours of the aqueous solutions for the **two** copper(II) complex ions shown.

Question 1

Question 1

[1]

(ii) Explain why aqueous complex ions of transition elements are usually coloured.

Question 1

(d) **(i)** When an excess of $NH_3(aq)$ is added to a solution of $[CuCl_4]^{2-}(aq)$, $[Cu(NH_3)_4(H_2O)_2]^{2+}(aq)$ is formed.

State the type of reaction.
Complete the equation for this reaction. State symbols are **not** required.

Question 1

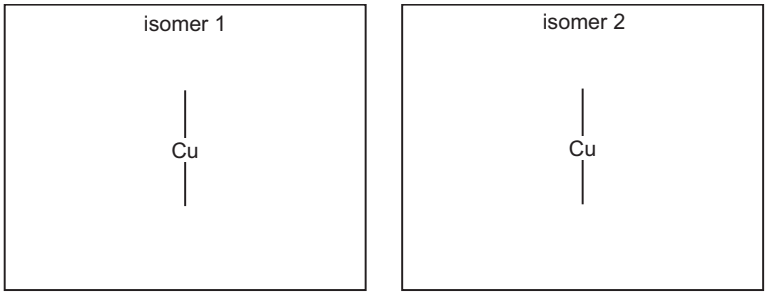
equation

Question 1

[2]

(ii) The $[Cu(NH_3)_4(H_2O)_2]^{2+}$ complex ion shows stereoisomerism.

Complete the three-dimensional diagrams in Fig. 1.1 to show the **two** different stereoisomers of $[Cu(NH_3)_4(H_2O)_2]^{2+}$.



Question 1

Fig. 1.1

Question 1

Fig. 1.1

[2]

(iii) Deduce which stereoisomer in **(d)(ii)** is polar.

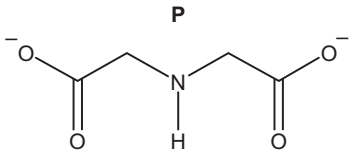
Explain your answer.

Question 1

[1]

(e) The dianion **P** can act as a tridentate ligand.

P



(i) Suggest how **P** can form **three** dative covalent bonds.

Question 1

(ii) 2 moles of dianion **P**, $C_4H_5NO_4^{2-}$, react with 1 mole of aqueous cobalt(III) ions, $[Co(H_2O)_6]^{3+}$ to form 1 mole of complex ion **Q**.

Deduce the formula and charge of **Q**.

Question 1

(f) Table 1.1 shows values for the stability constants, K_{stab}, of some silver(I) complexes.

Table 1.1

complex	value of K_{stab}
$[Ag(CN)_2]^-(aq)$	1.1×10^{18}
$[Ag(NH_3)_2]^+(aq)$	1.2×10^{7}
$[Ag(S_2O_3)_2]^{3-}(aq)$	2.9×10^{13}

(i) Define the stability constant of a complex.

Question 1

(ii) Use the information in Table 1.1 to identify the most stable silver(I) complex.

Explain your answer.

Question 1

Question 1

Question 1

[1]

(g) Sodium sulfite, Na_2SO_3, is used as a food preservative.

A 3.75 g sample of impure Na_2SO_3 is dissolved in distilled water and made up to 250 cm^3 in a volumetric flask.

10.0 cm^3 of this solution requires 18.70 cm^3 of acidified 0.0150 mol dm^{-3} MnO_4^-(aq) to reach the end-point.

The equation for the reaction is shown.

$$2MnO_4^- + 5SO_3^{2-} + 6H^+ \rightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O$$

Calculate the percentage by mass of Na_2SO_3 in the sample.

Question 1

Question 1

[Total: 19]

Solution 1

(a)

Mark scheme

- forms (one or more) stable ions / compounds / oxidation states
- with incomplete / partially filled (3)d orbital(s) / d shell / d sub-shell
- 1

Solution 1

(b)(i)

Mark scheme

- (orbitals) are at the same energy
- 1

(b)(ii)

Mark scheme

- (1s2) 2s2 2p6 3s2 3p6 3d9
- 1

Solution 1

(c)(i)

Mark scheme

H3)4(H2O)2 2+(aq) deep / dark / royal blue

- AND

CuCl4 2–(aq)

- yellow
- 1

Solution 1

(c)(ii) Mark scheme

- M1:
- d orbital(s) of different energy / d-d splitting occurs / d sub-shell splits
- M2:
- electron(s) promoted / excited
- M3:
- light / wavelength / frequency / photon absorbed AND complementary colour seen
- 3

Solution 1

(d)(i)

Mark scheme

- M1: ligand exchange / replacement / substitution / displacement
- M2: $[CuCl_4]^{2-} + 4NH_3 + 2H_2O \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4Cl^-$
- 2

Solution 1

(d)(ii)

Mark scheme

- M1: one correct 3D structure of [Cu(H2O)2(NH3)4]2+
- M2: correct 3D stereoisomer structure of isomer 1/2

(d)(iii)

Mark scheme

- cis isomer AND dipoles do not cancel
- 1

Solution 1

(e)(i)

Mark scheme

- (two) oxygen and (one) nitrogen (can donate) three lone pair(s) of electrons (to the metal ion)
- 1
- 9701/44
- October/November 2025

Solution 1

(e)(ii)

Mark scheme

C4H5NO4)2 –

- 1

Solution 1

(f)(i)

Mark scheme

- equilibrium constant for the formation of the complex (ion)
- in a solvent / water / solution OR from its constituent ions or molecules
- 1

Solution 1

(f)(ii)

Mark scheme

$Ag(CN)_2^-$(aq) AND largest (value of) Kstab

- 1

Solution 1

(g) Mark scheme

- M1 M2: any two [1], all four [2]
- ▪
- moles MnO4– = 0.015 ×18.70/1000 = 2.805 × 10–4
- ▪
- moles SO32– = 2.805 × 10–4 × 5/2 = 7.0125 × 10–4 (in 10 cm3)
- ▪
- moles SO32– = 1.753 × 10–2 (in 250 cm3)
- ▪

Solution 1

- mass Na2SO3 = 1.753 × 10–2 × 126.1 = 2.21 g
- M3: % purity = 100 × 2.21 / 3.75 = 58.9 – 59.0 % min 2sf
- 3