2 Elements with atomic number 22 to 29 (titanium to copper) are transition metals.

(a) What is a transition metal? [2]

(b) Give **three** typical properties of transition metals. [3]

(c) What is the electronic structure, in terms of s, p and d orbitals of:

(i) chromium

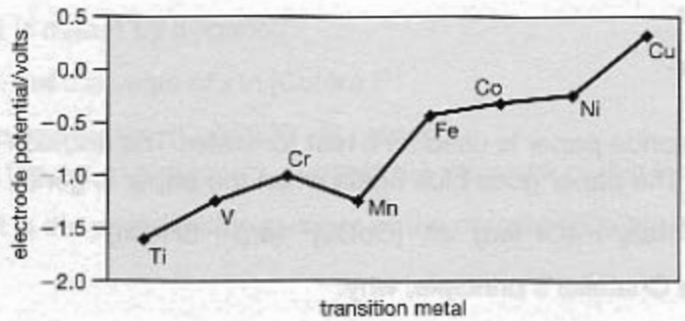
(ii) copper? [2]

(d) Use your answer to **(c)** to explain why:

(i) chromium can have an oxidation state of +6 [2]

(ii) anhydrous copper(I) chloride is a white solid. [1]

(e) The graph below shows the standard electrode potentials for the cells $M^{2+}(aq)|M(s)$.



(i) Write the half-reaction for iron in an $Fe^{2+}(aq)|Fe(s)$ cell. [1]

(ii) Which of the elements Ti to Cu has the greatest reducing power? Explain your answer. [2]

(iii) What reaction would take place, if any, if chromium metal were added to an aqueous solution of manganese(II) sulphate? Explain your answer. [2]

[Total: 15]

Answers on pages 38–39

3 Cobalt has an atomic number of 27. Its principal oxidation states are +2 and +3.

(a) Write down the electronic structure of:

(i) Co

(ii) Co^{2+}. [2]

(b) Give the formula of an ion of another transition element that has the same number of electrons as Co^{2+}. [1]

(c) Why is cobalt classified as a transition metal? [1]

(d) What is a complex ion? [2]

(e) What is the oxidation number and the co-ordination number of cobalt in each of the following complex ions? [3]

(i) $[CoCl_4]^{2-}$

(ii) $[Co(H_2O)_6)]^{2+}$

(iii) $[Co(NH_3)_6]^{3+}$

(f) Blue cobalt(II) chloride paper is used as a test for water. The addition of water turns the blue paper pink. The paper goes blue again when the paper is gently heated.

$$[Co(H_2O)_6)]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CoCl_4]^{2-}(aq) + 6H_2O(l)$$

Explain, using Le Chatelier's principle, why:

(i) the paper goes pink on the addition of water [2]

(ii) this shows that the forward reaction is endothermic. [2]

(g) **(i)** Complete the table below showing the colour of ions. [2]

ion	colour	ion	colour
$[Mn(H_2O)_6]^{2+}$	pale pink	$[Cr(H_2O)_6]^{3+}$	
$MnO_4^-(aq)$		$Cr_2O_7^{2}$ (aq)	orange

(ii) Explain, in terms of d orbitals, why transition metal ions are coloured. [2]

[Total: 17]

Answers on pages 38–39 Answers on pages 38–39 Answers on pages 38–39

4 **(a)** When dilute sulphuric acid is warmed with copper(I) oxide, a pink solid **X** and a blue solution **Y** are formed. The pink solid **X** conducts electricity.

(i) Identify **X** and **Y**. [2]

(ii) Write an equation for the reaction. [1]

(iii) Use the reaction to explain the meaning of disproportionation. [2]

(b) The equilibrium $2Cu^+(aq) \rightleftharpoons Cu(s) + Cu^{2+}(aq)$ lies well over to the right hand side. Suggest **two** ways that the above equilibrium can be moved to the left. [2]

(c) Ethane-1,2-diamine (en) is a *bidentate ligand* that forms complex ions, such as the complex ion $[Cu(en)_x]^{2+}$.

Using a colorimeter it was found that 10.0 cm^3 of 0.10 mol dm^{-3} copper(II) ions reacted exactly with 20 cm^3 of 0.10 mol dm^{-3} ethane-1,2-diamine (en) to form this complex ion.

(i) What is meant by a *bidentate ligand*? [2]

(ii) What is meant by a *ligand*? [2]

(iii) Work out the value of x in $[Cu(en)_x]^{2+}$ [3]

(iv) The complex ion, $[Cu(en)_x]^{2+}$, is planar.
With the aid of a diagram, suggest the structure of this ion. [2]

(v) What is the coordination number of the complex $[Cu(en)_x]^{2+}$? [1]

[Total: 17]

Answers on pages 38–39
Answers on pages 38–39 Answers on pages 38–39

3 The table below shows the enthalpy changes in a Born-Haber cycle for the formation of potassium chloride, KCl, from its elements.

Enthalpy change	Equation
atomisation of potassium	
1st ionisation energy of potassium	
atomisation of chlorine	
electron affinity of chlorine	
lattice enthalpy	
formation of potassium chloride	

(a) Complete the table by writing equations, including state symbols, in the spaces. [6]

(b) The lattice enthalpy of KCl is -718 kJ mol^{-1} but that of NaCl is -788 kJ mol^{-1}

(i) Define the term *lattice enthalpy*.

.....

.....

.....

.....

..... [2]

(ii) Suggest why there is a difference between these lattice enthalpies.

.....

.....

.....

.....

..... [2]

[Total: 10]

5 Each of the answers to parts **(a)** and **(b)** of this question uses **one of the oxides below**. You can use each oxide once, more than once or not at all.

Oxides: Na_2O; MgO; SiO_2; SO_3

(a) Identify an oxide from the list above that

(i) reacts with water forming a strongly alkaline solution ..... [1]

(ii) is insoluble in water ..... [1]

(iii) has a simple molecular structure at room temperature. ..... [1]

(b) Suggest equations for the reaction of water with one of the oxides in the list above to form

(i) an acidic solution

..... [1]

(ii) an alkaline solution.

..... [1]

(c) Suggest an equation for the reaction that would take place if the two solutions in **(b)** were mixed together.

..... [1]

(d) **(i)** State and explain the trend in the oxidation number shown in the **highest** oxides of the elements Na to Cl across Period 3 of the Periodic Table.

trend .....

explanation .....

.....

.....

..... [2]

(ii) Predict the formula of the **highest** oxide of chlorine. ..... [1]

(e) Use the data given below to answer the questions which follow.

$14H^+(aq) + Cr_2O_7^{2-}(aq) + 6e^-$	$\rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	$E^\ominus = +1.33$ V
$Fe^{3+}(aq) + e^-$	$\rightleftharpoons Fe^{2+}(aq)$	$E^\ominus = +0.77$ V
$8H^+(aq) + FeO_4^{2-}(aq) + 3e^-$	$\rightleftharpoons Fe^{3+}(aq) + 4H_2O(l)$	$E^\ominus = +2.20$ V
$4H^+(aq) + VO_3^-(aq) + e^-$	$\rightleftharpoons VO^{2+}(aq) + 2H_2O(l)$	$E^\ominus = +1.00$ V
$8H^+(aq) + MnO_4^-(aq) + 5e^-$	$\rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	$E^\ominus = +1.52$ V

(i) Which transition metal species shown above is the most powerful oxidising agent?

..... [1]

(ii) Identify **two** transition metal species which could be used to reduce acidified dichromate(VII) ions.

species 1 .....

..... [1]

species 2 .....

..... [1]

(iii) Construct an overall equation to show the reaction of acidified dichromate(VII) with **one** of the species that you have chosen in **(ii)**.

..... [1]

[Total: 13]

A2 Mock Exam 2

Centre number _____
Candidate number _____
Surname and initials _____

Letts Examining Group

Chemistry

Time: 1 hour Maximum marks: 60

This paper is based on: Chapter 4 The Periodic Table: Transition Metals; Chapter 5 Isomerism, Aldehydes, Ketones and Carboxylic Acids; Chapter 6 Aromatics, Amines, Amino Acids and Polymers; Chapter 7 Analysis and Synthesis

Instructions
Answer **all** questions in the spaces provided. Show all steps in your working.
The marks allocated for each question are shown in brackets.
Any data required for a question are given where appropriate.

Grading
Boundary for A grade 48/60
Boundary for C grade 36/60

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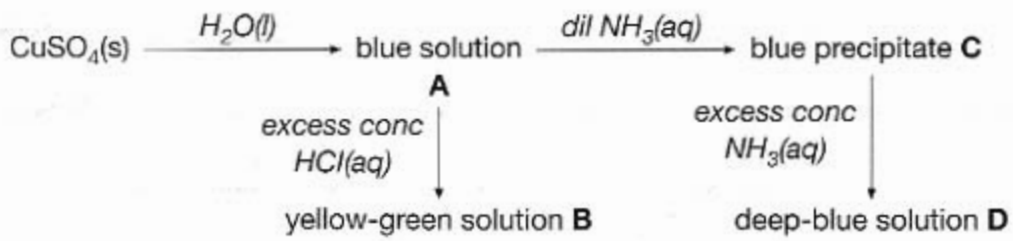
1 Examine the reaction scheme below.



(a) State the formula of each of the species in the products lettered **A** to **D**.

Formula of **A**: .....

Formula of **B**: .....

Formula of **C**: .....

Formula of **D**: ..... [4]

(b) This part refers to the conversion of **A** into **B**.

(i) State the type of reaction that converts **A** into **B**.

.....

[1]

(ii) Write the equation for the conversion of **A** into **B**.

.....

[1]

(iii) State the shape of **B**.

.....

[1]

(c) Sulphur dioxide gas was bubbled through the yellow-green solution of compound **B**. The colourless species $CuCl_2^-$ is formed together with SO_4^{2-} ions.

(i) Identify the oxidation state of copper in $CuCl_2^-$.

.....

.....

[1]

(ii) Deduce the role of sulphur dioxide in the conversion of **B** into $CuCl_2^-$.

.....

.....

[1]

(iii) Explain, in terms of electronic configurations, why **B** is coloured but $CuCl_2^-$ is colourless.

.....

.....

.....

.....

.....

.....

.....

[3]

(d) When water is added to **B**, a blue solution is obtained. Write an equation for this reaction.

.....

[1]

[Total: 13]

5 **(a)** Complete the table below to show the oxidation state of the **transition metal.**

Species	$Cr_2O_7^{2-}$	$[VO(H_2O)_5]^{2+}$
oxidation state		

[2]

(b) State **two** examples of the use of transition elements as catalysts in industrial processes.

.....

..... [2]

(c) State **two** properties that are typical of a *transition element*.

.....

..... [2]

(d) Complete the electronic configuration of:

(i) an iron atom, Fe, $1s^2 2s^2 2s^6 3s^2 3p^6$ ..... [1]

(ii) an iron(II) ion, Fe^{2+} $1s^2 2s^2 2s^6 3s^2 3p^6$ ..... [1]

(e) Iron(II) ions form aqueous solutions containing the complex ion $[Fe(H_2O)_6]^{2+}$.
State the likely shape and bond angles of $[Fe(H_2O)_6]^{2+}$.

shape .....

bond angles .....

..... [2]

(f) A transition metal compound **X** was analysed with the following percentage composition by mass: K, 32.0%, F, 46.7%. The remaining mass was the transition metal. The molar mass of compound **X** was 244.2 g mol^{-1}. Each mole of **X** contains 2 moles of K^+.

Identify the transition metal in compound **X** and deduce the complex ion and ligand present in compound **X.**

[4]

[Total: 14]