

An Introduction to the Chemistry of the Transition Elements

Question Paper 6

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	An Introduction to the Chemistry of the Transition Elements
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 6

Time Allowed: 75 minutes

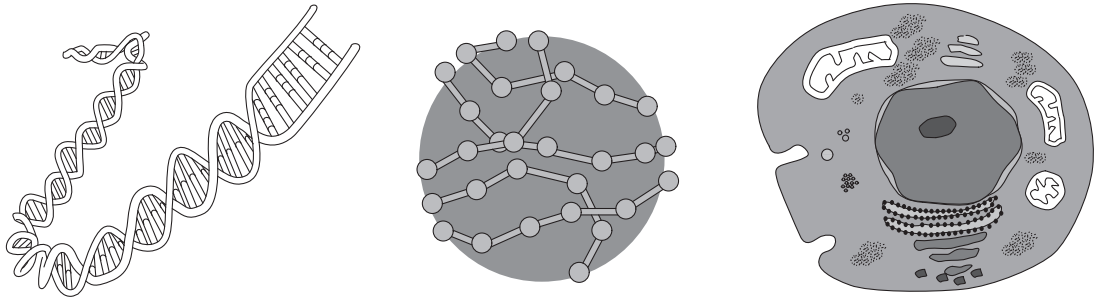
Score: /62

Percentage: /100

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	77.5%	70%	62.5%	57.5%	45%	<45%

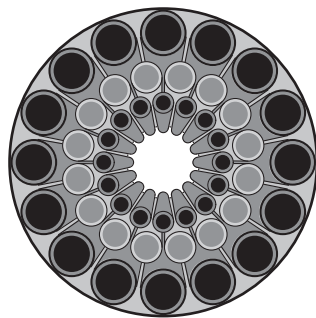
- 1 (a) Put the following items in order of **increasing** size. Use the number 1 to indicate the smallest and 3 to indicate the largest.



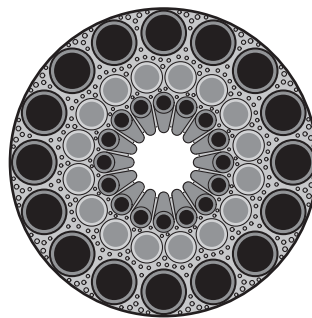
length of DNA molecule in a chromosome	nanosphere diameter	cell diameter

[2]

- (b) Nanotechnology has an increasing range of uses across a number of fields including sport. For example, golf clubs are now being made using nanomaterials.



cross-section of normal golf club shaft



cross-section of golf club shaft with nanomaterial fill

Use the diagrams above and your knowledge of nanomaterials to suggest **two** properties of the new shafts. Explain your answers.

(i)

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(ii)

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[2]

- (c) A mixture of nano-sized particles of tungsten and vanadium(IV) oxide can be applied to the surface of windows and reflects heat whilst letting all light in the visible range through.

Suggest how this variable reflective property is possible using nano-sized particles.

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..... [2]

- (d) Although silver is well-known as a precious metal, its medicinal properties have been used for hundreds of years. In ancient Greece silver was used to purify water and until the development of antibiotics, silver was important in the treatment of large wounds.

(i) What property of silver makes it useful for jewellery?

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(ii) Suggest the property of silver that makes it useful in the treatment of large wounds.

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(iii) Suggest why nano-sized silver particles are more useful in treating wounds.

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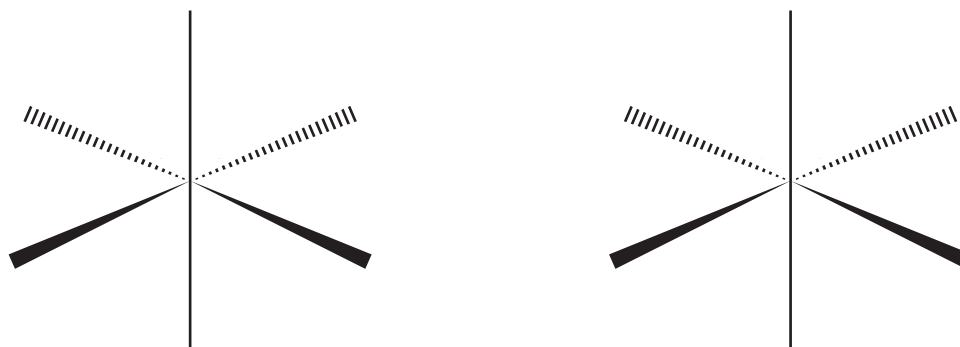
[3]

[Total: 9]

2 The following passage is taken from an A level Chemistry text book.

“In an isolated atom, the five d-orbitals have the same energy. In an octahedral complex ion, however, the presence of the ligands splits the five orbitals into a group of three and a group of two. These two groups have slightly different energies.”

(a) Use the following sets of axes to draw the shape of **one** d-orbital in **each** of the two groups mentioned above.



[2]

(b) Explain how the presence of the six ligands, L , in $[FeL_6]^{3+}$ splits the 3d orbitals into two groups of different energy, and explain whether the two-orbital group or the three-orbital group has the higher energy.

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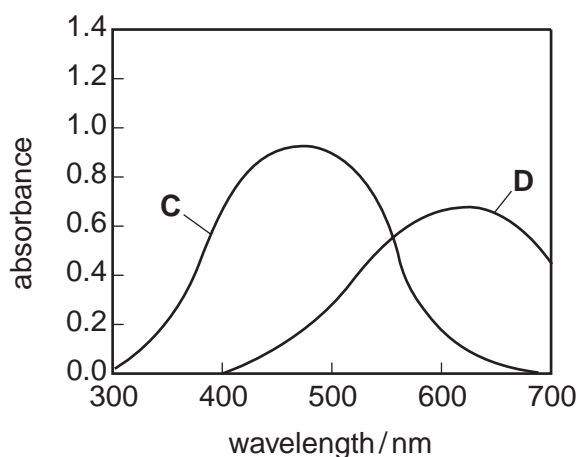
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[3]

- (c) The following table lists the colours and energies of photons of light of certain wavelengths.

wavelength /nm	energy of photon	colour of photon
400	high	violet
450	↓	blue
500	lower	green
600	↓	yellow
650	low	red

The visible spectra of solutions of two transition metal complexes **C** and **D** are shown in the diagram below.



- (i) A list of possible colours for these complexes is as follows.

yellow red green blue

Choose **one** of these words to describe the observed colour of each solution.

solution **C** solution **D**

- (ii) In which complex, **C** or **D**, will the energy gap between the two groups of orbitals be the larger? Explain your answer.

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[3]

[Total: 8]

3 (a) A transition element X has the electronic configuration [Ar] 4s² 3d³.

(i) Predict its likely oxidation states.

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(ii) State the electronic configuration of the ion X³⁺.

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[2]

(b) Potassium manganate(VII), KMnO₄, is a useful oxidising agent in titrimetric analysis.

(i) Describe how you could use a 0.0200 mol dm⁻³ solution of KMnO₄ to determine accurately the [Fe²⁺] in a solution. Include in your description how you would recognise the end-point in the titration, and write an equation for the titration reaction.

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(ii) A 2.00 g sample of iron ore was dissolved in dilute H₂SO₄ and all the iron in the salts produced was reduced to Fe²⁺(aq). The solution was made up to a total volume of 100 cm³.

A 25.0 cm³ portion of the solution required 14.0 cm³ of 0.0200 mol dm⁻³ KMnO₄ to reach the end-point.

Calculate the percentage of iron in the ore.

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[8]

(c) High-strength low-alloy (HSLA) steels are used to fabricate TV masts and long span bridges. They contain very low amounts of phosphorus and sulphur, but about 1% copper, to improve resistance to atmospheric corrosion. When dissolved in nitric acid, a sample of this steel gives a pale blue solution.

(i) What species is responsible for the pale blue colour?

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(ii) Describe and explain what you would see when dilute aqueous ammonia is added to this solution.

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[4]

[Total: 14]

4 (a) (i) State the electronic configuration of the iron atom.

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(ii) Apart from its electronic structure, state **two** properties of iron or its compounds that are characteristic of a transition element.

.....

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[3]

(b) Acidified solutions of iron(II) salts can be titrated using a dilute solution of potassium manganate(VII), KMnO_4 .

(i) Use the *Data Booklet* to calculate the standard cell potential and to write a balanced ionic equation for the reaction that takes place during the titration.

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(ii) Explain why no indicator is required for this titration. What colour change would you see at the end point?

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[4]

(c) Use the reaction between Fe^{3+} ions and water molecules to explain the meanings of the terms *ligand* and *complex formation*.

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..... [2]

(d) An important biological molecule containing iron is haemoglobin.

(i) What is the role of haemoglobin in the body?

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(ii) Use your answer to (i) to explain why carbon monoxide is poisonous.

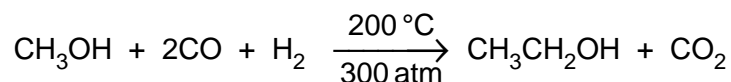
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[2]

(e) In a possible industrial synthesis of ethanol, the complex $\text{Fe}(\text{CO})_5$ catalyses the reaction between carbon monoxide, hydrogen and methanol according to the following equation.



Describe a test (reagents and observations) that would distinguish ethanol from methanol.

reagents

observation with methanol

observation with ethanol..... [2]

[Total: 13]

5 (a) Explain what is meant by the term *transition element*.

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..... [1]

(b) (i) How do the atomic radii of the transition elements vary from chromium to copper?

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(ii) Predict, with a reason, the variation in the densities of the transition elements from chromium to copper.

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..... [3]

(c) Complete the following electronic configuration of the Cu^{2+} ion.

$1s^2 2s^2 2p^6 3s^2 3p^6$ _____ [1]

(d) Copper ions in aqueous solution are pale blue, due to the formation of a complex ion.

(i) Explain what is meant by the term *complex ion*.

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(ii) Draw the structure of the complex ion formed in a solution of $\text{Cu}^{2+}(\text{aq})$.

[2]

(e) When dilute aqueous ammonia is added to a solution of $\text{Cu}^{2+}(\text{aq})$, the colour changes as a new complex ion is formed.

(i) State the colour of the new complex

(ii) Write an equation showing the formation of the new complex.

..... [2]

(f) When concentrated hydrochloric acid is added to a solution of $\text{Cu}^{2+}(\text{aq})$, the colour changes to yellow-green. On adding water, the colour returns to pale blue.

Suggest an explanation for these changes.

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.....[3]

[Total: 12]

6 (a) Titanium is an important transition metal. The metal itself is a component of many high-strength low-weight alloys, and its oxide is used as an opaque agent in many paints and pigments.

(i) Write out the electronic configuration of the titanium atom.

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(ii) Titanium forms two chlorides. Suggest possible formulae for them.

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[2]

(b) Anhydrous copper sulphate, $\text{CuSO}_4(\text{s})$, is a white powder that readily dissolves in water.

(i) Describe and explain what is seen when $\text{CuSO}_4(\text{s})$ is stirred with water.

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(ii) Describe and explain the final colour change seen when an excess of $\text{NH}_3(\text{aq})$ is added to $\text{CuSO}_4(\text{aq})$.

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[4]

[Total : 6]