Candidate Name	Centre Number	Candidate Number

WJEC CBAC

A LEVEL CHEMISTRY

COMPONENT 1

Physical and Inorganic Chemistry

SPECIMEN PAPER

2 hours 30 minutes

eduqas

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1. to 11.	**15**	
12.	**15**	
13.	**10**	
14.	**10**	
15.	**7**	
16.	**15**	
17.	**12**	
18.	**22**	
19.	**14**	
Total	**120**	

Section A — 1. to 11.
Section B — 12. onwards

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a data sheet and a calculator.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

You are reminded of the need for good English and orderly, clear presentation in your answers.

No certificate will be awarded to a candidate detected in any unfair practice during the examination.

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SECTION A

*Answer **all** questions in the spaces provided.*

1. Explain the term *dynamic equilibrium*. [1]

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2. Place the following compounds in order of **increasing** bond angles. [1]

CH_4 H_2O BF_3 NH_3

smallest .... *largest*

3. Draw a dot and cross diagram to show the bonding present in an ammonium ion, NH_4^+.

[1]

4. The table below gives the electronegativity values.

Atom	B	H	C	O	Cl
Electronegativity value	2.0	2.1	2.5	3.5	3.0

Use the data in the table to identify any dipoles present in the following bonds, marking their polarity clearly. [2]

O—H C—H B—Cl C=O

PMT

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5. XeF_2 is one of the few noble gas compounds known. It reacts with water in the presence of a base according to the equation below.

$$2XeF_2 + 2H_2O \rightarrow 2Xe + 4HF + O_2$$
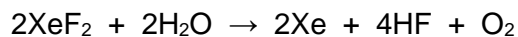
Complete the table below to give the initial and final oxidation states of the xenon and oxygen atoms, noting whether oxidation or reduction has occurred. [2]

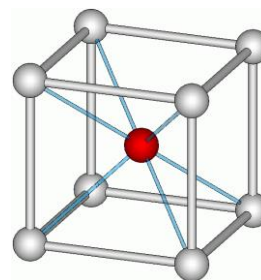| Element	Initial oxidation state	Final oxidation state	Oxidation/Reduction
xenon			
oxygen			

6. The reaction of magnesium metal with phosphoric acid, H_3PO_4, produces magnesium phosphate. Give the formula of magnesium phosphate. [1]

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7. The diagrams below represent the arrangement of particles in two substances.
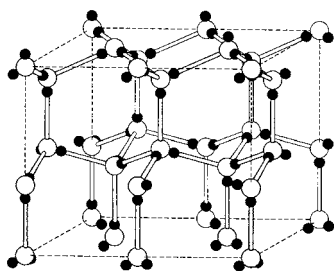
substance **A**   substance **B**

Choose the names of the substances represented from the following list:

sodium chloride, diamond, ice, graphite, caesium chloride
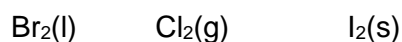
[1]

Substance **A** …………………………………………………………………………..

Substance **B** …………………………………………………………………………..

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8. Place the following in order of increasing entropy, giving a reason. [1]

$$Br_2(l) \qquad Cl_2(g) \qquad I_2(s)$$

Lowest entropy   *Highest entropy*

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Reason…………………………………………………………………………………………

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9. Ammonia is produced from hydrogen and nitrogen in the Haber process.

$$N_2(g) \quad + \quad 3H_2(g) \quad \rightleftharpoons \quad 2NH_3(g)$$
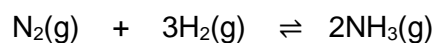
Write the expression for the equilibrium constant in terms of pressure, K_p, for this reaction Give the units for K_p assuming that pressures are given in atmospheres (atm). [2]

Units ………………………………

10. 1 mol of a gas occupies 24.0 dm^3 at 298 K and 1 atm. Calculate the temperature at which it occupies 25.0 dm^3 at the same pressure. [2]

Temperature = ……………… K

11. Write an ionic equation for the reaction of aqueous I$^-$ and Cu^{2+} ions to form copper(I) iodide and iodine. [1]

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SECTION B

*Answer **all** questions in the spaces provided.*

12. Our current understanding of the structure of the atom is based on evidence that has been collected over many years and from many sources.

(a) Rutherford introduced the idea of a small nucleus surrounded by a space where the electrons are found, based on an experiment where alpha particles fired at a thin gold film passed straight through it.

(i) An isotope of gold, ^{190}Au, can be produced by the emission of an alpha particle from a radioactive atom. This in turn decays by positron emission. Deduce the mass number and symbol of the initial and final nuclides in this decay series. [2]

	Mass number	Symbol
Initial nuclide		
Final nuclide		

(ii) Four other radioactive isotopes with the same mass are given in the table.

Isotope	Half-life	Radioactive emission
^{190}W	30 minutes	β
^{190}Re	3.1 minutes	β
^{190}Pt	6.5×10^{11} years	α
^{190}Bi	6.3 seconds	α

Describe why radioactivity is dangerous to living cells. Use all the data given to identify which of these isotopes would cause most damage to cells if consumed. [4]

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(b) The energy levels of electrons are quantised, with the higher energy levels becoming closer together. These energy levels form shells and there are fixed maximum numbers of electrons in each shell.

(i) Part of the evidence for this model comes from the atomic emission spectra of the elements. Describe the atomic emission spectrum of hydrogen and explain how this provides evidence for aspects of the model above. [6]

(Your ability to construct an extended response will be assessed in this question.)

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(ii)   Further evidence for this model comes from successive ionisation energies. Explain how these provide evidence for aspects of the model described. Sketch the expected pattern of successive ionisation energies for an atom of aluminium and use it to illustrate your answer.   [3]

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13. Sodium and magnesium are both typical *s*-block metals while copper is a typical *d*-block metal.

(a) Describe what happens when sodium oxide and magnesium oxide are added **separately** to cold water. Your answer should be illustrated by relevant chemical equations. [2]

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(b) Describe **one** chemical test, other than a flame test, which would distinguish between unlabelled aqueous solutions of sodium chloride and magnesium chloride. Your answer should include reagent(s) used and **observations** in **each** case. [2]

Reagent(s) …………………………………………………………………………...

Observation(s)……………………………………………………………………...

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(c) Sodium ethanoate and sodium chloride are both salts of sodium.
Explain why an aqueous solution of sodium ethanoate has a pH greater than 7 while the pH of aqueous sodium chloride is 7. [2]

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(d) The enthalpy of formation of copper(II) fluoride, CuF_2, can be determined indirectly using a Born-Haber cycle. Use the data given below to calculate the enthalpy change of formation of copper(II) fluoride in kJ mol^{-1}. [4]

Process	$\Delta H^\ominus$ (kJ mol^{-1})
$Cu(s) \longrightarrow Cu(g)$	339
$\frac{1}{2}F_2(g) \longrightarrow F(g)$	79
$Cu(g) \longrightarrow Cu^+(g) + e^-$	745
$Cu^+(g) \longrightarrow Cu^{2+}(g) + e^-$	1960
$F(g) + e^- \longrightarrow F^-(g)$	–348
$Cu^{2+}(g) + 2F^-(g) \longrightarrow CuF_2(s)$	–3037

Enthalpy change of formation = ... kJ mol^{-1}

10

14. Dinitrogen pentoxide, N_2O_5, decomposes in the gas phase according to the equation below.

$$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$$
colourless gas   brown gas   colourless gas
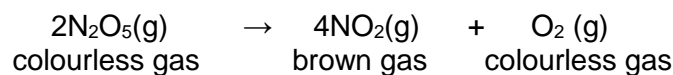
(a) One method of studying the rate of this reaction is to measure the pressure of the gas at constant volume. State how the pressure will change during the reaction. Explain why this is the case. [2]

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(b) The initial rates of this reaction for different concentrations of N_2O_5 were measured and are given in the table below.

Concentration of N_2O_5 (mol dm^{-3})	Initial rate (mol dm^{-3} s^{-1})
4.00×10^{-3}	5.97×10^{-5}
6.00×10^{-3}	8.98×10^{-5}
8.00×10^{-3}	1.19×10^{-4}

The rate equation for this reaction is:

Rate = $k[N_2O_5]^1$

(i) Show that the rate equation is consistent with the data above. [2]

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(ii)   Two possible mechanisms have been suggested for this reaction.
These are shown below.

Mechanism **A**	Mechanism **B**
$N_2O_5 \rightarrow NO_2 + NO_3^{\bullet}$	$2N_2O_5 \rightarrow 2NO_3^{\bullet} + N_2O_4$
$NO_3^{\bullet} \rightarrow NO^{\bullet} + O_2$	$NO_3^{\bullet} + N_2O_4 \rightarrow NO^{\bullet} + 2NO_2 + O_2$
$NO^{\bullet} + N_2O_5 \rightarrow 3NO_2$	$NO^{\bullet} + NO_3^{\bullet} \rightarrow 2NO_2$

Giving your reasons, state which of the mechanisms is compatible
with the rate equation.   [2]

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(*c*)   The activation energy of the reaction can be calculated by finding the value of the rate constant, *k*, at a series of different temperatures, T.

The following graph shows a plot of ln *k* against 1/T. The gradient, m, of the line is related to the activation energy, E_a.

$$m = \frac{-E_a}{R} \qquad (R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1})$$
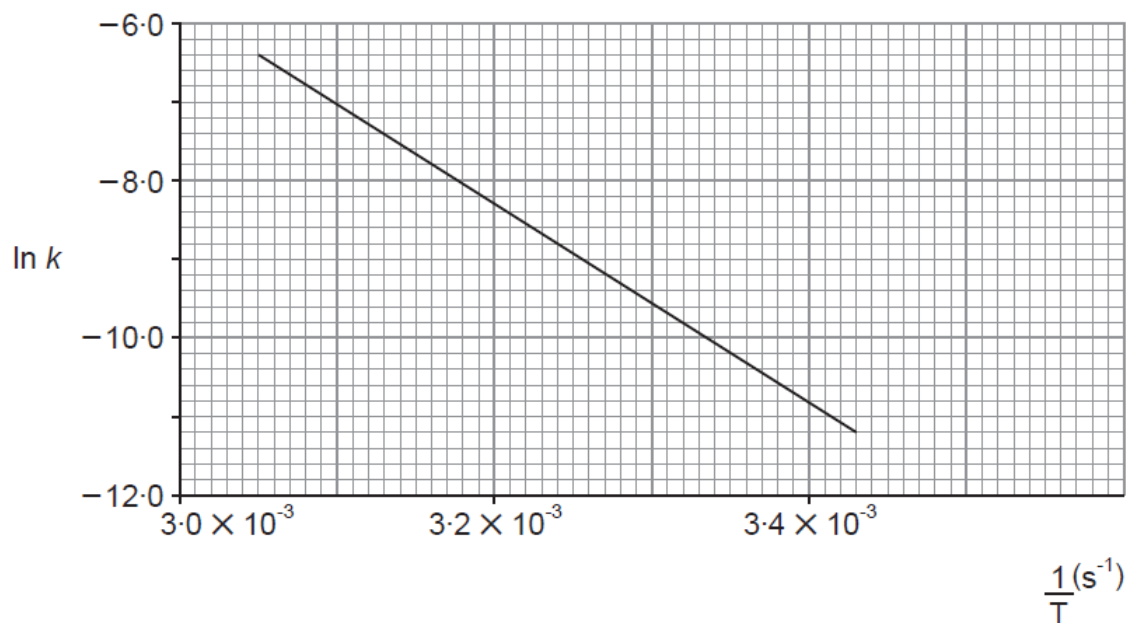
Find the activation energy for this reaction in kJ mol^{-1}.   [4]

Activation energy = ... kJ mol^{-1}

10

15.   Methanol, CH_3OH, can be oxidised according to the equation below.

$$CH_3OH(l) + 1\frac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$
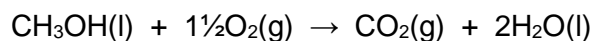
Substance	Standard enthalpy change of formation, $\Delta_f H^\ominus$ (kJ mol^{-1})	Entropy, S (J K^{-1} mol^{-1})
$CH_3OH(l)$	–239	127
$O_2(g)$	0	206
$CO_2(g)$	–394	214
$H_2O(l)$	–286	70

(a)   Use the information in the table to calculate the Gibbs free energy, ΔG, for this reaction at 298 K. You must show your working.   [6]

ΔG = ... kJ mol^{-1}

(b)   State what information your answer to part *(a)* gives about the feasibility of the reaction.   [1]

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7

16. *(a)* (i) Bromine is obtained commercially by passing chlorine into sea water, which contains bromide ions. Write an ionic equation for this reaction.
[1]

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(ii) Describe a test to show that an aqueous solution contains bromide ions, stating reagent(s) and observation(s). [2]

Reagent(s)..

Observation(s)..

(b) Sodium chloride and sodium bromide both react with concentrated sulfuric acid but with different results.

(i) When **solid** sodium chloride reacts, a steamy gas is produced. Name this gas. [1]

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(ii) When **solid** sodium bromide reacts, a steamy gas, a brown gas and a colourless gas are produced. Name the colourless gas. [1]

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(c) Write the equation for the reaction of chlorine with aqueous sodium hydroxide at room temperature and explain why this is classified as a disproportionation reaction. [3]

Equation

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Explanation

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(d) A buffer solution was made by adding 19.6 g of sodium 3-chloropropanoate, CH_2ClCH_2COONa, to 1 dm^3 of 0.100 mol dm^{-3} 3-chloropropanoic acid, CH_2ClCH_2COOH, at 298 K.

(K_a for 3-chloropropanoic acid = 7.94×10^{-5} mol dm^{-3} at 298 K)

Calculate the pH of the buffer solution at 298 K. [4]

pH = ...

(e) Explain how an aqueous solution of 3-chloropropanoic acid and sodium 3-chloropropanoate can act as a buffer solution when a small amount of acid and alkali is **separately** added to it. You may assume that 3-chloropropanoic acid and sodium 3-chloropropanoate act in a similar way to ethanoic acid and sodium ethanoate. [3]

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17. Schönite is a hydrated ionic compound with general formula $Q_2Z(SO_4)_y.xH_2O$ where Q and Z are two different *s*-block metal ions with atomic numbers of less than 40.

(a) A flame test on a sample of schönite gives a lilac flame. State what information this test provides. [1]

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(b) In order to find the value of x in the formula above a sample of schönite was heated and weighed several times until the sample reached constant mass.

(i) Give a reason why the sample is heated to constant mass. [1]

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(ii) When a sample of 0.010 mol of schönite was heated to constant mass, the mass lost was 1.081 g. Use this information to calculate the value of x. [2]

x = ...

(c) 25.0 cm³ of a solution of schönite of concentration 0.100 mol dm⁻³ was treated with excess barium chloride solution, which produced a precipitate of barium sulfate.

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

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(ii) Explain why an excess of barium chloride solution was needed and suggest how you could ensure that sufficient barium chloride had been added. [2]

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(iii)   The barium sulfate produced was isolated and dried, and its mass was found to be 1.166 g. Calculate the value of y in the formula $Q_2Z(SO_4)_y.xH_2O$.   [3]

y = ...

(d)   The M_r of the **anhydrous** schönite produced in part (*c*) was 294.7. Use all the information above to write the formula of schönite, explaining your reasoning.   [2]
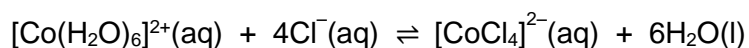
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12

18. Cobalt forms the complex ions $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$.

    (a)   Draw the structures of these two complex ions. [2]

    (b)   The two different coloured Co(II) complex ions exist together in equilibrium in solution in the presence of chloride ions:

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

These complexes are coloured and the visible spectra below show the absorbance of light of different wavelengths by the two compounds.
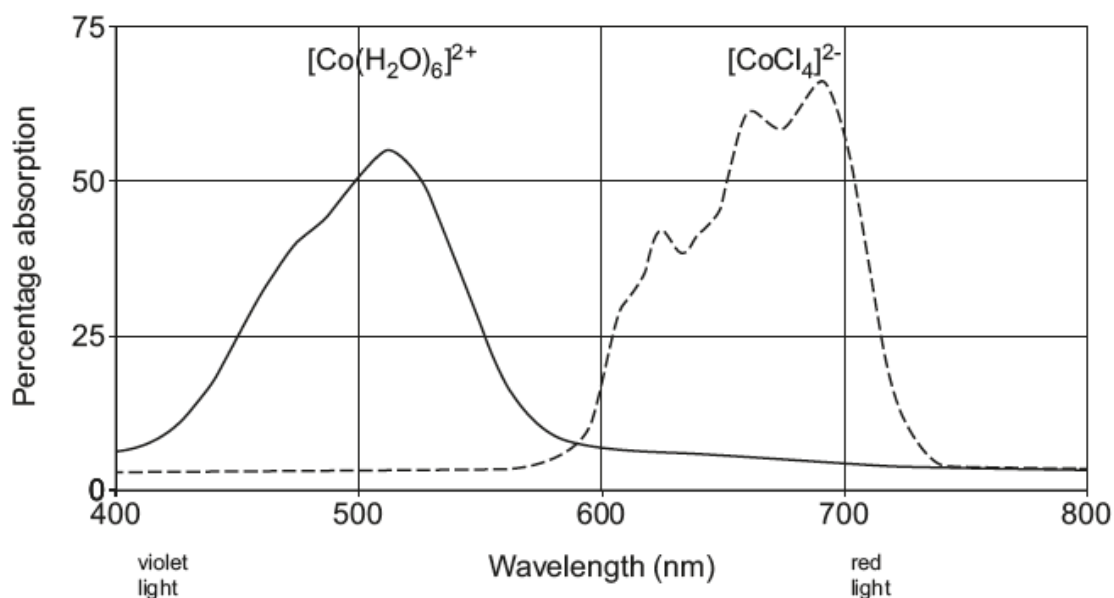
        (i)   Both complexes have the same percentage absorption at 590 nm. Calculate the energy associated with this wavelength. [2]

$$h = 6.63 \times 10^{-34} \text{ J s} \qquad c = 3.00 \times 10^8 \text{ m s}^{-1}$$

Energy = ... J

(ii)   One of the two complexes is blue. State which complex this is, giving
         a reason for your choice. Explain why this complex ion is coloured.
                                                                            [6]

(Your ability to construct an extended response will be assessed in this question.)

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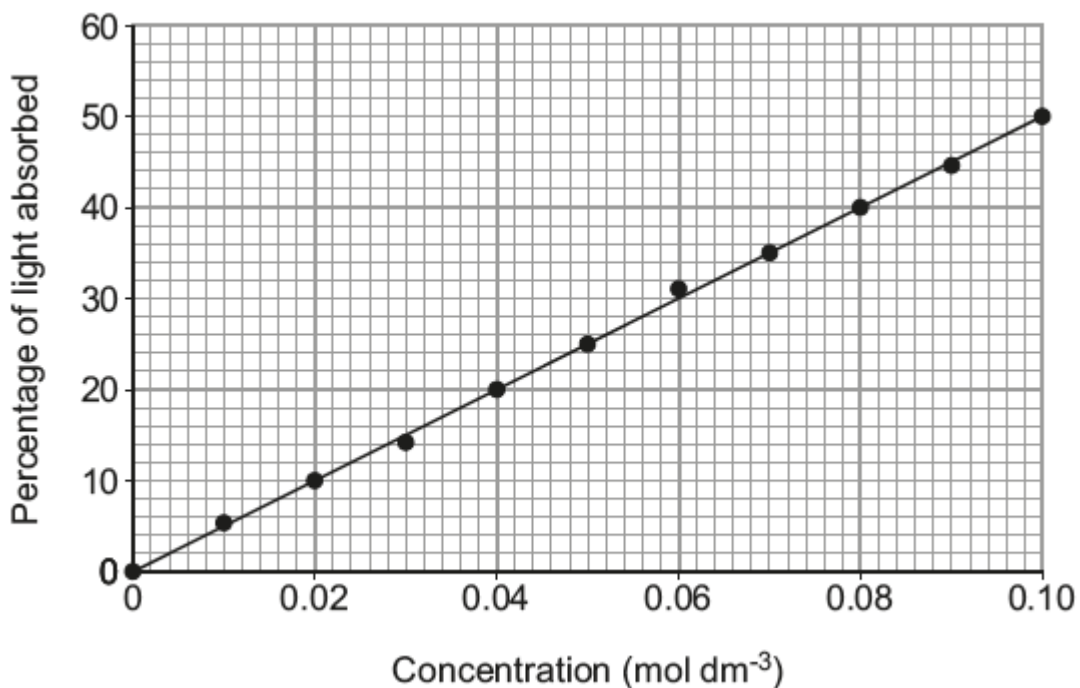
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(iii)   The relationship between the percentage of light absorbed and the concentration of a complex ion can be used to find the concentration of a given solution.

The graph below shows the relationship between the percentage of light of a particular wavelength absorbed and the concentration of $[Co(H_2O)_6]^{2+}$.

This relationship can also be expressed as a mathematical equation:

concentration of $[Co(H_2O)_6]^{2+}$ = $1.942 \times 10^{-3} \times$ percentage of light absorbed

Determine a value for the concentration of a solution that absorbs 33.6 % of the light of this wavelength using the graph and another value using the equation. Comment on the values obtained.   [3]
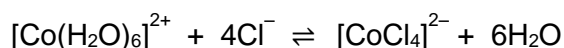
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(c) (i) Write an expression for the equilibrium constant, K_c, for the equilibrium between $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$. [1]

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

(ii) A non-aqueous solution initially containing 0.20 mol dm^{-3} $[Co(H_2O)_6]^{2+}$ and 0.50 mol dm^{-3} Cl$^-$ was allowed to come to equilibrium. The concentration of $[CoCl_4]^{2-}$ at equilibrium was 0.08 mol dm^{-3}.
Calculate the value of K_c under these conditions and give its units. [4]

K_c = ...

Units ....

(d) Silver nitrate solution is added to a solution containing $[CoCl_4]^{2-}$ ions which causes the solution to become cloudy and then change colour. Explain these observations. [4]

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19. A student was given a solution containing a mixture of Fe^{2+} and Fe^{3+} ions (solution **X**) and was asked to determine the concentrations of each ion in the solution. He followed Method **A** described below.

Method **A**

Part 1

Pipette 25.00 cm^3 of solution **X** into a conical flask and add 10 cm^3 of dilute sulfuric acid. Titrate this solution with a 0.0200 mol dm^{-3} solution of potassium manganate(VII) until the first permanent pink colour remains in the solution. Repeat the titration as many times as necessary and calculate a mean titre.
The results of the titrations were 15.00 cm^3, 14.90 cm^3, 15.70 cm^3 and 14.95 cm^3.

Part 2

Pipette 25.00 cm^3 of solution **X** into a conical flask and add acid and granulated zinc. Warm the flask for 10 minutes to allow the all of the Fe^{3+} ions to be reduced to Fe^{2+} ions. After the solution has cooled, remove the excess zinc by filtering and titrate it against the same manganate(VII) solution used in Part 1. This time 19.10 cm^3 of the manganate(VII) solution were required.
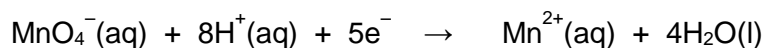
(a) (i) Outline **two** safety precautions that the student would have taken during the experiment, giving a reason for each. [2]

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(ii) The half-equations for the reaction between Fe^{2+} ions and acidified manganate(VII) ions are:

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$$

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

Use the titration results from Method **A** Part 1 to calculate the concentration, in mol dm^{-3}, of the Fe^{2+} ions in the mixture. [3]

Concentration Fe^{2+} = ... mol dm^{-3}

(iii)   Use the results from Method **A** Part 2 to calculate the concentration, in mol dm^{-3}, of the total Fe^{2+} and Fe^{3+} content in the mixture. Hence calculate the concentration, in mol dm^{-3}, of the Fe^{3+} ions in the mixture. [3]

Concentration Fe^{3+} = ... mol dm^{-3}

(iv)   Comment on the accuracy and reliability of the measurements in Method **A** Part 1 and suggest improvements that could be made to improve the accuracy of the results. [3]

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Method **B** includes an alternative to Part 2. The concentration of Fe^{3+} ions is determined by atomic absorption spectroscopy.

In this technique a sample of a solution is vaporised and atomised. A beam of light is passed through this and the absorbance of a specific wavelength of the light is measured using an electronic detector. This frequency is one of the absorption frequencies of the metal's atomic absorption spectrum.
To use this device, a control (usually a mixture of distilled water and another solution) is used in the spectrometer to calibrate the machine. After the device has been calibrated the concentration can be found by repeating the procedure using solution **X**.

(b)   Justify which of the two procedures would be likely to give the more accurate result for the concentration of Fe^{3+} ions in solution **X**. [3]

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