Class	Register Number	Name

南洋女子中學校
Nanyang Girls' High School

A

End-of-Year Examination 2022
Secondary 3

IP CHEMISTRY
Paper 2

1 hour 45 minutes

Wednesday 5 October **1030 – 1215**

READ THESE INSTRUCTIONS FIRST

Write your name, register number and class in the spaces at the top of this page.
Write in dark blue or black pen.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid / tape.

Section A
Answer all questions in the spaces provided.

You are advised to spend no longer than 1 hour on **Section A**, and no longer than 45 minutes on **Section B**.

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is on page **11**.

The use of an approved scientific calculator is expected, where appropriate.

Section A (40 marks)	
Section B (30 marks)	
Total (70 marks)	

This document consists of **10** printed pages and **2** blank pages.

Section A (40 marks)

Answer **all** questions.
Write your answers in the spaces provided.

A1 Epsom salt is a bitter-tasting salt with the chemical formula, $MgSO_4.\mathbf{n}H_2O$. It is widely used as bathing salt to relieve body aches.

(a) **(i)** Suggest the chemical formulae of two suitable reactants for making aqueous magnesium sulfate, stating which one is in excess. [2]

.....

(ii) State how the excess reactant can be removed from aqueous magnesium sulfate. [1]

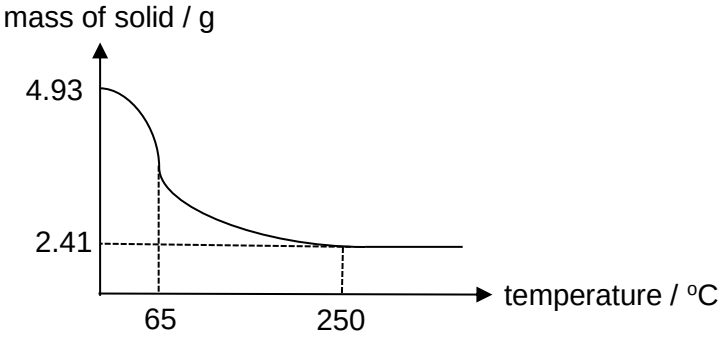
.....

(iii) State the most suitable method by which Epsom salt can be obtained from aqueous magnesium sulfate. [1]

.....

(b) A sample of Epsom salt weighing 4.93 g initially was strongly heated in an evaporating dish until it decomposed to form the anhydrous salt, $MgSO_4$.

The following graph was obtained.



(i) State the minimum temperature required to decompose the Epsom salt into the anhydrous salt. [1]

_____ °C

(ii) Calculate the relative molecular mass of anhydrous magnesium sulfate, $MgSO_4$. [1]

(iii) Calculate the number of moles of $MgSO_4.\mathbf{n}H_2O$ in 4.93 g of Epsom Salt. [1]

(iv) Using the information in the graph and answer in **(b)(iii)**, derive the exact chemical formula of Epsom salt, showing all necessary working. [3]

Total [10]

A2 A sample of **X** contains three substances, **A**, **B** and **C**.

(a) In an experiment, a student conducting the experiment accidentally dripped a drop of sample **X** into the solvent. The student observed that the colour of sample **X** spread through the solvent.

Name this phenomenon, and explain why the phenomenon occur. [2]

.....

.....

(b) The retention factor (R_f) values of substances **A**, **B** and **C** in the respective solvents are given in the table below.

	A	**B**	**C**
water	0.20	0.20	0.60
ethanol	0.80	0.40	0.40

Another experiment is carried out on the sample **X** using two-dimension (2D) paper chromatography. The following steps show how 2D paper chromatography is carried out to separate the substances in **X**:

1. Separate the sample using water.
2. Rotate the paper 90 degrees clockwise.
3. Carry out further separation on the sample using ethanol as solvent.

(i) Use the information in the table to explain why it is necessary to use 2D paper chromatography. [2]

.....

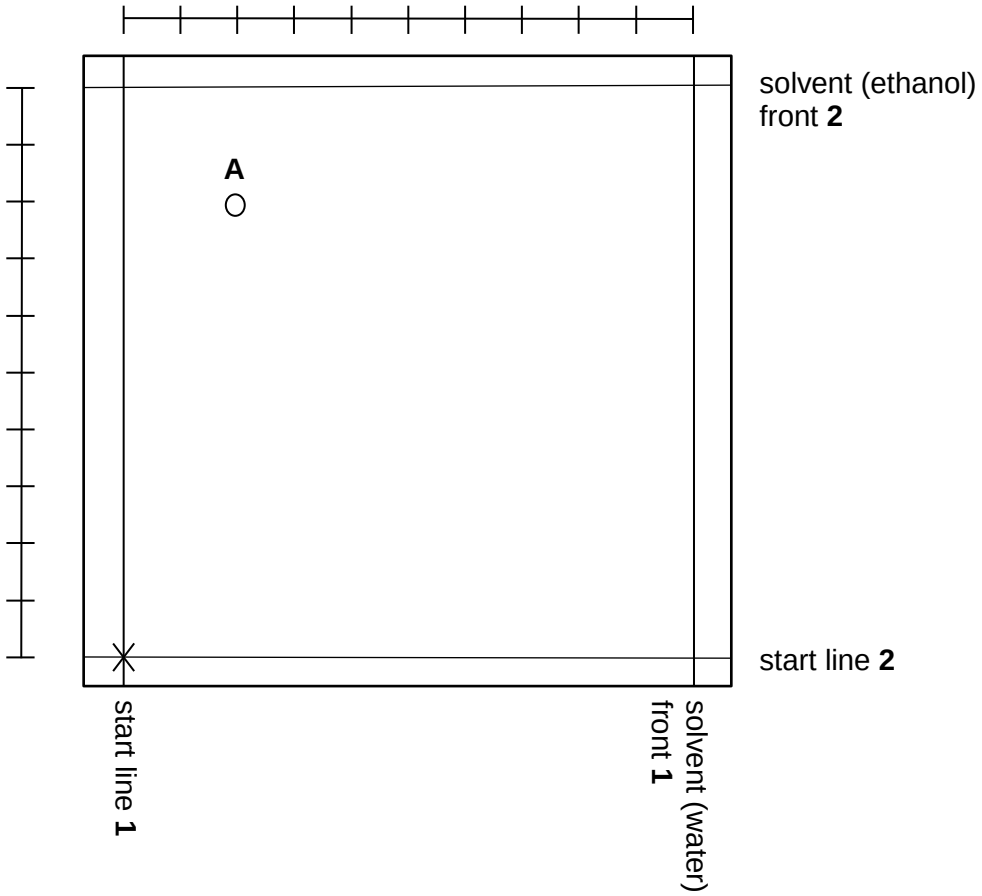
.....

.....

(ii) In the 2D paper chromatography that was done, the distance of the solvent front from the start line when water and ethanol are used as solvents are both 10 cm.

In the paper chromatogram shown below, each point on the scale represents 1 cm. The position of substance **A** is shown in the paper chromatogram.

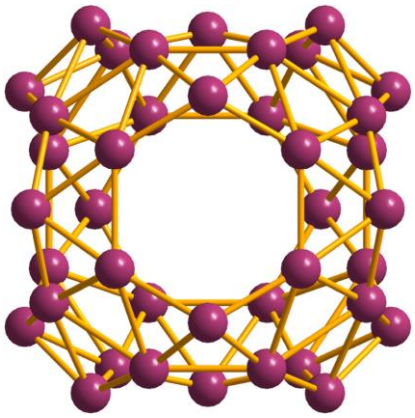
On the paper chromatogram, draw the location of the spots for substances **B** and **C**, and label them accordingly. [2]



Start line **1** and solvent front **1**: water is used as a solvent.
Start line **2** and solvent front **2**: ethanol is used as a solvent.
The point marked as X is the initial position of sample **X**.

Total [6]

A3 Borospherene, B_{40}, is a new molecule discovered in 2014. The structure of borospherene is shown below.



(a) In terms of its structure, explain why borospherene is expected to have poor electrical conductivity. [2]

(b) State and explain whether borospherene is expected to have a high or low boiling point. [2]

(c) Predict and explain whether the boiling point of borospherene is expected to be higher or lower than that of methane, CH_4. [2]

(d) By considering the number of valence electrons that boron has, explain why the bonding between boron atoms in borospherene is unusual. [1]

Total [7]

A4 A new element **Z** was discovered and found to have the following properties.

- melting point of 25 °C
- conducts electricity in solid and liquid state
- reacts violently with water and hydrochloric acid

(a) (i) Identify the Group that element **Z** is in. [1]

.....

(ii) Other than the properties given, state another physical property that element **Z** is expected to have. [1]

.....

(b) (i) Write a chemical equation, with state symbols, for the reaction between element **Z** and water. [2]

.....

(ii) Element **Z** is an element below Period 6 in the Periodic Table.

By considering the trend in the tendency of elements to lose electrons down the Group, explain why element **Z** is very reactive. [3]

.....

.....

.....

.....

.....

(iii) Element **X** is an element one period above **Z** in the Periodic Table. Element **Y** contains one more proton than element **X**.

By considering how the tendency of the elements to lose electrons changes across the Period and down the Group, arrange the elements in order of the most reactive to the least reactive. [1]

.....

Total [8]

A5 The atmosphere of an unknown planet was analysed and it was found to contain nitrogen, carbon dioxide, oxygen and argon. The following set-up was used to determine the volume of oxygen in the planet's atmosphere.

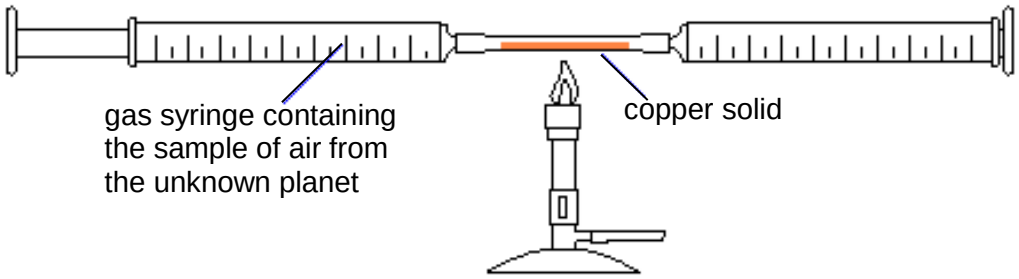


Fig. 1

The oxygen present in the sample of air reacts with copper solid to form copper(II) oxide, a black solid.

$$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$$

The volume of air used for the experiment was originally 80.0 cm^3 while the original mass of copper used was 2.50 g.

After the experiment, the unreacted copper was separated from the copper(II) oxide formed by dissolving the copper(II) oxide in excess dilute nitric acid.

The mixture was filtered to obtain a filtrate while the unreacted copper residue was washed, dried and weighed to be 2.25 g.

(a) **(i)** Calculate the number of moles of copper reacted with oxygen. [1]

(ii) Calculate the volume of oxygen reacted, expressing the answer in cm^3. [1]

(iii) Calculate the percentage of oxygen present in the planet's atmosphere. [1]

(b) After filtration, 25.0 cm^3 of the filtrate was pipetted into a conical flask and titrated with 3.20 g dm^{-3} aqueous sodium hydroxide using methyl orange indicator.

$$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$$

The average titration reading obtained was 19.30 cm^3.

(i) Write a balanced equation for the reaction between nitric acid and copper(II) oxide. [1]

.....

(ii) Using your answer in **(a)(i)**, calculate the number of moles of nitric acid that reacted with copper(II) oxide. [1]

(iii) Calculate the number of moles of nitric acid that reacted with sodium hydroxide. [2]

(iv) The volume of nitric acid used was 150 cm^3.

Calculate the number of moles of nitric acid that was added to the mixture of copper and copper(II) oxide. [2]

Total [9]

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The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0	Key: atomic number / atomic symbol / name / relative atomic mass										5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

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Section B
Answer all questions in the spaces provided.

The last question, **B8** is in the form of an **EITHER/ OR** and only one of the alternatives should be attempted.

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

The use of an approved scientific calculator is expected, where appropriate.

Indicate the question attempted for **B8** with a tick (✓).	
Either ☐	**Or** ☐

Section B (30 marks)	

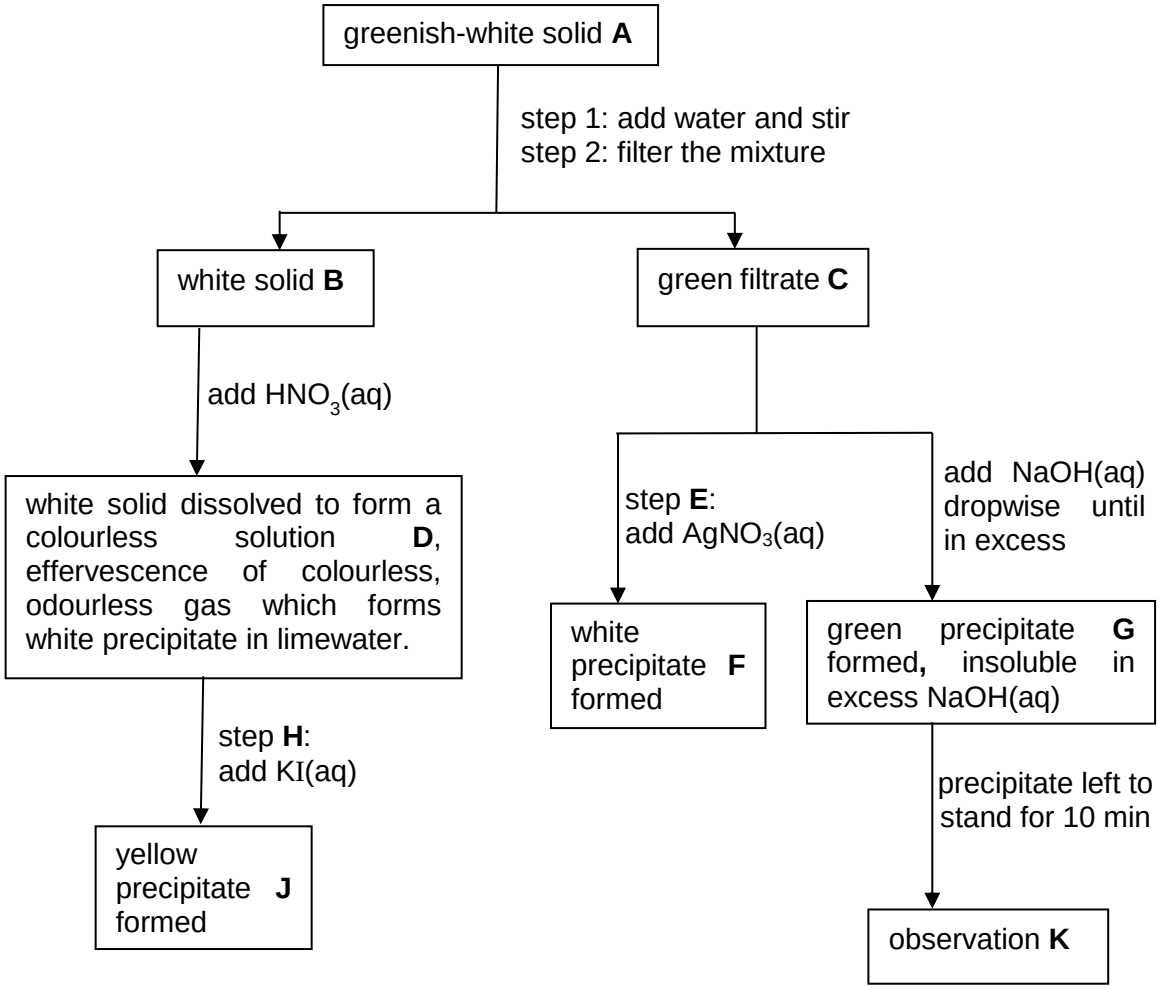
This document consists of **9** printed pages and **1** blank page.

Section B (30 marks)

Answer all **three** questions from this section in the spaces provided.

The last question is in the form of either/or and only **one** of the alternatives should be attempted.

B6 Refer to the reaction scheme below when answering the following questions.



(a) **(i)** Describe observation **K**. [1]

.....

(ii) Write the ionic equation for the formation of precipitate **G**. [1]

.....

(b) **(i)** Identify precipitate **F**. [1]

.....

(ii) Explain why it is not necessary to add HNO_3(aq) in step **E**. [2]

.....

.....

(c) **(i)** Identify the anion in solid **B**. [1]

.....

(ii) Identify precipitate **J**. [1]

.....

(iii) State the chemical formula of an alternative reagent for step **H** that gives a different observation but leads to the same deduction. [1]

.....

(d) Identify the two compounds that make up solid **A**. [2]

.....

Total [10]

B7 Hydrogen halides are diatomic covalent molecules with the formula H**X**, where **X** is a halogen (Group 17 element). When dissolved in water, hydrogen halides form hydrohalic acids, H**X**(aq), which dissociate in water to form ions.

pK_a is a number that measures the strength of an acid. The **smaller** the pK_a value, the greater the extent of the dissociation of the acid in solution and hence the **stronger** the acid.

Bond energy is defined as the amount of energy required to break one mole of a particular type of bond. For example, the bond energy of H−**X** is the energy required to break all the H−**X** bonds in one mole of H**X** molecules.

The table below shows the bond energy of hydrogen halides H**X** and the pK_a value of their corresponding hydrohalic acids.

Table 7

hydrogen halide	H−**X** bond energy / kJ mol^{-1}	pK_a of hydrohalic acid
HF	562	3.1
HC*l*	431	−3.9
HBr	366	−5.8
HI	299	−10.4

(a) **(i)** HC*l* is a *strong acid*. Define the term '*strong'*. [1]

.....

.....

(ii) Describe the trend in the strength of the hydrohalic acids down Group 17. [1]

.....

(iii) Describe the trend in the bond energy of H−**X** down Group 17. [1]

.....

(iv) State and explain the relationship between the bond energy of H−**X** and the strength of the corresponding hydrohalic acid formed. [3]

.....

.....

.....

.....

.....

.....

.....

(b) Write an ionic equation for the reaction between aqueous sodium hydroxide and a solution of hydrohalic acid. [1]

.....

(c) pH is a measure of the concentration of H^+ ions in a solution.
Hydrofluoric acid is a weak acid while hydrochloric acid is a strong acid.

(i) Write an equation for the dissociation of hydrofluoric acid in solution. [1]

.....

(ii) State and explain whether it is possible for a solution of hydrofluoric acid to have the same pH as a solution of hydrochloric acid. [2]

.....

.....

.....

.....

Total [10]

EITHER

B8 This question is about tests for cations.

(a) A student decides to conduct the tests for magnesium ion.

(i) Oxides and hydroxides of elements react similarly with acids and alkalis.

State whether magnesium hydroxide is acidic, basic, amphoteric or neutral. [1]

.....

(ii) Using your answer in **part (ai)** and considering the test for other cations, predict the observation when aqueous sodium hydroxide is added dropwise to a solution containing magnesium ion until in excess. [1]

.....

.....

(iii) Magnesium hydroxide does not react with aqueous ammonia to form a soluble substance.

Describe the observation when aqueous ammonia is added dropwise to a solution containing magnesium ion until in excess. [1]

.....

.....

(b) In a separate experiment, the student added aqueous sodium hydroxide to lead(II) sulfate.

Explain why precipitation would not occur in this experiment. [2]

.....

.....

.....

(c) In another experiment, the student did the following.

- Add aqueous ammonia dropwise until in excess to a 2 cm^3 solution containing aluminium ions,
- Filtered the mixture to obtain white precipitate.
- Washed precipitate with distilled water
- Dried precipitate between sheets of filter paper
- Precipitate was found to have a mass of 0.1 g.

(i) Calculate the concentration in mol dm^{-3} of aluminium ion in the 2 cm^3 solution. [2]

(ii) State and explain whether you expect the concentration calculated in part **(ci)** to be higher or lower than the concentration present in the 2 cm^3 solution containing aluminium ion. [2]

.....

.....

.....

(iii) State and explain whether adding aqueous ammonia until in excess to a 2 cm^3 solution containing zinc ions to find the concentration will be feasible. [1]

.....

.....

Total [10]

OR

B8 This question is about transition metals and the ions they form.

(a) **(i)** One property that transition metals share with a Group 2 metal like magnesium is their high melting point.

Explain why transition metals have high melting point. [2]

.....

.....

.....

(ii) State two characteristic properties of transition metals that are different from those of a Group 2 metal like magnesium. [2]

.....

.....

(b) Write the electronic configuration of chromium and nickel. [2]

Cr: $1s^2$ .....

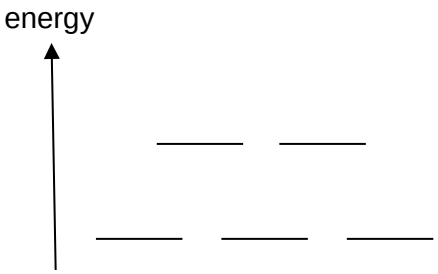
Ni: $1s^2$ .....

(c) Complete the dot-and-cross diagram of zinc chloride in the space provided below. [1]

Zn^{2+}

(d) Cobalt metal can lose electrons to form cobalt(III) ions.
In water, cobalt(III) ion generally interact with water molecules to form a complex ion, $[Co(H_2O)_6]^{3+}$.

(i) In $[Co(H_2O)_6]^{3+}$, the energy levels for the d-orbitals of Co^{3+} are shown below.



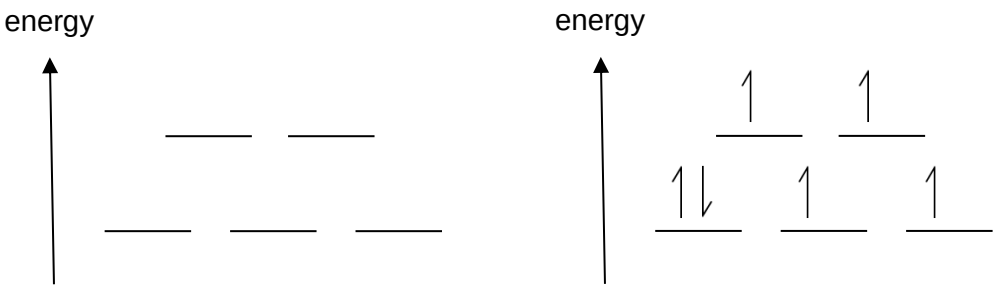
State what is unusual about the energy levels of the d-orbitals in $[Co(H_2O)_6]^{3+}$. [1]

.....

.....

The electronic configurations of the d-orbitals in $[Co(H_2O)_6]^{3+}$ are shown below.

<u>expected electronic configuration</u> <u>actual electronic configuration</u>



(ii) In the diagram above, fill in the expected electronic configuration of the d-orbitals in $[Co(H_2O)_6]^{3+}$ using Aufbau's Principle, which states that electrons occupy orbitals in order of energy level. [1]

(iii) Suggest a reason why electrons are occupying the d-orbitals in $[Co(H_2O)_6]^{3+}$ in the way that was shown in the actual electronic configuration. [1]

.....

Total [10]

END OF PAPER

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