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A Level Chemistry A

H432/01 Periodic table, elements and physical chemistry

Practice paper – Set 2

Time allowed: 2 hours 15 minutes

2016

You must have:
- the Data Sheet for Chemistry A

You may use:
- a scientific or graphical calculator

First name										
Last name										
Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **28** pages.

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SECTION A

You should spend a maximum of 20 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

1 Which ion has a different number of electrons from the other three ions?

A Ca^{2+}

B Cl^{-}

C Ga^{3+}

D S^{2-}

Your answer ☐ **[1]**

2 What is the percentage, by mass, of O in $Mg(NO_3)_2 \cdot 4H_2O$?

A 29.05%

B 43.58%

C 50.84%

D 72.63%

Your answer ☐ **[1]**

3 50 cm^3 of 6.0 mol dm^{-3} HCl is mixed with 90 cm^3 of 3.0 mol dm^{-3} HNO_3.

What is the $H^+(aq)$ concentration in the resulting solution?

A 1.9 mol dm^{-3}

B 2.1 mol dm^{-3}

C 4.1 mol dm^{-3}

D 4.5 mol dm^{-3}

Your answer ☐ **[1]**

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4 Phosphorus reacts with aqueous sodium hydroxide as in the equation below.

$$P_4 + 3NaOH + 3H_2O \rightarrow PH_3 + 3NaH_2PO_2$$

Which element is oxidised?

A hydrogen

B oxygen

C phosphorus

D sodium

Your answer ☐ **[1]**

5 Ethene reacts with hydrogen to form ethane.

$$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g) \qquad \Delta H = -125\,kJ\,mol^{-1}$$

The table below shows some average bond enthalpies.

Bond	Average bond enthalpy / kJ mol^{-1}
H–H	+436
C–C	+347
C=C	+612

What is the bond enthalpy of the C–H bond?

A $-826.0\,kJ\,mol^{-1}$

B $-413.0\,kJ\,mol^{-1}$

C $+413.0\,kJ\,mol^{-1}$

D $+826.0\,kJ\,mol^{-1}$

Your answer ☐ **[1]**

6 The reaction below is first order with respect to **A**.

$$\mathbf{A}(aq) \rightarrow \text{products}$$

When the initial concentration of **A** is $1\,mol\,dm^{-3}$, the half-life is 20 minutes.

What is the half-life when the initial concentration of **A** is $2\,mol\,dm^{-3}$?

A 10 minutes

B 20 minutes

C 40 minutes

D 60 minutes

Your answer ☐ **[1]**

7 Nitrogen dioxide, NO_2 reacts with carbon monoxide, CO, as shown in the equation.

$$NO_2(g) + CO(g) \rightarrow CO_2(g) + NO(g)$$

A proposed mechanism for this reaction is shown below.

$$NO_2(g) + NO_2(g) \rightarrow NO_3(g) + NO(g) \quad \text{slow}$$

$$NO_3(g) + CO(g) \rightarrow NO_2(g) + CO_2(g) \quad \text{fast}$$

Which rate equation is consistent with this mechanism?

A $rate = k[NO_2]$

B $rate = k[NO_2][CO]$

C $rate = k[NO_2]^2$

D $rate = k[NO_2]^2[CO]$

Your answer ☐ **[1]**

8 Ammonia, NH_3, is formed in the reversible reaction below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

A mixture at equilibrium contains 0.320 mol N_2, 0.960 mol H_2 and 0.120 mol NH_3.

What is the mole fraction of H_2 in the equilibrium mixture?

A 0.279

B 0.686

C 0.837

D 2.06

Your answer ☐ **[1]**

9 A 0.040 mol dm^{-3} solution of a weak monobasic acid is 1.0% dissociated.

What is the value of K_a for the acid?

A 2.0×10^{-7} mol dm^{-3}

B 4.0×10^{-6} mol dm^{-3}

C 4.0×10^{-4} mol dm^{-3}

D 4.0×10^{-2} mol dm^{-3}

Your answer ☐ **[1]**

10 Which equation matches the enthalpy change of atomisation of iodine?

A $I_2(g) \rightarrow 2I(g)$

B $\frac{1}{2}I(g) \rightarrow I(g)$

C $I_2(s) \rightarrow 2I(g)$

D $\frac{1}{2}I_2(s) \rightarrow I(g)$

Your answer ☐ **[1]**

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11 Electrode potentials are given below.

$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$ $\quad -1.676\,V$

$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$ $\quad -0.137\,V$

A standard cell is constructed from $Al^{3+}(aq)|Al(s)$ and $Sn^{2+}(aq)|Sn(s)$ half cells.

Which statement is correct for the standard cell?

A Al is oxidised and the cell potential is 1.539 V.

B Sn is oxidised and the cell potential is 1.539 V.

C Al is oxidised and the cell potential is 1.813 V.

D Sn is oxidised and the cell potential is 1.813 V.

Your answer ☐ **[1]**

12 What is the reason that zinc is **not** classified as a transition element?

A Zinc atoms contain a full d-sub-shell.

B There are no zinc ions with an incomplete d-sub-shell.

C Zinc does not form complex ions.

D Zinc ions are colourless.

Your answer ☐ **[1]**

13 Hydrogen iodide, HI(g), is formed in the reversible reaction below.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9\,kJ\,mol^{-1}$$

Which statement(s) is/are correct?

1 This is a redox reaction.

2 The equilibrium yield of HI(g) is changed by increasing the pressure.

3 The equilibrium yield of HI(g) increases as the temperature is increased.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

14 Which substance(s) experience(s) induced dipole–dipole interactions (London forces)?

1 C_2H_5OH

2 H_2O

3 SiO_2

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

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15 Which statement(s) is/are correct for copper(II) ions?

1 They form a copper(II) complex ion with chloride ions that has a square planar shape.

2 They can be reduced to copper(I) by iodide ions.

3 They have the electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

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SECTION B

Answer **all** the questions.

16 This question is about atomic structure and electron configuration.

(a) Most elements exist as different isotopes.

Complete the table for an atom and an ion of two different isotopes of titanium.

Isotope	Protons	Neutrons	Electrons
^{48}Ti	…….	…….	…….
…….	…….	24	19

[2]

(b) The accurate relative isotopic masses and relative abundances of the isotopes in a sample of bromine are shown below.

Isotope	Relative isotopic mass	Relative abundance (%)
^{79}Br	78.9183361	50.69
^{81}Br	80.9162896	49.31

(i) What is the relative atomic mass of bromine in this sample?

Give your answer to **three** decimal places.

relative atomic mass = ... **[2]**

(ii) Write the electron configuration, in terms of all sub-shells, for an atom of bromine.

..... **[1]**

(c) Ionisation energies have been used to develop a model for electron configuration.

(i) **Fig. 16.1** shows the first ionisation energies for Li, Be, F and Ne.

Add points for the missing elements across Period 2.

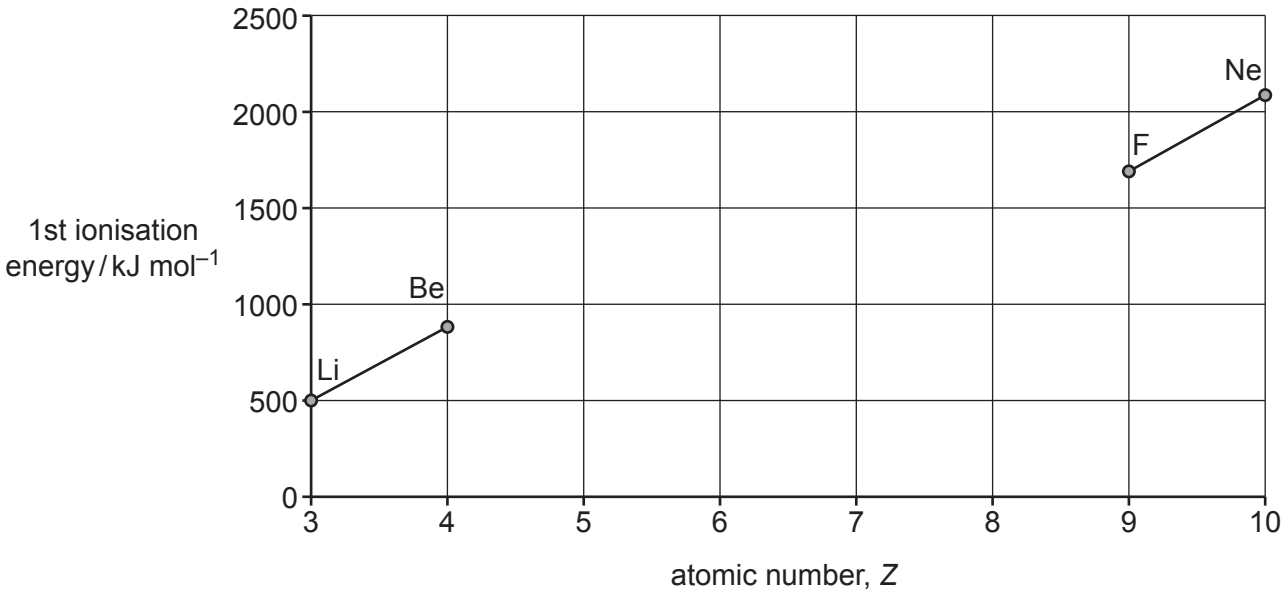

Fig. 16.1

[2]

(ii) First ionisation energies decrease down groups in the Periodic Table.

Explain this trend and the effect on the reactivity of groups containing metals.

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..... **[3]**

17 Methane is an important raw material for manufacturing chemicals. Hydrogen can be manufactured from methane and steam as shown below in **equation 17.1**.

$$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g) \qquad \Delta H = +210\,kJ\,mol^{-1} \qquad \textbf{Equation 17.1}$$

The rate of reaction is increased by using a catalyst.

(a)* Using the Boltzmann distribution model, explain why the rate of the reaction is increased in the presence of a catalyst and suggest the benefits of using a catalyst for energy demand and the environment.

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..... **[6]**

(b) A chemist investigates the equilibrium shown in **equation 17.1** as outlined below.

$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$ $\Delta H = +210\,kJ\,mol^{-1}$ **Equation 17.1**

- A chemist mixes together 1.000 mol CH_4 and 1.400 mol of H_2O in a sealed container.
- The mixture is heated to constant temperature and allowed to reach equilibrium. The equilibrium mixture contains 0.200 mol of CH_4 and the total pressure is 30.0 atm.

Use this information to calculate K_p for the equilibrium in **equation 17.1**.

Show all your working.

[7]

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18 This question is about reactions of sulfur compounds.

(a) A student neutralises aqueous sulfuric acid, $H_2SO_4(aq)$, with aqueous sodium hydroxide, NaOH(aq), to determine the enthalpy change of neutralisation, $\Delta_{neut}H$.

(i) Define the term *enthalpy change of neutralisation* and write the ionic equation for the this change. Include state symbols.

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..... **[2]**

(ii) Write a full equation for the complete neutralisation of H_2SO_4 with NaOH(aq).
State symbols are **not** required.

..... **[1]**

(iii) In their experiment, the student follows the method below.

- Add 50.0 cm^3 of 1.50 mol dm^{-3} NaOH(aq) to a polystyrene cup.
- Measure out 25.0 cm^3 of 1.50 mol dm^{-3} $H_2SO_4(aq)$.
- Measure the initial temperature of both solutions.
- Add the $H_2SO_4(aq)$ to the NaOH(aq) in the polystyrene cup, stir the mixture, and record the maximum temperature reached.

Results

Initial temperature of both solutions	22.0 °C
Maximum temperature of mixture	35.5 °C

Calculate $\Delta_{neut}H$, in kJ mol^{-1}.

Assume that the density and specific heat capacity of all solutions are the same as for water.

$\Delta_{neut}H$ = ... kJ mol^{-1} **[3]**

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(b) Much of the sulfur required for production of sulfuric acid is obtained from sulfur impurities in natural gas, such as hydrogen sulfide, H_2S.

The H_2S is converted into sulfur in two steps.

Step 1: Some of the H_2S is reacted with oxygen to form sulfur dioxide, SO_2.

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$

Step 2: The remaining H_2S is reacted with the SO_2 to produce sulfur.

$$2H_2S(g) + SO_2(g) \rightarrow 3S(s) + 2H_2O(g)$$

(i) Construct the overall equation for the two steps above.

..... **[1]**

(ii) A natural gas supply contains 16.0% H_2S by volume.
The $H_2S(g)$ in $1.50 \times 10^8\,dm^3$ of this natural gas supply, measured at RTP, is processed into sulfur with an overall percentage yield of 95.0%.

Calculate the mass of sulfur, in g, obtained from $1.50 \times 10^8\,dm^3$ of natural gas supply.

Give your answer to **three** significant figures and in standard form.

mass of sulfur = ... g **[3]**

(c) The enthalpy change for the equation in **step 2** is shown below.

$2H_2S(g) + SO_2(g) \rightarrow 3S(s) + 2H_2O(g)$ $\Delta H = -145.6\,kJ\,mol^{-1}$

Standard entropies, S, and enthalpy changes of formation, $\Delta_f H$, are given in the table.

Substance	$H_2S(g)$	$SO_2(g)$	$S(s)$	$H_2O(g)$
S / J mol^{-1} K^{-1}	205.7	248.1	31.8	188.7
$\Delta_f H$ / kJ mol^{-1}	–20.6		0	–241.8

(i) Calculate ΔG at 25 °C, and explain whether the reaction in **step 2** is feasible at 25 °C.

Calculate the temperature, in K, at which the feasibility changes.

Show your working and explain your reasoning.

[5]

(ii) Calculate $\Delta_f H$ for $SO_2(g)$.

$\Delta_f H$ for $SO_2(g)$ = ... kJ mol^{-1} **[2]**

19 This question is about vitamin C, $C_6H_8O_6$.

(a) Vitamin C is a weak monobasic acid with a K_a value of 6.76×10^{-5} mol dm^{-3}.

(i) Write the expression for K_a for vitamin C.

[1]

(ii) Calculate pK_a for vitamin C, to **two** decimal places.

[1]

(iii) A bottle of vitamin C supplements contains tablets, each containing 500 mg of vitamin C.

A student dissolves three vitamin C tablets in water and makes up the solution to a volume of 250.0 cm^3.

Calculate the pH of the solution.

Give your answer to **two** decimal places.

pH = ... **[4]**

(b) Low acidity vitamin C tablets are less acidic than tablets containing just vitamin C.

A student dissolves a low acidity vitamin C tablet in water.

- The tablet contains a mixture of 300 mg of vitamin C, $C_6H_8O_6$, and the sodium salt of vitamin C, $C_6H_7O_6Na$.
- The pH of the solution is 4.02.

(i) Calculate the ratio $C_6H_7O_6^-$: $C_6H_8O_6$ in the solution.

Show your working.

$$\frac{[C_6H_7O_6^-]}{[C_6H_8O_6]} = \frac{\text{.....}}{1}$$ **[3]**

(ii) Calculate the mass of $C_6H_7O_6Na$, in mg, in the low acidity vitamin C tablet.

mass = ... mg **[1]**

(c) The sodium salt of vitamin C can be made by reacting vitamin C with aqueous sodium hydroxide.

An aqueous solution of sodium hydroxide had a pH of 12.72 at 298 K.

Calculate the concentration, in mol dm^{-3}, of the NaOH solution.

concentration = ... mol dm^{-3} **[2]**

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20 This question is about redox reactions.

(a)* Bromine, Br_2, is formed in the redox reaction shown below.

$$5Br^-(aq) + BrO_3^-(aq) + 6H^+(aq) \rightleftharpoons 3Br_2(aq) + 3H_2O(l)$$

A student plans an investigation, using the initial rates method, to determine the rate equation and rate constant for this reaction.

The student is supplied with solutions containing the following:
- $0.300\,mol\,dm^{-3}$ $Br^-(aq)$
- $0.300\,mol\,dm^{-3}$ $BrO_3^-(aq)$
- $0.300\,mol\,dm^{-3}$ $H^+(aq)$.

The student is also supplied with distilled water and normal laboratory glassware.

The student uses a total volume of $30\,cm^3$ for each experiment and measures the initial rate of formation of $Br_2(aq)$.

The results of the student's experiments are shown below.

Experiment	$[Br^-(aq)]$ / mol dm^{-3}	$[BrO_3^-(aq)]$ / mol dm^{-3}	$[H^+(aq)]$ / mol dm^{-3}	Initial rate /10^{-3} mol dm^{-3} s^{-1}
1	0.100	0.100	0.100	1.20
2	0.025	0.100	0.100	0.30
3	0.100	0.050	0.100	0.60
4	0.100	0.050	0.050	0.15

Show how the student could obtain the concentrations for experiments **1**–**4** and determine the rate constant for this reaction.

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..... **[6]**

(b) When heated with dilute acid, $MnO_4^{2-}(aq)$ ions disproportionate into MnO_4^- and MnO_2.

(i) Balance the equation for this disproportionation reaction.

..... $MnO_4^{2-}(aq)$ + …… $H^+(aq)$ $\rightleftharpoons$ …… $MnO_4^-(aq)$ + …… $MnO_2(s)$ + …… $H_2O(l)$ **[1]**

(ii) Although $MnO_4^{2-}(aq)$ ions disproportionate in acidic conditions, $MnO_4^{2-}(aq)$ ions are stable under alkaline solutions.

Explain this difference in stability, in terms of equilibrium.

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..... **[2]**

(c) Hydrogen fuel cells generate energy from redox reactions. Hydrogen fuel cells have been developed to operate in either an acidic or alkaline electrolyte.

Standard electrode potentials for several redox systems are shown below.

$2H_2O(l) + 2e^-$	$\rightleftharpoons$	$2OH^-(aq) + H_2(g)$	$E^\ominus$ = –0.83 V
$2H^+(aq) + 2e^-$	$\rightleftharpoons$	$H_2(g)$	$E^\ominus$ = 0.00 V
$O_2(g) + 2H_2O(l) + 4e^-$	$\rightleftharpoons$	$4OH^-(aq)$	$E^\ominus$ = +0.40 V
$O_2(g) + 4H^+(aq) + 4e^-$	$\rightleftharpoons$	$2H_2O(l)$	$E^\ominus$ = +1.23 V

Using this information, show how acidic and alkaline hydrogen fuel cells produce the same overall cell equation and cell potential, despite different reactions taking place at each electrode.

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..... **[4]**

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21 This question is about reactions and properties of d-block elements.

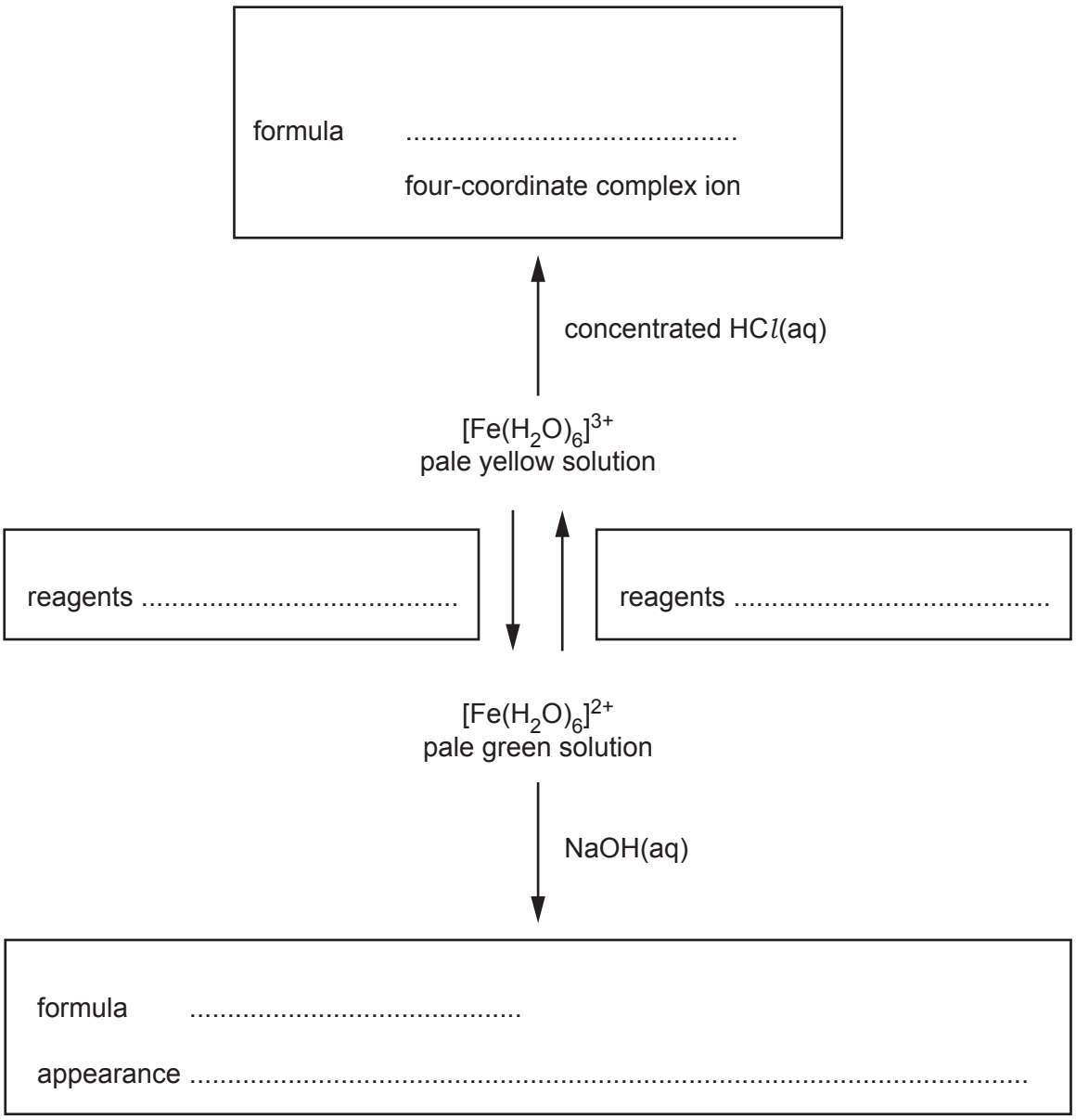
(a) Iron forms many compounds and ions in the +2 and +3 oxidation states.

(i) Complete the electron configuration of iron in its +2 oxidation state.

$1s^2$ ..... **[1]**

(ii) The flowchart below shows reactions of iron in its +2 and +3 oxidation states.

Complete the flowchart using formulae for reagents and iron-containing products.



[4]

(b) A student is supplied with an unknown d-block element, **M**, from Period 4 (Sc–Zn).

The student knows that element **M** is oxidised by hydrochloric acid to form hydrogen gas and a solution containing ions of **M**. The student is unsure whether the element **M** reacts to form ions in the +2 or +3 oxidation state. The student writes down two possible equations:

Equation 1 **M**(s) + 2HCl(aq) $\rightarrow$ **M**Cl_2(aq) + H_2(g)

Equation 2 2**M**(s) + 6HCl(aq) $\rightarrow$ 2**M**Cl_3(aq) + 3H_2(g)

The student carries out an experiment to identify element **M** and to find out which equation is correct.

In the experiment, the student reacts a weighed mass of **M** with an excess of hydrochloric acid and collects the hydrogen gas over water in an inverted measuring cylinder.
The student records the volume of hydrogen collected at RTP.

The student's results are shown below.

Results
Mass of element **M** = 0.188 g
Volume of gas collected at RTP = 150 cm^3

Analyse the student's results to determine the identity of element **M**.

Show **all** your working.

[4]

(c) A student investigates reactions of cobalt ions, as outlined below.

- A student dissolves cobalt(II) chloride in water. A pink solution forms containing the hexaaqua complex ion **B**.
- The student adds an excess of concentrated ammonia solution to the pink solution until there is no further change.
- A pale brown solution forms which contains the complex ion $[Co(NH_3)_6]^{2+}$.

(i) Write the equation for the formation of $[Co(NH_3)_6]^{2+}$ from complex ion **B**.

State the type of reaction.

Equation .....

Type of reaction ..... **[2]**

(ii) Draw a 3-D diagram of the $[Co(NH_3)_6]^{2+}$ ion.

On your diagram, show the value of the bond angles involving Co.

[2]

(iii) A solution containing $[Co(NH_3)_6]^{2+}$ is reacted as outlined below.

- The solution is warmed with aqueous hydrogen peroxide, $H_2O_2(aq)$.
  The H_2O_2 oxidises cobalt(II) to cobalt(III), to form a red-brown solution containing a six-coordinate complex ion **C**.

- Concentrated hydrochloric acid is added to the red-brown solution.
  Yellow crystals of a complex **D** are formed.

Complex **D** has the percentage composition by mass:

Co, 22.03%; N, 31.41%, H, 6.73%; C*l*, 39.83%.

Determine the formulae of **C** and **D**, showing clearly the ligands and any charges.

Show all your working.

[4]

(iv) Write half equations and an overall equation for the oxidation of $[Co(NH_3)_6]^{2+}$ to **C** by hydrogen peroxide in **(iii)**.

Half equations

Overall equation

[3]

END OF QUESTION PAPER

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