Catholic Junior College

JC2 Preliminary Examinations

Higher 2

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY **9729/04**

Paper 4 Practical **16 August 2017**

2 hour 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

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READ THESE INSTRUCTIONS FIRST

Write your name and class in the boxes above.
Give details of the practical shift and laboratory, where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.
Qualitative Analysis Notes are printed on pages 15 and 16.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

Suggested Solutions

This document consists of **15** printed pages and **1** blank page.

[Turn over

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

1 'Washing soda' is made from crystals of sodium carbonate, which contains 62.94 % water and 37.06 % sodium carbonate. When stored, these crystals lose some of the water in the crystals to the atmosphere.

FA 1 is solid 'washing soda', originally sodium carbonate decahydrate, $Na_2CO_3.10H_2O$.
FA 2 is 0.100 mol dm^{-3} hydrochloric acid, HCl.

In this question, you will perform a titration to determine the amount of water in **FA 1** that has been lost to the atmosphere.

(a) Method

(i) Preparation of FA 3

- Weigh the 100 cm^3 beaker provided. Record the mass in the space below.
- Tip the 'washing soda' crystals, **FA 1**, into the beaker. Weigh the beaker with **FA 1** and record the mass.
- Calculate the mass of **FA 1** used and record this in the space below.
- Add distilled water to the beaker to dissolve the crystals. Carefully transfer the solution to a 250 cm^3 graduated (volumetric) flask labelled **FA 3**. Wash the beaker twice with small quantities of water and add these washings to the volumetric flask.
- Make the solution up to the mark using distilled water. Stopper the flask and invert a number of times to ensure thorough mixing.

mass of beaker + **FA1** / g	**21.138**
mass of beaker / g	**17.746**
mass of **FA 1** used / g	**3.392**

[1]

(ii) Titration of FA 3 against FA 2

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask and add a few drops of the indicator provided.
- Titrate the solution with **FA 2**. Record your results in the space provided on page **3**. Make certain that the recorded results show the precision of your practical work.
- Repeat the titration until consistent results are obtained.

Titration Results:

	1	2
final burette reading / cm^3	28.50	30.50
initial burette reading / cm^3	3.00	5.00
volume of FA 2 used / cm^3	25.50	25.50
	✓	✓

[6]

(iii) From your titrations, obtain a suitable volume of **FA 2** to be used in your calculations. Show clearly how you obtained this volume.

average titre = $\frac{25.50+25.50}{2}$

= 25.50 cm^3

volume of **FA 2** = ……25.50 cm^3……… [1]

(b) **(i)** Calculate the amount of hydrochloric acid run from the burette.

mol of HC*l* = *cV* = 0.100 × $\frac{25.50}{1000}$

= 2.55 x 10^{-3} mol

amount of HC*l* =……2.55 x 10^{-3} mol…… [1]

(ii) Sodium carbonate reacts with hydrochloric acid as follows.

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

Calculate the amount of sodium carbonate, Na_2CO_3, in 250 cm^3 of **FA 3**.

mol of Na_2CO_3 in 25.0 cm^3 of FA3 = $\frac{1}{2}$ × mol of HC*l*

= $\frac{1}{2}$ × 2.55 x 10^{-3}

= 1.275 x 10^{-3} mol

mol of Na_2CO_3 in 250 cm^3 of FA 3 = $\frac{250}{25.0}$ × 1.275 x 10^{-3}

= 1.275 x 10^{-2} mol

amount of Na_2CO_3 in 250 cm^3 of **FA 3** =……1.275 x 10^{-2} mol…… [2]

(iii) Calculate the mass of sodium carbonate, Na_2CO_3, dissolved in 250 cm^3 of **FA 3**.
[A_r: C, 12.0; O, 16.0; Na, 23.0]

M_r of Na_2CO_3 = 2(23.0) + 12.0 + 3(16.0) = 106.0

mass of Na_2CO_3 in 250 cm^3 FA 3 = nM_r = (1.275 x 10^{-2}) x 106.0
= 1.351 g

mass of Na_2CO_3 in 250 cm^3 of **FA 3** =……**1.351 g**……....… [1]

(iv) Calculate the mass of water present in the washing soda crystals.

mass of water = mass of FA 1 – mass of Na_2CO_3 in 250 cm^3 of FA 3
= 3.392 – 1.351
= 2.041 g

mass of water =……**2.041 g**……....… [1]

(v) Hence calculate the percentage of water in the sodium carbonate crystals, **FA 1**.

% of water = $\frac{2.041}{3.392}$ **x 100**

= 60.2 %

percentage of water in **FA 1** =……**60.2 %**……....… [1]

(c) The maximum error for a 25 cm^3 pipette commonly used in schools is ±0.06 cm^3.
The maximum error in any single burette reading is ±0.05 cm^3.

Calculate the maximum percentage error in each of the following.

(i) The volume of **FA 3** pipetted into the conical flask.

max % error = $\frac{0.06}{25.0}$ **× 100 = 0.240 %**

maximum percentage error in pipette volume =……**0.240**……....… %

(ii) The titre volume calculated in **(a)(iii)**.

max % error = $\frac{(2 \times 0.05)}{25.50}$ **× 100 = 0.392 %**

maximum percentage error in titre volume =……**0.392**……....… %
[2]

[Total: 16]

2 The enthalpy change for the reaction of sodium carbonate, Na_2CO_3, with water and carbon dioxide to form sodium hydrogencarbonate, $NaHCO_3$ cannot be determined directly. However both $Na_2CO_3(s)$ and $NaHCO_3(s)$ react with dilute hydrochloric acid.

Reaction 1 $NaHCO_3(s) + HCl(aq) \rightarrow NaCl\ (aq) + H_2O(l) + CO_2(g)$ ΔH_1

Reaction 2 $Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl\ (aq) + H_2O(l) + CO_2(g)$ ΔH_2

In this experiment you will determine the enthalpy change ΔH_1 for **reaction 1** and ΔH_2 for **reaction 2**, and then use your results to calculate ΔH_3 for the reaction:

$$Na_2CO_3(s) + H_2O(l) + CO_2(g) \rightarrow 2NaHCO_3(s) \qquad \Delta H_3$$

FA 4 is sodium hydrogen carbonate, $NaHCO_3$.
FA 5 is sodium carbonate, Na_2CO_3.
FA 6 is 2.0 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

(i) Experiment 1: $NaHCO_3(s) + HCl(aq) \rightarrow NaCl\ (aq) + H_2O(l) + CO_2(g)$

- Use a measuring cylinder to transfer 25 cm^3 of the acid, **FA 6**, into the plastic cup supported in a 250 cm^3 beaker. The acid is in excess.
- Weigh the container with **FA 4** and record the balance reading.
- Place the thermometer in the acid and record its temperature at 1 minute interval for the first two minutes.
- At 2½ minutes, carefully tip all the **FA 4**, in small portions, into the acid and stir to dissolve.
- Record the temperature of the solution at 1 minute interval from 3 minutes up to 8 minutes.
- Reweigh the container with any residual **FA 4** and record the balance reading and the mass of **FA 4** used.
- Rinse out the plastic cup and shake it to remove excess water.

Results

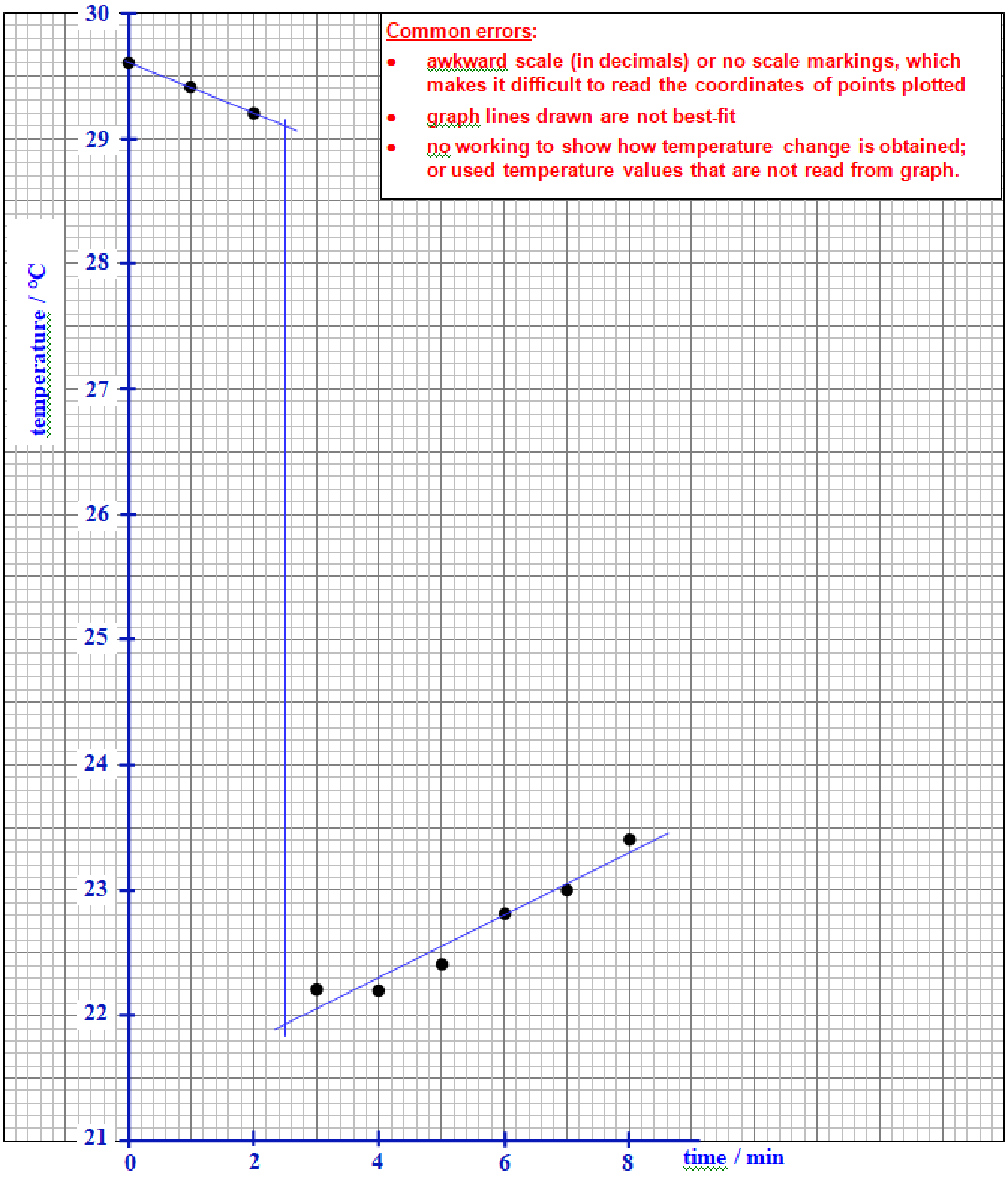
Record **all** weighings and temperature readings in the space below.

mass of container + **FA 4** / g	**5.976**
mass of container + residual **FA 4** / g	**3.489**
mass of **FA 4** used / g	**2.487**

time / min	0	1	2	3	4	5	6	7	8
temperature / °C	29.6	29.4	29.2	22.2	22.2	22.4	22.8	23.0	23.4

[5]

(ii) Plot on the grid below, a graph of temperature on the *y*-axis against time on the *x*-axis. The scale for the temperature should extend at least 1°C below the lowest recorded temperature.



Common errors:

- awkward scale (in decimals) or no scale markings, which makes it difficult to read the coordinates of points plotted
- graph lines drawn are not best-fit
- no working to show how temperature change is obtained; or used temperature values that are not read from graph.

Draw two straight lines of best fit and extrapolate the two lines to 2½ minutes. Determine the change in temperature at this time.

temperature change = 29.10 – 21.95 = 7.15 °C

temperature change at 2½ minutes = ...7.15......... °C

[4]

(iii) **Experiment 2**: $Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl\,(aq) + H_2O(l) + CO_2(g)$

- Use a measuring cylinder to transfer 25 cm^3 of the acid, **FA 6**, into the plastic cup supported in a 250 cm^3 beaker. The acid is in excess.
- Weigh the container with **FA 5** and record the balance reading.
- Place the thermometer in the acid and record its initial temperature.
- Carefully tip all the **FA 5**, in small portions, into the acid and stir to dissolve.
- Record the highest temperature reached.
- Reweigh the container with any residual **FA 5** and record the balance reading and the mass of **FA 5** used.

Results

Record **all** weighings and temperature readings in the space below.

mass of container + **FA 5** / g	**5.535**
mass of container + residual **FA 5** / g	**3.521**
mass of **FA 5** used / g	**2.014**
initial temperature of **FA 5** / °C	**30.0**
highest temperature / °C	**35.7**
temperature rise / °C	**5.7**

[3]

(b) **(i)** Using your answer to **2(a)(ii)**, calculate the heat energy absorbed when **FA 4** was added to the acid in **Experiment 1**.
[Assume that 4.3 J of heat energy changes the temperature of 1.0 cm^3 of solution by 1.0 °C.]

heat absorbed $= mc\,\Delta T$

$= 25 \times 4.3 \times 7.15$

$= 768.6$ J

heat energy absorbed =……**768.6**……. J [1]

(ii) Calculate the enthalpy change, in kJ mol^{-1}, when 1 mol of **FA 4**, $NaHCO_3$, reacts with the acid. [A_r: H, 1.0; C, 12.0; O, 16.0; Na, 23.0]

M_r **of** $NaHCO_3$ $= 23.0 + 1.0 + 12.0 + 3(16.0) = 84.0$

mol of $NaHCO_3 = \frac{2.487}{84.0} = 0.0296$ mol

$\therefore\ \Delta H_1 = +\frac{768.6}{0.0296}$ J mol^{-1}

$= +25970$ J mol^{-1}

$= +26.0$ kJ mol^{-1}

enthalpy change, ΔH_1 = ...**+26.0**.......... kJ mol^{-1} [1]

(iii) Using your results in **2(a)(iii)**, calculate the heat energy produced when **FA 5** was added to the acid in **Experiment 2**.
[Assume that 4.3 J of heat energy changes the temperature of 1.0 cm^3 of solution by 1.0 °C.]

heat evolved = mc ΔT

$= 25 \times 4.3 \times 5.7$

$= 612.8$ J

heat energy produced =……**612.8**……… J [1]

(iv) Calculate the enthalpy change, in kJ mol^{-1}, when 1 mol of **FA 5**, Na_2CO_3, reacts with the acid. [A_r: C, 12.0; O, 16.0; Na, 23.0].

M_r of Na_2CO_3 $= 2(23.0) + 12.0 + 3(16.0) = 106.0$

mol of Na_2CO_3 $= \frac{2.014}{106.0} = 0.0190$ mol

$\therefore \quad \Delta H_2 = -\frac{612.8}{0.0190}$ $J mol^{-1}$

$= -32250$ J mol^{-1}

$= -32.3$ kJ mol^{-1}

enthalpy change, ΔH_2 = ……**–32.3**……… kJ mol^{-1} [1]

(v) Using your answers to **2(b)(ii)** and **2(b)(iv)** and the equations for **Experiment 1** and **Experiment 2**, determine the enthalpy change for the reaction:

$$\begin{tikzcd}
Na_2CO_3(s) + H_2O(l) + CO_2(g) \arrow[rr] \arrow[dr, "+\ 2HCl(aq)"', "\Delta H_2"] & & 2NaHCO_3(s) \arrow[dl, "+\ 2\ HCl(aq)", "2\Delta H_1"'] \\
& 2NaCl(aq) + 2H_2O(l) + 2CO_2(g) &
\end{tikzcd}$$

By Hess' Law,

$\Delta H = \Delta H_2 - 2\Delta H_1$

$= (-32.3) - 2(+26.0)$

$= -84.3$ kJ mol^{-1}

enthalpy change, ΔH_3 = ……**–84.3**……… kJ mol^{-1} [3]

(c) Planning

You are provided with **FA 4**, solid sodium hydrogencarbonate, $NaHCO_3$, distilled water and apparatus commonly found in the school laboratory.

Using only these materials, you are to plan an additional experiment to determine a further enthalpy change, ΔH_4, which can be put together with those from **Experiment 1** and **Experiment 2** to determine the enthalpy change for the reaction:

$$Na_2CO_3(s) + H_2O(l) + CO_2(g) \rightarrow 2NaHCO_3(aq) \qquad \Delta H_5$$

In your plan, you should include details of:

- the quantity of reactants and apparatus that you would use,
- the procedure you would follow,
- the measurements you would take, and
- an outline of how you would use your results to determine ΔH_5.

DO NOT CARRY OUT YOUR PLAN.

Plan

- **Weigh a sample (say, 2.50 g of FA 4), adds to known volume of water (say, 25 cm^3) and measure change in temperature (record initial temperature of water (T_i) and lowest temperature (T_f) reached on adding FA 4 to water).**

Treatment of results

Let mass of FA 4 added be m_1 g

temperature change, $\Delta T = (T_f) - (T_i) = \quad x$ °C

heat energy absorbed = $mc\Delta T = (25)(4.3)(x)$ J = $108x$ J

mol of $NaHCO_3$ = $\frac{m_1}{84.0}$ mol

$$\Delta H_4 = \frac{\text{energy absorbed}}{\text{mol of NaHCO}_3} = +\frac{108x}{m_1/84.0}\text{ J mol}^{-1} = +9072\frac{x}{m_1}\text{ J mol}^{-1} = +9.07\frac{x}{m_1}\text{ kJ mol}^{-1}$$

From (b)(iv),

$$Na_2CO_3(s) + H_2O(l) + CO_2(g) \rightarrow 2NaHCO_3(s) \qquad \Delta H_3 = -84.3\text{ kJ mol}^{-1}$$

$$NaHCO_3(s) \rightarrow NaHCO_3(aq) \qquad \Delta H_4 = +9.07\frac{x}{m_1}\text{ kJ mol}^{-1}$$

$$Na_2CO_3(s) + H_2O(l) + CO_2(g) \rightarrow 2NaHCO_3(aq) \qquad \Delta H_5$$

$$\therefore \quad \Delta H_5 = \Delta H_3 + 2\Delta H_4$$

$$= -83.4 + 2(+9.07\frac{x}{m_1}) = (-83.4 + 18.1\frac{x}{m_1})\text{ kJ mol}^{-1}$$

[5]

[Total: 24]

3 Qualitative Analysis

In this question, you will carry out tests, make observations and come to conclusions about the compounds.

If the evolution of a gas is observed at any stage, the gas should be tested and identified. Details of the test carried out, the observations from the test and the identity of the gas should be given with the observations.

If it appears that no reaction has taken place, this should be clearly recorded

(a) **FA 7** is an organic solid. Carry out the tests described in Table 3.1 and use the observations to identify two functional groups present in **FA 7**.

Table 3.1

tests	*observations*
Add 10 cm^3 of ethanol to your **FA 7** in a boiling tube. Stopper the boiling tube and shake to dissolve the solid. Then add 10 cm^3 of deionised water. Shake again to ensure complete mixing. Divide the solution into four clean test-tubes and use a fresh tube for each of the following tests:	
(i) add a piece of magnesium ribbon to the solution	**brisk effervescence;** **gas gives a "pop" sound with a lighted splint.** **$H_2(g)$ evolved.** ***Need to include identity of gas***
(ii) add solid sodium carbonate to the solution	**effervescence;** **gas gives a white ppt with limewater.** **$CO_2(g)$ evolved.** ***Need to include identity of gas***
(iii) add a few drops of aqueous iron(III) chloride to the solution	**violet (or purple) coloration**
(iv) add 2 cm depth of bromine water. (Take care: bromine water is corrosive.)	**orange $Br_2(aq)$ decolourised;** **white ppt.** ***accept reddish-brown $Br_2(aq)$***

[4]

(v) Complete Table 3.2, using the observations in Table 3.1 to identify the two functional groups present in **FA 7**. In each case, give evidence to support your conclusion.

Table 3.2

functional group	*evidence*
phenol	**- violet coloration with aq. $FeCl_3$** **- white ppt with aq. bromine water** ***correct functional group & with underlined evidence***
carboxylic acid ***'carboxyl group' not acceptable***	**- $CO_2(g)$ with solid sodium carbonate** **- $H_2(g)$ with magnesium ribbon** ***correct functional group & with underlined evidence***

[2]

(b) **Plan**

You are provided with four solutions, labelled **FA 8**, **FA 9**, **FA 10** and **FA 11**.

Each solution contains one of the following compounds.

- lead nitrate, $Pb(NO_3)_2$
- sodium chloride, $NaCl$
- sodium hydroxide, $NaOH$
- zinc sulfate, $ZnSO_4$

The order in the list of solutions does **not** correspond to the **FA** numbers.

(i) Using the *Qualitative Analysis Notes* on page 14, complete Table 3.3 to show the expected observations when pairs of the solutions are mixed. Solutions should be added a little at a time, with shaking, until no further change is observed.

Expected observations for $Pb(NO_3)_2$ have already been recorded in Table 3.3.

Table 3.3

	$NaCl$	**$NaOH$**	**$ZnSO_4$**
$Pb(NO_3)_2$	white ppt.	white ppt. soluble in excess NaOH	white ppt.
$NaCl$		**no ppt.**	**no ppt.**
$NaOH$			**white ppt. soluble in excess NaOH**

complete table (with correct observations)

Explain how you could use the expected observations in Table 3.3 to identify **each** of the solutions.

- **$Pb(NO_3)_2$ - gives white ppt with the other 3 solutions**
- **NaC*l* - gives white ppt with only 1 other solution**
- **NaOH - gives white ppt with 2 other solutions (ppt soluble in both cases)**
- **$ZnSO_4$ - gives white ppt with 2 other solutions (ppt soluble in only one)**

[5]

(ii) Carry out the experiment using **FA 8**, **FA 9**, **FA 10** and **FA 11** and record your results in a suitable table.

	FA 8 (excess)	**FA9 (excess)**	**FA 10 (excess)**	**FA 11 (excess)**
FA 8		no ppt	no ppt.	white ppt.
FA 9	no ppt.		white ppt. soluble in excess **FA 10**	white ppt.
FA10	no ppt.	white ppt.		white ppt.
FA 11	white ppt.	white ppt.	white ppt. soluble in excess **FA 10**	

[3]

(iii) Identify the substance present in each of the solutions.

FA 8 **NaC*l***

FA 9 **$ZnSO_4$**

FA 10 **NaOH**

FA 11 **$Pb(NO_3)_2$**

[1]

[Total: 15]

Qualitative Analysis Notes
[*ppt. = precipitate*]

(a) Reactions of aqueous cations

cation	***reaction with***	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	ammonia produced on heating	–
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

ion	***reaction***
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives pale cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^-(aq)	NH_3 liberated on heating with OH^-(aq) and A*l* foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and A*l* foil; NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-}(aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in dilute strong acids)

(c) Tests for gases

gas	***test and test result***
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	"pops" with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns aqueous acidified potassium manganate(VII) from purple to colourless

(d) Colour of halogens

halogen	***colour of element***	***colour in aqueous solution***	***colour in hexane***
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas / liquid	orange	orange-red
iodine, I_2	black solid / purple gas	brown	purple

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