VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME ……………………………………………………………..

CT GROUP ……………………………..

CHEMISTRY **9729/04**

Paper 4 Practical **27 August 2025**

Candidates answer on the Question Paper. **2 hours 30 minutes**

Additional Materials: As listed in the instructions below

READ THESE INSTRUCTIONS FIRST

Write your name and CT group on all the work you hand in.
Give details of the shift and laboratory in the boxes provided.
Write in dark blue or black pen.
You may use a 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 **17** and **18**.

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	**/ 14**
2	**/ 17**
3	**/ 12**
4	**/ 12**
Total	**/ 55**

This document consists of **18** printed pages.

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

1 Determination of the molar enthalpy change of reaction

When zinc powder is added to an aqueous solution of copper(II) ions, a displacement reaction occurs.

$$Cu^{2+} + Zn \rightarrow Zn^{2+} + Cu$$

In this question, you will perform an experiment to determine a value for Δ*H*.

You are provided with:
- solid **FA 1**, zinc
- **FA 2**, containing 0.80 mol dm^{-3} copper(II) ions

(a) **(i)** You will measure the temperature of the contents in a polystyrene cup at regular time intervals, before and after zinc is added. You will analyse your results graphically to obtain an accurate value of the temperature change caused by the reaction.

You will use this value to calculate the heat change, *q*, for the experiment and hence determine a value for the molar enthalpy change of the reaction, Δ*H*.

In the space provided on page 4, prepares tables in which to record for your experiment:
- all weighings to an appropriate level of precision,
- all values of temperature, *T*, to an appropriate level of precision,
- all values of time, *t*, recorded to 0.5 min.

It is important that you measure each temperature at the specified time.

Procedure

1. Weigh the capped container containing solid **FA 1**.
2. Place one polystyrene cup inside another polystyrene cup and place both in a glass beaker.
3. Use the measuring cylinder to transfer 30 cm^3 of **FA 2** into the cup.
4. Carefully stir the **FA 2** in the polystyrene cup with the thermometer. Read and record the temperature, *T*. Start the stopwatch (t = 0.0 min). The stopwatch must be left to run for the rest of the experiment.
5. Continue to stir **FA 2**. Read and record *T* every 0.5 minutes for two minutes.
6. At **exactly** 2.5 minutes, transfer all the solid **FA 1** to the polystyrene cup. Stir the mixture but do not read *T*.
7. Continue to stir the mixture. Read and record *T* at t = 3.0 min and every 0.5 minutes until t = 8.0 min.
8. Reweigh the empty capped container.

Note: You should keep **FA 2** for use in Question 2.

Question 1 continues on the next page.

Results

Mass of container and FA 1 / g	
Mass of container and residual FA 1 / g	
Mass of FA 1 used / g	

time / min	***temperature / °C***		***time / min***	***temperature / °C***
0.0			**5.0**	
0.5			**5.5**	
1.0			**6.0**	
1.5			**6.5**	
2.0			**7.0**	
2.5	**-**		**7.5**	
3.0			**8.0**	
3.5			**8.5**	
4.0			**9.0**	
4.5				

[2]

- **1m for correct headers and units**
- **1m for 3 d.p. for mass and correct mass of FA1, 1 d.p. for temperature and no temperature reading at 3 min**

(ii) Plot a graph of temperature, *T*, on the y-axis, against time, *t*, on the x-axis, on the grid in Fig. 1.1.

Draw a best-fit straight line taking into account all of the points before *t* = 2.5 min.

Draw another best-fit straight line taking into account all of the points after the temperature of the mixture has started to fall steadily.

Extrapolate both lines to *t* = 2.5 min. [3]

Fig. 1.1

- **1m for axes correctly labelled and appropriate scales**
- **1m for all points correctly plotted**
- **1m for 2 lines of best fit**

(iii) From your graph, read the minimum temperature, T_{min}, and the maximum temperature, T_{max}, at t = 2.5 min. Record these values in the spaces below.

Calculate the temperature change, ΔT, at t = 2.5 min.

T_{min} = ……………………………………

T_{max} = ……………………………………

ΔT = ……………………………………
[3]

- **1m for correct ΔT from the graph**
- **1m for ΔT ±0.5 °C of supervisor value**
- **1m for ΔT_1 ($\Delta T_1 = T_{max} - T_{t=2}$) ±2.0 °C of supervisor value**

(iv) Calculate the heat change, *q*, for your experiment using the value you calculated in **(a)(iii)**.

Assume that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1}, and that the density of the reaction mixture is 1.00 g cm^{-3}.

- **Heat change = 30 × 4.18 × ans (a)(iii) J**

q = …………………………… [1]

(v) Determine the molar enthalpy change of reaction, Δ*H*, for the reaction between zinc and copper(II) ions.

Include the sign of Δ*H* in your answer.

[A_r: Zn, 65.4, Cu, 63.5]

Amount of Zn used = mass of FA1 used ÷ 65.4 mol

Amount of Cu^{2+} used = 0.8 × 0.03 = 0.0240 mol

- **Cu^{2+} is the limiting reagent.**
- **ΔH = –ans (a)(iv) ÷ 0.0240 J mol^{-1} = convert to kJ kJ mol^{-1}**
  Must include sign + units

Δ*H* = …………………………… [3]

(b) A student followed the procedure in **(a)(i)** to perform the experiment, except that he used 60 cm^3 of 0.40 mol dm^{-3} copper(II) ions.

State and explain the effect on the temperature change as compared to the value in **(a)(iii)**.

- **Amount of Cu^{2+} ions remained the same so heat change will be the same.**
- **Since vol. of solution doubled, temperature change will half.**

…………………………………………………………………………………… [2]

[Total: 14]

2 Qualitative analysis

FA 2, which you used in Question 1, contains one anion.
FA 3 is a solid metal oxide.
FA 4 is an aqueous solution of an organic compound, $C_6H_{12}O_6$, containing a functional group which is either an alcohol, an aldehyde or a carboxylic acid.

You will carry out tests to identify the anion in **FA 2**, cation in **FA 3** and whether an alcohol, an aldehyde or a carboxylic acid functional group is present in **FA 4**.

You will also carry out some reactions involving **FA 2**.

Carefully record your observations in Table 2.1 and 2.2.

Unless otherwise stated, the volumes given in Table 2.1 and 2.2 are approximate and should be estimated rather than measured.

Test any gases evolved during the tests.

If there is no observable change, write **no observable change**.

(a) **(i)** Half-fill the 250 cm^3 beaker with water and place it on a tripod and gauze. Heat the water until boiling then switch off your Bunsen burner. This will be your hot water bath.

Table 2.1

	test	observations
1	Add 1 cm depth of **FA 2** to a test-tube. Add 1 cm depth of dilute nitric acid followed by 1 cm depth of aqueous barium nitrate.	**● No observable change / no effervescence and white ppt. formed.**
2	Add about 3 cm depth of dilute sulfuric acid to the boiling tube containing **FA 3**. Gently shake the boiling tube for one minute. Leave to settle, then decant the liquid into a clean test-tube. This solution is **FB 1** to be used for Test 3.	**● Blue solution and reddish brown / brown ppt. formed.** **(Blue solution)**
3	Add 1 cm depth of **FB 1** to a test-tube. Add aqueous ammonia, slowly with shaking, until no further change is seen, then	**● Blue ppt. soluble in excess giving dark blue solution.**
4	Place a ½ cm depth of aqueous silver nitrate in a test-tube. Add 1 or 2 drops of aqueous sodium hydroxide to form a brown precipitate. Add aqueous ammonia dropwise with	

	shaking until the precipitate just dissolves. Add 1 cm depth of **FA 4** to this mixture and place the test-tube in the hot water bath.	● Silver mirror formed
	When you have completed Test 4 pour the contents in the test-tube down the sink with plenty of water and rinse the test-tube.	
5	Add 1 cm depth of **FA 4** to a test-tube. Add 10 drops of dilute sulfuric acid, then 1 or 2 drops of **FA 5** (potassium manganate(VII)) and place the test-tube in the hot water bath.	● Purple colour decolourised
6	Add 1 cm depth of **FA 4** to a test-tube. Add 1 cm depth of aqueous sodium carbonate.	● No observable change / no effervescence.

[6]

(ii) State the anion present in **FA 2**.

● SO_4^{2-} [1]

(iii) In Test 2, a disproportionation reaction occurred. The cation in **FA 3** is both reduced and oxidised.

Consider the observations you made in Test 2 and 3, deduce the identity of the cation. Write an overall equation for the reaction that occurred when you added dilute sulfuric acid to **FA 3** in Test 2.

cation present in **FA 3** ● Cu^+

● $2Cu^+ \rightarrow Cu + Cu^{2+}$ [2]

(iv) State which functional group is present in **FA 4**. Explain your answer.

● Aldehyde is present, as FA 4 gives a silver mirror with Tollen's reagent.

[1]

(b) **(i)** Reheat your water bath to boiling then switch off your Bunsen burner.

Table 2.2

test		observations
7	Add 1 cm depth of **FA 2** to a test-tube.	

	Add 2 cm depth of aqueous EDTA, then	**• Solution turned darker/deeper blue.**
	add a few drops of aqueous sodium hydroxide, then	**• No observable change / no ppt. formed**
	add a 1 cm depth of **FA 4** and place the test-tube in the hot water bath.	**• Solution turned green / yellow / brown and ppt. formed.**

[3]

The following questions are on the reactions in Test 7 on page 9.

Fig. 2.1 shows the structure of EDTA. It is a hexadentate ligand and forms very stable water-soluble octahedral complexes with many metal ions. These complexes have the general formula $[M(edta)]^{(n-4)}$, where n is the charge of the metal ion M.

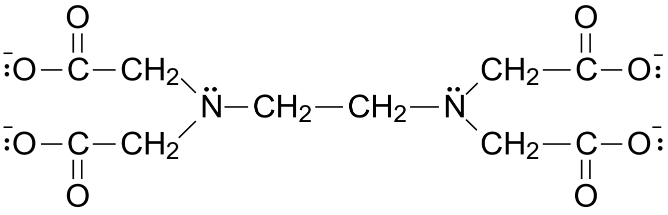

Fig. 2.1

(ii) Suggest an explanation, in terms of the copper-containing complexes present, for the observation when EDTA was added to **FA 2**.

• When EDTA was added, $[Cu(H_2O)_6]^{2+}$ undergone ligand exchange to form $[Cu(edta)]^{2-}$ hence the colour of the solution turned darker blue.

.... [1]

(iii) When certain conditions are met, hydroxide ions react with some metal ions, causing them to precipitate out as metal hydroxides. In qualitative analysis, this process is useful to identify the presence of certain metal ions.

Use your knowledge in solubility equilibria and the information given about EDTA complexes, explain the observation when sodium hydroxide was added.

$Cu^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Cu(OH)_2(s)$ ---- (1)

• The formation of the stable copper complex with EDTA decrease $[Cu^{2+}]$, the position of equilibrium 1 shift backwards.

• The ionic product of $Cu(OH)_2$ will be less than K_{sp}, hence no blue ppt was seen.

.... [2]

(iv) Consider the nature of the functional group present in **FA 4**, suggest an explanation for the observation(s) when **FA 4** was added.

• A redox reaction occurred whereby the aldehyde is oxidised and the copper complex ([Cu(edta)]$^{2-}$) is reduced.

…………………………………………………………………………………………. [1]

[Total: 17]

3 Investigation of reaction between iron(III) ions and hydroxylamine

A redox reaction takes place between hydroxylamine, NH_2OH, and iron(III) ion, Fe^{3+}, in acidic conditions. The iron(III) ion is reduced to an iron(II) ion, Fe^{2+}. The reaction is slow at room temperature but is complete in a few minutes at 100 °C. The reaction is shown by one of the following equations.

equation 1 $NH_2OH(aq) + Fe^{3+}(aq) \rightarrow Fe^{2+}(aq) + \frac{1}{2}N_2(g) + H^+(aq) + H_2O(l)$

equation 2 $NH_2OH(aq) + 2Fe^{3+}(aq) \rightarrow 2Fe^{2+}(aq) + \frac{1}{2}N_2O(g) + 2H^+(aq) + \frac{1}{2}H_2O(l)$

equation 3 $NH_2OH(aq) + 3Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq) + NO(g) + 3H^+(aq)$

You will carry out a titration to determine which of equations 1, 2 or 3 best represents the reaction. The iron(II) ions formed in the reaction with the hydroxylamine are oxidised by manganate(VII) ions.

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

FA 5 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 6 is a solution prepared by boiling a 1.00 dm^3 aqueous mixture consisting 3.30 g of hydroxylamine hydrochloride, $NH_2OH•HCl$, excess iron(III) chloride, $FeCl_3$, and excess sulfuric acid. Any water lost by evaporation was replaced after cooling.
FA 7 is 1.0 mol dm^{-3} dilute sulfuric acid.

Assume that one mole of hydroxylamine hydrochloride gives one mole of hydroxylamine in solution.

(a) **(i) Titration of FA 6 against FA 5**

1. Fill the burette with **FA 5**.
2. Pipette 25.0 cm^3 of **FA 6** into a conical flask.
3. Use a 25 cm^3 measuring cylinder to add 10 cm^3 of **FA 7** to the same conical flask.
4. Run **FA 5** from the burette into the flask. The end-point is reached when the solution changes from yellow to permanent pale pink.
5. Record your titration results, to an appropriate level of precision in Table 3.1.
6. Repeat steps 2 to 5 until consistent titre values are obtained.

Table 3.1

final burette reading / cm^3						
initial burette reading / cm^3						
volume of **FA 5** added / cm^3						

[5]

- **All accurate burette readings to 0.05 cm^3**
- **Correct subtraction of burette readings**
- **At least TWO consistent tiitre values to ±0.10 cm^3**
- **Accuracy: 2m for ±0.20 cm^3; 1m for ±0.50 cm^3 compared to supervisor value.**

(ii) From your titrations, obtain a suitable volume of **FA 5** to be used in your calculations. Show clearly how you obtained this volume.

Volume of **FA 5** = ... cm^3 [1]

(b) **(i)** Calculate the amount, in mol, of potassium manganate(VII) present in the volume of **FA 5** in **(a)(ii)**.

- **amount of $KMnO_4$ = $0.0200 \times \frac{\text{ans (a)(ii)}}{1000}$**

amount of $KMnO_4$ =………………………… mol [1]

(ii) Use your answer to **(b)(i)** to calculate the amount, in mol, of iron(II) ions in 25.0 cm^3 of solution **FA 6**.

- **amount of Fe^{2+} = 5 × ans (b)(i)**

amount of Fe^{2+} = ……………………… mol [1]

(iii) Calculate the amount, in mol, of hydroxylamine hydrochloride that has reacted in 25.0 cm^3 of solution **FA 6.**
[A_r: H, 1.0; N, 14.0; O, 16.0; C*l*, 35.5]

Amount of $NH_2OH{\cdot}HCl$ in 1.00 dm^3 FA 6 = 3.30 / 69.5 = 0.0475 mol

Amount of $NH_2OH{\cdot}HCl$ in 25.0 cm^3 FA 6 = 0.0475 × (25 /1000) = 1.19 × 10^{-3} mol

- **Correct M_r**
- **Correct calculation of amount in 25.0 cm^3 FA 6**
- **Clear statements, correct sf.**

Amount of $NH_2OH{\cdot}HCl$ = …………………………… mol [3]

(iv) Use your answers in **(b)(ii) and (iii)** to deduce which of the three suggested equations corresponds to your results. Show your working.

Amount of Fe^{2+} : amount of $NH_2OH{\bullet}HCl$ = ans (b)(ii) : ans (b)(iii)

- **Correct use mole ratio of Fe(II): $NH_2OH{\cdot}HCl$ from answer (b)(ii) and (b)(iii) AND State the correct equation number based on the mole ratio calculated.**

The correct equation number is …………………… [1]
[Total: 12]

4 Planning

Benzenediazonium chloride, $C_6H_5N_2Cl$, an aromatic diazonium compound, decomposes in solution at a temperature higher than 45 °C to produce phenol and nitrogen gas.

$$C_6H_5N_2Cl(aq) + H_2O(l) \rightarrow C_6H_5OH(aq) + N_2(g) + HCl(aq)$$

The rate equation for this reaction is

$$\text{Rate} = k[C_6H_5N_2Cl]$$

where k is the rate constant.

The order with respect to $C_6H_5N_2Cl$ may be confirmed to be first order by warming the solution at 50 °C and recording the volume of nitrogen evolved over time.

In this experiment, there is no need to calculate $[C_6H_5N_2Cl]$ as $V_{final} - V_t$ is proportional to the concentration of the $C_6H_5N_2Cl$, where

- V_{final} is the final volume of nitrogen gas measured once the decomposition is complete
- V_t is the volume collected at time = t.

You may assume that you are provided with:

- 1.5 g of solid benzenediazonium chloride
- 200 cm^3 gas syringe
- the equipment normally found in a school or college laboratory

(a) Describe how you would make a standard solution of 0.100 mol dm^{-3} of benzenediazonium chloride (M_r = 140.5) for your experiment.

Preparation of 0.100 mol dm^{-3} standard solution of $C_6H_5N_2Cl$

Using a 100 cm^3 volumetric flask,
amount of $C_6H_5N_2Cl$ to prepare = 0.100 × 0.1 = 0.0100 mol
mass of $C_6H_5N_2Cl$ to weigh out = 0.0100 × 140.5 = 1.41 g

1. **Weigh accurately 1.40 g of $C_6H_5N_2Cl$ in a clean and dry 100 cm^3 beaker using a weighing balance.**
2. **Add some deionised water to dissolve the solid.**
3. **Transfer the solution quantitatively into a 100 cm^3 volumetric flask. Rinse the beaker and transfer the washings into the volumetric flask.**
4. **Top up to the mark with distilled water, stopper the volumetric flask and shake this solution to obtain a homogeneous solution.**

1m: Correct calculation of mass
1m: choice of volumetric flask used such that mass used <1.5g
1m: procedure of preparing standard solution with details of quantitative transfer.
1m: description on how to obtain a homogeneous solution.

[4]

(b) Plan an experiment to collect sufficient data for a graph of $V_{final} - V_t$ against *time* to be plotted.

In your plan, you should use the standard solution of benzenediazonium chloride made in **(a)** and include brief details of:

- justification of volume of benzenediazonium chloride solution you would use,
- the apparatus you would use,
- the procedure you would follow,
- the measurements you would make.

You should assume that all gases are measured at r.t.p. with molar gas volume of 24 dm^3 mol^{-1}.

Justification for the volume of $C_6H_5N_2Cl$

The volume of nitrogen gas evolved should not exceed the capacity of the gas syringe.

Assume 50.0 cm^3 of $C_6H_5N_2Cl$ solution is used,
amount of $C_6H_5N_2Cl$ = 0.005 mol
amount of N_2 gas evolved after complete decomposition = 0.005 mol
V_{final} expected = 0.005 × 24000 = 120 cm^3

V_{final} expected < 200cm^3 capacity syringe, hence 50cm^3 of solution is suitable.

1m: correct calculation of expected volume of N_2
1m: volume chosen is appropriate to be within the capacity of gas syringe

Procedure:

1. Using a 50 cm^3 measuring cylinder, transfer 50 cm^3 of 0.100 mol dm^{-3} into a conical flask.
2. Stopper the conical flask with a tube connected to 200 cm^3 gas syringe, making sure that the syringe reading is at 0 cm^3.
3. Submerge the conical flask in a water bath maintained at 50 °C and start the stopwatch.
4. Record the volume of gas evolved, V_t, at an interval of 2 minutes until the volume remains constant, where V_{final} is obtained.
5. Record *time*, t, and V_t in a suitable table.

1m: appropriate apparatus (measuring cylinder, conical flask, gas syringe, stopwatch)
1m: use water bath to maintain temperature at 50°C
1m: record volume of gas at time intervals
1m: demonstrate knowledge of when the thermal decomposition has completed

[6]

(c) The order of reaction with respect to benzenediazonium chloride is expected to be first order.

Sketch, on Fig. 4.1, the graph of $V_{final} - V_t$ against *time* you would expect to obtain.

Explain how the order of reaction with respect to benzenediazonium chloride may be determined from your graph.

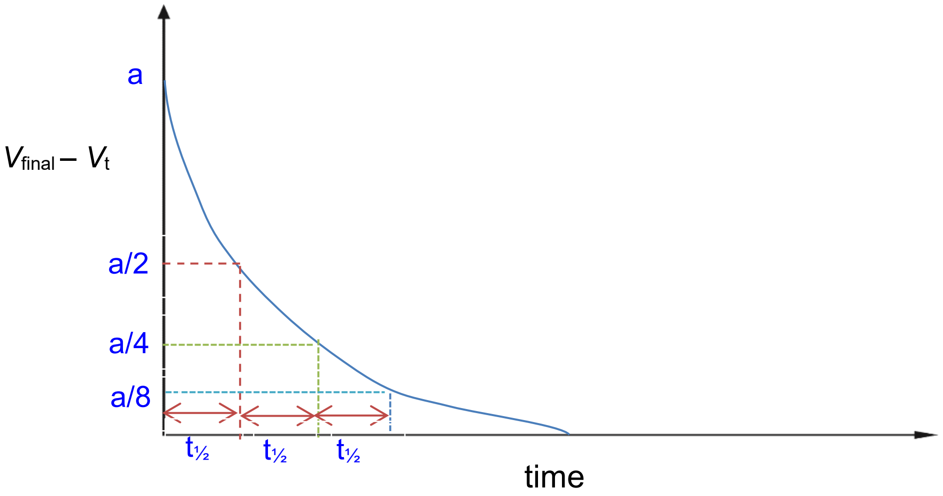

Fig. 4.1

explanation The $V_{final} - V_t$ at time t, is proportional to [$C_6H_5N_2Cl$] present in the reaction mixture at time t. Since the graph has a constant $t_{½}$, the rate of reaction is proportional to [$C_6H_5N_2Cl$]. Hence, it is a first order reaction with respect to $C_6H_5N_2Cl$. [2]

1m: correct sketch of graph with constant $t_{½}$
1m: use constant $t_{½}$ to explain rate is proportional to [$C_6H_5N_2Cl$]

[Total: 12]

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

anion	*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