YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME			
CLASS		DATE	

H2 CHEMISTRY 9729/04

Paper 4
Practical Paper

22 August 2023
2 hours 30 minutes

Candidates answer on question paper.
No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
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 23 and 24.
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	13
2	18
3	12
4	12
Total	55

This document consists of **19** printed pages and **5** blank pages.

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

1 Determination of enthalpy change of reaction

FA 1 is solid sodium hydrogencarbonate, $NaHCO_3$.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

equation 1 $NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$ $\Delta H_r(NaHCO_3(s))$

The molar enthalpy change of reaction of solid sodium hydrogencarbonate with hydrochloric acid in equation 1 is the enthalpy change when one mole of solid sodium hydrogencarbonate reacts with excess hydrochloric acid.

equation 2 $Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$ $\Delta H_r(Na_2CO_3(s))$

The molar enthalpy change of reaction of sodium carbonate with hydrochloric acid in equation 2 is the enthalpy change when one mole of sodium carbonate reacts with excess hydrochloric acid.

You are to perform an experiment by which you will determine the enthalpy change $\Delta H_r(NaHCO_3(s))$. You will also determine the enthalpy change $\Delta H_r(Na_2CO_3(s))$ using the data provided. You will then use your results in a Hess' Law calculation to determine the enthalpy change, ΔH, for the reaction of sodium carbonate, Na_2CO_3, with water and carbon dioxide to form sodium hydrogencarbonate, $NaHCO_3$, as shown in equation 3.

equation 3 $Na_2CO_3(s) + H_2O(l) + CO_2(g) \rightarrow 2NaHCO_3(s)$ ΔH

(a) Follow the instructions below to determine the maximum temperature change when a known mass of solid sodium hydrogencarbonate, **FA 1**, reacts with hydrochloric acid.

In an appropriate format in the space provided below, record
- all weighings to an appropriate level of precision,
- all values of temperature to an appropriate level of precision.

Procedure

1. Weigh the capped bottle containing **FA 1**.
2. Place one polystyrene cup inside a second polystyrene cup. Place these in a glass beaker to prevent them from tipping over.
3. Use a measuring cylinder to transfer 25.0 cm^3 of the acid, **FA 2**, into the first polystyrene cup.
4. Stir the solution in the cup with the thermometer. Read and record its temperature.
5. Transfer all the **FA 1** to the polystyrene cup. Stir the mixture.

Note: This reaction is very vigorous. Be careful when you pour in the solid. Minimise inhalation of gas produced.

6. Continue to stir the mixture. Observe the temperature and record the value that shows

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the maximum change from the initial temperature.

7. Reweigh the empty bottle and its cap.

Determine the maximum temperature change and the mass of **FA 1** used.

Results

[4]

(b) In the following calculations, you should assume that the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}, and the density of the solution is 1.00 g cm^{-3}.

(i) Use your results from **1(a)** to calculate the heat change for your experiment.

Heat change = …………………………….. [1]

(ii) Hence, determine a value for $\Delta H_r(NaHCO_3(s))$.

Include the sign of $\Delta H_r(NaHCO_3(s))$ in your answer.

[A_r: H, 1.0; C, 12.0; O, 16.0; Na, 23.0]

$\Delta H_r(NaHCO_3(s))$ = ... [1]

(iii) The results of an experiment where sodium carbonate, $Na_2CO_3(s)$, was reacted completely with an excess of dilute hydrochloric acid, **FA 2**, are shown in Table 1.1.

Table 1.1

mass of Na_2CO_3 (s) used / g	5.235
volume of **FA 2** used / cm^3	50.0
initial temperature of **FA 2** / °C	33.5
maximum temperature reached / °C	41.8

Use the results given in Table 1.1 to calculate a value for $\Delta H_r(Na_2CO_3(s))$.

[A_r: C, 12.0; O, 16.0; Na, 23.0]

$\Delta H_r(Na_2CO_3(s))$ = ... [2]

(iv) Use your answers from **1(b)(ii)** and **1(b)(iii)** and the equations 1 and 2 to determine the enthalpy change for the following reaction, ΔH. Show your working clearly.

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

If you are not able to determine a value for **1(b)(ii)** and/or **1(b)(iii)**, you may use x and y to represent the respective enthalpy changes and proceed with this part of the question.

ΔH = ………………………………………… [3]

(c) A student repeated **1(b)(iii)** using ethanoic acid in place of hydrochloric acid.

Explain how the temperature rise when using ethanoic acid would compare to the temperature rise recorded in **1(b)(iii)**. Assume all volumes and concentrations of solutions are the same.

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[Total:13]

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2 Investigation of the kinetics of an acid-catalysed reaction between propanone and iodine

FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HCl.
FA 3 is 0.0100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 4 is aqueous iodine, I_2.
FA 5 is 1.50 mol dm^{-3} propanone, CH_3COCH_3.
FA 6 is 0.50 mol dm^{-3} sodium hydrogen carbonate, $NaHCO_3$.

You are also provided with a starch indicator.

The iodination of propanone to form iodopropanone proceeds as shown in the equation below. This reaction is catalysed by hydrogen ions.

equation 4 $CH_3COCH_3(aq) + I_2(aq) \xrightarrow{H^+} CH_3COCH_2I(aq) + HI(aq)$

This reaction is first order with respect to both CH_3COCH_3 and H^+ ions.

You are to investigate the order of reaction with respect to I_2.

A reaction mixture containing **FA 2**, **FA 4** and **FA 5** is first prepared. At different chosen times, aliquots (portions) of this reaction mixture are removed and added to excess **FA 6**.

It is necessary that you titrate each aliquot against **FA 3** before transferring the next aliquot. I_2 and $S_2O_3^{2-}$ react as shown in equation 5.

equation 5 $2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

The required order of reaction can be obtained by graphical analysis of your results.

(a) (i) Preparation and titration of the reaction mixture

Notes:
- Please cap **FA 4** and **FA 5** after use.
- You will perform each titration **once** only. Great care must be taken that you do not overshoot the end-point.
- Once you have started the stopwatch, it must continue running for the duration of the experiment. You must **not** stop it until you have finished this experiment.
- You should aim to transfer your first aliquot within the first three minutes of starting the reaction.
- You should aim **not** to exceed a maximum reaction time of 25 minutes for this experiment.

In an appropriate format in the space provided, prepare a table in which to record for each aliquot
- the time of transfer, t, in minutes and seconds,
- the decimal time, t_d, in minutes, to 0.1min, for example, if t = 3min 11s then t_d = 3 min + 11/60 min = 3.2 min,
- the burette readings and the volume of **FA 3** added.

Procedure

1. Fill a burette with **FA 3**.

2. Using measuring cylinders, add 50.0 cm^3 of **FA 4** and 25.0 cm^3 of **FA 2** to the conical flask labelled **reaction mixture**.

3. Using a measuring cylinder, add 25.0 cm^3 of **FA 5** to the same conical flask. Start the stopwatch. Swirl the mixture thoroughly to mix its contents.

4. Using a measuring cylinder, add 20.0 cm^3 of **FA 6** to a second conical flask.

5. Transfer a 10.0 cm^3 aliquot (portion) of the reaction mixture to a 10 cm^3 measuring cylinder, using a dropping pipette.

6. **Immediately** transfer this aliquot into the conical flask containing **FA 6** and vigorously swirl the mixture. Read and record the time of transfer in minutes and seconds, to the nearest second, when the aliquot is added.

7. Immediately titrate the I_2 in the conical flask with **FA 3** until the solution is pale yellow. Add approximately 10 drops of starch indicator into this solution and continue titrating until the point when the solution just turns colourless. Record your titration results.

8. Wash out the conical flask with water.

9. Repeat steps **4** to **8** until a total of **five** aliquots have been titrated and their results recorded.

Results

[4]

(ii) Plot a graph of the volume of **FA 3** added, on the y-axis, against decimal time, t_d, on the x-axis on the grid in Fig. 2.1.

Draw the most appropriate best-fit line taking into account all of your plotted points. Extrapolate (extend) your graph to t_d = 0.0 min.

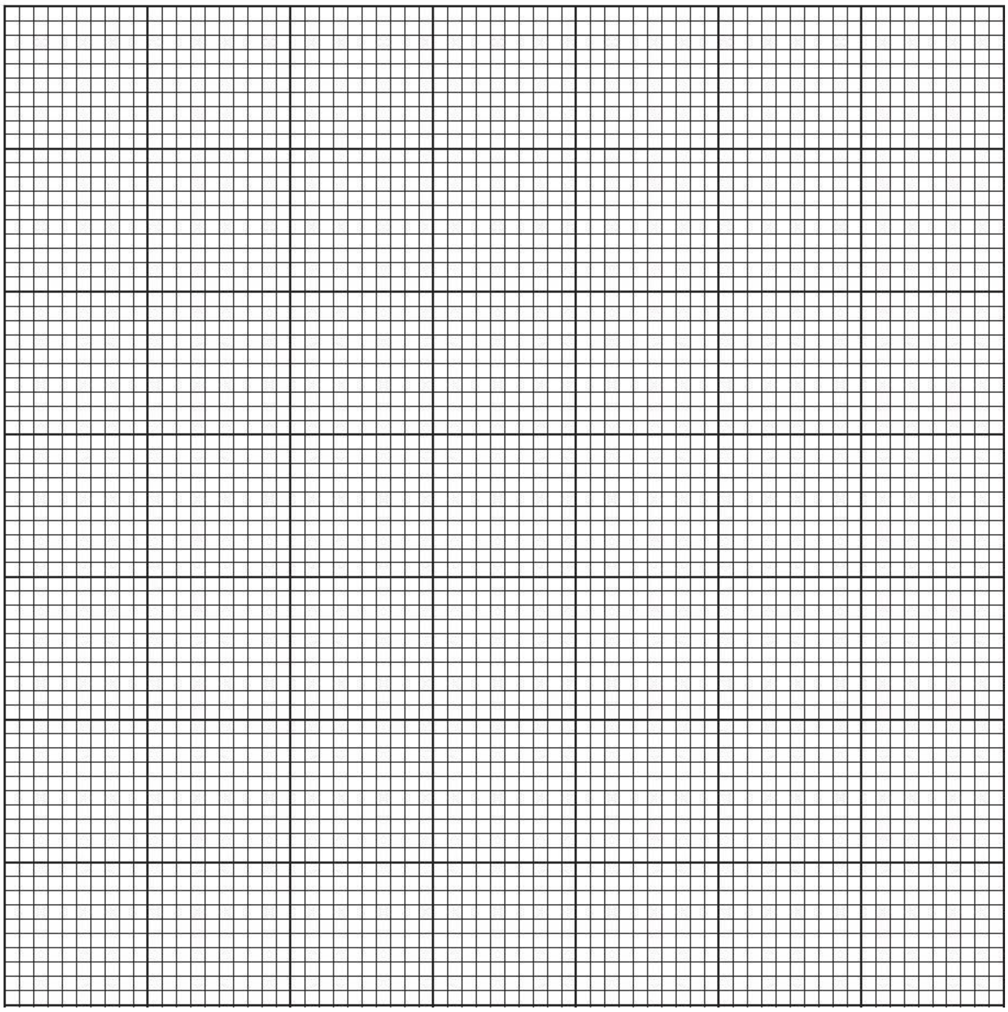

Fig. 2.1

[3]

(b) **(i)** State the relationship between the concentration of iodine remaining in the reaction mixture and the volume of **FA 3** used in the titration.

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

(ii) Deduce the order of reaction with respect to I_2. Use evidence from your graph in Fig. 2.1 to support your answer.

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(c) The initial rate of change of the concentration of iodine, **FA 4**, [I_2], can be determined from the gradient of the graph in Fig. 2.1 at time t_d = 0.0 min.

(i) Determine the gradient of the graph at time t_d = 0.0 min, showing clearly the coordinates on the graph how you did this.

gradient = ………………………… $cm^3\,min^{-1}$ [2]

(ii) Use your gradient to determine the rate of change of the amount of $S_2O_3^{2-}$ ions required in mol min^{-1}.

rate of change of the amount of $S_2O_3^{2-}$ ions required = ………………….… mol min^{-1} [1]

(iii) Sodium thiosulfate and iodine react as shown in equation 5.

equation 5 $2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

Determine the change in amount of I_2 per minute and hence deduce the rate of change of [I_2] at t_d = 0.0 min, in mol $dm^{-3}\,min^{-1}$.

change in amount of I_2 per minute = …………………..……… mol min^{-1}

rate of change of $[I_2]$ at t_d = 0.0 min = …………….………… $mol\,dm^{-3}\,min^{-1}$ [4]

(d) Step 6 requires you to add each aliquot immediately to an excess of sodium hydrogen carbonate solution, **FA 6**. Suggest an explanation for this requirement.

……………………………………………………………………………………………………

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

(e) Explain why the concentration of iodine in **FA 4** used is very much lower than the concentrations of propanone in **FA 5** and of hydrochloric acid in **FA 2**.

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[Total: 18]

3 Investigation of an organic compound and an inorganic compound

FA 6 is 0.50 mol dm^{-3} sodium hydrogen carbonate, $NaHCO_3$ from question 2.
FA 7 is an organic solid, **Y**, which contains two different functional groups.
FA 9 contains two cations and one anion.

You will perform tests to identify:

- the functional groups in **Y** and hence deduce its possible structure.
- the ions present in **FA 9**.

(a) (i) Place one spatula of solid **FA 7** in a boiling tube. Add to the solid about 5 cm^3 of ethanol followed by 5 cm^3 of distilled water. Shake to ensure complete mixing. Label this solution **FA 8**.

Use a fresh sample for each of the following tests. Carefully record your observations in Table 3.1. The volumes given below are approximate and should be estimated rather than measured.

Test and identify any gases evolved.

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

Table 3.1

	tests	observations
1	Using a test-tube holder for the test-tube, place about 5 drops of aqueous silver nitrate in a test-tube; add aqueous sodium hydroxide dropwise until brown ppt appears. Then add aqueous ammonia drop-wise until the ppt just dissolves. Add about 10 drops of the **FA 8** solution, shake and warm for 5 minutes in the water bath. Continue with the remaining parts of Question 3.	
2	To a 2 cm depth of **FA 8** in a test-tube, add 1 cm^3 of **FA 6**.	
3	Place about 1 cm depth of **FA 8** into a test tube. Using a test-tube holder, add 8 drops of aqueous bromine at the fumehood.	

Please dispose all organic waste into the bottle labelled "Organic Waste" and cap the bottle.

[3]

(ii) Identity the functional group that test 1 is used to determine in **Table 3.1**.

……[1]

(iii) Suggest **two** functional groups that could be present in **FA 7**.

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

(iv) The molecular formula of **Y** is $C_7H_7O_2N$. Draw one possible structure for **Y**. Use your observations in Table 3.1.

[1]

(b) **(i)** Use a fresh sample for each of the following tests. Carefully record your observations in Table 3.2.

Table 3.2

	tests	observations
1	To a 1 cm depth of **FA 9** in a test-tube, add aqueous ammonia slowly, with shaking, until no further change is seen.	
2	To a 1 cm depth of **FA 9** in a test-tube, add aqueous sodium hydroxide slowly, with shaking, until no further change is seen. Warm the mixture using the water bath.	
3	To a 1 cm depth of **FA 9** in a test-tube, add 4–5 drops of aqueous silver nitrate.	

[3]

(ii) Identify the anion present in **FA 9**. Use evidence from your observations in **Table 3.2** to support your deduction.

Anion: ……………………...……………….

Evidence:
……………….…………………………..……………….……………………...…………………

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

(iii) Describe one further test you can carry out to confirm the identity of the anion present in **FA 9**.

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(iv) Identity the cations present in **FA 9**.

Cation: ……………………………………and …………………………………….. [1]

[Total:12]

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4 Planning

We usually think of iron occurring in compounds in the +2 or +3 oxidation states. However, other oxidation states of iron are possible; for example, potassium ferrate(VI), K_2FeO_4, contains iron in the +6 oxidation state.

Solutions containing the FeO_4^{2-} ion are dark red in colour. The FeO_4^{2-} ion is a stronger oxidising agent than the MnO_4^- ion. In acidic conditions, FeO_4^{2-} ions are reduced to Fe^{3+} ions.

A student was given a solution, **FB 1**, containing potassium ferrate(VI). She was told that by titrating a standard solution of sodium chloride, NaC*l*, against **FB 1**, the concentration of FeO_4^{2-} ions in **FB 1** can be found. At the end point, the reaction mixture turns from colourless to orange.

Chloride ions are oxidised as shown:

$$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$$

The overall equation in the reaction between FeO_4^{2-} and Cl^- is as shown:

$$6Cl^-(aq) + 16H^+(aq) + 2FeO_4^{2-}(aq) \rightarrow 3Cl_2(g) + 2Fe^{3+}(aq) + 8H_2O(l)$$

She tested the 0.100 moldm^{-3} solution of NaC*l* provided. She found that 10 drops of **FB 1**, when suitably acidified, reacted completely with 32 drops of NaC*l* solution.

(a) Explain why the 0.100 mol dm^{-3} solution of NaC*l* first provided would have been unsuitable for use in the student's titration.

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

(b) She correctly deduced that a suitable concentration of the solution of NaC*l* for titration against the **FB 1** solution was 0.320 mol dm^{-3}. This solution of NaC*l* is labelled as **FB 2**.

(i) Using this data, calculate the mass of solid sodium chloride, NaC*l*, required to make a 250 cm^3 standard solution of **FB 2** for the experiment.

[A_r: Na, 23.0; C*l*, 35.5]

[1]

(ii) Write a plan for the volumetric analysis of **FB 1**. Your plan should include the preparation of a 250 cm^3 standard solution of **FB 2**.

You may assume that you are provided with:

- aqueous potassium ferrate(VI), **FB 1**
- 6 g solid sodium chloride
- 1 mol dm^{-3} sulfuric acid
- distilled water
- the equipment normally found in a school or college laboratory

Include in your plan:

- the apparatus you would use,
- the quantities you would use,
- the procedure you would follow,
- the measurements you would make.

Note: No heating is needed for this titration although activation energy is high for similarly charged ions to react.

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[7]

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(c) In the student's titration, she found that ***p*** cm^3 of **FB 1** reacted with exactly ***q*** cm^3 of **FB 2** of concentration **M** mol dm^{-3}.

Outline how you would use her results to determine the concentration of **FB 1**.

[2]

(d) Explain the effect of using hydrochloric acid in place of sulfuric acid on the titre value.

………

………[1]

[Total: 12]

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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