RIVER VALLEY HIGH SCHOOL

JC 2 PRELIM PRACTICAL EXAMINATION

H2 CHEMISTRY 9729

26 AUGUST 2019

2 HOURS 30 MINUTES

NAME ______________________________

CLASS 18J (   )

INDEX NO. ______________________________

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.

Write your name, class and index number 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 a 2B pencil for any diagrams or graph.
Do not use staples, paper clips, highlighters, 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.

Shift
Laboratory

For Examiner's Use	
3 s.f.	
Units	
Total	55

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

1 An experiment to investigate the behaviour of acids and bases in aqueous solution

FA 1 is 1.00 mol dm^{-3} sodium hydrogencarbonate, $NaHCO_3$

FA 2 is sodium hydroxide, NaOH, between 1.5 to 2.5 mol dm^{-3}

FA 3 is 2.00 mol dm^{-3} sulfuric acid, H_2SO_4

According to the *Arrhenius* theory of acids and bases, an acid produces $H^+(aq)$ ions and a base produces $OH^-(aq)$ ions, in aqueous solution.
Using the *Arrhenius* theory, an acid-base neutralisation reaction involves reacting together these two ions to produce water molecules.

The equation for this neutralisation reaction is given below.

$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l) \qquad \Delta H_{neutralisation} = -57.1 \text{ kJ mol}^{-1}$

The reaction between $H^+(aq)$ and $OH^-(aq)$ involves bond formation and is exothermic. It is possible to make use of this fact to perform a thermometric titration. This task involves two different acid-base reactions.

The first reaction is between sodium hydrogencarbonate, **FA 1**, and sodium hydroxide, **FA 2**.

Reaction 1:

$NaHCO_3(aq) + NaOH(aq) \longrightarrow Na_2CO_3(aq) + H_2O(l) \qquad \Delta H_{reaction\ 1}$

The molar enthalpy change for **Reaction 1**, $\Delta H_{reaction\ 1}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with NaOH.

Instead of using an indicator to determine the endpoint, you will perform a thermometric titration to determine the equivalence point of the reaction. The equivalence point is that point where $H^+(aq)$ from the acid and $OH^-(aq)$ from the base are present in equal molar amounts.

The second reaction is between sodium hydrogencarbonate, **FA 1**, and sulfuric acid, **FA 3**.

Reaction 2:

$NaHCO_3(aq) + ½H_2SO_4(aq) \longrightarrow ½Na_2SO_4(aq) + H_2O(l) + CO_2(g)$

$\Delta H_{reaction\ 2}$

The molar enthalpy change for **Reaction 2**, $\Delta H_{reaction\ 2}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with H_2SO_4.

In your first experiment, you will perform a thermometric titration by adding portions of **FA 2** progressively to a known volume of **FA 1**. You will continue adding **FA 2** until the equivalence point is reached and passed. Throughout the experiment, you will note and record the temperature of the mixture after each addition.

You will then analyse your results graphically in order to determine the
• titration volume at the equivalence point, $V_{equivalence}$,
• maximum temperature change, $\Delta T_{maximum\ 1}$,
• molar enthalpy change, $\Delta H_{reaction\ 1}$, for **Reaction 1**.

In your second experiment, you will mix together a given volume of **FA 1** with a suitable volume of **FA 3**.

You will then determine the
• maximum temperature change, $\Delta T_{maximum\ 2}$,
• molar enthalpy change, $\Delta H_{reaction\ 2}$, for **Reaction 2**.

Reaction between FA 1 and FA 2

(a) **(i)** In this task you will need to record the maximum temperature of the reaction mixture when specified volumes of **FA 2** have been added. It is important that the volume of **FA 2** recorded is the total volume you have added up to that point when the temperature reading was made.

Note:
If you overshoot on an addition, record the **actual** total volume of **FA 2** added up to that point.

In an appropriate format in the space provided, record all values of temperature, *T,* to 0.1 °C, and each total volume of **FA 2** added to 0.05 cm^3.

1. Fill a burette with **FA 2**.
2. Place a Styrofoam cup inside a second Styrofoam cup which is held in a glass beaker to prevent it tipping over.
3. Using a pipette, transfer 25.0 cm^3 of **FA 1** to the first Styrofoam cup.
4. Stir the **FA 1** solution in the cup with the thermometer. Read and record its temperature.
5. From the burette, add 2.00 cm^3 of **FA 2** to the cup and stir the mixture thoroughly.
6. Read and record the maximum temperature of the mixture, *T,* and the volume of **FA 2** added.
7. Repeat points 5 and 6 until a total of 30.00 cm^3 of **FA 2** has been added. After each addition of **FA 2**, record the maximum temperature of the mixture and the total volume of **FA 2** added up to that point.

Results

For Examiner's Use

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(a) **(ii)** On the grid below, plot a graph of temperature, T against volume of **FA 2** added.

For Examiner's Use

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(iii) Draw **two** smooth lines of best fit. Extrapolate these lines until they cross. Extrapolate these lines until they cross.

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(iv) Determine from your graph,

- the maximum temperature reached, $T_{maximum}$,
- the maximum temperature change, $\Delta T_{maximum\ 1}$,
- the volume, $V_{equivalence}$, of **FA 2** needed to completely react with 25.0 cm^3 of **FA 1**.

Show on your graph how you obtained these values.

Record these values in the spaces provided below.

Maximum temperature reached, $T_{maximum}$ = ...

Volume of **FA 2** used, $V_{equivalence}$ = ...

Supervisor
Student
Difference

Hence, calculate the maximum temperature change, $\Delta T_{maximum\ 1}$ = ...

Supervisor
Student
Difference

Reaction between FA 1 and FA 3

For Examiner's Use

(b) The molar enthalpy change for **Reaction 2**, $\Delta H_{\text{reaction 2}}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with H_2SO_4.

In this task you will calculate a value for the molar enthalpy change, $\Delta H_{\text{reaction 2}}$. To do this you will need to determine the maximum temperature change produced when measured volumes of **FA 1** and **FA 3** are mixed. After considering the concentrations of **FA 1** and **FA 3**, you will select a suitable volume of **FA 3** to add to 40 cm^3 of **FA 1**.

(i) Choose a suitable volume of **FA 3**, $V_{\textbf{FA 3}}$, to be added to 40 cm^3 of **FA 1**. Explain your answer.

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(ii) Identify the apparatus you intend to use to measure the volume of **FA 1**.

Explain your choice.

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(iii) In an appropriate format in the space provided below, record all values of measured temperature for this experiment.

1. Label one Styrofoam cup, **A**. Label a second Styrofoam cup, **B**.
2. Place cup **A** inside a Styrofoam cup which is held in a glass beaker to prevent it from tipping over.
3. Transfer 40 cm^3 of **FA 1** into cup **A**.
4. Stir the **FA 1** solution in cup with the thermometer. Read and record its temperature, $T_{\textbf{FA 1}}$. This is the initial temperature of **FA 1**.
5. Wash and dry the thermometer.
6. Transfer your chosen volume of **FA 3** into cup **B**. Stir the **FA 3** solution with the thermometer. Read and record its temperature, $T_{\textbf{FA 3}}$. This is the initial temperature of **FA 3**.
7. Carefully add the contents of cup **B** to cup **A** in **small** portions to avoid too much frothing.
8. Place the lid on the cup and insert the thermometer through the lid. Stir the mixture.
9. Continue to stir the mixture. Measure and record the temperature, T_{mixture} that shows the maximum change from the initial temperature.

Results

For Examiner's Use

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Calculations

(c) For the purposes of these calculations, you should assume that the reaction mixture has a density of 1.00 g cm^{-3} and a specific heat capacity, *c*, of 4.18 J g^{-1} K^{-1}.

(i) Calculate the concentration of sodium hydroxide, [NaOH], in **FA 2**.

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[NaOH] in **FA 2** = ...

(ii) Calculate the heat change, *q*, for the reaction occurring in **(a)(i)**, and hence determine a value for the molar enthalpy change for **Reaction 1**, $\Delta H_{\text{reaction 1}}$.

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q =..............................

$\Delta H_{\text{reaction 1}}$= ....

(d) Use your results from **(b)(iii)** to calculate a value for the molar enthalpy change for **Reaction 2**, $\Delta H_{\text{reaction 2}}$. For the experiment in **(b)(iii)**, the weighted average initial temperature, T_{average}, of **FA 1** and **FA 3** may be calculated using the formula given below.

For Examiner's Use

$$T_{average} = \frac{(V_{FA1} \times T_{FA1}) + (V_{FA3} \times T_{FA3})}{(V_{FA1} + V_{FA3})}$$

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19	

T_{average} = ...

q =.............................

$\Delta H_{\text{reaction 2}}$ = ...

(e) Ionic equations for neutralisation, **Reaction 1**, and **Reaction 2** are shown below.

For Examiner's Use

HCO_3^- (aq) + OH^- (aq) $\longrightarrow$ CO_3^{2-} (aq) + H_2O (l) $\Delta H_{\text{reaction 1}}$

HCO_3^-(aq) + H^+ (aq) $\longrightarrow$ H_2O (l) + CO_2 (g) $\Delta H_{\text{reaction 2}}$

Use your answers in **(c)(ii)** and **(d)**, draw an energy cycle to determine a value for the molar enthalpy change, $\Delta H_{\text{reaction 3}}$, for **Reaction 3**.

Reaction 3:

H_2O(l) + CO_2(g) + OH^-(aq) $\longrightarrow$ CO_3^{2-}(g) + H_2O(l) + H^+(aq) $\Delta H_{\text{reaction 3}}$

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(f) An alternative definition of acid-base behaviour was proposed by Brønsted and Lowry. **Reaction 1** and **Reaction 2** are both acid-base reactions involving hydrogencarbonate ions, HCO_3^-.

In terms of the *Brønsted-Lowry* theory of acids and bases, suggest the role of hydrogencarbonate ions, HCO_3^-, in **Reaction 1**.

Explain your answer.

Reaction 1

Role of HCO_3^- : ……………………………………………………………………

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Explanation : ……………………………………………………………………….

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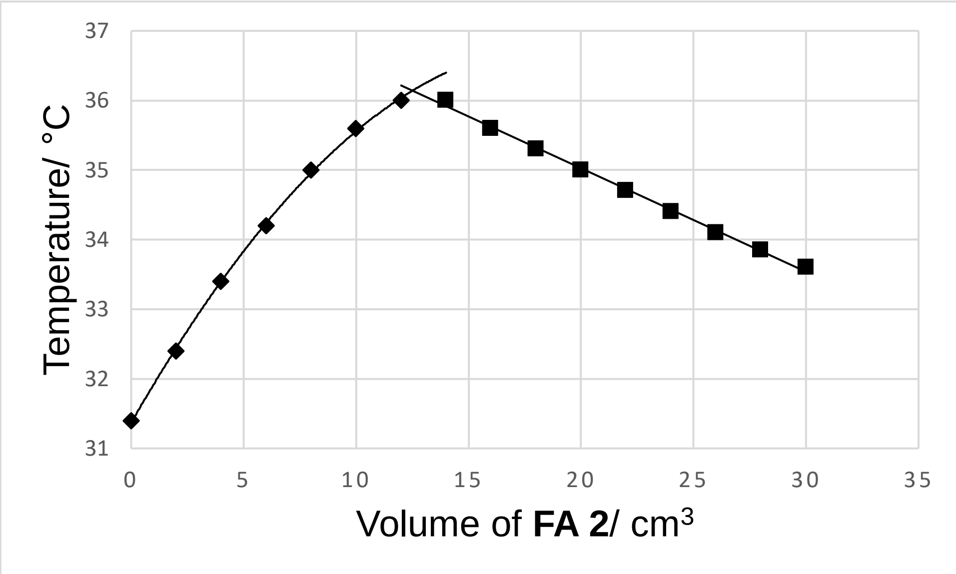
For Examiner's Use

(g) A student conducted the same experiment using a digital thermometer and obtained the graph as shown below.



Explain the shape of the graph.

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For Examiner's Use

(h) In the calculation of **(d)**, explain why the weighted average initial temperature was used.

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(h) With reference to the reaction between **FA 1** and **FA 2**, if the volume of NaOH is doubled, explain how it will affect the maximum temperature change?

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[Total: 27]

2 To determine the proticity of an unknown acid

For Examiner's Use

Acid base titration is commonly used to determine the concentration of an acid or base. In this experiment, the concentration of the acid is given and the aim of this investigation is to determine its proticity.

Acids are defined as substances that can donate hydrogen ions, H^+, to bases. Monoprotic acids contain one H^+ that can be donated per molecule. Diprotic acids contain two H^+ that can be donated per molecule.

You will determine using a titration method whether acid **Z** is monoprotic or diprotic.

- **FA 4** is a solution containing 11.55 g dm^{-3} of acid **Z**.
- **FA 5** is 0.105 mol dm^{-3} aqueous sodium hydroxide, NaOH.
- Thymol blue indicator

(a) Method

1. Pipette 25.0 cm^3 of solution **FA 4** into a conical flask.
2. Fill a burette with **FA 5**.
3. Add 3 drops of thymol blue indicator to the conical flask.
4. The colour change at the endpoint is yellow to blue.
5. Carry out as many accurate titrations as you think necessary to obtain consistent results.
6. Record, in a suitable form below, all of your burette readings and the volume of **FA 5** added in each accurate titration.

Results

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(b) From your titration results, obtain a suitable value for the volume of **FA 5** to be used in your calculations. Show clearly how you obtained this value.

For Examiner's Use

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Volume of **FA 5** =............................

(c) Calculations

(i) Calculate the amount of H^+ present in 25.0 cm^3 of **FA 4**.

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Amount of H^+ in 25.0 cm^3 of **FA 4** = ...

(ii) Calculate the amount of H^+ present in 1 dm^3 of **FA 4**.

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Amount of H^+ in 1 dm^3 of **FA 4** = ...

For Examiner's Use

(iii) **FA 4** contains 11.55 g dm^{-3} of acid **Z**. The relative molecular mass of **Z** is 126. Calculate amount of **Z** in 1 dm^{3} of **FA 4**.

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Amount of **Z** in 1 dm^{3} of **FA 4** = ...

(iv) Use your answers to **(ii)** and **(iii)** to determine whether **Z** is a monoprotic or a diprotic acid. Explain your answer.

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(v) Student **A** conducted this experiment on the day when the chemicals were freshly prepared. His average titre value was found to be *h* cm^{3}.

Three days later, he conducted the same experiment using the same chemicals but he found that the bottle of NaOH(aq) was left uncovered.

Suggest how his new titre value would compare to *h* cm^{3} and explain your answer.

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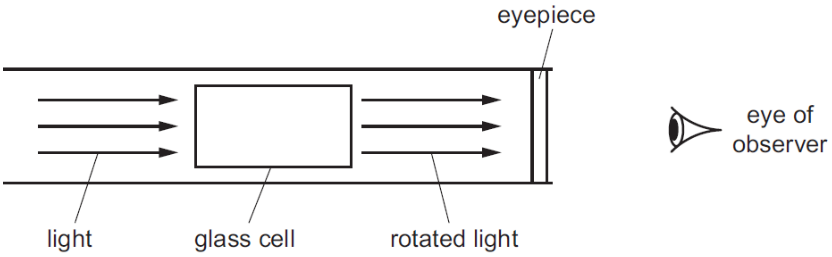
(d) Planning

For Examiner's Use

Sucrose, $C_{12}H_{22}O_{11}$, is a sugar. The concentration of a solution of sucrose can be measured by the optical rotation, α, of a sucrose solution instead of acid–base titration. The more concentrated the solution, the greater the optical rotation of the solution.

A polarimeter is used to measure optical rotation. Plane–polarised light is passed through a sample of the sucrose solution in a glass cell, and the observed angle of rotation, α_{obs}, is measured.

A simplified diagram of a polarimeter is shown.



If a glass cell of length 1 cm is filled with a solution of sucrose of concentration 1 g cm^{-3}, the measured angle of rotation is known as the specific rotation, [α].

The observed angle of rotation, α_{obs}, measured by the polarimeter is related mathematically to the concentration of the sucrose solution by the equation shown.

$$\alpha_{obs} = [\alpha]lc$$

α_{obs} is the observed angle of rotation.

[α] is a constant and is known as the specific rotation of sucrose solution.

l is path length which is 1 cm in the above description.

c is the concentration of sucrose, in g cm^{-3}

(i) Explain why a sucrose solution is able to rotate plane–polarised light.

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For Examiner's Use

(ii) Using the information given above, you are required to write a plan to determine the concentration of sucrose in a solution **X**.

You may assume that you are provided with:

- solid sucrose, $C_{12}H_{22}O_{11}$;
- solution **X**, of an unknown sucrose concentration less than 0.0800 g cm^{-3};
- access to a polarimeter and instructions for use;
- graph paper;
- the apparatus and chemicals normally found in a school or college laboratory.
- glass cell of length 10 cm.

Your plan should include details of:

- the preparation of 250 cm^3 0.0800 g cm^{-3} sucrose solution using solid sucrose provided;
- the preparation of a suitable range of diluted solutions of accurate concentrations;
- an outline of how the results would be obtained;
- a sketch of the calibration curve you would expect to obtain;
- how the calibration line would be used to determine the concentration of sucrose in solution **X**.

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For Examiner's Use

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For Examiner's Use

(iv) The glass cell of 10 cm length is expensive, so one cell is used for all the solutions that are placed in the polarimeter.

Suggest how you would ensure that the concentration of solution in the cell is accurate each time the cell is used for the different sucrose solutions.

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(v) Concentration of sucrose is the independent variable in this polarimeter experiment.

The glass cell of 10 cm length is replaced by a glass cell of 20 cm length. The 20 cm glass cell is filled with 0.0750 g cm^{-3} sucrose solution.

Given that α_{obs} of 0.0750 g cm^{-3} sucrose solution is $+6.11^{o}$, predict the value for the observed angle of rotation, α_{obs}, for the sucrose solution of concentration 0.0750 g cm^{-3} when the 20 cm cell is used.

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Predicted angle = …………………………..

[Total: 20]

3 Inorganic qualitative analysis

For Examiner's Use

(a) **FA 6** and **FA 7** each contain one anion and one cation.

Carry out the following tests and record your observations. For each test you should use a small spatula measure of **FA 6** or **FA 7**

	observations	
test	**FA 6**	**FA 7**
Add a small spatula measure to a 1 cm depth of deionised water in a test-tube and shake. Add 2 drops of universal indicator. Record the pH of the mixture.		
Heat a small spatula measure in a dry boiling tube until no further change is observed.		
Add a small spatula measure in a 2 cm depth of dilute hydrochloric acid in a boiling tube. Decant 1 cm depth of this solution into two test-tubes.		

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To one test-tube, add aqueous sodium hydroxide.		
To the second test-tube, add aqueous ammonia.		

(b) Mix a spatula measure of **FA 6** with a spatula measure of **FA 7**. Heat the mixture in a boiling tube. Record your observations.

State the type of reaction that has occurred.

Observations: ……………………………………………………………………

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Type of reaction: ………………………………………………………………

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(c) From your observations in **(a)** and **(b)**, identify the possible ions present in **FA 6** and **FA 7**.

If you are unable to identify an ion, write 'unknown'.

	cation	anion
FA 6		
FA 7		

54	
55	

[Total: 8]

END OF PAPER

9 Qualitative Analysis Notes

[ppt. = precipitate]

9(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

9(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 Al foil
nitrite, NO_2^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (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)

9(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

9(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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