CHEMISTRY

Student Name: _____

Teacher Name: _____

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time for paper: two and a half hours

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet
Multiple-choice Answer Sheet
Chemistry Data Sheet

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction tape/fluid, eraser, ruler, highlighters

Special items: up to three non-programmable calculators approved for use in the ATAR examinations

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination
Section One: Multiple-choice	20	20	40	40	25.0 %
Section Two: Short answer	8	8	50	58	36.25 %
Section Three: Extended answer	6	6	60	62	38.75 %
				Total	100.0 %

Instructions to candidates

1. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question that you are continuing to answer at the top of the page.

Section One: Multiple-choice 25% (40 Marks)

This section has **20** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 40 minutes.

1.   Which of the following are homogeneous mixtures?

         i   sodium chloride
         ii.   white vinegar
         iii.   white wine
         iv.   baked beans

      (a)   i and iii only
      (b)   ii and iii only
      (c)   iii and iv only
      (d)   ii, iii and iv only

2.   A covalent bond would be expected to form between atoms which have the electron configurations

      (a)   2,7 and 2,6.
      (b)   2,8,8 and 2.
      (c)   2,8,1 and 2,8,7.
      (d)   2,8,5 and 2,8,8,1.

3.   Which one of the following descriptions relates correctly to an ionic solid?

      (a)   an ordered lattice arrangement of cations and free valence electrons
      (b)   a crystalline form that is hard and has lustre
      (c)   a high melting point due to strong electrostatic interaction
      (d)   valence electrons are free to conduct charge

4.   Which one of the following compounds contains only ionic bonds?

      (a) CH_3COOH
      (b) HCl
      (c) NaH
      (d) $NaNO_3$

5. Which one of the following statements best describes a covalent bond?

   (a) The atoms have a noble gas configuration.
   (b) The atoms have formed an infinite network.
   (c) One of the atoms involved in the bond is a metal and the other is a non-metal.
   (d) There is simultaneous attraction of both nuclei to a shared electron pair.

6. Which one of the following characteristics does not apply to solutions?

   (a) They are homogeneous mixtures.
   (b) They contain two or more substances.
   (c) They have uniform composition.
   (d) They always contain a solid that has dissolved in a liquid

7. Which one of the following statements about elements in Groups 1 and 2 on the Periodic Table is correct?

   (a) They can only become positively charged and form strong covalent molecules.
   (b) They form negative ions because they have few valence electrons.
   (c) They can share electrons to form positive ions.
   (d) They can form positive ions because they have loosely held valence electrons.

8. Use the table to identify a pair of isotopes.

Element	No. of Protons	No. of Electrons	No. of Neutrons
W	20	21	21
X	19	18	19
Y	19	21	19
Z	20	19	20

   (a) Elements X and W
   (b) Elements X and Y
   (c) Elements W and Z
   (d) Elements Y and W

9. Which one of the following correctly classifies the substances listed?

	Covalent molecular	Ionic	Covalent Network	Metallic
(a)	$C_6H_{12}O_6$	KBr	SiC	Mg
(b)	KNO_3	$CaCO_3$	CO_2	Brass
(c)	CO_2	$NH_4C\ell$	$C\ell_2$	Ca
(d)	$NH_4C\ell$	$NaC\ell$	C	Fe

10. Which one of the following statements about nanomaterials is **false**?

    (a) Nanomaterials are substances that contain particles with specific properties which may differ from those of the equivalent bulk material.
    (b) Nanomaterials are materials made of nano-particles which range from 1 – 100 nm in size.
    (c) Fullerene, an allotrope of carbon, can be used to make nanomaterials.
    (d) Nanomaterials are substances that contain only particles of 1 nm in size.

11. Which one of the following is the correct formula for magnesium phosphate?

    (a) $MgPO_4$
    (b) $Mg_3(PO)_4$
    (c) Mg_2PO_2
    (d) $Mg_3(PO_4)_2$

12. Which of the following is the electronic configuration for the Phosphide Ion, P^{3-}?

    (a) $1s^2\ 2s^2\ 3s^6\ 2p^2\ 3p^6$
    (b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
    (c) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$
    (d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

13. Which one of following is the best explanation as to why ionic substances conduct electricity in both the molten and aqueous form?

    (a) Ionic bonding is similar to metallic bonding in that when molten and aqueous they both have freely moving electrons.
    (b) In both the molten and aqueous solution ionic substances have mobile ions.
    (c) In both the molten and aqueous solution ionic substances have mobile electrons
    (d) Ionic substances have high melting points and are brittle.

14. Separating pure water from sea water can be done simply by:

    (a) evaporation.
    (b) distillation.
    (c) decantation.
    (d) filtration.

5

15. Which two of these species represent an element, and its positive ion?

| Species	Number of protons	Number of electrons	Number of neutrons
1	37	37	38
2	38	36	38
3	38	36	41
4	37	37	41

(a) 1 and 2
(b) 1 and 3
(c) 2 and 3
(d) 2 and 4

16. Which of the following has the molecules in order of **decreasing** bond polarity?

(a) HF, HCℓ, CH_4, H_2
(b) HCℓ, HF, CH_4, H_2
(c) CH_4, H_2, HCℓ, HF
(d) H_2, CH_4, HCℓ, HF

17. Which of the following statements is the best description of the trends in the 1st ionisation energy of the elements on the Periodic Table?

(a) 1st ionisation energy increases across Period 3 and increases down groups of the Periodic Table.
(b) 1st ionisation energy decreases across Period 3 and decreases down groups of the Periodic Table.
(c) 1st ionisation energy increases across Period 3 and decreases down groups of the Periodic Table.
(d) 1st ionisation energy decreases across Period 3 and increases down groups of the Periodic Table.

18. Identify all of the types of bonding present in a 0.1 mol L^{-1} solution of nickel(II) chloride in ethanol.

I   dispersion forces
II   ion-dipole forces
III   hydrogen bonds
IV   ionic bonds

(a) II and IV
(b) I, III and IV
(c) I, II, and III
(d) All of the above.

19. Which of the following groups of solutions will produce a coloured precipitate when mixed?

   All solutions are 0.1 mol L^{-1}.

(a)	Potassium hydroxide	Copper(II) sulfate	Calcium bromide
(b)	Copper(II) sulfate	Sodium chloride	Barium nitrate
(c)	Strontium bromide	Iron(III) nitrate	Sodium iodide
(d)	Ammonium nitrate	Iron(II) chloride	Potassium sulfate

20. Substance A is made up three components (G, B and R). A small sample of substance A was dotted onto chromatography paper, and a chromatogram was developed using an appropriate solvent.
   G has moved the most while B is in the middle and R is the lowest spot.in the result that is shown below.
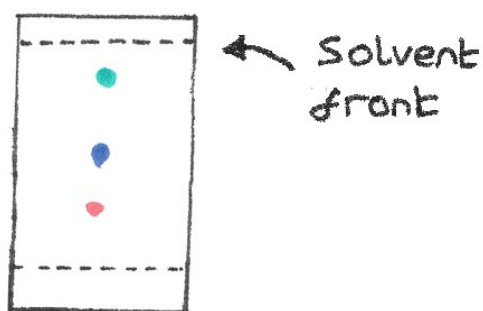
   Compound G is adsorbed

   (a) more strongly onto the stationary phase and has a smaller R_f value than component B.
   (b) more strongly onto the stationary phase and has a larger R_f value than component B.
   (c) less strongly onto the stationary phase and has a smaller R_f value than component B.
   (d) less strongly onto the stationary phase and has a larger R_f value than component B.

End of Section One

Section Two: Short answer 36.25% (58 Marks)

This section has **8** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

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Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 50 minutes.

Question 21 **(6 marks)**

(a) Write the formulae of each of the following compounds. (3 marks)

Name	Formula
Calcium hydrogen carbonate	
Vanadium (IV) bromide	
Phosphorus pentoxide	

(b) Write the names of each of the following species. (3 marks)

Formula	Name
SO_4^{2-}	
Li_2O	
$Cu(OH)_2$	

Question 22 (9 marks)

Draw the Lewis structures for the following substances, showing all valence electrons. State whether each substance is polar or non-polar.

Substance	Lewis Structure	Polarity
Silicon dioxide		
Carbon tetrafluoride		
Nitrogen triiodide		

9

Question 23   **(11 marks)**

Five unlabelled solutions are known to be; sodium sulfate, sodium iodide, sodium carbonate, sodium nitrate, barium hydroxide.

These 5 solutions are randomly labelled V, W, X, Y, Z and samples are tested with reagents. These tests are described in the table below.

Reagents	Solutions				
	V	W	X	Y	Z
$Mg(NO_3)_2$	no visible reaction	no visible reaction	no visible reaction	white ppt	white ppt
$Ba(NO_3)_2$	no visible reaction	no visible reaction	white ppt	white ppt	no visible reaction
$Pb(NO_3)_2$	no visible reaction	yellow ppt	white ppt	white ppt	white ppt

In the space below deduce what can be inferred about the identity of the samples when each of the reagents are used.

(a) $Mg(NO_3)_2$ (3 marks)

_____

_____

_____

(b) $Ba(NO_3)_2$ (3 marks)

_____

_____

_____

(c) $Pb(NO_3)_2$ (3 marks)

_____

_____

_____

(d)   Identify the solutions: (2 marks)
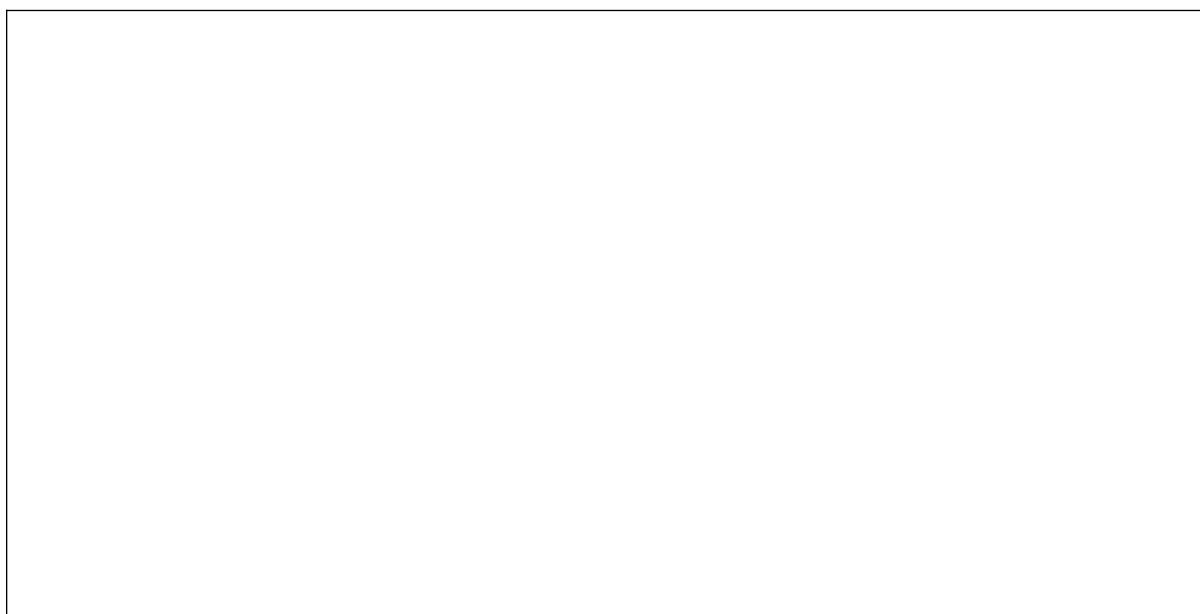
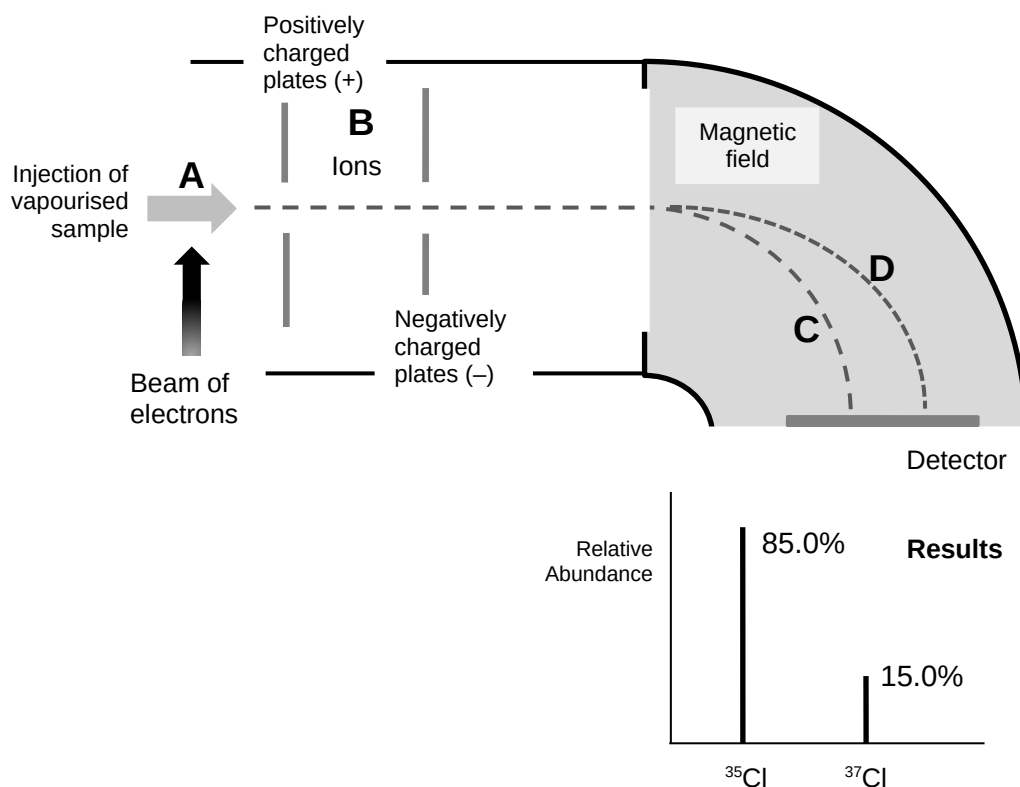| Sample	V	W	X	Y	Z
Identify of Solution:					

Question 24 **(4 marks)**

Using a labelled diagram, show how ion-dipole forces are formed when potassium chloride dissolves in water.

Question 25 **(9 marks)**

The diagram below shows a **Mass Spectrometry** apparatus being used to analyse a sample of chlorine, which contains the isotopes chlorine-35 and chlorine-37.

(a) Ionisation of chlorine atoms occurs at **A**. Explain what is meant by the term ionisation in this situation. In your answer explain why energy is required for ionisation to occur.

(2 marks)

_____

_____

_____

_____

_____

(b) Write the formula of the ions present at **B**.

(1 mark)

_____

(c) (i) The ions of which isotope are present at **C**? (1 mark)

_____

  (ii) Explain you answer to part (c) (i). (2 marks)

_____

_____

_____

_____

_____

(d) Use the results shown to calculate the relative atomic mass (atomic weight) of this sample of chlorine.

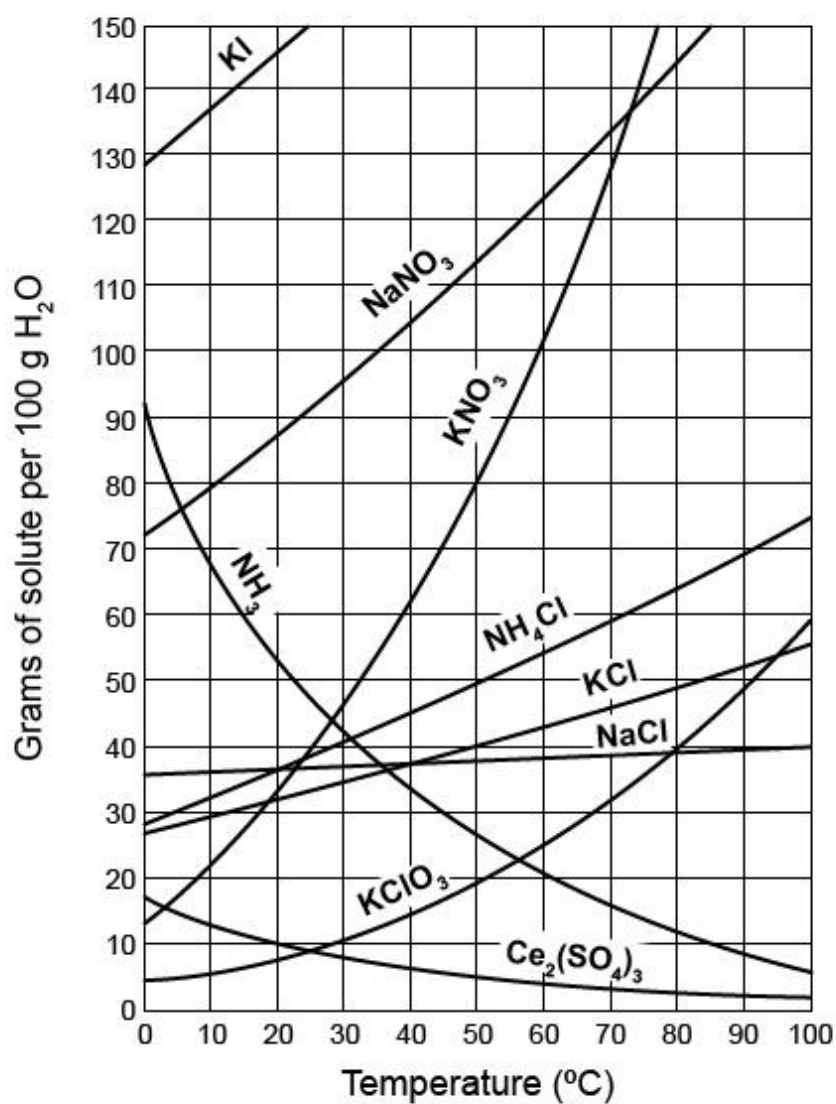(2 marks)

_____

_____

_____

(e) Explain why this sample is probably not naturally occurring chlorine.

(1 mark)

_____

_____

Question 26 **(5 marks)**

(a)   Use the graph above to estimate the solubility of: (2 marks)

(i) Potassium nitrate at 55 ºC.

_____

(ii) Ammonia at 70 ºC.

_____

(b)   If a solution of potassium nitrate is described as 5.5 g L^{-1}, calculate the concentration in mol L^{-1}.   (1 mark)

_____

_____

_____

(c)   Explain the difference between the terms saturated and unsaturated, with reference to the data for a solution of sodium nitrate at 30 ^{o}C.   (2 marks)

_____

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Question 27 **(5 marks)**

Consider the information about some pure substances.

Substance	Melting point (°C)	Boiling point (°C)	Electrical conductivity in solid state	Electrical conductivity in liquid state	Solubility in water
1	1535	2750	good	good	insoluble
2	800	1410	non	good	soluble
3	-259	-253	non	non	insoluble
4	1710	2590	non	non	insoluble
5	50	265	non	non	insoluble

(a)   Which **one** of the substances above is most likely a **gas** at room temperature?

(1 mark)

_____

(b)   Which **one** of the substances above is most likely to be a **covalent molecular solid**?
(1 mark)

_____

(c)   Which **one** of the substances above is most likely to be a **metal**?   (1 mark)

_____

(d)   Which **one** of the substances above is most likely a **covalent network** substance?
(1 mark)

_____

(e)   Which **one** of the substances above is most likely an **ionic** substance?   (1 mark)

_____

Question 28 **(9 marks)**

Write ionic equations **including state symbols** the following equations, and describe the observations you would expect to see for each reaction.

(a)   Barium nitrate solution is mixed with iron(II) sulfate solution.

Ionic Equation: (2 marks)

Observations: (1 mark)

_____

_____

_____

(b)   Lead(II) nitrate solution is mixed with magnesium iodide solution.

Ionic Equation: (2 marks)

Observations: (1 mark)

_____

_____

_____

(c)   Sodium sulfide solution is mixed with silver nitrate solution.

Ionic Equation: (2 marks)

Observations: (1 mark)

_____

_____

_____

Section Three: Extended answer   **38.75% (62 Marks)**

This section contains 6 questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
    Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

Question 29   **(7 marks)**

The approximate boiling points of the Group 14, 15, 16 and 17 hydrides are plotted on the graph below.
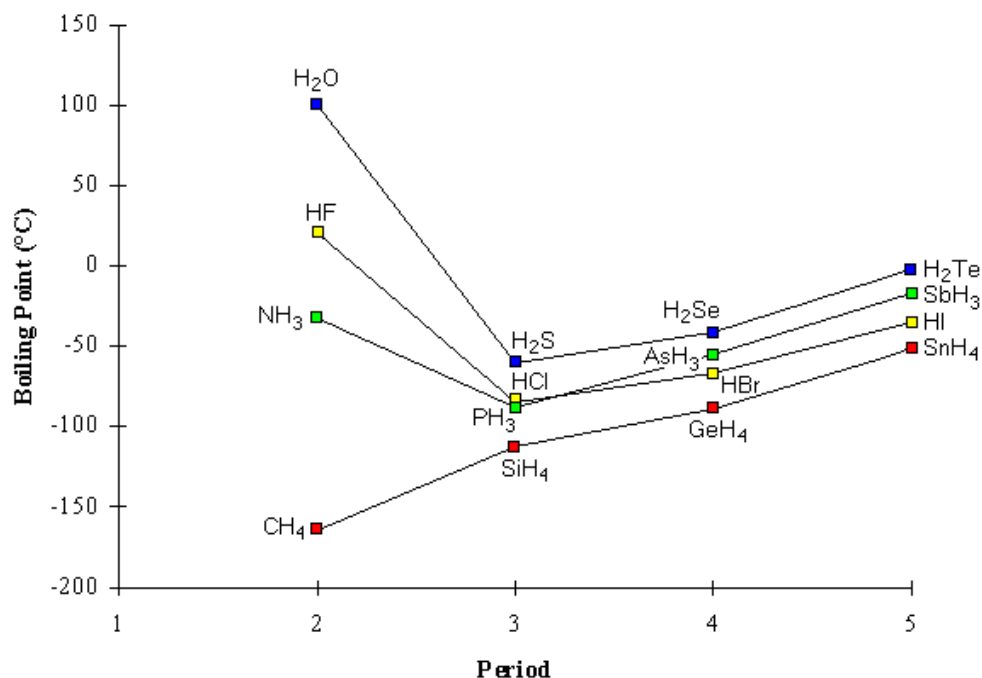
(a) The hydrides of Group 14 are non-polar molecules. Apply your understanding of intermolecular interactions to explain the steadily increasing boiling points of the Group 14 hydrides CH_4, SiH_4, GeH_4 and SnH_4.

(2 marks)

_____

_____

_____

_____

(b) The Group 15, 16 and 17 hydrides are polar molecules. Consider the Group 17 hydrides HCl, HBr and HI. **List** HCl, HBr and HI in order of **increasing** polarity.

(1 mark)

_____

(c) Compare the trend in polarities of HCl, HBr and HI with the observed trend in their boiling points. Briefly explain your reasoning.

(2 marks)

_____

_____

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(d) The first member of each hydride series (NH_3 in Group 15, H_2O in Group 16, and HF in Group 17) has a much higher boiling point than the next hydride in its series. Apply your understanding of intermolecular interactions to explain the anomalous boiling points of NH_3, H_2O and HF.

(2 marks)

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Question 30 **(12 marks)**

Diamond and graphite are two allotropes of carbon with distinctly different covalent network structures and physical properties. Compare them in terms of the following points.

(a)   Compare the covalent network structures of both diamond and graphite, using a diagram if you wish. (4 marks)

_____

_____

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_____

(b)   Electrical conductivity.

    (i) Explain why diamond does not conduct electricity. (2 marks)

_____

_____

_____

_____

    (ii) Explain why graphite does conduct electricity. (2 marks)

_____

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_____

(c)   Hardness of the solid.

   (i) Explain why diamond is so hard.   (2 marks)

_____

_____

_____

_____

   (ii) Explain why graphite is soft.   (2 marks)

_____

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Question 31 **(5 marks)**

A solution contains three cations, Ba^{2+}, Cu^{2+} and Pb^{2+}. The flow chart indicates the plan used to confirm the identity of these cations.

```
         Solution containing
         Ba²⁺, Cu²⁺ and Pb²⁺
                    │
                    │         ┌──────────────┐
                    │         │   Addition   │
                    ┘         │ of excess HCl │
                              └──────────────┘
              ┌──────────┐
              │ Filtered │
              └──────────┘
          ┌─────────┴──────────┐
    ┌──────────────┐      ┌───────────┐
    │ Precipitate 1│      │ Filtrate 1│
    └──────────────┘      └───────────┘
                               │        ┌──────────────┐
                               │        │  Addition of │
                               ┘        │  excess NaOH │
                                        └──────────────┘
                          ┌──────────┐
                          │ Filtered │
                          └──────────┘
                    ┌──────────┴──────────┐
            ┌──────────────┐      ┌───────────┐
            │ Precipitate 2│      │ Filtrate 2│
            └──────────────┘      └───────────┘
```
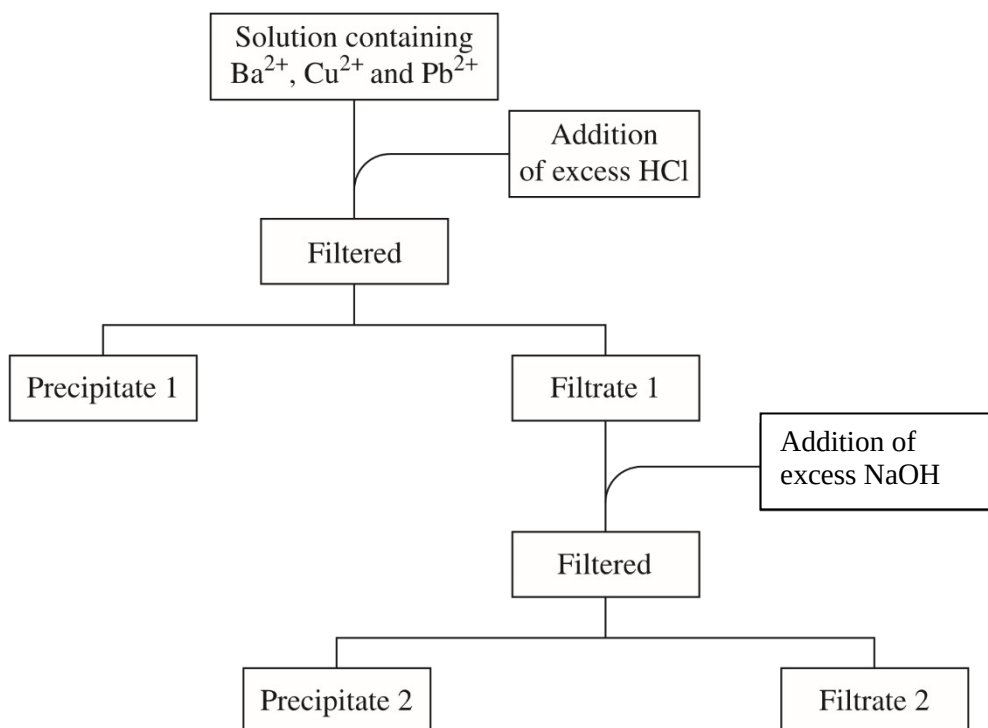
(a) Name Precipitate 2

(1 mark)

_____

(b) Write a balanced equation for the formation of Precipitate 1

(2 marks)

_____

(c) Suggest a test and the expected result that would confirm the identity of the metal cation remaining in Filtrate 2.

(2 marks)

_____
_____
_____
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**Question 32** **(17 marks)**

(a)   What was Niels Bohr's contribution to the understanding of atomic structure?

(2 marks)

_____

_____

_____

_____

(b)   How does his contribution contribute to our understanding of analytical techniques such as Flame tests?   (3 marks)

_____

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(c)   A drinking water sample was thought to be contaminated with lead(II) ions. The absorbance readings, on an Atomic Absorption Spectrometer, of some **known** samples of lead(II) ions are shown below. Draw a **graph** showing the relationship between lead(II) ion concentration and the absorbance level.   (5 marks)

Concentration of lead(II) ions (mg L^{-1})	Absorbance
0.0010	10
0.0030	35
0.0070	70
0.010	95
0.013	125
0.016	160
0.020	195
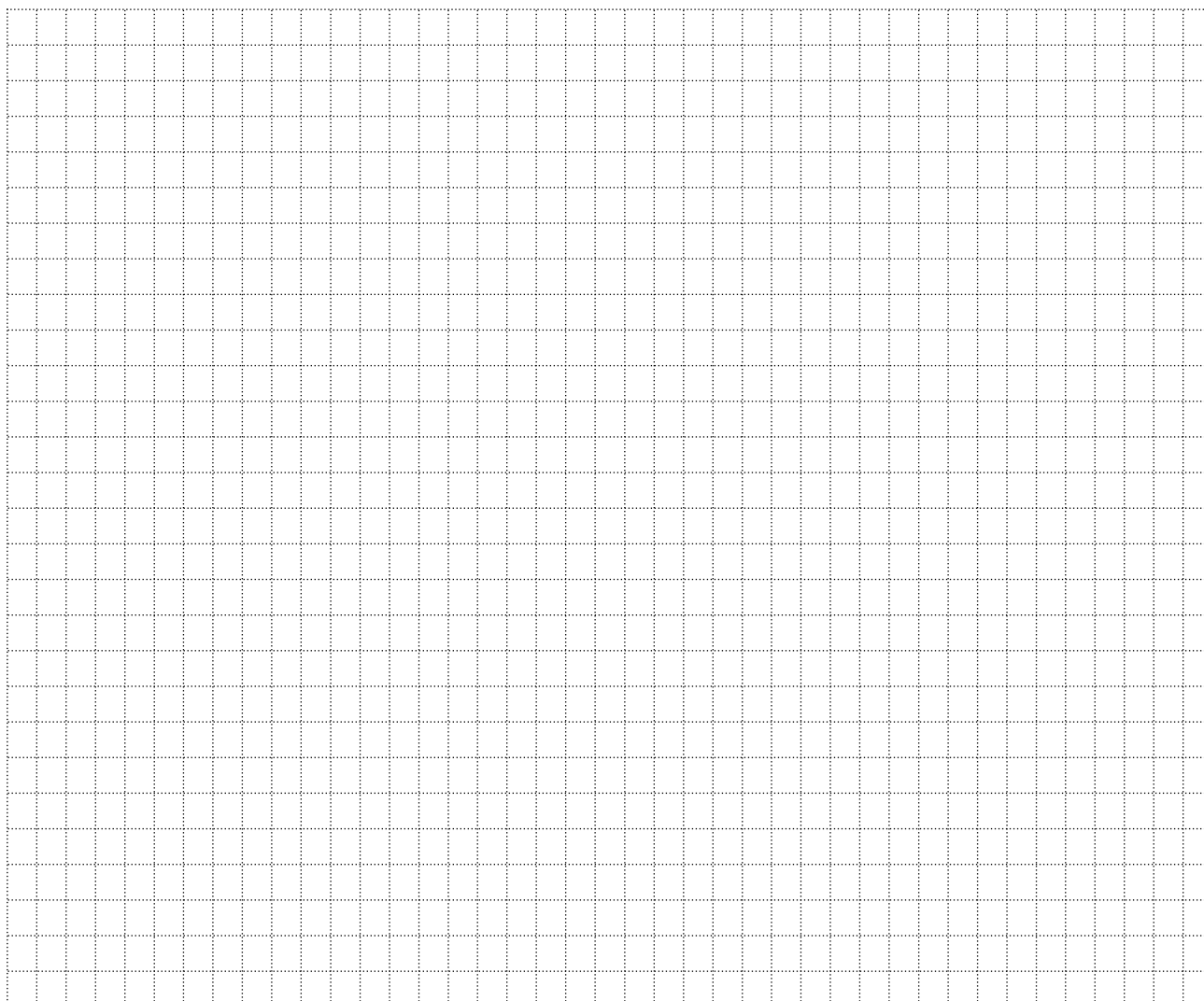
Note: A spare grid is provided at the end of the examination if required

(d)   The suspect drinking water sample was then tested on the same Atomic Absorption Spectrometer and the absorbance measured at 105. Find the concentration of lead(II) ions, and use this to determine if the water is safe to drink. Briefly show your reasoning on the graph itself or in the space below.

(The maximum acceptable level of lead in drinking water has been established by t National Health and Medical Research Centre at 0.01 mg L^{-1})

(2 marks)

Source: https://www.nhmrc.gov.au/guidelines-publications/eh52

(e) An alternative way to monitor the concentration of contaminants in drinking water is using a precipitation reaction. Barium ions are harmful to health, and the National Health and Medical Research Centre state that they should not be present at a concentration greater than 2 parts per million. A sample of drinking water can be tested for barium ions by adding potassium sulfate solution.

Write an ionic equation for the precipitation reaction that takes place.   (1 mark)

_____

(f) A 2.00 kg sample of drinking water is tested for barium ions by the addition of 100 mL of 1.00 mol L^{-1} potassium sulfate solution. The mixture is stirred until no more precipitate forms, and the water is evaporated, until only a white solid remains. The mass of solid produced is 5.73 mg.

Assuming all of the white solid is barium sulfate, calculate the concentration of barium in the water sample in parts per million, and determine whether the barium level poses a risk to health.

Note: Your answer MUST be to the correct number of significant figures

(4 marks)

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Question 33 **(7 marks)**

Barium hydroxide is used as an additive in thermoplastics (such as PVC) to improve the plastic properties relating to hardness – ie to resist scratching. It also finds applications when used as a general-purpose additive for lubricants and greases to improve their performance especially in high temperature applications such as motor racing.

Barium hydroxide is a white crystalline solid that has a melting point 407 $^{\circ}$C when in the anhydrous form.

Barium hydroxide can be prepared by dissolving Barium oxide (BaO) in water:

$$BaO + x\ H_2O \rightarrow Ba(OH)_2 \cdot xH_2O$$
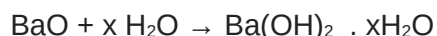
To determine the water of hydration and the molecular formula for a sample of Barium hydroxide was placed in a clean and dry porcelain crucible and lid before placed in an oven set at 250°C. The after heating for 15 minutes the crucible with lid on was allowed to cool and weighed. This heating, cooling, weighing procedure was repeated on the same sample until it reached a constant weight.

The analyst's results are below:

Mass of empty crucible and lid	16.28g
Initial mass of crucible, lid and sample	17.72g
Mass after first heating/cooling	17.19g
Mass after second heating/cooling	17.07g
Mass after third heating/cooling	16.95g
Mass after fourth heating/cooling	16.95g
Mass after fifth heating/cooling	16.96g

(a)   Determine the number of moles of water that was in the hydrated lattice structure.

(2 marks)

_____

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(b)   Determine the molecular formula for the barium hydroxide sample.

(3 marks)

_____

_____

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_____

(c)   Suggest a source of error and how it may affect the results.

(2 marks)

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Question 34 (14 marks)

A chewable tablet that is used to treat indigestion has a claim on the label that each tablet contains:

"250mg of sodium alginate, 133.5mg of sodium bicarbonate, 80 mg of calcium carbonate as the active ingredients and xylitol, mannitol (E421), polyethylene glycol, aspartame (E951, magnesium stearate, peppermint flavour and colouring (E132)."

(a)   Calculate the amount, in moles, of calcium carbonate and sodium hydrogen carbonate (also known as "sodium bicarbonate") in one tablet.

(4 marks)

_____

_____

_____

_____

_____

(b)   Determine the number of moles of calcium ions in one tablet.
.

(2 marks)

_____

_____

_____

_____

_____

(c)   It was also displayed on the box that:

"Each four tablet dose contains 10.6 mmol of sodium and 3.2 mmol of calcium. If you have been advised a diet restricted of any of these please consult your doctor before taking this product".

Show how the figure of 3.2 mmol of calcium was calculated from 80 mg of calcium carbonate in each tablet.

(3 marks)

_____

_____

_____

_____

_____

(d)   Sodium alginate is an extract from seaweed. It is composed of a long chain of molecules similar to carbohydrate chains. The formula for sodium alginate can be represented as $(C_6H_7NaO_6)_n$. Where n is a very large number.
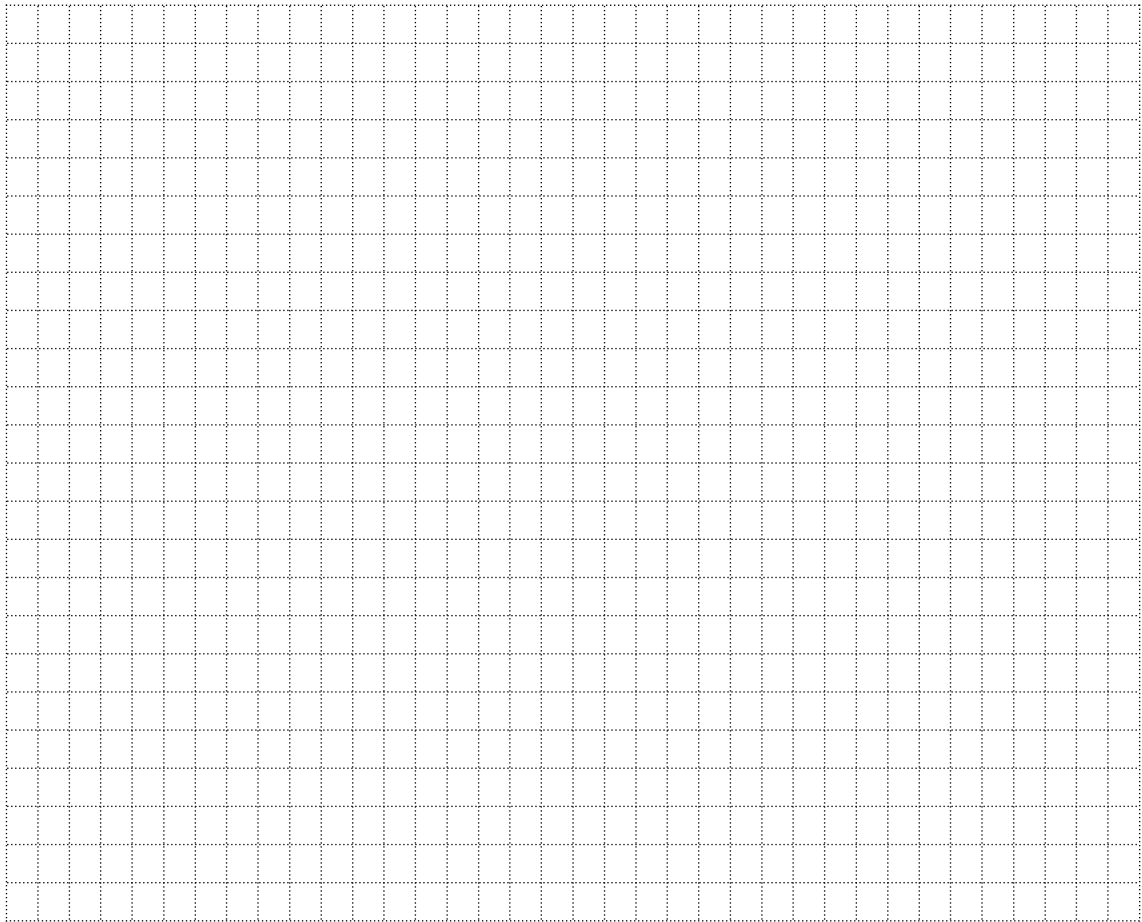
From the information that four tablets contain 10.6 mmol of sodium ions and assuming that sodium alginate and sodium hydrogen carbonate are the only substances in the tablets that contain sodium, calculate the mass of sodium (as sodium ions) present in the sodium alginate for a four tablet dose.

(5 marks)

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End of questions

Additional Working Space

Spare grid for Question 32