Answer **all** the questions.

1. A chemist carries out reactions of barium and barium nitride, Ba_3N_2.

Reaction 1 Barium is reacted with water.

Reaction 2 Barium nitride is reacted with water, forming an alkaline solution and an alkaline gas.

Reaction 3 Barium is reacted with an excess of oxygen at 500°C, forming barium peroxide, BaO_2.

(i) Write equations for **Reaction 1** and **Reaction 2**.

Ignore state symbols.

Reaction 1: _____

Reaction 2: _____

[3]

(ii) Predict the structure and bonding of Ba_3N_2.

_____ **[1]**

(iii) BaO_2 formed in **Reaction 3** contains barium and peroxide ions.
The peroxide ion has the structure $[O{-}O]^{2-}$.

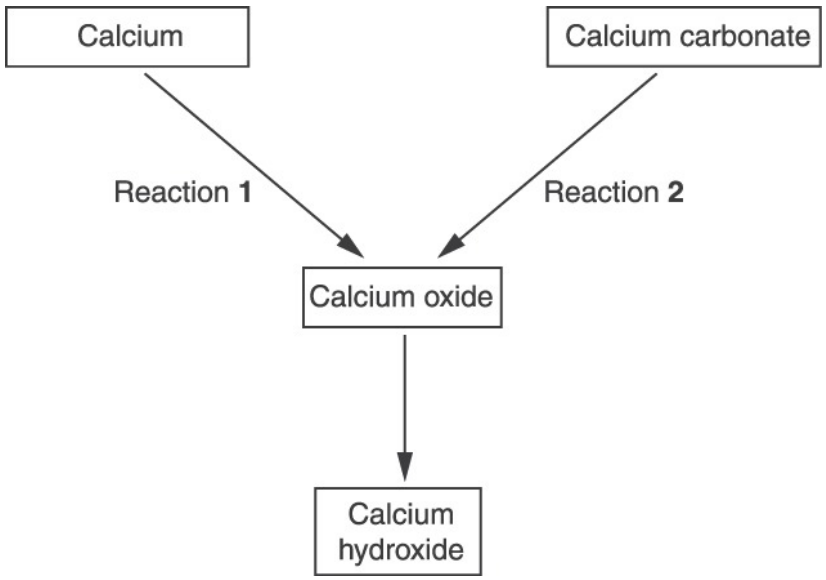
Suggest a '*dot-and-cross*' diagram for BaO_2.

Show outer shell electrons only.

[1]

2(a). Calcium is in Group 2 of the Periodic Table.

The diagram shows some reactions of calcium and its compounds.



Reactions **1** and **2** both form calcium oxide.

(i) Write the equation for reaction **1**.

_____ [1]

(ii) What type of reaction is reaction **2**?

_____ [1]

(b). A student prepared some calcium hydroxide by adding a small piece of calcium to a large excess of water.

Describe what the student would observe and write the equation for the reaction.

Observation _____

_____

Equation _____ [2]

3. This question looks at groups in the periodic table.

Calcium and strontium are Group 2 metals. They both react with water.
A chemist reacts 0.200 g of strontium with 250 cm^3 water, leaving a colourless solution containing strontium ions.
The volume remains at 250 cm^3.

(i) Write an equation for the reaction between strontium and water.

Include state symbols.

---------- [1]

(ii) Calculate the concentration, in mol dm^{-3}, of strontium ions in the resulting solution.

concentration of strontium ions = _____ mol dm^{-3} **[2]**

(iii) A student plans to carry out this experiment using 0.200 g of calcium instead of 0.200 g of strontium.
Predict the difference, if any, between the volume of gas produced by calcium and strontium.
Explain your reasoning and include a calculation in your answer.

---------- [3]

4. Ionisation energies have been used to develop a model for electron configuration.

(i) **Fig. 16.1** shows the first ionisation energies for Li, Be, F and Ne.

Add points for the missing elements across Period 2.

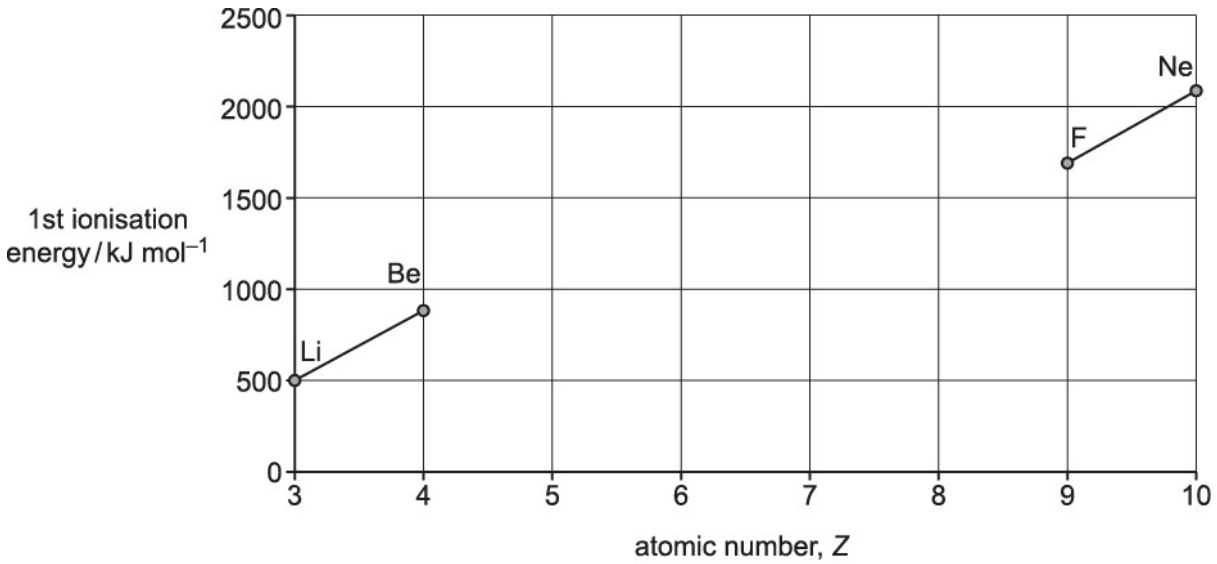


Fig. 16.1

[2]

(ii) First ionisation energies decrease down groups in the Periodic Table.

Explain this trend and the effect on the reactivity of groups containing metals.

[3]

5(a). This question is about chemicals used by gardeners.

A garden product contains hydrated ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$. $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$ contains 27.55% by mass of water of crystallisation.

Calculate the value of x in the formula $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$.

Show your working.

x = _____ [3]

(b). The garden product in the previous question part is a solid mixture of the following ingredients:

- Hydrated ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$, which is soluble in water
- Crushed limestone (calcium carbonate)
- Sand.

(i) Suggest why crushed limestone has been included in this garden product.

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[1]

(ii) *Plan a procedure on a test tube scale to show that the solid mixture contains the following ions:

- NH_4^+, Fe^{2+} and SO_4^{2-} present in $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$
- CO_3^{2-} present in crushed limestone.

Show your reasoning, including relevant equations.

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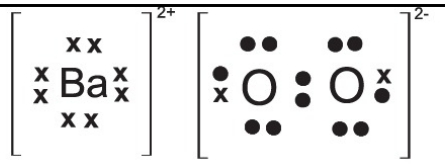
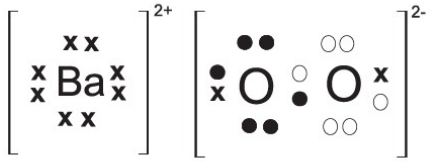
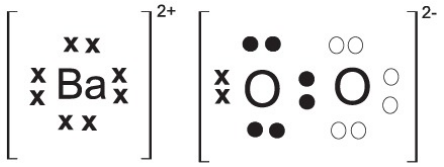
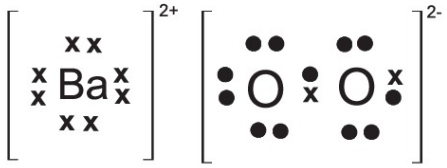
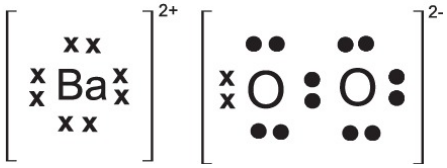
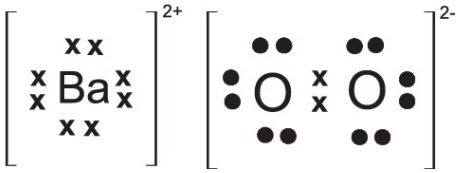
[6]

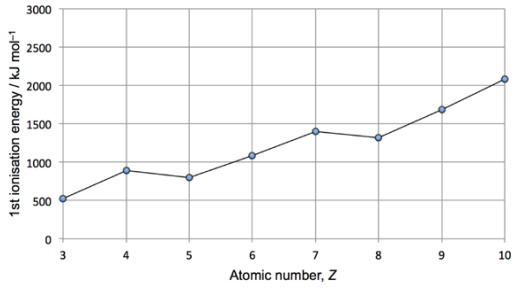
END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1		i	**Reaction 1:** $Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$ ✓ **Reaction 2:** $Ba_3N_2 + 6H_2O \rightarrow 3Ba(OH)_2 + 2NH_3$ Correct products ✓ Balancing ✓	3	Ignore state symbols **Examiner's Comments** Both equations were relatively challenging. Reaction 1 was a direct question about reactions of Group 2 elements. Reaction 2 demanded a higher level of application based upon information given. Many identified the alkaline gas as NH3, but then incorrectly assumed that the alkaline solution was BaO instead of $Ba(OH)_2$. Weaker candidates suggested equations with hypothetical species that could not have born any relation to formulae that they might have encountered before.
		ii	Giant ionic (lattice) ✓	1	**ALLOW** 'Giant lattice with ionic bonds' **ALLOW** 'Giant ionic bonds' **DO NOT ALLOW** 'atoms or molecules or dipoles' **Examiner's Comments** This question was relatively well answered, although some candidates did negate the mark by referring to molecules of Ba_3N_2 either directly or by indirect reference to intermolecular forces.
		iii		1	Ba must have a 2+ charge Ba can be with or without octet. **IGNORE** lack of charge on O_2^{2-} ion

Question	Answer/Indicative content	Marks	Guidance
			O_2^{2-} ion to have 12 electrons belonging to O atoms + 2 other electrons of another symbol. The 2 other electrons must match Ba if Ba has an octet.
	OR		
			If O electrons are shown as 6 of one symbol and 6 of another, each O must have six electrons of the same symbol
	OR		
			**ALLOW**
	OR		
			**OR**
			
			Examiner's Comments This question was designed to be difficult, but many candidates rose to the challenge. Weaker candidates simply drew a *'dot-and-cross'* diagram for BaO_2 in which they treated each oxygen species as an oxide ion each having a single negative charge. Many stronger candidates did realise from the structure given in the question that there was only a single bond between the two oxygen atoms, as was clear from their suggested diagram. Only the stronger candidates managed to incorporate correctly the electrons from barium, to arrive at a correct version of the bonding of BaO_2.

Question			Answer/Indicative content	Marks	Guidance
			Total	5	
2	a	i	$2Ca + O_2 \rightarrow 2CaO$ ✓	1	**ALLOW** multiples e.g. $Ca + ½O_2 \rightarrow CaO$ **IGNORE** state symbols **Examiner's Comments** This straightforward equation was well known.
		ii	Thermal decomposition ✓	1	**Examiner's Comments** Some candidates omitted 'thermal' and so did not secure the mark while others wrote out the equation rather than stating the type of reaction.
	b		Effervescence **OR** fizzing **OR** bubbling **OR** gas produced **AND** The solid **OR** calcium **OR** the metal would dissolve **OR** disappear **OR** a (colourless) solution forms ✓ $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$ ✓	2	**IGNORE** 'hydrogen produced' but **ALLOW** 'hydrogen gas produced' **DO NOT ALLOW** an incorrectly named gas (eg CO_2) produced **ALLOW** multiples **IGNORE** state symbols **Examiner's Comments** In the observation section most candidates noted effervescence but few then added the necessary observation of the calcium dissolving often despite $Ca(OH)_2(aq)$ appearing in the equation. The equation was well answered generally, although CaOH was not an uncommon species.
			Total	4	

Question			Answer/Indicative content	Marks	Guidance
3		i	$Sr(s) + 2H_2O(l) \rightarrow Sr(OH)_2(aq) + H_2(g)$ **Note: all** state symbols required	1	**allow** multiples
		ii	$n(Sr) = n(Sr^{2+}) = 0.200 / 87.6 = 2.28 \times 10^{-3}$ (1) $[Sr^{2+}] = 2.28 \times 10^{-3} \times 1000 / 250 = 9.13 \times 10^{-3}$ (mol dm^{-3}) (1)	2	**allow ecf**
		iii	Greater volume with Ca **AND** larger amount / more moles of Ca **OR** A_r Ca is smaller (1) $n(Ca) = 0.200/40.1 = 0.005(0)$ (mol) (1) volume H_2 with Sr = 55 cm^3 **AND** volume with Ca = 120 cm^3 **OR** 65 cm^3 more H_2 with Ca (1)	3	**ora** **allow** values up to calculator values **allow** volumes ± 1 cm^3
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
4		i	 Increase from 5–7 (B→N) **AND** 5 below 4 but above 3 ✓ 8(O) below 7 and 9 **AND** above 6 ✓	2	**ALLOW** if points correct but straight lines not drawn
		ii	Trend described down group *Atomic radius* larger atomic radius **OR** more shells ✓ *Effect of nuclear charge/shielding* Increased nuclear charge is outweighed by increased distance/shielding **OR** **more/increased** shielding ✓ *Reactivity **AND** Nuclear attraction* Reactivity increases **AND** less nuclear attraction **OR** less attraction on electrons ✓	3	*FULL ANNOTATIONS MUST BE USED* _ **ALLOW ORA** but comparison should be used for each mark. **ALLOW** ‘more/higher energy levels’ **ALLOW** ‘electrons further from nucleus’ **ALLOW** ‘different shell’ **OR** ‘new shell’ **IGNORE** more orbitals **OR** more sub-shells **ALLOW more** electron repulsion from inner shells **IGNORE** responses with no comparison e.g. ‘is shielding’ Mark requires statement that reactivity increases **AND** reason **IGNORE** nuclear charge/effective nuclear charge **ALLOW** ‘less nuclear pull’ **OR** ‘electrons held less tightly’

Question			Answer/Indicative content	Marks	Guidance
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
5	a		$n(H_2O)$ = 27.55/18.0 = 1.5306 (mol) ✓ $n((NH_4)_2Fe(SO_4)_2)$ = 72.45/284.0 = 0.2551 (mol) ✓ whole number ratio of $(NH_4)_2Fe(SO_4)2$: H_2O = 0.2551 : 1.5306 = 1 : 6 **OR** x = 6 ✓	3	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW** calculator value or rounding to two significant figures or more but **IGNORE** 'trailing zeroes' if wrong *M* produces such numbers throughout. **ALLOW ECF** If no working, **ALLOW** 1 mark for x = 6.
	b	i	To neutralise acidic soil ✓	1	

Question			Answer/Indicative content	Marks	Guidance
		ii	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Describes practical details of tests and observations that allows all four ions to be identified **AND** Attempts associated equations, with most correct. *There is a well-developed line of reasoning and the method is clear and logically structured. The information presented is relevant and substantiated by observations from the tests described and practical details.* **Level 2 (3–4 marks)** Describes most practical details of tests including the observations that allows most ions to be identified **AND** Attempts associated equations, with some correct. *There is a line of reasoning presented and the method has some structure. The information presented is in the most-part relevant and supported by some evidence of observations from the tests described but practical details may be absent.* **Level 1 (1–2 marks)** Describes some of the practical details of tests and observations would only allow some ions to be identified. **OR** Attempts associated equations, with some correct. *The information is basic and the method lacks structure. The information is supported by limited evidence of the observations, the relationship to the evidence may not be clear.* **0 marks** No response or no response	6	**Indicative scientific points may include** **Practical details:** • Sample stirred with water and mixture filtered. • SO_4^{2-}, Fe^{2+}, NH_4^+ tests on filtrate. • CO_3^{2-} test on residue or garden product **Tests and associated equations:** CO_3^{2-} test: *Test:* Add nitric acid. *Observation:*effervescence. *Equation:* $CaCO_3 + 2H^+ \rightarrow Ca^{2+} + CO_2 + H_2O$ ***ALLOW*** $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ ***OR*** overall equation of $CaCO_3$ and an acid. SO_4^{2-}test: Add $BaCl_2(aq)/Ba(NO_3)_2(aq)/Ba^{2+}(aq)$. Observation: white precipitate. Equation: $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$ Fe^{2+} test: Test: Add NaOH(aq) Observation: green precipitate Equation: $Fe^{2+} + 2OH_- \rightarrow Fe(OH)_2$ NH_4^+ test: *Test:* Add NaOH(aq) and warm *Observation:* gas turns red litmus indicator blue *Equation:* $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$

Question			Answer/Indicative content	Marks	Guidance
			worthy of credit.		
			Total	10	