Answer **all** the questions.

1 The element titanium, Ti, atomic number 22, is a metal that is used in the aerospace industry for both airframes and engines.

A sample of titanium for aircraft construction was analysed using a mass spectrometer and was found to contain three isotopes, ^{46}Ti, ^{47}Ti and ^{48}Ti. The results of the analysis are shown in Table 1.1 below.

Table 1.1

isotope	^{46}Ti	^{47}Ti	^{48}Ti
relative isotopic mass	46.00	47.00	48.00
percentage composition	8.9	9.8	81.3

(a) **(i)** Explain the term *isotopes*.

....

....[1]

(ii) Complete the table below for atoms of two of the titanium isotopes.

isotope	protons	neutrons	electrons
^{46}Ti			
^{47}Ti			

[2]

(b) Using the information in Table 1.1, calculate the relative atomic mass of this sample of titanium.

Give your answer to three significant figures.

[2]

(c) Complete the electronic configuration of a titanium atom.

$1s^22s^22p^6$ ....[1]

(d) Titanium has metallic bonding.

(i) Explain what is meant by *metallic bonding*. Use a diagram in your answer.

....

....[2]

(ii) How does metallic bonding allow titanium to conduct electricity?

....

....[1]

(e) A student reacted 1.44 g of titanium with chlorine to form 5.70 g of a chloride **X**.

(i) How many moles of Ti atoms were reacted?

[1]

(ii) How many moles of Cl atoms were reacted?

[2]

(iii) Determine the empirical formula of **X**.

[1]

(iv) Construct a balanced equation for the reaction between titanium and chlorine.

....[1]

(v) At room temperature, **X** is a liquid which does **not** conduct electricity. What does this information suggest about the bonding and structure in **X**?

....

....

....[2]

[Total: 16]

2 The Group 2 element radium, Ra, is used in medicine for the treatment of cancer. Radium was discovered in 1898 by Pierre and Marie Curie by extracting radium chloride from its main ore pitchblende.

(a) Predict the formula of radium chloride.

....[1]

(b) Pierre and Marie Curie extracted radium from radium chloride by reduction.
Explain what is meant by *reduction*, using this reaction as an example.

....

....[2]

(c) Radium reacts vigorously when added to water.

$$Ra(s) + 2H_2O(l) \longrightarrow Ra(OH)_2(aq) + H_2(g)$$

(i) Use the equation to predict **two** observations that you would **see** during this reaction.

....

....[2]

(ii) Predict a pH value for this solution.

....[1]

(d) Reactions of the Group 2 metals involve removal of electrons. The electrons are removed more easily as the group is descended and this helps to explain the increasing trend in reactivity.

(i) The removal of one electron from each atom in 1 mole of gaseous radium atoms is

called the ....[2]

The equation for this process in radium is:

....[2]

(ii) Atoms of radium have a greater nuclear charge than atoms of calcium.

Explain why, despite this, **less** energy is needed to remove an electron from a radium atom than from a calcium atom.

....

....

....

....[3]

[Total: 13]

3 A student had a stomach-ache and needed to take something to neutralise excess stomach acid. He decided to take some Milk of Magnesia, which is an aqueous suspension of magnesium hydroxide, $Mg(OH)_2$.

(a) The main acid in the stomach is hydrochloric acid, $HCl(aq)$, and the unbalanced equation for the reaction that takes place with Milk of Magnesia is shown below.

$$.....Mg(OH)_2(s) + ...HCl(aq) \longrightarrow .....MgCl_2(aq) + ...H_2O(l)$$

Balance the equation by adding numbers where necessary in the unbalanced equation above. [1]

(b) The student's stomach contained 500 cm^3 of stomach fluid with an acid concentration of 0.108 mol dm^{-3}. The student swallowed some Milk of Magnesia containing 2.42 g $Mg(OH)_2$. He wondered whether this dose was sufficient to neutralise the stomach acid.

Assume that all the acid in the stomach fluid was 0.108 mol dm^{-3} hydrochloric acid.

(i) How many moles of HCl were in the 500 cm^3 of stomach fluid?

[1]

(ii) Calculate the mass of $Mg(OH)_2$ necessary to neutralise this stomach fluid.

[3]

(iii) Determine whether the student swallowed too much, too little, or just the right amount of Milk of Magnesia to neutralise the stomach acid.

....

....[1]

(c) Chewing chalk has been used for many years to combat excess stomach acid and indigestion tablets often contain calcium carbonate, $CaCO_3$. Suggest, with the aid of an equation, how these tablets work.

....

....

....[2]

[Total: 8]

4 Chlorine is used in the preparation of many commercially important materials such as bleach and iodine.

(a) Bleach is a solution of sodium chlorate(I), NaOC*l*, made by dissolving chlorine in aqueous sodium hydroxide.

$$Cl_2(g) + 2NaOH(aq) \longrightarrow NaOCl(aq) + NaCl(aq) + H_2O(l)$$

Determine the changes in oxidation number of chlorine during the preparation of bleach and comment on your results.

....

....

....

....[3]

(b) Iodine is extracted commercially from seawater with chlorine gas. Seawater contains very small quantities of dissolved iodide ions, which are oxidised to iodine by the chlorine gas.

(i) Write an ionic equation for the reaction that has taken place.

....[2]

(ii) Use your understanding of electronic structure to explain why chlorine is a stronger oxidising agent than iodine.

....

....

....

....[2]

[Total: 7]

5 In this question, one mark is available for the quality of use and organisation of scientific terms.

Nitrogen and oxygen are elements in Period 2 of the Periodic Table. The hydrogen compounds of oxygen and nitrogen, H_2O and NH_3, both form hydrogen bonds.

(a) **(i)** Draw a diagram containing two H_2O molecules to show what is meant by *hydrogen bonding*. On your diagram, show any lone pairs present and relevant dipoles.

[3]

(ii) State and explain **two** anomalous properties of water resulting from hydrogen bonding.

....

....

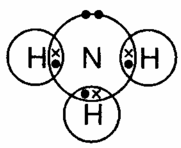
....

....

....

....[4]

(b) The '*dot-and-cross*' diagram of an ammonia molecule is shown below.



Predict, with reasons, the bond angle in an ammonia molecule.

....

....

....

....

....

....[4]

(c) The atomic radii of nitrogen and oxygen are shown below.

element	nitrogen	oxygen
atomic radius /nm	0.075	0.073

Explain why a nitrogen atom is larger than an oxygen atom.

....

....

....

....

....

....

....

....

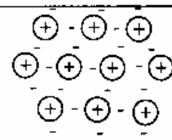
....[4]

Quality of Written Communication [1]

[Total: 16]

END OF QUESTION PAPER

Abbreviations, annotations and conventions used in the Mark Scheme	/ = alternative and acceptable answers for the same marking point ; = separates marking points NOT = answers which are not worthy of credit ( ) = words which are not essential to gain credit ___ = (underlining) key words which **must** be used to gain credit ecf = error carried forward AW = alternative wording ora = or reverse argument	

Question	Expected Answers	Marks
1 (a) (i)	atoms of same element/same atomic number….. with different numbers of neutrons/different masses ✓	[1]
(ii)	isotope protons neutrons electrons ^{46}Ti 22 24 22 ✓ ^{47}Ti 22 25 22 ✓	[2]
(b)	$A_r = \frac{(46 \times 8.9) + (47 \times 9.8) + (48 \times 81.3)}{100}$ / 47.724 ✓ = 47.7 ✓	[2]
(c)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$ ✓	[1]
(d) (i)	 positive ions ✓ electrons ✓ (must be labelled)	[2]
(ii)	electrons move ✓	[1]
(e) (i)	moles Ti = 1.44/47.9 = 0.0301 mol/0.03 mol (accept use of answer from (b))	[1]
(ii)	mass of Cl = 5.70-1.44 = 4.26 g ✓ moles Cl = 4.26/35.5 = 0.120 mol ✓ 5.70/35.5 = 0.161 mol gets 1 mark	[2]
(iii)	Ti:Cl = 0.0301 : 0.12 = 1:4. Empirical formula = $TiCl_4$ ✓ 0.0301 : 0.161 mol gives $TiCl_5$ for 1 mark	[1]
(iv)	$Ti + 2Cl_2 \longrightarrow TiCl_4$ ✓ (ecf possible from (iii))	[1]
(v)	covalent ✓ simple molecular ✓	[2]
		Total: 16

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Question	Expected Answers	Marks
2 (a)	$RaCl_2$ ✓	[1]
(b)	Reduction is gain of electrons/decrease in oxidation number ✓ Ra^{2+} gains 2 electrons $\longrightarrow$ Ra/ Oxidation state goes from +2 in $RaCl_2 \longrightarrow$ 0 in Ra ✓	[2]
(c) (i)	effervescence/bubbles ✓ Ra disappears/dissolves ✓	[2]
(ii)	8-14 ✓	[1]
(d) (i)	First ✓ ionisation (energy) ✓	[2]
	$Ra(g) \longrightarrow Ra^{+}(g) + e^{-}$ ✓✓ 1 mark for equation 1 mark for state symbols '–' not required on 'e'	[2]
(ii)	atomic radii of Ra > atomic radii of Ca/ Ra has electrons in shell further from nucleus than Ca/ Ra has more shells ✓ Ra has **more** shielding than Ca ✓ :'***more'*** *is essential* Ra electron held less tightly/less attraction on electron ✓	[3]
		Total: 13

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Question	**Expected Answers**	**Marks**
3 (a)	...$Mg(OH)_2(s)$ + **2**...$HCl(aq)$ → ....$MgCl_2(aq)$ + **2**...$H_2O(l)$ ✓	[1]
(b) (i)	moles HCl = 0.108 x 500/1000 = 0.054 ✓	[1]
(ii)	moles $Mg(OH)_2$ = ½ x moles HCl = 0.027 ✓ molar mass of $Mg(OH)_2$ = 24.3 + 17x2 = 58.3 ✓ (do not penalise 24) mass $Mg(OH)_2$ = 58.3 x 0.027 = 1.57 g / 1.5741 g ✓ (accept ans from (ii) x 0.027 = 1.566 g) (mass $Mg(OH)_2$ of 3.15 g would score 2 marks as 'ecf' as molar ratio has not been identified)	[3]
(iii)	Too much **if** 2.42 g (dose) > ans to (ii) ✓ (If answer to (ii) > 2.42 g then 'correct' response here would be 'Not enough'	[1]
(c)	$CaCO_3$ reacts with (or neutralises) HCl ✓ (or $CaCO_3$ + HCl in an equation) $CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$ ✓ (correct equation would score both marks)	[2]
		Total: 8

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Question	**Expected Answers**	**Marks**
4 (a)	$Cl_2(g) \longrightarrow NaOCl(aq)$: $Cl(0) \longrightarrow Cl(+1)$ ✓ $Cl_2(g) \longrightarrow NaCl(aq)$: $Cl(0) \longrightarrow Cl(-1)$ ✓ Cl is both oxidised (in forming NaOCl) and reduced (in forming NaCl)/disproportionation Cl reduces Cl to form NaCl AND Cl oxidises Cl in forming NaOCl ✓	[3]
(b) (i)	$Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$ ✓✓ 1 mark for species. 1 mark for balancing	[2]
(ii)	Cl atom is smaller/has less shells ✓ electron to be captured will be attracted more ✓	[2]
		Total: 7

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Question	Expected Answers	Marks
5 (a) (i)	H bonding from O of 1 H_2O molecule to H of another ✓ dipoles shown ✓ with lone pair involved in bond ✓	[3]
(ii)	Two properties from: Ice is lighter than water/ max density at 4°C ✓ *explanation:* H bonds hold H_2O molecules apart / open lattice in ice / H-bonds are longer ✓ Higher melting/boiling point than expected ✓ *explanation:* strength of H bonds that need to be broken ✓ *must imply that intermolecular bonds are broken* High surface tension/viscosity ✓ *explanation* strength of H bonds across surface ✓	[4]
(b)	NH_3: 107° ✓ (range 106 – 108°) electron pairs repel other electron pairs ✓ lone pair has more repulsion ✓ electron pairs get as far apart as possible ✓	[4]
(c)	N has less protons than O (ora) ✓ electrons are in same shell /have same or similar shielding ✓ weaker nuclear attraction in N (ora) ✓ shell drawn in less by nuclear charge in N (ora) ✓ watch for distinction between nuclear **attraction** and nuclear **charge** in candidates' scripts.	[4]
	QoWC: links together two statements in at least two of the sections (a)(ii), (b) and (c) ✓	[1]
		Total: 16