F321: Atoms, Bonds and Groups
Group 2

87 Marks

1. Magnesium and strontium are in Group 2 of the Periodic Table.

(i) When reacted with oxygen, magnesium forms a white powder called magnesium oxide.

Write the equation for the reaction of magnesium with oxygen.

.....

[1]

(ii) Magnesium reacts with dilute acids.

Describe what you would expect to see when magnesium ribbon is added to an excess of dilute hydrochloric acid.

.....

.....

[2]

(iii) Strontium reacts in a similar way to magnesium.

Describe **one** difference you might observe if strontium, instead of magnesium, was reacted with dilute hydrochloric acid.

.....

[1]

[Total 4 marks]

2. The Group 2 element barium, Ba, is silvery white when pure but blackens when exposed to air.

The blackening is due to the formation of both barium oxide and barium nitride. The nitride ion is N^{3-}.

(a) Predict the formula of:

barium oxide ..... barium nitride .....

[2]

(b) A 0.11 g sample of pure barium was added to 100 cm^3 of water.

$Ba(s) + 2H_2O(l) \rightarrow Ba(OH)_2(aq) + H_2(g)$

(i) Show that 8.0×10^{-4} mol of Ba were added to the water.

[1]

(ii) Calculate the volume of hydrogen, in cm^3, produced at room temperature and pressure.

volume = ... cm^3

[1]

(iii) Calculate the concentration, in mol dm^{-3}, of the $Ba(OH)_2(aq)$ solution formed.

concentration = ... mol dm^{-3}

[1]

(iv) State the approximate pH of the $Ba(OH)_2(aq)$ solution.

.....

[1]

(c) A student repeated the experiment in (b) using a 0.11 g sample of barium that had blackened following exposure to the air.

Suggest why the volume of hydrogen produced would be slightly less than the volume collected using pure barium.

.....

.....

.....

[1]

(d) Describe and explain the trend, down the group, in the reactivity of the Group 2 elements with water.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[5]

[Total 12 marks]

3. When heated strongly, $CaCO_3$ decomposes.

Write an equation, including state symbols, for the thermal decomposition of $CaCO_3$.

.....

[Total 2 marks]

4. Calcium oxide reacts with water and with nitric acid.

State the formula of the calcium compound formed when:

(i) calcium oxide reacts with water, ...

[1]

(ii) calcium oxide reacts with nitric acid. .....

[1]

[Total 2 marks]

5. A student prepared an aqueous solution of calcium chloride by reacting calcium with hydrochloric acid.

$$Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$$

(i) Using oxidation numbers, show that this is a redox reaction.

.....

.....

.....

.....

.....

[2]

(ii) The student had added the exact amount of calcium required to react with the hydrochloric acid used. After carrying out the experiment, the student accidentally added some more calcium. The student was surprised that the extra calcium still reacted.

Explain this observation. Include an equation in your answer.

.....

.....

.....

.....

.....

.....

[2]

[Total 4 marks]

6. Barium reacts with water in a redox reaction.

$$Ba(s) + 2H_2O(l) \rightarrow Ba(OH)_2(aq) + H_2(g)$$

(i) Explain, in terms of electrons, what is meant by oxidation.

.....

[1]

(ii) Which element has been oxidised in this reaction? Deduce the change in its oxidation number.

element .....

oxidation number changes from …… to……

[2]

[Total 3 marks]

7. Magnesium reacts with oxygen to form magnesium oxide.

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

(i) Use oxidation numbers to show that oxygen has been reduced in its reaction with magnesium.

.....

.....

.....

[2]

(ii) Draw a '*dot-and-cross*' diagram to show the arrangement of electrons in magnesium oxide. Show outer electron shells only and include any charges.

[2]

[Total 4 marks]

8. Old samples of magnesium oxide become contaminated with magnesium carbonate.

(i) Suggest how this contamination takes place.

.....

.....

[1]

(ii) A student added an excess of hydrochloric acid to an old sample of magnesium oxide that is contaminated with magnesium carbonate.

State **two** observations that the student would make.

.....

.....

[2]

(iii) Explain, with the aid of equations, why the resulting solution contained only one dissolved compound of magnesium.

.....

.....

.....

.....

.....

[3]

[Total 6 marks]

9. The elements calcium and strontium in Group 2 of the Periodic Table both react with water.

A student reacted 0.20 g of calcium and 0.20 g of strontium separately with 250 cm^3 of water. The student measured the volume of gas produced from each reaction.

The student's results are shown below.

metal	calcium	strontium
volume of gas / cm^3	120	55

(i) Name the gas produced.

.....

[1]

(ii) Write a balanced equation for the reaction of strontium with water.

.....

[1]

(iii) Explain why the student obtained different volumes of gas by reacting water with the same mass of calcium and strontium.

.....

.....

.....

.....

[2]

(iv) Predict the pH of the solutions formed in each of these reactions.

.....

[1]

[Total 5 marks]

10. In their reactions, calcium and strontium each lose electrons to form ions with a 2+ charge. The first and second ionisation energies of calcium and strontium are shown below.

	1st ionisation energy / kJ mol^{-1}	2nd ionisation energy / kJ mol^{-1}
calcium	590	1145
strontium	550	1064

(i) Write an equation, with state symbols, to represent the **second** ionisation energy of calcium.

.....

[2]

(ii) Why are the second ionisation energies of calcium and strontium greater than their first ionisation energies?

.....

.....

.....

[1]

(iii) Explain why the first and second ionisation energies of strontium are less than those of calcium.

.....

.....

.....

.....

.....

.....

[3]

[Total 6 marks]

11. Carbon dioxide can be prepared easily in the laboratory by the action of heat on most carbonates. Construct an equation to illustrate this reaction.

.....

[Total 1 mark]

12. A student prepared an aqueous solution of calcium chloride by reacting calcium with hydrochloric acid. Calcium chloride contains Ca^{2+} and Cl^- ions.

(a) Complete and balance the following equation for this reaction.

……Ca(s) + …… HCl(aq) → ……. $CaCl_2$(aq) + ……

[2]

(b) This is a redox reaction.
Use oxidation states to show that calcium has been oxidised.

.....

.....

.....

[2]

[Total 4 marks]

13. To prepare the aqueous calcium chloride, the student added the exact amount of calcium so that all the hydrochloric acid had reacted. She used 50 cm^3 of 2.0 mol dm^{-3} HC*l*.

(i) How many moles of HC*l* had she used?

[1]

(ii) Calculate the mass of calcium that she used.

[2]

(iii) The student added some more calcium and she was surprised that a reaction still took place.

- Explain this observation.
- Write a balanced equation for this reaction.

.....

.....

.....

[3]

[Total 6 marks]

14. 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]

[Total 3 marks]

15. Radium reacts vigorously when added to water.

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

(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]

[Total 3 marks]

16. 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.

.....

.....

.....

[Total 2 marks]

17. The Group 2 metal strontium, Sr, is very reactive.

Strontium metal is stored under oil and, when exposed to air, the shiny surface of the strontium becomes dull.

Predict, with an equation, what reaction takes place when strontium is exposed to air.

.....

.....

.....

[Total 2 marks]

18. The reaction of strontium with water is a redox reaction. A student reacted 0.438 g of strontium with 200 cm^3 of water.

$$Sr(s) + 2H_2O(l) \rightarrow Sr(OH)_2(aq) + H_2(g)$$

(i) Use oxidation numbers to show that strontium has been oxidised in this reaction.

.....

.....

.....

[2]

(ii) Calculate how many moles of Sr were reacted.

A_r: Sr, 87.6

answer ..... mol

[1]

(iii) Calculate the volume, in dm^3, of $H_2(g)$ produced. You can assume that, under the experimental conditions, 1.00 mol of $H_2(g)$ has a volume of 24.0 dm^3.

answer ..... dm^3

[1]

(iv) Calculate the concentration, in mol dm^{-3}, of the $Sr(OH)_2$ produced.

answer ..... mol dm^{-3}

[1]

[Total 5 marks]

19. An ore of strontium contains strontium carbonate, $SrCO_3$.

To obtain metallic strontium,

- the $SrCO_3$ is converted into strontium oxide, SrO;
- SrO is then reduced to produce strontium.

(i) Suggest how strontium carbonate is converted into strontium oxide.

.....

[1]

(ii) Aluminium can be used to reduce strontium oxide.

Balance the equation below for this conversion.

..... $SrO(s)$ + ... $Al(s) \rightarrow$ ..... $Sr(s)$ + ... $Al_2O_3(s)$

[1]

(iii) A chemical company receives an order to supply 100 tonnes of strontium. The company needs to work out how much ore to process

The ore typically contains 2% by mass of $SrCO_3$.

Calculate the mass of ore that the company would need in order to produce 100 tonnes of strontium.

1 tonne = 10^6 g

[3]

(iv) Suggest how the company could minimise the environmental impact of strontium production from the ore.

.....

.....

[1]

[Total 6 marks]

20. This question is about elements and compounds of Group 2 of the Periodic Table.

When calcium is added to water, a vigorous reaction takes place, releasing hydrogen gas.

$$Ca(s) + 2H_2O(l) \rightarrow Ca\{OH)_2(aq) + H_2(g)$$

(i) Suggest a value for the pH of the solution formed in this reaction.

.....

[1]

(ii) Complete the electronic configuration of calcium in

$Ca(s)$ $1s^2 2s^2 2p^6$ .....

$Ca(OH)_2(aq)$ $1s^2 2s^2 2p^6$ .....

[2]

[Total 3 marks]

21. When barium metal is added to water, the reaction taking place is much more vigorous than with calcium.

Explain why barium is more reactive than calcium.

.....

.....

.....

.....

.....

.....

[Total 4 marks]