

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname *StemUp Model Solution*

Forename(s)

Candidate signature

INTERNATIONAL AS CHEMISTRY (9620)

Unit 1: Inorganic 1 and Physical 1

Tuesday 14 May 2019

07:00 GMT

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL	



J U N 1 9 C H O 1 0 1

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

0 1

Titanium is an element that has several isotopes.

0 1 . 1

State why titanium is in the d block of the Periodic Table.

[1 mark]

Its outer (highest energy) electrons are in the 3d sub-shell (the d sub-shell is the one being filled).

0 1 . 2

The mass number of an isotope of titanium is 49

Deduce the number of **each** of the fundamental particles in this isotope of titanium.

[2 marks]

22 protons and 22 electrons

49 - 22 = 27 neutrons

The abundance of each isotope in a sample of titanium can be determined in a time of flight (TOF) mass spectrometer. The first stage of the process is ionisation by electron impact.

0 1 . 3

Write an equation, including state symbols, to show this ionisation.

[1 mark]

$Ti(g) \rightarrow Ti^+(g) + e^-$

0 1 . 4

Give **two** reasons why the sample must be ionised.

[2 marks]

Reason 1 *So the ions can be accelerated by (attracted to) the negative plate.*

Reason 2 *So the ions can be detected (they produce a current at the detector).*



0 1 . 5

Complete the full electron configuration of a Ti^+ ion.

[1 mark]

 $1s^2$ $2s^2 2p^6 3s^2 3p^6 3d^2 4s^1$

0 1 . 6

A sample of titanium contains three isotopes, ^{46}Ti , ^{48}Ti and ^{49}Ti , in a ratio of 2:9:1Calculate the relative atomic mass of this sample of titanium.
Give your answer to one decimal place.

[2 marks]

$$A_r = [(46 \times 2) + (48 \times 9) + (49 \times 1)] \div (2 + 9 + 1)$$

$$A_r = (92 + 432 + 49) \div 12 = 573 \div 12 = 47.75$$

$$A_r = 47.8 \text{ (1 d.p.)}$$

Relative atomic mass 47.8

Question 1 continues on the next page

Turn over ►



01.7

Another sample of titanium, containing a different isotope, is analysed in the TOF mass spectrometer.

The ion of this isotope takes 2.863×10^{-6} s to travel down the 1.570 m flight tube. The kinetic energy of this titanium ion is 1.248×10^{-14} J

Calculate the mass, in g, of this titanium isotope.

$$t = d \sqrt{\frac{m}{2E}}$$

t = time / s

d = distance / m

m = mass / kg

E = kinetic energy / J

[3 marks]

$$t = d\sqrt{m \div 2E} \quad \text{so} \quad m = 2Et^2 \div d^2$$

$$m = 2 \times 1.248 \times 10^{-14} \times (2.863 \times 10^{-6})^2 \div (1.570)^2$$

$$m = 8.300 \times 10^{-26} \text{ kg}$$

$$m = 8.300 \times 10^{-26} \times 1000 = 8.300 \times 10^{-23} \text{ g}$$

Mass 8.300×10^{-23} g

01.8

Use your answer to Question 01.7 to calculate the mass number of the titanium isotope.

Show your working.

The Avogadro constant, $L = 6.022 \times 10^{23} \text{ mol}^{-1}$

(If you were unable to answer Question 01.7 you should use the value 1.010×10^{-22} g This is not the correct answer.)

[2 marks]

$$\text{mass of 1 mol} = 8.300 \times 10^{-23} \times 6.022 \times 10^{23} = 49.98 \text{ g}$$

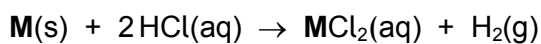
$$\text{mass number} = 50 \text{ (must be a whole number)}$$

Mass number 50



0 2

A metal, **M**, reacts with hydrochloric acid as shown in the equation.



When 0.500 g of **M** reacts with an excess of hydrochloric acid, 314 cm³ of hydrogen are produced, measured at 303 K and 100 kPa

Calculate the relative atomic mass of **M**.
Identify **M**.

The gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

[5 marks]

$$V = 314 \text{ cm}^3 = 314 \times 10^{-6} = 3.14 \times 10^{-4} \text{ m}^3$$

$$p = 100 \text{ kPa} = 100\,000 \text{ Pa}$$

$$n = pV \div RT = (100\,000 \times 3.14 \times 10^{-4}) \div (8.31 \times 303)$$

$$n(\text{H}_2) = 31.4 \div 2517.9 = 0.01247 \text{ mol (0.0125)}$$

$$n(\text{M}) = n(\text{H}_2) = 0.01247 \text{ mol (1 : 1 ratio)}$$

$$A_r = \text{mass} \div \text{moles} = 0.500 \div 0.01247 = 40.1$$

A_r of 40.1 matches calcium, which forms MCl_2

Relative atomic mass 40.1

Identity of **M** calcium (Ca)

5

Turn over ►



0 3

Metal hydrides are compounds formed when metals react with hydrogen.

0 3 . 1

Lithium hydride is an ionic compound. The formula of the hydride ion is H^-

Write an equation for the formation of lithium hydride from its elements.

[1 mark]



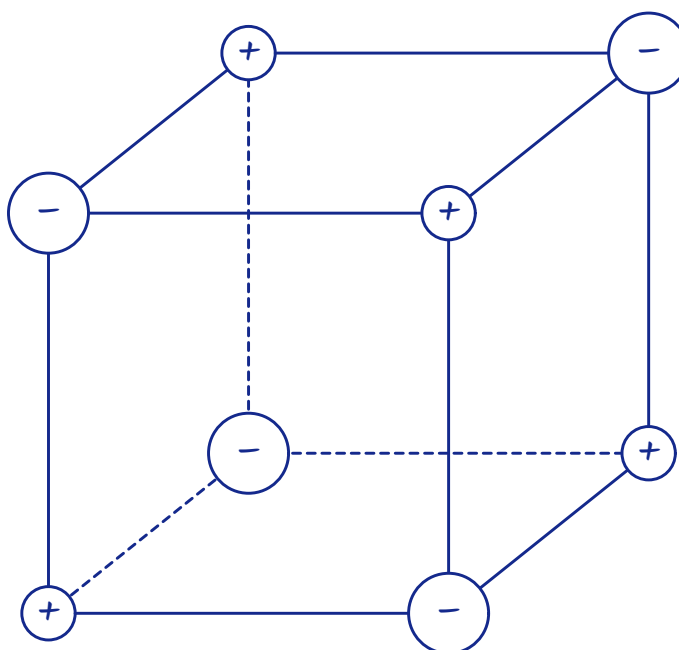
0 3 . 2

Lithium hydride has a similar structure to sodium chloride.

Draw a diagram to show the three-dimensional (3D) structure of lithium hydride. You should show at least eight particles.

In your diagram, show the charge on each ion.

[2 marks]



Key: $\oplus = \text{Li}^+$
 $\ominus = \text{H}^-$



0 3 . 3

At low temperature aluminium hydride exists as molecules of AlH_3

Name the shape of the aluminium hydride molecule and state its bond angle.
Identify the strongest type of force between molecules of AlH_3

[3 marks]Name of shape trigonal planarBond angle 120° Strongest force van der Waals forces (induced dipole to dipole)

Lithium hydride reacts with aluminium hydride to form the ionic compound
lithium tetrahydridoaluminate(III), LiAlH_4

0 3 . 4

In this reaction, an aluminium hydride molecule reacts with a hydride ion to form the AlH_4^- ion.

Explain how the H^- ion and AlH_3 molecule form a bond to make the AlH_4^- ion.
Name this type of bond.

[2 marks]

Explanation The H^- ion donates its lone pair of electrons (both electrons
in the bond) to the aluminium atom, which has only six outer electrons.

Type of bond co-ordinate (dative covalent) bond

0 3 . 5

Lithium tetrahydridoaluminate(III) reacts with oxygen to form lithium oxide, aluminium oxide and water.

Write an equation for this reaction.

[1 mark]

Turn over ►



0 4

Sodium hydrogencarbonate (NaHCO_3) reacts with hydrochloric acid as shown.



A student prepared 250 cm^3 of aqueous sodium hydrogencarbonate of concentration $0.150 \text{ mol dm}^{-3}$

0 4 . 1

Calculate the mass, in g, of sodium hydrogencarbonate needed to prepare 250 cm^3 of a $0.150 \text{ mol dm}^{-3}$ solution.

[2 marks]

$$n(\text{NaHCO}_3) = 0.150 \times (250 \div 1000) = 0.0375 \text{ mol}$$

$$M_r(\text{NaHCO}_3) = 23.0 + 1.0 + 12.0 + (3 \times 16.0) = 84.0$$

$$\text{mass} = 0.0375 \times 84.0 = 3.15 \text{ g}$$

Mass 3.15 g

Four 25.0 cm^3 samples of the sodium hydrogencarbonate solution were titrated with hydrochloric acid.

The results are shown in **Table 1**.

Table 1

	Rough	1	2	3
Final burette reading / cm^3	32.0	31.45	31.75	31.50
Initial burette reading / cm^3	0.0	0.40	0.55	0.20
Titre / cm^3	32.0	31.05	31.20	31.30

0 4 . 2

Complete **Table 1**.

Calculate the mean titre.

[2 marks]

titres 2 and 3 are concordant (within 0.10 cm^3):

$$\text{mean} = (31.20 + 31.30) \div 2 = 31.25 \text{ cm}^3$$

Mean titre 31.25 cm^3



0 4 . 3

Use your answer to Question **04.2** to calculate the concentration, in mol dm^{-3} , of the hydrochloric acid.

[2 marks]

$$n(\text{NaHCO}_3) \text{ in } 25.0 \text{ cm}^3 = 0.150 \times (25.0 \div 1000) = 3.75 \times 10^{-3} \text{ mol}$$

$$1 : 1 \text{ ratio, so } n(\text{HCl}) = 3.75 \times 10^{-3} \text{ mol}$$

$$[\text{HCl}] = 3.75 \times 10^{-3} \div (31.25 \div 1000) = 0.120 \text{ mol dm}^{-3}$$

Concentration 0.120 mol dm^{-3}

0 4 . 4

During each titration, the student rinsed the inside of the conical flask with distilled water.

Explain why this rinsing improves the accuracy of each titre.

[1 mark]

It washes any droplets of solution from the walls of the flask into the reaction mixture, so all of the solutions mix and react and none is lost.

0 4 . 5

In a separate experiment, the student reacted a 75.0 cm^3 sample of $0.200 \text{ mol dm}^{-3}$ sodium hydrogencarbonate solution with hydrochloric acid until the solution was neutral.

The solution formed was evaporated to leave solid sodium chloride.

The yield of sodium chloride was 93%

Calculate the mass, in g, of sodium chloride obtained.

[3 marks]

$$n(\text{NaHCO}_3) = 0.200 \times (75.0 \div 1000) = 0.0150 \text{ mol} = n(\text{NaCl})$$

$$M_r(\text{NaCl}) = 23.0 + 35.5 = 58.5$$

$$\text{mass at 100\% yield} = 0.0150 \times 58.5 = 0.8775 \text{ g}$$

$$\text{mass at 93\% yield} = 0.8775 \times 0.93 = 0.816 \text{ g} = 0.82 \text{ g}$$

Mass 0.82 g

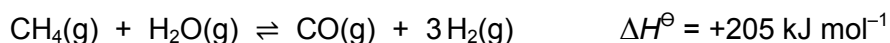
10

Turn over ►



0 5

Hydrogen is produced from methane as shown.



0 5 . 1

State how the rate of the forward reaction compares with the rate of the reverse reaction at equilibrium.

[1 mark]

The rate of the forward reaction is equal to (the same as) the rate of the reverse reaction.

0 5 . 2

Explain why an increase in temperature causes an increase in the equilibrium yield of hydrogen at constant pressure.

[2 marks]

The forward reaction is endothermic (ΔH is positive).

So the equilibrium shifts to the right, in the endothermic direction, to lower the temperature (to oppose the increase in temperature), producing more H_2 .

0 5 . 3

State and explain the effect of increasing the total pressure on the equilibrium yield of hydrogen at constant temperature.

[3 marks]

Effect on yield *The yield of hydrogen decreases.*

Explanation *There are more moles of gas on the right-hand side (4 mol) than on the left (2 mol).*

So the equilibrium shifts to the left, to the side with fewer gas moles, to decrease the pressure (to oppose the increase in pressure).



0 5 . 4

Write an expression for the equilibrium constant, K_c , for this equilibrium.

Give its units.

[2 marks]

$$K_c = \frac{[CO][H_2]^3}{[CH_4][H_2O]}$$

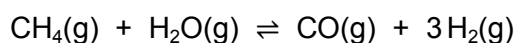
Units $\text{mol}^2 \text{dm}^{-6}$

0 5 . 5

A 1.5 mol sample of methane was heated with a 1.0 mol sample of steam in a sealed container.

At equilibrium, the mixture contained 1.2 mol of hydrogen.

Calculate the amount, in moles, of methane and of steam in this equilibrium mixture.



[2 marks]

 *H_2 formed = 1.2 mol, so CH_4 and H_2O used = $1.2 \div 3 = 0.40$ mol**methane left = $1.5 - 0.40 = 1.1$ mol**steam left = $1.0 - 0.40 = 0.60$ mol*Amount of methane 1.1 molAmount of steam 0.6 mol

10

Turn over ►



0 6

This question is about some test-tube reactions.

0 6 . 1

A student adds a few drops of barium chloride solution to some potassium sulfate solution. A white precipitate forms.

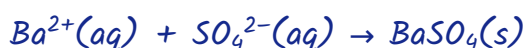
Give the formula of the white precipitate.

Write an equation for the formation of the white precipitate.

[2 marks]

Formula of precipitate BaSO₄

Equation



0 6 . 2

A student adds a few drops of concentrated sulfuric acid to a solid sodium halide. Hydrogen sulfide gas is produced.

Identify the sodium halide.

Write a half-equation for the formation of hydrogen sulfide from sulfuric acid.

State the role of sulfuric acid in the reaction.

[3 marks]

Sodium halide sodium iodide (NaI)

Half-equation



Role of sulfuric acid oxidising agent (it accepts electrons)

0 6 . 3

A student adds a few drops of silver nitrate solution to a solution of a **different** sodium halide. A precipitate forms that does not dissolve in dilute aqueous ammonia.

Identify the sodium halide.

Write an ionic equation, including state symbols, for the formation of the precipitate.

[2 marks]

Sodium halide sodium bromide (NaBr)

Ionic equation



06.4

A student adds a few drops of silver nitrate solution to another sodium halide solution.
No visible change is seen.

Give the formula of this sodium halide.

[1 mark]

NaF

8

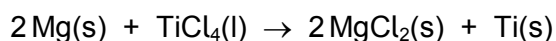
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0 7

Magnesium is used in the extraction of titanium from titanium chloride as shown.



0 7 . 1

Suggest why magnesium is used in this reaction rather than a cheaper metal such as iron.

[1 mark]

Magnesium is more reactive than titanium (iron is less reactive than titanium so cannot displace it).

Some standard enthalpies of formation are given in **Table 2**.

Table 2

Substance	$\Delta_f H^\ominus / \text{kJ mol}^{-1}$
$\text{TiCl}_4\text{(l)}$	–750
$\text{MgCl}_2\text{(s)}$	–642

0 7 . 2

State why the enthalpies of formation of magnesium and titanium do not need to be included in the table.

[1 mark]

They are elements in their standard states, so their enthalpies of formation are zero.

0 7 . 3

Give the meaning of the term enthalpy change.

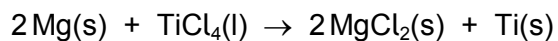
[1 mark]

The heat energy change (heat given out or taken in) at constant pressure.



07.4

Use the data in **Table 2** to calculate the enthalpy change, in kJ mol^{-1} , for the reaction of magnesium with titanium chloride.

**[2 marks]**

$$\Delta H = \Sigma \Delta H_f(\text{products}) - \Sigma \Delta H_f(\text{reactants})$$

$$\Delta H = [2 \times (-642) + 0] - [(-750) + 0]$$

$$\Delta H = -1284 + 750 = -534 \text{ kJ mol}^{-1}$$

Enthalpy change _____ *-534* _____ kJ mol^{-1}

5

Turn over for the next question

Turn over ►



0 8

This question is about the elements in Period 3 of the Periodic Table.

0 8 . 1

Identify the Period 3 element from Na to Cl that has the largest atomic radius.

Explain your answer.

[3 marks]

Element sodium (Na)

Explanation Sodium has the fewest protons (lowest nuclear charge) of the Period 3 elements.

The shielding is similar across the period (same number of inner shells), so there is the least attraction between the nucleus and the outer electron, so Na has the largest atomic radius.

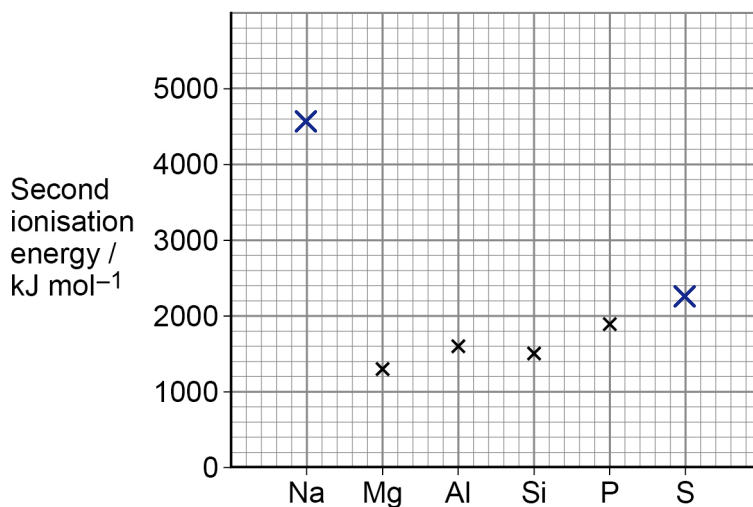
0 8 . 2

Write an equation, including state symbols, to represent the process that occurs when the **second** ionisation energy of magnesium is measured.

[1 mark]

Figure 1 shows the **second** ionisation energies of some Period 3 elements.

Figure 1



0 8 . 3 Draw a cross on **Figure 1** to show the **second** ionisation energy of sodium.

[1 mark]

0 8 . 4 Draw a cross on **Figure 1** to show the **second** ionisation energy of sulfur.

[1 mark]

Question 8 continues on the next page

Turn over ►



0 8 . 5

Explain why the **second** ionisation energy of silicon is lower than the **second** ionisation energy of aluminium.

[2 marks]

In silicon the second electron is removed from a 3p orbital, whereas in aluminium it is removed from a 3s orbital.

The 3p orbital is higher in energy (further from the nucleus and more shielded), so the electron is more easily lost.

0 8 . 6

An ion of silicon has the electron configuration $1s^2 2s^2 2p^6 3s^1$

Which ionisation of silicon produces this ion?

[1 mark]

Tick (✓) **one** box.

First ionisation

☐

Second ionisation

☐

Third ionisation

☒

9

END OF QUESTIONS



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2 4



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