Write your name here

Surname: StemUp Model Solution

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Pearson Edexcel GCE

Centre Number | Candidate Number

Chemistry

Advanced Subsidiary

Paper 1: Core Inorganic and Physical Chemistry

Friday 26 May 2017 – Morning

Time: 1 hour 30 minutes

Paper Reference **8CH0/01**

You must have:
Data Booklet
Scientific calculator, ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- For questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

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Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The presence of some ions in compounds can be identified using a Bunsen burner flame.

(a) (i) Some metal ions give characteristic colours in a flame test.

Describe how to carry out a flame test on an unknown solid.

(2)

Dip a clean nichrome wire (or platinum wire) into concentrated hydrochloric acid, then dip it into the solid sample.

Hold the wire in a hot, blue (roaring) Bunsen burner flame and observe the flame colour.

(ii) Which of the following ions does **not** give a red flame?

(1)

☒ **A** barium

☐ **B** calcium

☐ **C** lithium

☐ **D** strontium

(iii) Some anions can also be identified by heating in a Bunsen burner flame. A compound heated in a test tube in a Bunsen burner flame gave off a brown gas and caused a glowing splint to relight. The formula of the ion responsible is

(1)

☐ **A** Br^-

☐ **B** NO_2^-

☒ **C** NO_3^-

☐ **D** O^{2-}

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(b) A flame test on a white powder gave a lilac flame colour. Dilute hydrochloric acid was added to a second sample of the same powder in a boiling tube and the gas produced bubbled into limewater. The limewater turned cloudy.

Give a possible **formula** for the white powder.

(2)

K_2CO_3 (potassium carbonate)

(Total for Question 1 = 6 marks)

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2 This question is about water.

(a) Water is a polar covalent molecule. The strongest intermolecular forces between water molecules are hydrogen bonds.

(i) The O—H bond in water is polar because, when compared with the hydrogen atom, the oxygen atom has

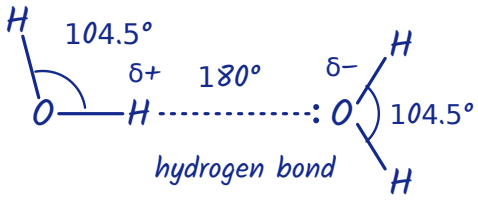
(1)

- ☐ **A** a higher mass number
- ☐ **B** a larger atomic radius
- ☒ **C** greater electronegativity
- ☐ **D** more electrons

(ii) Draw a diagram of a hydrogen bond between two water molecules in ice.

Show the value of the H—O—H angle within a molecule and the value of the O—H—O angle between the two molecules.

(2)



(iii) Explain why hydrogen bonding causes ice to be less dense than liquid water.

(2)

In ice, each water molecule forms hydrogen bonds to four other molecules, giving an open, three-dimensional (tetrahedral) lattice structure.

The hydrogen bonds are longer than the covalent O–H bonds, so the molecules are held further apart, with more space between them than in liquid water, so ice is less dense.

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(b) Liquid water is a good solvent for many, but not all, ionic compounds. Which is **least** soluble in water?

(1)

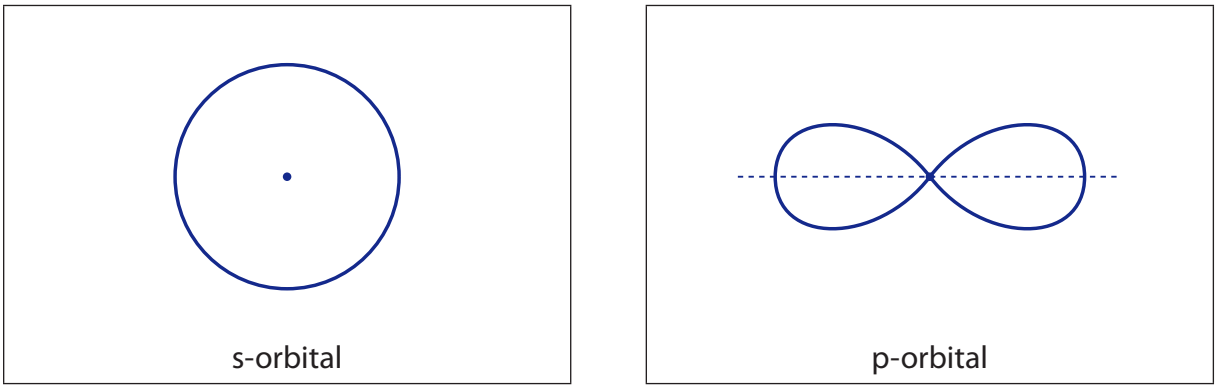
- ☒ **A** barium hydroxide
- ☒ **B** calcium hydroxide
- ☒ **C** magnesium hydroxide
- ☒ **D** sodium hydroxide

(Total for Question 2 = 6 marks)

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3 Electrons in atoms occupy orbitals.

(a) Draw in the boxes the shape of an s-orbital and a p-orbital.



(2)

(b) State what is meant by the term **first ionisation energy**.

(3)

The energy required to remove one electron from each atom in one mole of gaseous atoms, to form one mole of gaseous 1+ ions.

$X(g) \rightarrow X^{+}(g) + e^{-}$

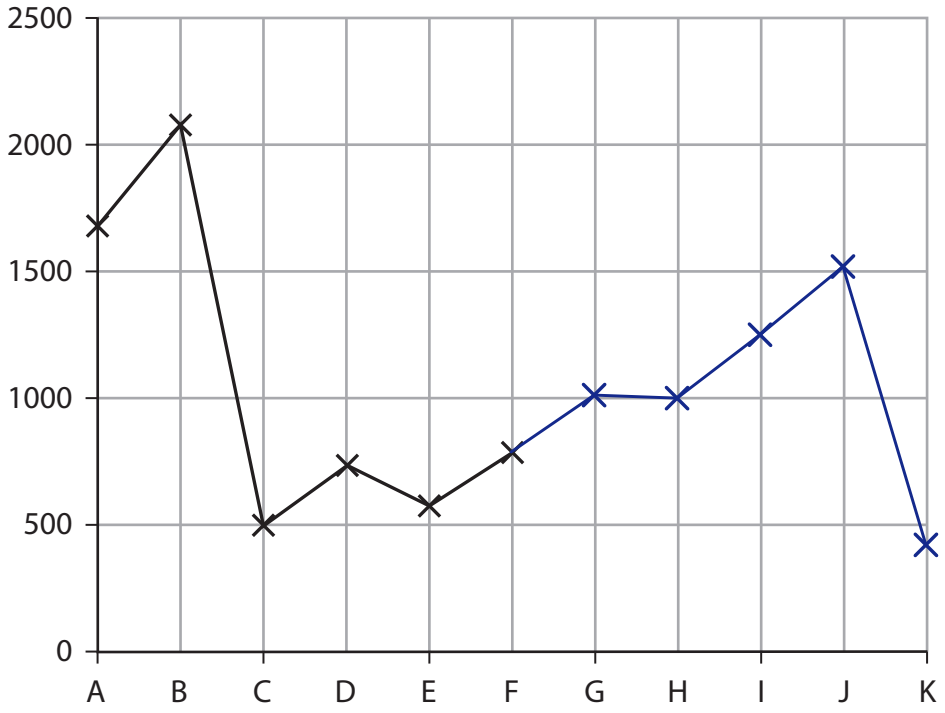
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(c) (i) The graph shows the first ionisation energies for a series of six consecutive elements **A**–**F**. The letters are not their chemical symbols.

Complete the graph of the first ionisation energies for the next five elements.

(3)



(ii) Explain why the value of the first ionisation energy for **D** is **greater** than for **C**.

(2)

D has one more proton than C, so it has a greater nuclear charge (and a smaller atomic radius).

The electron removed from C and from D is in the same s-subshell (same energy level), so the electron in D is more strongly attracted to the nucleus.

(iii) Explain why the value of the first ionisation energy of **E** is **less** than for **D**.

(2)

The electron removed from E is in a new, higher energy p-subshell (p-orbital), whereas in D it is removed from the s-subshell.

The p-subshell electron is more shielded from the nucleus than the s-subshell electrons, so less energy is needed to remove it.

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(d) Successive ionisation energies can give information about the electronic structure of an element.

Which of the following sets of data showing the first four ionisation energies, in kJ mol^{-1}, of four elements is most likely to belong to boron?

(1)

☒ **A** 1086, 2353, 4621, 6223.

☒ **B** 900, 1757, 14 849, 21 007.

☒ **C** 801, 2427, 3660, 25 026.

☒ **D** 578, 1817, 2745, 11 578.

(Total for Question 3 = 13 marks)

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4 This question is about redox chemistry.

(a) (i) Write an ionic half-equation for the reduction of chlorine molecules to chloride ions.
State symbols are not required.

(1)

$Cl_2 + 2e^- \rightarrow 2Cl^-$

(ii) Write an ionic half-equation for the oxidation of chlorine molecules to chlorate(I) ions in the presence of cold, aqueous hydroxide ions.
State symbols are not required.

(1)

$Cl_2 + 4OH^- \rightarrow 2ClO^- + 2H_2O + 2e^-$

(iii) Combine the two equations in (a)(i) and (ii) to give the ionic equation for the reaction of chlorine molecules with cold, aqueous hydroxide ions.

(1)

$Cl_2 + 2OH^- \rightarrow Cl^- + ClO^- + H_2O$

(iv) Use your answer to (a)(iii) to explain why the reaction is described as a **disproportionation** reaction.

(2)

Chlorine is simultaneously oxidised and reduced in the same reaction (the same element in one species).

The oxidation number of Cl changes from 0 in Cl_2 to −1 in Cl^- (reduction) and to +1 in ClO^- (oxidation).

(b) A different ion containing chlorine is formed if the solution of aqueous hydroxide ions is hot.

Give the formula of the chlorine-containing ion **and** the oxidation number of chlorine in this ion.

(2)

ClO_3^- (chlorate(V) ion)

Oxidation number of chlorine = +5

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(c) (i) Bromine can be extracted from seawater containing bromide ions using chlorine.

Write the ionic equation for this reaction. State symbols are not required.

(1)

$Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$

(ii) Identify **one** hazard associated with carrying out this reaction in a school laboratory and a safety precaution other than wearing a laboratory coat and eye protection.

(2)

Hazard: chlorine (and bromine) is toxic.

Precaution: carry out the reaction in a fume cupboard.

(Total for Question 4 = 10 marks)

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5 This question is about magnesium.

(a) (i) Complete the electronic structure of a magnesium atom.

(1)

$1s^2$ $2s^2\ 2p^6\ 3s^2$

(ii) The bonding in magnesium results from

(1)

- ☐ **A** strong electrostatic attractions between oppositely charged ions
- ☐ **B** strong electrostatic attractions between the nuclei of magnesium atoms and a shared pair of electrons
- ☒ **C** strong electrostatic attractions between positively charged ions and a sea of delocalised electrons
- ☐ **D** weak dispersion forces between magnesium atoms

(b) Magnesium exists as three stable isotopes. One isotope has a relative isotopic mass of 25.0.

State what is meant by the term **relative isotopic mass**.

(2)

The mass of an atom of an isotope, relative to 1/12th of the mass of an atom of carbon-12.

(c) What are the numbers of protons, neutrons and electrons in an atom of magnesium which has a mass number of 25?

(1)

- ☒ **A** 12 protons, 13 neutrons and 12 electrons
- ☐ **B** 12 protons, 25 neutrons and 12 electrons
- ☐ **C** 13 protons, 12 neutrons and 13 electrons
- ☐ **D** 25 protons, 13 neutrons and 12 electrons.

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(d) The relative atomic mass of a sample of magnesium was found to be 24.3.
The percentage composition for two of the three isotopes is given in the table.
Use these data to calculate the percentage composition of the third isotope and hence its relative isotopic mass. Give your answer to an appropriate number of significant figures. You **must** show your working.

Relative isotopic mass	Percentage abundance
25.0	10.00
26.0	11.01

(4)

% of third isotope = 100 − (10.00 + 11.01) = 78.99 %

24.3 = [(78.99 × m) + (25.0 × 10.00) + (26.0 × 11.01)] ÷ 100

2430 = 78.99m + 250 + 286.26

78.99m = 1893.74

m = 1893.74 ÷ 78.99 = 23.97

Relative isotopic mass of third isotope = 24.0 (3 s.f.)

(Total for Question 5 = 9 marks)

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6 Boron and aluminium are in the same group of the Periodic Table. Both form compounds with chlorine and with fluorine.

(a) Boron reacts directly with chlorine to produce a covalently bonded compound, BCl_3.

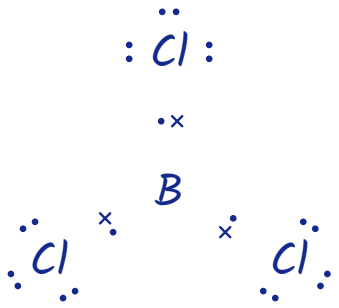
(i) Write the equation for this reaction. State symbols are not required.

(1)

$2B + 3Cl_2 \rightarrow 2BCl_3$

(ii) Draw a dot-and-cross diagram for BCl_3 showing only the outer shell electrons of the atoms.

(1)



(iii) Use your diagram to explain why BCl_3 has a trigonal planar shape with bond angles of 120°.

(2)

There are three bonding pairs of electrons around the boron atom and no lone (non-bonding) pairs.

The bonding pairs repel and move as far apart as possible to minimise repulsion, so BCl_3 is trigonal planar with bond angles of 120°.

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(b) Aluminium also reacts directly with chlorine to form a compound, aluminium chloride, containing only aluminium and chlorine.

A 0.500 g sample of aluminium chloride was analysed and found to contain 0.101 g of aluminium.

Another 0.500 g sample was heated to 473 K. The gas produced occupied a volume of 73.6 cm^3 at a pressure of 1.00×10^2 kPa.

Determine the molecular formula of the gas.

You will need to use the equation $pV = nRT$ and $R = 8.31\ J\ mol^{-1}\ K^{-1}$

(6)

mass of Cl = 0.500 − 0.101 = 0.399 g

mol Al = 0.101 ÷ 27.0 = 3.741×10^{-3} mol

mol Cl = 0.399 ÷ 35.5 = 1.124×10^{-2} mol

Cl : Al = $1.124 \times 10^{-2} \div 3.741 \times 10^{-3} = 3.005 \approx 3$

so the empirical formula is $AlCl_3$

$p = 1.00 \times 10^2$ kPa = 1.00×10^5 Pa, $V = 73.6\ cm^3 = 7.36 \times 10^{-5}\ m^3$

$n = pV \div RT = (1.00 \times 10^5 \times 7.36 \times 10^{-5}) \div (8.31 \times 473)$

$n = 1.872 \times 10^{-3}$ mol

$M_r = 0.500 \div 1.872 \times 10^{-3} = 267$

M_r of $AlCl_3 = 27.0 + (3 \times 35.5) = 133.5$, and $267 \div 133.5 = 2$

Molecular formula of the gas = Al_2Cl_6

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*(c) Aluminium fluoride and aluminium chloride are both crystalline solids at room temperature. Aluminium fluoride sublimes to form a gas at 1291 °C (1564 K), whilst aluminium chloride sublimes at 178 °C (451 K).

Use the Pauling electronegativity values in the Data Booklet to explain these differences in sublimation temperature.

(6)

Pauling electronegativities: Al = 1.5, Cl = 3.0, F = 4.0. The electronegativity difference between Al and F is 2.5, but between Al and Cl it is only 1.5, a significant difference of 1.0.

Because the difference is so large, the bonds in aluminium fluoride are much more polar, so it is mainly ionic. Aluminium fluoride therefore has a giant ionic lattice, with strong electrostatic forces of attraction between the Al^{3+} and F^- ions throughout the structure.

The smaller difference means the bonding in aluminium chloride is mainly covalent, so it exists as small molecules ($AlCl_3$ / Al_2Cl_6). Between these molecules there are only weak intermolecular forces (London forces and dipole-dipole forces).

When aluminium chloride sublimes, only these weak intermolecular forces are overcome (no covalent bonds are broken), so little energy is needed and the sublimation temperature is low (451 K).

When aluminium fluoride sublimes, the strong electrostatic attractions between ions in the giant lattice must be broken, which needs much more energy, so its sublimation temperature is much higher (1564 K).

(Total for Question 6 = 16 marks)

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7 Hydrochloric acid is prepared by dissolving hydrogen chloride gas in water. It is difficult to dissolve a known amount of hydrogen chloride, so the exact concentration of such solutions is uncertain. A solution of hydrochloric acid of concentration between 0.095 mol dm^{-3} and 0.105 mol dm^{-3} was prepared.

Before a class attempted a practical using this solution, a technician standardised the hydrochloric acid with sodium carbonate solution. The technician dissolved 1.30 g of anhydrous sodium carbonate in water and made up the solution to 100 cm^3.

The equation for the reaction which occurs is shown.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

A 10.0 cm^3 portion of the sodium carbonate solution was transferred to a conical flask. Three drops of methyl orange indicator were added and the solution titrated with hydrochloric acid. The results for the experiment are shown.

Titration	1	2	3	4	5
Final burette reading / cm^3	26.00	34.00	36.10	24.15	48.20
Initial burette reading / cm^3	0.00	10.00	11.00	0.05	24.15
Titre / cm^3	26.00	24.00	25.10	24.10	24.05
Concordant results (✓)		✓		✓	✓

(a) Complete the table and determine the concentration, in mol dm^{-3}, of the hydrochloric acid solution, giving the answer to an appropriate number of significant figures.

(5)

mean titre = (24.00 + 24.10 + 24.05) ÷ 3 = 24.05 cm^3

mol Na_2CO_3 in 100 cm^3 = 1.30 ÷ 106 = 0.012264 mol

mol Na_2CO_3 in 10.0 cm^3 = 0.012264 ÷ 10 = 1.2264×10^{-3} mol

mol HCl = $2 \times 1.2264 \times 10^{-3} = 2.4528 \times 10^{-3}$ mol

[HCl] = $2.4528 \times 10^{-3} \div (24.05 \div 1000) = 0.102$ mol dm^{-3} (3 s.f.)

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(b) The colour change at the end-point when methyl orange is used as an indicator for this titration is from

(1)

- ☒ **A** orange to yellow
- ☒ **B** red to orange
- ☒ **C** yellow to orange
- ☒ **D** yellow to red

(c) Explain **three** actions the technician might take in the procedure, just before the end-point of the titration, to ensure that the volume of acid added at the end-point is accurate.

(3)

Add the acid drop by drop near the end-point, so that too much acid is not added and the end-point is not overshot.

Swirl the flask after each drop, so the solution is mixed (homogeneous) and all the acid added reacts with the carbonate.

Rinse the inside of the flask with distilled water between additions, so all the reactants are washed into the solution and can react.

Place the flask on a white tile, so that the colour change at the end-point is seen clearly.

(Total for Question 7 = 9 marks)

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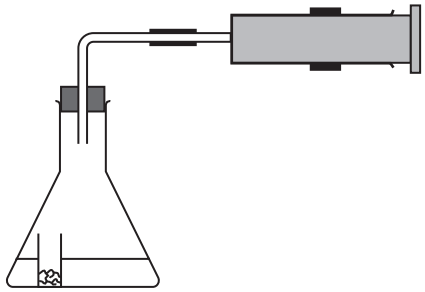
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8 A student wanted to measure the volume of a gas and use the results to find the volume occupied by one mole of the gas. The following method was used.

- A sample of calcium carbonate was weighed out in a small plastic container.
- 20 cm^3 of hydrochloric acid of concentration 2.00 mol dm^{-3} was added to a conical flask. A small pinch of calcium carbonate was added to the acid.
- The container was placed in the conical flask and a gas syringe was connected to the top of the conical flask.
- The flask was carefully shaken so that the small plastic container fell over, allowing the acid and calcium carbonate to mix.

The apparatus set up is shown.



The student repeated the experiment five times using different masses of calcium carbonate on each occasion, with the concentration and volume of the hydrochloric acid constant.

Experiment number	Mass / g	Volume of CO_2 / cm^3
1	0.10	23
2	0.20	44
3	0.30	67
4	0.40	96
5	0.50	115

(a) (i) Write the equation for the reaction between calcium carbonate and hydrochloric acid. Include state symbols.

(2)

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

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(ii) Calculate the molar mass of calcium carbonate.

(1)

$M = 40.1 + 12.0 + (3 \times 16.0) = 100.1$

100.1 g mol^{-1}

(iii) Show that, in each experiment, the hydrochloric acid is in excess.

(2)

Largest mass: mol $CaCO_3 = 0.50 \div 100.1 = 0.0050$ mol

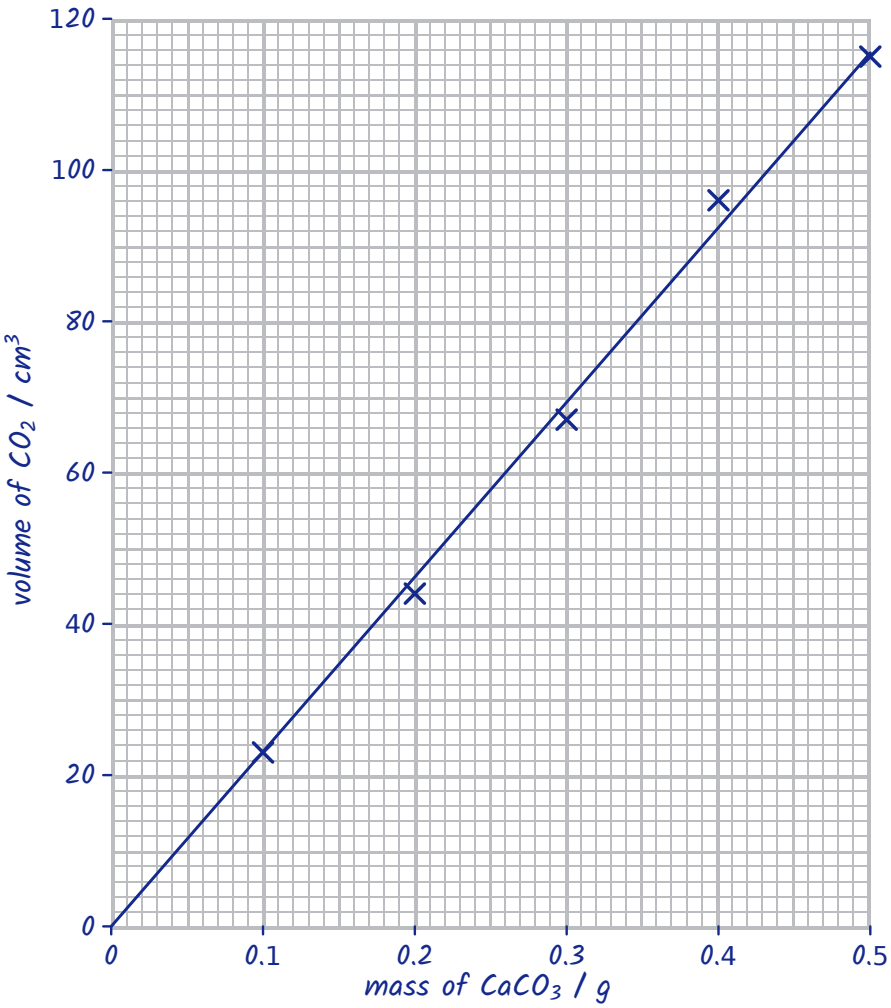
mol $HCl = 2.00 \times 20 \div 1000 = 0.040$ mol

$CaCO_3 : HCl = 1 : 2$, so 0.0050 mol $CaCO_3$ reacts with only 0.010 mol HCl.

$0.040 > 0.010$, so the acid is in (fourfold) excess in every experiment.

(b) (i) Plot a graph of volume of carbon dioxide produced against mass of calcium carbonate on the grid. Include a line of best fit.

(2)



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(ii) State how your graph supports the idea that the volume of gas produced depends directly on the mass of calcium carbonate added.

(1)

The graph is a straight line through the origin, so the volume of CO_2 is directly proportional to the mass of calcium carbonate.

(c) Calculate the volume, under these conditions, of one mole of carbon dioxide gas from these data. Give your answer in dm^3 to **two** significant figures.

(2)

gradient = 115.5 ÷ 0.50 = 231 $cm^3\ g^{-1}$

molar volume = gradient × M = 231 × 100.1 = 23 100 $cm^3\ mol^{-1}$

Volume of one mole of CO_2 = 23 dm^3 (2 s.f.)

(d) Give a reason why the student added a small pinch of calcium carbonate to the acid before starting the reaction.

(1)

To saturate the acid with CO_2, so that none of the CO_2 produced in the experiment dissolves in the acid and all of it is collected in the syringe.

(Total for Question 8 = 11 marks)

TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key: relative atomic mass / atomic symbol / name / atomic (proton) number									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
* Actinide series	232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

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