DULWICH COLLEGE
FOUNDED 1619

Upper School entrance examination
SPECIMEN PAPER
Chemistry

Your Last Name	
Your First Name	
Date of birth	
Current school	

Time allowed for this paper 75 minutes

1. (a) The electronic configuration of a magnesium atom can be represented as:

2, 8, 2

Give the electronic configuration of a calcium atom.

.....[1]

(b) If calcium metal is heated strongly in a stream of nitrogen gas, the compound calcium nitride is formed.

(i) Draw a dot-and-cross diagram to show the bonding in calcium nitride. *Only the outer shell electrons need to be shown.*

[4]

(ii) Give a fully balanced symbol equation to represent this reaction.

.....[2]

(iii) Molten calcium nitride conducts electricity. However, solid calcium nitride does not. Explain this observation.

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.....[3]

(c) Calcium metal reacts readily with cold water. However, magnesium metal (also in Group 2) only reacts with water in the form of steam.

By comparing their electronic structures, explain why magnesium is less reactive than calcium.

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13 marks

2. In a series of experiments to investigate the factors which control the rate of a chemical reaction, aqueous hydrochloric acid was added to calcium carbonate in a conical flask placed on an electronic balance. The following reaction took place:

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

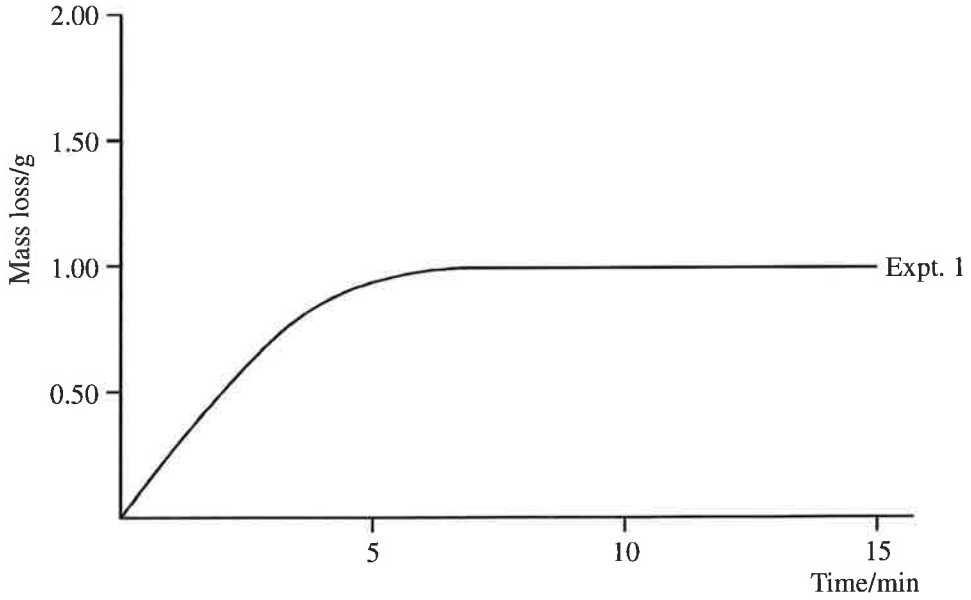
The loss in mass of the flask and its contents was recorded for 15 minutes.

Four experiments were carried out:

Experiments **1**, **3** and **4** were carried out at room temperature (20 °C).
The same mass of calcium carbonate (a large excess) was used in each experiment.
The pieces of calcium carbonate were the same size in experiments **1**, **2** and **4**.

Experiment	Calcium carbonate	Hydrochloric acid
1	Small pieces	50.0 cm^3 of 1.00 mol dm^{-3}
2	Small pieces	50.0 cm^3 of 1.00 mol dm^{-3} heated to 80°C
3	One large piece	50.0 cm^3 of 1.00 mol dm^{-3}
4	Small pieces	50.0 cm^3 of 2.00 mol dm^{-3}

(a) The results of experiment **1** give the curve shown on the graph below.



(i) Explain why there is a loss in mass as the reaction proceeds.

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..... [2]

(ii) Explain the shape of the curve drawn for experiment **1**.

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..... [2]

(b) Draw **curves on the graph** to represent the results you would expect for experiments **2, 3** and **4**. Label the curves **2, 3** and **4**. [3]

(c) (i) Calculate the mass of calcium carbonate which **exactly** reacts with 50.0 cm^3 of 1.00 mol dm^{-3} aqueous hydrochloric acid. $M_r(CaCO_3) = 100$.

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.....[3]

(ii) Based on your answer to **(c)(i)** suggest a suitable mass of calcium carbonate to use in the experiments. Explain your answer.

Suggested mass: .....

Explanation: .....

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[2]

(d) In a different experiment, the same mass of calcium carbonate, and the same volume of hydrochloric acid are mixed. However, the acid is twice as concentrated. Explain what happens to the reaction rate.

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(e) If the temperature of the acid is increased, the rate of reaction increases. Use collision theory to explain why this happens.

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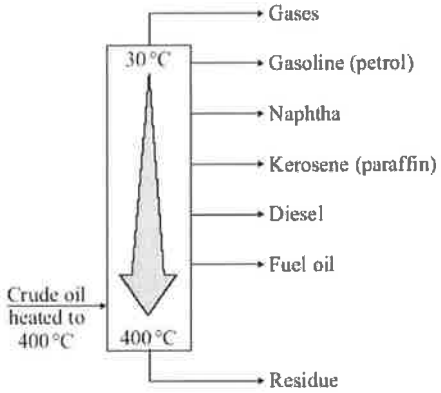
18 marks

3. Crude oil is the source of many useful materials. Crude oil is separated into fractions by fractional distillation.



(a) Describe how the naphtha fraction separates from the other fractions.

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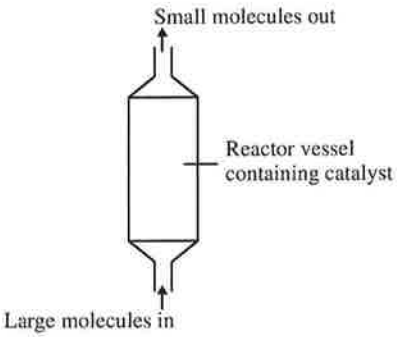
.....[2]

(b) The naphtha fraction is often used to make other useful materials. This involves the **cracking** of hydrocarbons in the naphtha fraction.



(i) Cracking involves a thermal decomposition reaction.

Define the term **thermal decomposition**.

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.....[2]

(ii) Suggest why air must be excluded from the reactor vessel.

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.....[1]

(iii) In the reactor vessel, a nonane (C_9H_{20}) molecule is split into two smaller molecules.

Complete the equation for this reaction by adding the missing formula.

$C_9H_{20} \longrightarrow$ ..... + C_2H_4 [1]

(iv) The product with the formula C_2H_4 is called ethene. Draw a line diagram to show the bonding in ethene.

[1]

(v) Bromine water can be used to distinguish between the two products from the cracking reaction in **(c) (i)** above.

Describe what you would see when each molecule is shaken (separately) with bromine water.

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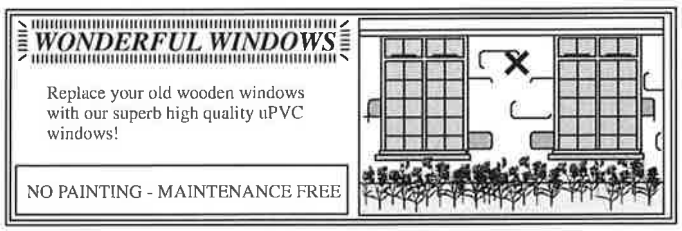
..... [3]

(d) Small molecules such as ethene can be joined together to make long-chained polymers.



Modern window frames are often made from uPVC plastic which contains the *polymer* called poly(chloroethene).

(i) State why plastic window frames need no painting or maintenance.

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..... [1]

(ii) Name the monomer that is used to make poly(chloroethene).

..... [1]

(iii) Draw a line diagram to show the repeating unit in poly(chloroethene).

[1]

(iv) Describe **one** environmental hazard with plastics such as poly(chloroethene).

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..... [2]

15 marks

4. When phosphorus is heated in bromine vapour, molecules of phosphorus bromide are produced. There are two possible bromides that can form – depending on the proportions of phosphorus and bromine in the reacting mixture.

If excess bromine is used, the molecule formed contains 7.19% phosphorus and 92.81% bromine (by mass).

(a) (i) What is the empirical formula of this compound?

[4]

(ii) Write a balanced symbol equation for this reaction.

.....[2]

(b) Under different conditions, phosphorus tribromide (PBr_3) can be produced.

(i) Draw a dot-and-cross diagram to show the bonding in a molecule of phosphorus tribromide. *Only the outer shell electrons need to be shown.*

[2]

(ii) Phosphorus tribromide has melting point of -41.5 °C. By describing its structure and bonding, explain why its melting point is relatively low.

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.....[3]

(iii) The most important reaction of phosphorus tribromide is with alcohols (such as ethanol) where it replaces an OH group with a bromine atom to produce an alkyl bromide. (These compounds are very useful for synthesising other organic molecules.)

$$PBr_3 + 3C_2H_5OH \longrightarrow 3C_2H_5Br + H_3PO_3$$

What mass of phosphorus tribromide is needed to make 90 tonnes of bromoethane (C_2H_5Br)? Give your answer (in tonnes) to 3 significant figures. *[1 tonne = 1000 kg]*

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..... [3]

(iv) In practice, the mass of phosphorus tribromide calculated above only generates 67 tonnes of bromoethane. What percentage yield is this?

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..... [1]

15 marks

5. Aluminium metal is manufactured by a process in which purified bauxite, dissolved in molten cryolite, is electrolysed at 800 °C. Graphite electrodes and a current of about 120 000 amperes are used.

(a) (i) Give the **ionic equations** for the reactions taking place at each electrode.

Anode: ..... [1]

Cathode: ..... [1]

(ii) State which of these reactions is an oxidation process.

..... [1]

(iii) Explain why the anodes need to be replaced frequently.

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..... [2]

(continued ...)

(b) The production of aluminium is expensive.

(i) Explain why, despite this high cost, aluminium is manufactured in large quantities.

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..... [2]

(ii) Give **two reasons** why it is worthwhile to recycle aluminium.

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..... [2]

(c) Aluminium is relatively high in the reactivity series and yet it tends to react much more slowly than expected. Why is this?

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..... [1]

10 marks

TOTAL: 75 MARKS

THIS IS THE END OF THE QUESTIONS

NOW GO BACK AND CHECK YOUR ANSWERS

THE PERIODIC TABLE

Period	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
1	1 H Hydrogen 1							2 He Helium 4
2	3 Li Lithium 7	4 Be Berylium 9	5 B Boron 11	6 C Carbon 12	7 N Nitrogen 14	8 O Oxygen 16	9 F Fluorine 19	10 Ne Neon 20
3	11 Na Sodium 23	12 Mg Magnesium 24	13 Al Aluminium 27	14 Si Silicon 28	15 P Phosphorus 31	16 S Sulphur 32	17 Cl Chlorine 35.5	18 Ar Argon 40
4	19 K Potassium 39	20 Ca Calcium 40	21 Sc Scandium 45	22 Ti Titanium 48	23 V Vanadium 51	24 Cr Chromium 52	25 Mn Manganese 55	26 Fe Iron 56	27 Co Cobalt 59	28 Ni Nickel 59	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 70	32 Ge Germanium 73	33 As Arsenic 75	34 Se Selenium 79	35 Br Bromine 80	36 Kr Krypton 84
5	37 Rb Rubidium 85	38 Sr Strontium 88	39 Y Yttrium 89	40 Zr Zirconium 91	41 Nb Niobium 93	42 Mo Molybdenum 96	43 Tc Technetium (99)	44 Ru Ruthenium 101	45 Rh Rhodium 103	46 Pd Palladium 106	47 Ag Silver 108	48 Cd Cadmium 112	49 In Indium 115	50 Sn Tin 119	51 Sb Antimony 122	52 Te Tellurium 128	53 I Iodine 127	54 Xe Xenon 131
6	55 Cs Caesium 133	56 Ba Barium 137	57 La Lanthanum 139	72 Hf Hafnium 178	73 Ta Tantalum 181	74 W Tungsten 184	75 Re Rhenium 186	76 Os Osmium 190	77 Ir Iridium 192	78 Pt Platinum 195	79 Au Gold 197	80 Hg Mercury 201	81 Ti Thallium 204	82 Pb Lead 207	83 Bi Bismuth 209	84 Po Polonium (210)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Unq Unnilquadium (261)	105 Unp Unnilpentium (262)	106 Unh Unnilhexium (263)												

Key

Atomic Number
Symbol
Name
Molar mass in g mol^{-1}

► Lanthanide elements	58 Ce Cerium 140	59 Pr Praseodymium 141	60 Nd Neodimium 144	61 Pm Promethium (147)	62 Sm Samarium 150	63 Eu Europium 152	64 Gd Gadolinium 157	65 Tb Terbium 159	66 Dy Dysprosium 163	67 Ho Holmium 165	68 Er Erbium 167	69 Tm Thulium 169	70 Yb Ytterbium 173	71 Lu Lutetium 175
►► Actinide elements	90 Th Thorium 232	91 Pa Protactinium (231)	92 U Uranium 238	93 Np Neptunium (237)	94 Pu Plutonium (242)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (245)	98 Cf Californium (251)	99 Es Einsteinium (254)	100 Fm Fermium (253)	101 Md Mendelevium (256)	102 No Nobelium (254)	103 Lr Lawrencium (257)