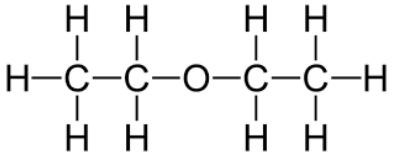
St. Joseph's Institution
2024 Year 4 OP Preliminary Exam Answer Scheme

Paper 1

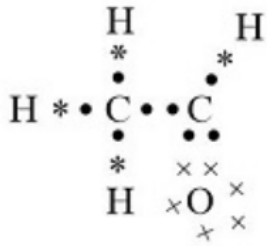
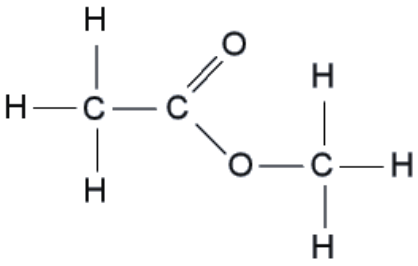
1	2	3	4	5	6	7	8	9	10
D	B	A	C	C	A	A	C	B	B
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
D	A	B	B	B	B	C	D	C	C
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
B	B	A	C	B	B	D	C	B	C
31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
C	A	B	D	A	A	C	B	C	C

Paper 2 Section A

Qn	Suggested answers	Mark
1a	hydrogen	1
1b	argon	1
1c	chlorine	1
1d	sodium **and** chlorine	1
1ei	lithium **and** sodium	1
1eii	$2Li + 2H_2O \rightarrow 2LiOH + H_2$ **OR** $2Na + 2H_2O \rightarrow 2NaOH + H_2$	1
	TOTAL	**6**
2a	**Chlorine is oxidised** as the **oxidation number of chlorine increases** from **0 in Cl_2 to +5 in ClO_3^-.** **Chlorine is reduced** as the **oxidation number of chlorine decreases** from **0 in Cl_2 to -1 in Cl^-.** As the same element, chlorine, is both oxidised and reduced, this is a disproportionation reaction. [must state but no mark]	1 1
2b	No. of moles of 1.0 g of Si_2OCl_6 = 1.0 / [28(2) + 16 + 35.5(6)] = 0.0035088 mol No. of moles of chloride ions in 1.0 g of Si_2OCl_6 = 0.0035087 x 6 = 0.0210526 mol ≈ 0.0211 mol (to 3 s.f.) No. of moles of 1.0 g of $Si_3O_2Cl_8$ = 1.0 / [28(3) + 16(2) + 35.5(8)] = 0.00250 mol No. of moles of chloride ions in 1.0 g of $Si_3O_2Cl_8$ = 0.00250 x 8 = 0.0200 mol (to 3 s.f.) Reasoning: The 1.0 g sample of Si_2OCl_6 contains a larger amount / no. of moles of chloride ions → larger amount of $AgCl$(s) ppt formed → larger mass of $AgCl$(s) ppt formed	2 1
	TOTAL	**5**

Qn	Suggested answers	Mark
3a	Diesel engine [must state but no mark] The **carbon dioxide and carbon monoxide emissions** are the **highest at 160 and 408** respectively.	1
3bi	**incomplete combustion** of **carbon-containing fuels**	1
3bii	$2CO + 2NO \rightarrow CO_2 + N_2$ $2CO + O_2 \rightarrow 2CO_2$ Carbon monoxide is oxidised by nitrogen monoxide to form carbon dioxide and nitrogen which are **harmless**. Carbon monoxide is also oxidised by oxygen to form carbon dioxide which is **harmless**.	1 1 1
3c	Carbon dioxide is a **greenhouse gas** which **traps** excess **heat** in the atmosphere, causing **global warming.** This causes negative effects on the environment such as **ice bergs melting**, **seas levels rising** and **flooding in lowland areas.**	1 1
	TOTAL	**7**
4ai	High temperature **and** high pressure **and** acid catalyst / phosphoric acid	1
4aii	Ethene is obtained **from crude oil / petroleum / fossil fuels**, which is a **finite resource** that will run out. In contrast, glucose is **obtained from plants**, of which there is a **continuous supply / will not run out**	1
4b	(M_r of propan-1-ol = 12(3) + 1(8) + 16(1) = 60) Enthalpy change of combustion of propan-1-ol = -(134/4) x 60 = -2010 kJ/mol **OR** No of mol of 4.0g of propan-1-ol = 4.0 / 60 = 0.0667 mol Enthalpy change of combustion of propan-1-ol = -134 / 0.0667 = -2010 kJ/mol	 1
4c	In these combustion reactions, more energy is given out from bond forming in the products (CO_2 and H_2O), than absorbed / taken in for bond breaking in the reactants (alcohol and O_2); Butan-1-ol contains the most carbon (and hydrogen) atoms (of the four alcohols shown). Burning butan-1-ol would form more moles of CO_2 and H_2O and give out more energy than burning the same amount of methanol / ethanol / propan-1-ol **OR** Number of carbon (and hydrogen) atoms increase, going down the homologous series; **Increase in** energy given out from bond forming in products (CO_2 and H_2O) is **even larger** than **increase in** energy absorbed / taken in for bond breaking in reactants (alcohol and O_2)	1 1 (1) (1)
4di	$C_4H_{10}O$	1
4dii		1
4ei	The total energy **absorbed** to **break bonds** is different, as butan-1-ol and diethylether contain **different numbers / types of bonds**.	1
4eii	-2673 kJ/mol	1
	TOTAL	**9**

Qn	Suggested answers	Mark
5a	iron, chromium, manganese	1
5b	**[Stating both properties]** (i) exhibiting variable oxidation states in their compounds **and** (ii) forming coloured compounds **[Explanation for variable oxidation states]** iron has oxidation states of **+2 (pale green solution) and +3 (Fe_2O_3),** **OR** manganese had oxidation states of **+2 ($MnSO_4$) and +3 (Mn_2O_3)** **[Explanation for coloured compounds]** reference to **green Cr_2O_3(s), red manganese (II,III) oxide, dark brown Fe_2O_3(s)**	1 1 1
5c	$Mn(s) + 2H^+(aq) \rightarrow Mn^{2+}(aq) + H_2(g)$ [1] – balanced ionic equation with correct species [1] – state symbols	2
5d	**[Experiment 1]** grey solid / coating / deposit formed, **and** pale green solution turns pale pink **[Experiment 2]** no visible reaction	1 1
5e	Mercury is **lower than iron** in the reactivity series [must state, but no mark] When heated, iron(II) carbonate (only) **decomposes to its oxide** [iron(II) oxide], while mercury(II) carbonate **decomposes to its metal element** [mercury]. Thus, iron(II) carbonate is **more thermally stable** than mercury(II) carbonate, and iron is **more reactive** than mercury.	 1 1
	TOTAL	**10**
6a	**[ethene gas]** **bubble** (excess) ethene gas into **aqueous bromine** **[ethanoic acid]** changes from green to orange (OR yellow / red)	 1 1
6bi	Each carbon atom is bonded to two hydrogen atoms Mass of **one mole** of poly(ethene) molecule = 6000 x $M_r(CH_2)$ = 6000 x 14 = 84,000 g Mass of **one single** poly(ethene) molecule = 84,000 / (6.02×10^{23}) = 1.40×10^{-19} g (to 3 s.f.)	 1 1
6bii	**[Economic]** Recycling plastics is **energy-intensive / manpower-intensive** as the plastic waste must first be sorted and cleaned. The process of recycling plastics may thus be **more costly** than disposing of plastics in landfills (and/or the market value of the recycled plastics) **[Environmental]** If **wastewater** generated from the recycling of plastics is not treated properly before being discharged into water bodies, this can lead to water pollution.	 1 1

<table>
<tr><th>Qn</th><th>Suggested answers</th><th>Mark</th></tr>
<tr><td>6c</td><td> 
[1] – correct bond pairs
[1] – correct lone pairs on oxygen</td><td>2</td></tr>
<tr><td>6di</td><td>  </td><td>1</td></tr>
<tr><td>6dii</td><td>methanol</td><td>1</td></tr>
<tr><td>6e</td><td><table>
<tr><td></td><td>C</td><td>H</td><td>O</td></tr>
<tr><td>mass (in 100 g sample) / g</td><td>62.1</td><td>10.3</td><td>100 – 62.1 – 10.3 = 27.6</td></tr>
<tr><td>no. of moles / mol</td><td>62.1 / 12 = 5.175</td><td>10.3 / 1 = 10.3</td><td>27.6 / 16 = 1.725</td></tr>
<tr><td>mole ratio</td><td>3</td><td>6</td><td>1</td></tr>
</table>
[1] % by mass of oxygen = 27.6%
[1] no. of mol of each element
[1] empirical formula: C_3H_6O; and molecular formula: $C_6H_{12}O_2$
[carboxylic acids contain two oxygen atoms]</td><td>3</td></tr>
<tr><td></td><td>TOTAL</td><td>13</td></tr>
<tr><td>7a</td><td>Concentration of sodium ions
= 100 ppm
= 100 x 10^{-3} g per 1000 cm^3
= 0.100 g/dm^3

Mass of sodium ions in 250 cm^3 sample
= (250/1000) x 0.100
= 0.0250 g

Amount of sodium ions (in mol) in 250 cm^3 sample
= (0.0250 / 23)
= 0.00109 mol</td><td>

1

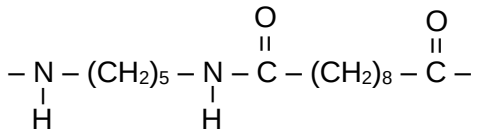
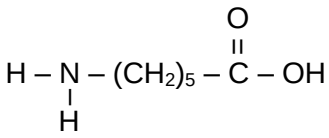
1</td></tr>
<tr><td>7bi</td><td>From Fig. 7.1, I agree that retention time is affected by ionic charge. All ions with a higher 2+ charge have a longer retention time than ions of a lower 1+ charge.

However, I disagree that retention time is (fully) affected by ions' relative masses. While ions of lower relative mass generally have shorter retention times, this is not true for Mg^{2+} (A_r = 24), which has a lower relative mass but a longer retention time than K^+ (A_r = 39).</td><td>1

1</td></tr>
<tr><td>7bii</td><td>Retention time within range of 7 to 9 min.
Nitrate ion has a charge of 1- and a relative (molecular) mass of 62. Thus, the retention time is likely between that of Cl^- ion (A_r = 35.5) and Br^- ion (A_r = 80).</td><td>1
1</td></tr>
<tr><td>7c</td><td>CH_3COOH</td><td>1</td></tr>
</table>

Qn	Suggested answers	Mark
7di	At *t* = 10 min, the reaction mixture contains **ethanoic anhydride** (**R2**), **aspirin** (**P**), **ethanoic acid / known by-product** (**BP**), **and one unknown substance.**	1
7dii	The student concluded that the reaction was complete as **salicylic acid**, the limiting reactant, was **used up**. (Thus there was no spot corresponding to R1 / salicylic acid at *t* = 10 min.)	1
7e	Ethanoic anhydride (R2) and aspirin (P) have **similar solubilities in ethanol**, as evidenced by their similar R_f values in Fig. 7.4. Thus, some ethanoic anhydride might have left the column (and got collected) at the same time as aspirin.	1
7f	Differences between ion and column chromatography **[Any two]** • Ion chromatography is (only) able to quantify very **low concentrations** of ions, while column chromatography is used to separate (and collect) **large quantities / amounts** of various components. • Ion chromatography is usually used to **identify** ions, while column chromatography is usually used to **collect** the various components of the mixture. • Ion chromatography only helps in detecting **ions / ionic species**, while column chromatography can be used to separate **many different compounds** (i.e. not just ions). • Ion chromatography is **automated** (or 'makes use of a **detector**'), while column chromatography is done **manually** (or 'does not make use of a **detector**').	2
	TOTAL	**12**
8ai	$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$	1
8aii	At **high temperatures**, the **graphite rod will react with the oxygen gas formed** (at graphite anode) to **form carbon dioxide** gas, which forms a white precipitate in limewater.	1
8b	Solution turns from **pale red to colourless**. **Cobalt(II) ions** (which caused solution to be pale red) are selectively **discharged / reduced** at the platinum cathode. Solution turns colourless after some time as **concentration of cobalt(II) ions decreases**.	1 1
8c	pH **decreases** to below 7. **Hydroxide ions are selectively discharged over nitrate ions** at the anode (while cobalt(II) ions are selectively discharged over hydrogen ions at the cathode). **Concentration of H^+ ions is greater than that of OH^- ions**, thus electrolyte turns acidic / pH decreases	1 1
8d	Mass of solution increases. In the displacement reaction, the **cobalt(II) ions in solution are replaced with zinc ions**. As the **relative atomic mass** of zinc (65) is **larger** than that of cobalt (59), the mass of solution will increase.	1 1
	TOTAL	**8**

Paper 2 Section B

Qn	Suggested answers	Mark
9ai		1
9aii	M_r of one repeating unit = 14 + 1 + 5(12+2) + 14 + 1 + 12 + 16 + 8(12+2) + 12 + 16 = 268 Minimum number of repeating units = 11000 / 268 = 41.045 ≈ 42 Maximum number of repeating units = 20000 / 268 = 74.63 ≈ 74 Range: **42 to 74** repeating units [1] – correct M_r of one repeating unit, and/or correct calculations on number of repeating units [1] – correct range	1 1
9b		1
9c	**Both (different) functional groups** (carboxyl and amine) needed to form the amide linkage in nylon can be found on opposite ends **in the same monomer molecule** for nylon-6, thus monomer is able to react with itself to form nylon-6.	1
9d	**[correct structures]** • nylon-6: **macromolecular**; • hydrogen chloride: **simple covalent / molecular structure**; • graphite: **giant covalent / molecular structure**. Graphite has the highest melting point, as the **largest amount of energy** is needed to **break/overcome the extensive network of strong covalent bonds between carbon atoms**, (than the weaker intermolecular forces of attraction in nylon-6 and hydrogen chloride) Nylon-6 has a higher melting point than hydrogen chloride, due to its larger M_r / molecular size. Thus, more **energy** is needed to **overcome** the **stronger intermolecular forces of attraction** in nylon-6 than hydrogen chloride Graphite can conduct electricity. Only three out of four of carbon's **valence** electrons are used in covalent bonding in graphite, which thus contains **mobile electrons** that can **act as mobile charge carriers**. Aqueous hydrogen chloride can conduct electricity. HCl is an **acid**, and (dissolves and) **dissociates in water** to form (a high concentration of) H^+ and Cl^- ions. These **mobile ions** can act as mobile charge carriers.	1 1 1 1 1 1
	TOTAL	**10**

<table>
<tr><th>Qn</th><th>Suggested answers</th><th>Mark</th></tr>
<tr><td>10a</td><td>At lower temperatures, reactant particles have lower average kinetic energies. Less particles have the required activation energy (OR “less particles have energies more than or equal to the activation energy),
Thus, there will be a lower frequency of effective collisions between reacting particles, and a slower rate of reaction.</td><td>1

1</td></tr>
<tr><td>10b</td><td>$CaCO_3 + 2CH_3COOH \rightarrow Ca(CH_3COO)_2 + CO_2 + H_2O$</td><td>1</td></tr>
<tr><td>10c</td><td>
<table>
<tr><th>experiment</th><th>acid</th><th>time taken</th><th>total volume of gas</th></tr>
<tr><td>1</td><td>nitric</td><td>7</td><td>150</td></tr>
<tr><td>2</td><td>hydrochloric</td><td>15</td><td>150</td></tr>
<tr><td>3</td><td>ethanoic</td><td>1500</td><td>150</td></tr>
<tr><td>4</td><td>oxalic</td><td>any value between 7 and 1500, e.g. 1000</td><td>300</td></tr>
</table>
[2] for 4 correct values (award 1m for 2-3 correct values, and 0m otherwise)

Time taken (to collect 10 cm^3 of gas) depends on the concentration of H^+ ions present. Oxalic acid’s concentration of H^+ ions is lower than nitric / hydrochloric acid (as it is a weak acid that only partially dissociates in water), but higher than ethanoic acid (as oxalic acid is a dibasic acid). Time taken for Experiment 4 should thus be between 7 s (Expt 1) and 1500 s (Expt 3)

In all four experiments, the amount of limiting reactant (acid) is the same. However, the mole ratio of acid : CO_2 is 2:1 for experiments 1-3, and 2:2 (or 1:1) for experiment 4. Total volume of gas in experiment 4 is thus double that of other three experiments (which are identical).</td><td>2

1

1</td></tr>
<tr><td>10d</td><td>Add excess $HNO_3(aq)$ to solid calcium carbonate, and stir until the solid fully dissolves

To the resulting solution, add aqueous sodium sulfate / potassium sulfate / dilute sulfuric acid / any other soluble sulfate salt. Precipitate of calcium sulfate will form.

Filter the mixture to obtain the residue, rinse residue with distilled water, and press dry between pieces of filter paper.</td><td>1

1

1</td></tr>
<tr><td></td><td>TOTAL</td><td>10</td></tr>
</table>