	Section A	
A1	**(a)**	calcium chloride
	(b)	ammonium chloride
	(c)	hydrogen chloride
	(d)	aluminium chloride
	(e)	hydrogen chloride

A2	**(a)**	**(i)**	The catalyst provides an alternative pathway of lower activation energy for the reaction to occur. More molecules/particles have energy greater than or equal to the activation energy. This leads to a higher frequency of effective collisions, leading to a greater rate of reaction. [1] role of a catalyst [1] explanation in terms of collisions and energy Discussion: • Reject: catalyst 'lowers Ea' more molecules have the minimum Ea (doesn't cover the idea of greater than or equal to; Ea is an indication of energy, not energy itself) • Ignore: Greater frequency of collisions
		(ii)	Catalysts are not chemically changed/regenerated at the end of the reaction so they can be reused infinitely. Hence, no additional cost is needed to purchase more new catalysts after each process. Catalysts provide an alternative pathway with lower activation energy for the reaction to occur, hence the reaction consumes less energy and lowers costs. [1] each - show an understanding of the workings of a catalyst: • regenerated at the end of the reaction, • requires less energy to operate since the reaction occurs with a lower E_a Note: student just needs to mention alternative pathway of lower E_a in (i) Discussion: • Reject: catalyst allows more hydrogen to be produced within a shorter period of time (does not relate to cost) unless they explain further about reduced manpower costs/labour costs only a small amount is needed (not about the quantity, but the fact that this small amount is regenerated and hence reused) (counter example: purchasing a catalyst requires a higher expenditure compared to when no catalyst is used) to include in Markers' report: • Students need to write in a concise manner to avoid contradicting themselves in lengthy answers

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(b)

The reaction removes carbon monoxide/CO. [1]

It is important to remove carbon monoxide, which is toxic/poisonous/dangerous. It reduces the ability of haemoglobin/red blood cell/blood to transport/carry oxygen to the rest of the body [1]

[1] highlight what Stage 2 removes
[1] impact of carbon monoxide on human health (don't need to mention toxicity)

Discussion:

- mark allocation
  1st mark: purpose of reaction
  2nd mark: impact of CO on human health
- allow:
  any other that CO causes reduced oxygen carrying ability (accounts for explain) (TB pg 394)
  eg. "CO reduces the amount of oxygen in the body"
  eg. "Lowers the amount of oxygen in the blood"
- reject:
  no reference to oxygen carrying ability "CO can cause breathing problems and death in humans" (does not account for 'explain', but states the 'effect')

Follow up:

- check if 'toxicity' is required in the answer (2018/2/6b)

(b) The gases from stage 1 are separated. The waste gas produced in stage 1 is burned as a fuel.

Explain why it is important that this gas is collected and burned.

.....

.....

..... [2]

(b) Better performing candidates identified that the hazard was related to the carbon monoxide content of the waste gas and clearly discussed its toxicity. Few candidates discussed the importance of burning the gas. Candidates who performed less well discussed vague problems with 'waste gases' in general, which were not relevant.

Markers' report implies that students need to elaborate on its toxicity

Additional point for 2024 onwards (old syllabus uses 'poisonous')

Key points to note – Maintaining Air Quality

Describe carbon monoxide as "**toxic**" rather than "poisonous".

- "Poisonous" is not a recognised hazard. Hence, the term "toxic" should be used instead.



USS (E/NA)
Zonal Engagemen

(c)

Updated:
'change from +1 in H_2O to 0 in H_2'
'change from +1 to 0'
'decreases from +1 to 0'

Discussion:

- 'change': if it is colour change, initial colour and final colour

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		• 'change in oxidation state': if it is numerical? (ref: 2012/2/3bi, 2022/2/6bii) From 2022: **(ii)** Deduce the change in oxidation state of nitrogen and sulfur in process 2. nitrogen ..... sulfur ..... [2] **(ii)** This question was not well answered. Some gave +3 for the initial oxidation state of nitrogen. Some gave +2 for the final oxidation state of sulfur. Marker's report implies that students need to work out both initial and final oxidation states From 2012: **(b)** Nitrogen monoxide, NO, damages the ozone layer by reacting with ozone in a two step reaction. $NO + O_3 \rightarrow NO_2 + O_2$ step 1 $NO_2 + O_3 \rightarrow NO + 2O_2$ step 2 **(i)** Use oxidation states to identify which element is **oxidised** in step 1. element ..... change in oxidation state ..... [2] **(b)** Candidates showed sound understanding of working out oxidation states, with most gaining full credit for showing the oxidation state change of nitrogen during the reaction. Marker's report implies that students need to work out both initial and final oxidation states
	(d)	$2H_2 + O_2 \rightarrow 2H_2O$ [1] Only water is produced from the combustion of hydrogen, which <u>does not cause pollution.</u> [1] [1] chemical equation for the combustion of hydrogen [1] comment on water formed which is harmless [need to relate the product] Reject: • No "harmful products" are produced
	(e)	No. of moles of hydrogen = $\frac{1000}{2}$= 500 mol [1] Enthalpy change in kJ/kg = $-286 \times 500 = -143\,000\ \text{kJ/kg}$ [1] [1] calculate no. of moles of hydrogen from the given mass [1] calculate enthalpy change in kJ/kg Note: no penalty if no units are given, but annotate on the script Include in markers' report: • Need to have clear statements and working

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A3	**(a)**	$I^-(aq) + Ag^+(aq) \rightarrow AgI(s)$ [1] correct equation [1] state symbols Accept: • State symbols all correct if correct chemical equation is given
	(b)	Step 2: Iron is more reactive than silver. Iron displaced silver from silver iodide to form iron(II) iodide and silver (product A) Step 3: Chlorine is more reactive than iodine. Chlorine displaced iodine from iron(II) iodide to form iodine and iron(II) chloride (product B). [1] relative reactivity of iron and silver [1] explain what has been displaced and identify product A [1] relative reactivity of chlorine and iodine [1] explain what has been displaced and identify product B Note: • Reject: comparison between reactivity of halogen and halides (eg. chlorine is more reactive than iodide) • Reject: incorrect terms (eg. …displaced iodide from…) • Reject: "greater distance in reactivity", "higher up in the reactivity series"
	(c)	Sublimation • Reject: "heating"

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A4 **(a)**

	metal	positive or negative electrode
cathode	**copper**	**positive**
anode	**zinc**	**negative**

[1] one mark for any two boxes

(b)

The size of the copper discs will increase and the size of zinc discs will decrease. [1]

Zinc will be oxidised to form zinc ions as it is more reactive than copper. [1]
Copper(II) ions will be **reduced/preferentially discharged/gain electrons** to form copper. [1]

[1] describe the effect on mass of individual discs
[1] state what is oxidised and explain based on relative reactivity of metals (not about relative *position* in the reactivity series)
[1] state is reduced and explain based on the ease of discharge based on the electrochemical series for cations

Reject:
- "Zinc is discharged"

Discussion:
- If students mix up metals at the electrodes, they would have the wrong analysis of the chemistry behind it
- But – award mark for specific chemistry (Eg. copper(II) ions being preferentially discharged)

(c)

There is a greater difference in reactivity between silver and zinc compared to between copper and zinc.

[1] compare between Zn and Ag vs Zn and Cu; not between Cu and Zn

Discussion:
- Allow:
  Silver is less reactive than copper. Greater difference in reactivity between silver and zinc
  'Further apart in reactivity', 'greater distance between the metal reactivity series'
- Reject:
  'higher or lower in the reactivity series' instead of 'relative reactivity'
  "silver is lower than zinc in the reactivity series"
  "silver is lower in the reactivity series"

(d) **(i)**

Positive electrode: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ [1]
Negative electrode: $2H^+(aq) + 2e^- \rightarrow H_2(g)$ [1]

Discussion:
- Missing or incorrect state symbols or "aqueous electrons" (-1 overall)

(ii)

The volume of gases collected will be the same.

In the overall equation, the molar ratio of chlorine gas to hydrogen gas formed is the same/ratio of chlorine gas: hydrogen gas = 1:1

[1] conclusion and explanation on the ratio of products formed

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			Allow: because implies that the same ratio of products would be formed • mole ratio of electrons in half-equation are the same Reject: incorrect because they should focus on the products • mole ratio of chloride ions and hydrogen ions is the same • ratio of H to C*l* in concentrated hydrochloric acid is 1:1

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		(iii)	Chlorine gas is <u>soluble</u> in water OR some chlorine gas <u>dissolved</u> in water [1] answers must relate to solubility of chlorine in water. Allow: • soluble/dissolved in acid/electrolyte (because links to context) Reject: • chloride gas • soluble in solvents (too generic; not linked to question) • chlorine gas is more dense/diffuse out
		(iv)	The white precipitate is <u>silver chloride/AgC*l*</u>. [1] Silver anode was <u>oxidised/lose electrons</u> to form <u>silver ions</u>. Silver ions <u>react</u> with <u>chloride</u> ions to form silver chloride. [1] [1] identity of the white precipitate [1] explanation for the formation of silver chloride Reject: • $AgCl_2$ • "silver chlorine" • chlorine ions • 'silver' reacts with chloride ions

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A5	**(a)**	Effervescence/bubbles of gas was observed. [1] Blue/green solid dissolved to form a blue solution. [1] Alternative answer: reaction mixture feels warm, solid decreases in size "solid dissolved" → accept, but prompt [1] description of the observation due to formation of gas [1] description of the colour of the solution formed Discussion: • Reject: Solution becomes less acidic Test for carbon dioxide gas "white ppt" formed in solution "solid dissolved to form a reddish-brown solution"
	(b)	$CuCO_3 \cdot Cu(OH)_2 + 4HNO_3 \rightarrow 2Cu(NO_3)_2 + CO_2 + 3H_2O$ [1] correct formula of the products [1] correctly balanced chemical equation To include in markers' report: • need to write the formula of copper(II) nitrate correctly
	(c)	Step 1: No. of moles of carbon dioxide = $\frac{96}{24000} = 0.004$ mol [1] No. of moles of carbonate = 0.004 mol Formula mass of carbonate = 12 + 3(16) = 60 [1] Mass of carbonate = 0.004 x 60 = 0.240 g [1] [1] calculate number of moles of carbon dioxide [1] calculate formula mass of carbonate (this working can be merged with the third mark) [1] calculate mass of carbonate present Discussion: • Allow full ecf from (b) • Allow full ecf from step 1

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A6	**(a)**		Exothermic. Increased in temperature/temperature change is positive. [1] show an understanding of exothermic reaction by making reference to the increase in temperature Reject: • Endothermic Allow: • "temperature of reactants is lower than the products" – misinterpretation of the graph, thinking that it is an energy profile diagram
	(b)	**(i)**	$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$ Reject: • Wrong chemical formula for sodium sulfate (eg. $NaSO_4$)
		(ii)	No. of moles of NaOH = 4/40 = 0.1 mol No. of moles of H_2SO_4 = 100/1000 x 1 = 0.1 mol [1] <u>Mole ratio of NaOH: H_2SO_4 = 2:1</u> OR: If 0.1 mol of NaOH was used, 0.05 mol of H_2SO_4 is required. <u>NaOH is the limiting reactant</u> [1] correct calculation of number of moles of NaOH and H_2SO_4 to reflect the mole ratio of 1:1 [1] correct conclusion by <u>using</u> the reacting ratio in the equation to show that NaOH is the limiting reactant (source: 2021 B8 OR) Allow: • Full ecf from (b)(i) • ecf for second mark only if NaOH is the LR (Eg. no credit if H_2SO_4 is the LR) • wrong equation for (b)(i) and conclude that BOTH are limiting reject: • wrong equation for (b)(i) and conclude that NEITHER are limiting
	(c)	**(i)**	Since the temperature change of +<u>4.8 °C</u> is the <u>same</u> for both experiments, the same quantity of reactants were used. [1] calculated the temperature change **and** mention that it is the 'same' (allow a range of 4.7 to 4.9 °C) Allow: • temperature 'rise', gain Reject: • no mention of data '4.8' • only mention 'nearly the same', 'almost the same' – no mention of data
		(ii)	The <u>gradient/slope</u> of the graph is <u>steeper</u> for <u>experiment 1</u> compared to experiment 2. Sodium hydroxide of a <u>smaller particle size/powdered form</u> could be used in experiment 1 compared to experiment 2. OR 200 cm^3 of 0.5 mol/dm^3 of sulfuric acid was used in experiment 2. [1] description of the gradient of the graph [1] explanation wrt particle size since sodium hydroxide used is a solid OR explanation wrt different concentration of acid used in Experiment 2 (better if specify volume to align with 'same quantity of reactants')

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			Note: do not accept ideas such as • Larger mass of sodium hydroxide (since same quantity was used) • Conducted at a higher temperature (this would go against the aim of the experiment which is to collect information about temperature) • Conducted at higher pressure (solid and aqueous reactants were used) Reject (wrt shape of shape): • "graph is…" instead of gradient • "rate of increase of T…" instead of gradient • Experiment 1 takes a shorter time (need to refer to the shape of the graph to justify) Reject (wrt reason): • Catalyst was used in experiment 1 (neutralisation rxn usually doesn't involve catalyst. Details for experiment 1 has been given in A6b) • Specifying different concentration of Experiment 1 (given in question as 1.0 mol/dm^3) Allow (wrt reason): • An "inhibitor" was used in experiment 2
	(d)	80 seconds [1] any value more than 50 seconds (as it demonstrates an understanding that the *initial* concentration of hydrogen ions is lower in ethanoic acid compared to sulfuric acid, hence a slower rate of reaction Note: though the amount of H^+ ions added is different, when ethanoic acid is used, both reactants will be completely used up. Discussion: • 3600 s as an upper limit (ref from student 240 min – "BOD" for min)	

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		Section B
B7	**(a)**	Potassium oxide/ K_2O To share in Markers' Report: • Address the misconception of SiO_2 as a compound of alkali metals
	(b)	The forces of attraction are **weak** enough to: • allow the layers of clay to slide past each other when a force is applied • OR allow the clay to be moulded into shape/shape easily The forces of attraction are **useful** to: • keep/maintain/hold the shape of the clay object once shaped/when the force is removed [1] why the intermolecular forces of attraction are weak [1] why the intermolecular forces of attraction are useful To share in Markers' Report: • "application" of weak intermolecular forces of attraction where it can be useful (shaping clay, use of blue tac, hair curlers…practical scenarios in daily life)
	(c)	Water boils to form water vapour/steam when heated above boiling point. [1] Steam/water vapour expands when heated/occupies a large volume [1]. The clay pot will explode if heated too quickly, destroying the ceramic. [1] behaviour of particles in a change of state (move rapidly, random direction, high speed) [1] behaviour of particles in gaseous state (expansion in volume, increase pressure against the clay, force against the clay particles) Discussion: take reference to Chapter 1 WS(B) – a better answer because it covers concepts of Kinetic Particle Theory (microscopic perspective) Original answer: macroscopic perspective • Allow: 1st mark: Description of how liquid water has changed to gaseous state 2nd mark: Steam occupies a larger volume than liquid water/ larger space between particles of water/ clear explanation of increased pressure as a result of expansion of gas/ increased pressure • Reject: particles move at great speed and move randomly, gain kinetic energy, Gas particles have no fixed volume, acts against inside of the clay, leading to explosion (doesn't imply that it has expanded, because gas an be compressed), To share in Markers' Report: • Not to blindly use change in state in KPT (describe the behaviour of steam/particles of water vapour)

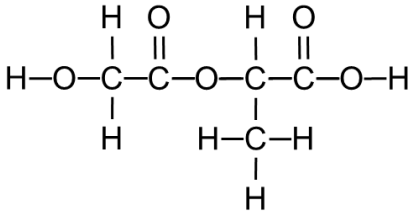
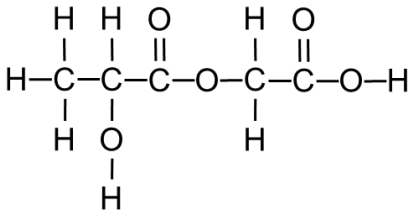
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	(d)	The removal of chemical water requires more energy because of the strong covalent bonds that require much more energy to overcome. [1] Hence a higher temperature is required. The removal of free water via evaporation requires less energy because of the weak intermolecular forces of attraction between water molecules that are easy to overcome. [1] Hence a lower temperature is required. Or one mark for bonding and another mark for energy Alternative: Compare physical change vs chemical change [1] [1] explain the energy required to overcome strong covalent bonds in stage 2 [1] energy required to overcome weak intermolecular forces of attraction in stage 1
	(e)	Sulfur dioxide/sulfur trioxide It is acidic gas/oxide. • Reject: need to talk the nature of the gas Harmful gas
	(f)	As quartz melts, the particles change from vibrating and rotating from fixed positions to slipping and sliding over one another. [1] In the liquid state, quartz can flow freely throughout/move freely, filling up spaces/gap between the clay particles. [1] [1] description of the change in arrangement from solid to liquid [1] description of movement of liquid particles in the context of filling up spaces between the clay particles
	(g)	coloured/colourful oxides [1] answer must related to decorative reasons Note: do not accept generic properties of transition metal oxides • high melting/boiling point • used as catalyst

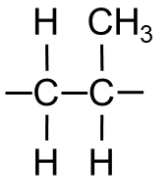
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B8	**(a)**	$2Fe + 3/2O_2 + nH_2O \rightarrow Fe_2O_3.nH_2O$ or $4Fe + 3O_2 + 2nH_2O \rightarrow 2Fe_2O_3.nH_2O$ Iron reacts with <u>oxygen in the presence of water</u> to form rust. [1] – correctly balanced equation [1] – correct description of rusting, stating conditions (i.e., O_2 and H_2O) Reject: because BOTH water and oxygen are reactants • iron reacts with oxygen and it is "hydrated" by water • water "hydrates" the rust	
	(b)	**(i)**	Y < Fe < X [1]
		(ii)	In beaker **3**, iron nail does not rust shows that *metal **X** is more reactive than Fe* as **X** <u>is oxidised instead of Fe/metal X corrodes in place of/preferentially to Fe</u> In beaker **4**, iron nail rusts completely shows that Fe is more reactive than metal **Y**, hence <u>*Fe is preferentially oxidised to* Fe^{3+}/Fe rusts/corrodes in place of/</u>preferentially to <u>metal Y/</u> [1m each] – correctly linking observations to *relative reactivity of metals* **<u>or</u>** *stating which metal is preferentially oxidised*] (see answer examples above) Allow: • Iron metal went through oxidation, acting as <u>sacrificial metal</u> for Y (BOD)
		(iii)	**X** can be either Mg, Zn or any metal above Fe in reactivity series [1] (reject Na, K as they will react explosively in cold water).
	(c)	In an alloy, the <u>atoms</u> of the different metals or elements have <u>different sizes</u>. The regular <u>arrangement of atoms</u> in the pure metal is <u>disrupted</u>. The <u>layers of atoms</u> of different sizes <u>cannot slide over each other easily</u> <u>when a force is applied</u>. As a result, an alloy is stronger and harder than pure iron metal. (source: Textbook pg 249) [1] correct description of atoms in an alloy and how the arrangement is disrupted [1] impact of layers of atoms having different sizes	

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B9 E	**(a)**	**(i)**	ethyl ethanoate [1]
		(ii)	Add Na_2CO_3 or any other metal carbonate [reject Mg, Na as they react with water, not just acids] Effervescence of carbon dioxide that forms a <u>white precipitate in limewater</u> [1] – correct chemical test [1] – correct observations Allow: • Add "metal carbonate" (BOD)
		(iii)	Reactants side – break 1 C-O bond in ester A and 1 O-H bond in water Products side – form 1 C-O bond in ethanoic acid and 1 O-H bond in ethanol Same number and same type of bonds broken and formed so net enthalpy change is zero as $\Delta H = \Sigma$ BE (bonds broken) - Σ BE (bonds formed) [1] – for correcting stating the type of bonds broken and bonds formed [1] – for explaining net change is zero due to same number and same bonds broken and formed or using equation for ΔH to explain.
		(iv)	Oxidation. [1] Acidified $KMnO_4$ or $KMnO_4$ / H_2SO_4 [1]
	(b)	**(i)**	 *(–COOH from glycolic acid with –OH from lactic acid)*  *(–COOH from lactic acid with –OH from glycolic acid)* Allow: –OH, $–CH_3$ or –COOH, $–CH_2–$, –COO– allowed. Not all bonds need to be shown as question asks for structural formula, not displayed / full structural formula
		(ii)	The polyesters formed will hydrolyse / <u>break up</u> / react with water to form constituent glycolic acid and lactic acid which are highly soluble in water and are natural compounds found in the body. [1] - any possible answer showing understanding of hydrolysis in body either to form soluble compounds or natural compounds

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B9 OR	**(a)**	Alkanes [1]	
	(b)	**(i)**	mass of kerosene = 10.8 x 10700 = 115 560 kg ≈ 116 000 kg (3sf) [1] Accept: • "115 560 kg"
		(ii)	Step 1: number of mol of kerosene = $\frac{115560 \times 10^3}{(14\times12)+30}$ = 583636.36 mol [1] Step 2: number of mol of CO_2 = $\frac{583636.36}{2} \times 28$ = 8170909.09 mol [1] Step 3: mass of CO_2 = 8170909.09 x (12+32) = 359520000 g = 359 520 kg ≈ 360 000 kg (3 sf) [1] *Notes:* • Marks should be awarded for correct method and computation. [*Errors to look out for:* – Step 1: correct conversion of kg to g before calculation of mole – Step 2: use correct mol ratio (i.e. multiply by 1/2) • Allow ecf marking from (i) / or any other mistakes made in Step 1 & 2 – Punch in data from ECF to check whether computation is correct before awarding ecf mark.
	(c)	**(i)**	Identified compound: $CH_3CHBrCH_2Br$ Hence, E is propene / $CH_3CH=CH_2$ [reject molecular formula, C_3H_6] } [1] E has molecular formula C_3H_6 as deduced from the cracking of Kerosene E must be alkene which undergoes addition reaction with bromine to form dibromoalkane with 2 bromine atoms attached to adjacent C. [1] – correct identification of $CH_3CHBrCH_2Br$ *and* correct identify of E. [No mark awarded for molecular formula given] [1] – correct reasoning to why E is alkene, either from molecular formula of E deduced from cracking equation or from addition reaction to form dibromoalkane [1] – correctly stating type of reaction (i.e., Addition reaction) and correct description to form dibromoalkane with 2 bromine atoms attached to adjacent C [correct description can be exemplified by using relevant equation shown]
		(ii)	 [1] - correct structure of polypropene, showing at least 1 repeating unit (allow ecf from (c)(i) [1] - any possible environment consequence (cannot be a general statement eg 'pollution', 'water pollution' Possible environmental consequence: focus on the disposal of plastic (TB Pg 479) • Land pollution: Plastics are non-biodegradable, hence filling up landfill. • Air pollution: Burning / incinerating plastics produce poisonous / toxic gases. • Water pollution: endanger marine sea animals who may mistake plastic bags for food and consume them

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