NAME:		( )	CLASS:	

YISHUN TOWN SECONDARY SCHOOL

G3

PRELIMINARY EXAMINATION 2025

SECONDARY 4

G3 CHEMISTRY

(6092/2)

DATE : 21 August 2025 **DAY : Thursday**

DURATION : 1 h 45 min **MARKS : 80 marks**

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number in the spaces provided at the top of this page.

Section A

Answer **all** questions.
Write your answers in the spaces provided.

Section B

Answer **one** question.
Write your answers in the spaces provided.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

You may use an approved calculator.

A copy of the Periodic Table is printed on the last page.

Section A	
Section B	
TOTAL	

This question paper consists of **18** printed pages, including the cover page.

SECTION A

Answer **all** questions.

1 Some nuclide notations are given below.

^{1}H	^{12}C	^{14}C	^{18}O	^{56}Fe	^{58}Ni	^{65}Zn

Use the nuclide notations to answer the following questions. You may use them once, more than once or not at all.

(a) Which is used as the basis for the definition of relative atomic and molecular masses?

..... [1]

(b) Which is used in Haber Process?

..... [1]

(c) Which is a metal but not a transition element?

..... [1]

(d) Which **two** have the same number of neutrons?

..... [1]

(e) Which **two** forms elements which are diatomic molecules?

..... [1]

(f) Which **two** have the same chemical properties but different physical properties?

..... [1]

[Total: 6]

2 Group 1 metals react with water.

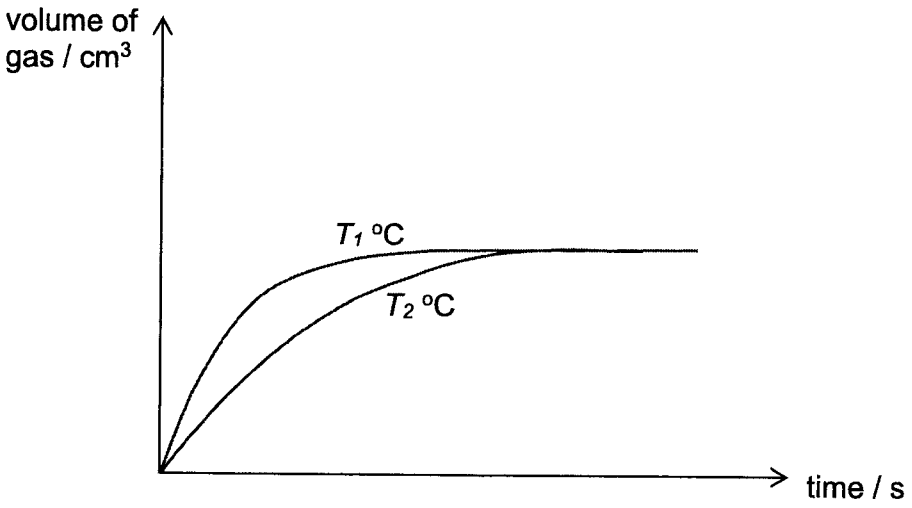
Group 1 metal	reaction with water	melting point / °C
lithium		
sodium	bubbles form rapidly with no flame	
potassium	bubbles form very rapidly with flame	
rubidium	explodes	

(a) **(i)** Complete the table above for the reaction of lithium with water. [1]

(ii) The melting points of the four Group 1 metals shown above are 64 °C, 39 °C, 181 °C and 98 °C (not arranged in any sequence).

Complete the table above with the correct melting points of the Group 1 metals. [1]

(b) Two small 0.6 g pieces of lithium are reacted with 100 cm^3 of water (an excess) at T_1 °C and T_2 °C respectively. The following graphs show the volume of gas produced when plotted against the time taken for the reactions.



(i) Use the graphs to explain whether T_1 °C or T_2 °C is at a higher temperature.

.....

.....

..... [2]

(ii) Sketch a graph to show what would happen when 0.3 g of lithium is reacted with 100 cm^3 of water at T_1 °C. [1]

[Total: 5]

3 The composition of polluted water is as shown.

ion	concentration of ion in polluted water / mg/dm^3
ammonium	0.6
bromide	0.3
calcium	2.5
chloride	2.5
bicarbonate (HCO_3^-)	12.0
magnesium	0.8
nitrate	0.4
phosphate (PO_4^{3-})	0.5
potassium	5.3
silicate (SiO_3^{2-})	3.0
sodium	9.2
sulfate	0.5

(a) Write the **formula** of the compound formed from the Group 2 cation with the lower concentration and the anion with the highest concentration.

..... [1]

(b) Calcium phosphate is insoluble in water. Calculate the maximum mass of calcium phosphate that can be precipitated from 100 cm^3 of polluted water. (1 mg = 0.001 g)

$$3Ca^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ca_3(PO_4)_2(s)$$

[4]

(c) (i) Suggest how you may test for the presence of chloride in the sample of polluted water.

.....

.....

..... [2]

(ii) Suggest why the sample may not give the intended result when tested for the presence of chloride.

.....

..... [1]

(d) Identify **two** compounds that can be used to prepare calcium chloride. You need to specify the state (solid or aqueous) of the substances clearly.

..... [2]

(e) Polluted water may be cleaned using a suitable concentration of ethanoic acid. Ethanoic acid may stimulate the growth of naturally occurring bacteria which helps to break down certain pollutants.

Some information about ethanoic acid and a model showing the dissociation of aqueous ethanoic acid are shown below.

substance	ethanoic acid, CH_3CO_2H
solubility	soluble in both water and organic solvents like alcohols
nature	weak acid which dissociates less than 1% in water
density	1.05 g/cm^3
melting point	16 °C
boiling point	118 °C

$CH_3CO_2^-$	H^+
CH_3CO_2H	CH_3CO_2H
CH_3CO_2H	CH_3CO_2H
CH_3CO_2H	CH_3CO_2H
CH_3CO_2H	CH_3CO_2H

aqueous ethanoic acid

One inaccuracy depicted in the model is the fact that water molecules are not shown despite the solution being aqueous.

Explain **two** other inaccuracies depicted by the model. Include relevant data or information in your explanation.

.....

.....

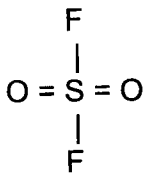
.....

..... [2]

[Total: 12]

4 Sulfur has the ability to accommodate **12 electrons in its valence shell** when it forms compounds. Two of these sulfur-containing compounds are sulfuryl fluoride (SO_2F_2) and sodium pyrosulfate ($Na_2S_2O_7$).

(a) The structural formula of sulfuryl fluoride is shown. Draw the dot-and-cross diagram for sulfuryl fluoride, showing only the valence electrons.



[2]

(b) Sulfuryl fluoride can be prepared using two methods.

The **first method** consists of a three-step reaction.

Step 1: $SO_2 + KF \rightarrow KSO_2F$
Step 2: $KSO_2F + Cl_2 \rightarrow SO_2ClF + KCl$
Step 3: $SO_2ClF + KSO_2F \rightarrow SO_2F_2 + KCl + SO_2$

The **second method** produces sulfuryl fluoride by reacting sulfur dioxide with fluorine.

$$SO_2 + F_2 \rightarrow SO_2F_2$$

(i) Write an overall equation for the **first method** to prepare sulfuryl fluoride.

..... [1]

(ii) Suggest the role of sulfur dioxide in the **first method**.

..... [1]

(iii) Explain the effect that sulfur dioxide can have on the environment.

.....

.....

..... [2]

(c) (i) Using the bond energy values given below, calculate the enthalpy change for the reaction of the **second method**.

Note: The structure of SO_2 is O = S = O.

bond	F – F	S – F
bond energy / kJ/mol	155	265

[2]

(ii) Hence, draw an energy level diagram for the reaction of the **second method**.

[3]

(d) Sodium pyrosulfate is a colourless salt which reacts readily with water.

When sodium pyrosulfate is heated to about 460 °C, it decomposes.

$$Na_2S_2O_7 \rightarrow Na_2SO_4 + SO_3$$

In terms of oxidation numbers, explain whether the decomposition of sodium pyrosulfate is a redox reaction.

.....

.....

..... [2]

[Total: 13]

5 This question is about the chemistry of chromium.

Chromium is extracted from iron (II) chromite, $FeCr_2O_4$. Iron (II) chromite is first heated with sodium carbonate in the presence of oxygen to obtain sodium chromite.

Reaction 1: $4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$

Chromium is then extracted by treating sodium chromite with carbon.

Reaction 2: $Na_2CrO_4 + 2C \rightarrow Cr + Na_2O + CO + CO_2$

(a) Calculate the **total** volume of carbon dioxide produced from both **Reaction 1** and **Reaction 2** when 22.4 g of iron (II) chromite is fully converted into chromium.
(M_r of $FeCr_2O_4$ = 224)

[3]

(b) Chromium is commonly added together with carbon and iron to produce stainless steel.

Explain why stainless steel is stronger than pure iron.

.....

.....

..... [2]

(c) Solid anhydrous chromium (III) chloride is violet. Chromium (III) chloride can be reacted with carbon monoxide under high pressure in the presence of either magnesium or zinc to produce chromium hexacarbonyl, $Cr(CO)_6$. A by-product is also formed.

(i) Predict whether magnesium or zinc requires a higher pressure when reacted with chromium (III) chloride and carbon monoxide. Explain your answer.

.....

.....

..... [2]

(ii) Name the by-product formed when magnesium is used.

..... [1]

(d) Some information of chromium (III) chloride and chromium hexacarbonyl are shown below.

compounds	$CrCl_3$	$Cr(CO)_6$
melting point / °C	1150	90
boiling point / °C	decomposes before boiling	210
solubility in water	slightly soluble	insoluble
solubility in organic solvent	insoluble	soluble

In terms of structure and bonding, explain whether chromium hexacarbonyl behaves as an ionic or covalent compound. Use all relevant data in the table to support your answer.

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..... [3]

(e) Chromium (III) hydroxide is insoluble in water but reacts readily with aqueous nitric acid. When aqueous sodium hydroxide is added to chromium (III) hydroxide, the following reaction takes place.

$$Cr(OH)_3 + NaOH \rightarrow NaCrO_2 + 2H_2O$$

(i) Write the equation for the reaction of chromium (III) hydroxide with aqueous nitric acid. Include the state symbols.

..... [2]

(ii) State the acid-base nature of chromium (III) hydroxide.

..... [1]

[Total: 14]

6 Chemistry of Honey

Honey contains at least 180 substances that give its unique taste. Honey produced from different plants, climates and geographical areas have different aroma and taste. Honey is one of the very few foods that can be kept for a very long time even at room temperature due to its very low water level.

Production of Honey

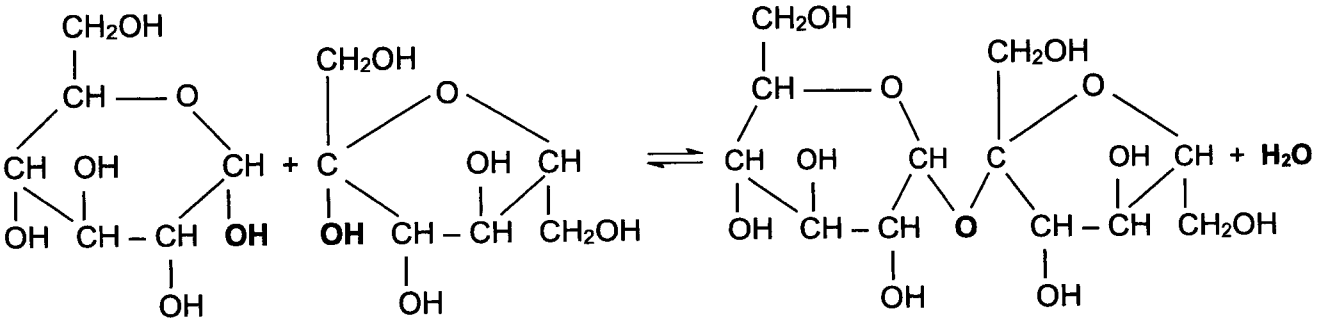
The production of honey begins with bees obtaining nectar from plants. Nectar consists mainly of about 80% water, 20% sucrose and many other substances. Bees continuously re-drink and regurgitate nectar into their alternative stomach (not the one used for eating and digestion) until the water level of nectar decreases from 80% to 20%.

Throughout this process, the enzymes in their stomachs break down some, but not all, sucrose into glucose and fructose. The honey at this stage is deposited into honeycomb in the bees' nests. Bees then use their wings to fan the honey until the water level falls further to 15%.

Sucrose, Glucose and Fructose

Sucrose is a disaccharide, or "two sugars", since it is made up by combining a glucose molecule with a fructose molecule. Glucose and fructose are monosaccharides, or "one sugar".

The structures of glucose, fructose and sucrose and the reaction involved are shown below. For ease of reference, only the atoms involved in the reaction is highlighted in **bold**. All other atoms are not involved.

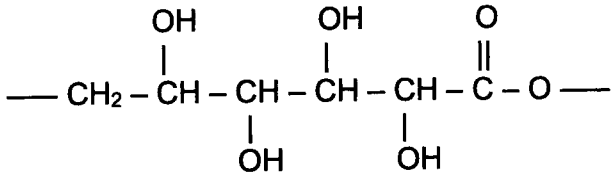


glucose ($C_6H_{12}O_6$) fructose ($C_6H_{12}O_6$) sucrose ($C_{12}H_{22}O_{11}$) water (H_2O)

Other Substances Found in Honey

Besides water and sugars, honey also contains many other substances. Some of these include formic acid, citric acid, gluconic acid and hydrogen peroxide.

Citric acid has the same empirical and molecular formula with 37.5% carbon, 4.2% hydrogen and 58.3% oxygen. Gluconic acid and hydrogen peroxide are produced when some glucose molecules react with the enzymes in the bees' stomachs. Gluconic acid can be used to produce a polymer with the following partial structure.



The presence of these acids results in honey having a pH of approximately 3 to 4. These acids help to boost the antibacterial properties of honey since most bacteria thrive in neutral rather than acidic conditions. Hydrogen peroxide contributes further to prevent the growth of microbes.

Hygroscopic Nature of Honey

However, honey contains a small quantity of yeast and is hygroscopic (absorbs moisture easily). When the water level of honey left in the open rises to about 25%, the glucose present undergoes significant fermentation which alters the taste of honey. Some people do this intentionally to make honey wine and other delicacies.

(a) The equation for the conversion of glucose and fructose into sucrose and vice versa is a reversible reaction.

Complete the following sentence with a phrase taken from the section titled "**Production of Honey**" to illustrate that the reaction is a reversible reaction.

The reversible reaction is illustrated by the phrase "....". [1]

(b) (i) State the relationship between glucose and fructose.

..... [1]

(ii) Suggest the name of the reaction when glucose and fructose become sucrose.

..... [1]

(c) (i) Calculate the empirical and molecular formula of citric acid.

[3]

(ii) Draw the structure of gluconic acid.

[1]

(iii) Honey is so sweet that another taste associated with it is not easily noticeable. Using the information provided, state this taste.

..... [1]

(d) (i) Write the chemical equation when glucose undergoes fermentation.

..... [1]

(ii) Explain, using energy and collisions, how the presence of yeast contributes to fermentation.

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..... [3]

[Total: 12]

7 Crude oil can be separated into fractions. Cracking may then be performed on some of the long-chain *hydrocarbons* found in the fractions.

fractions	main number of carbon atoms per molecule
natural gas	1 to 4
petrol	5 to 12
kerosene	10 to 16
diesel	15 to 20
lubricating oil	18 to 34
bitumen	up to about 70

(a) (i) Name the process used to separate crude oil into its fractions.

..... [1]

(ii) Define what is meant by *hydrocarbons*.

..... [1]

(iii) Name the main substance present in natural gas.

..... [1]

(b) Butene and hydrogen can be produced from the cracking of $C_{17}H_{36}$. Only one other by-product is formed. One mole of each product is formed from one mole of $C_{17}H_{36}$.

(i) Write the equation for the cracking of $C_{17}H_{36}$.

..... [1]

(ii) State which fraction of the crude oil the by-product belongs to.

..... [1]

(c) Pent-2-ene may be formed during cracking. The structure of pent-2-ene is $CH_3CHCHCH_2CH_3$.

Draw the **two** addition polymers that can be formed from pent-2-ene, each showing two repeating units.

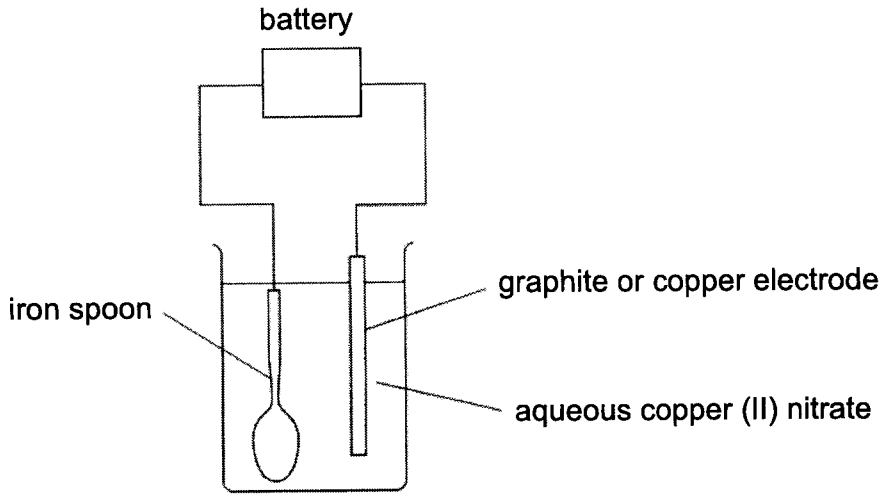
[3]

[Total: 8]

SECTION B

Answer **one** question from this section.

8 An iron spoon is to be electroplated with copper. One electrode is the spoon while the other electrode can be either graphite or copper. The electrolyte used is aqueous copper (II) nitrate.



(a) In the box above, draw the symbol for the battery. [1]

(b) Explain the difference in the colour of the electrolyte when copper and graphite is used for electroplating.

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..... [4]

(c) Graphite is suitable to be used as an electrode because of the nature of its melting point and electrical conductivity. Explain these properties in terms of structure and bonding.

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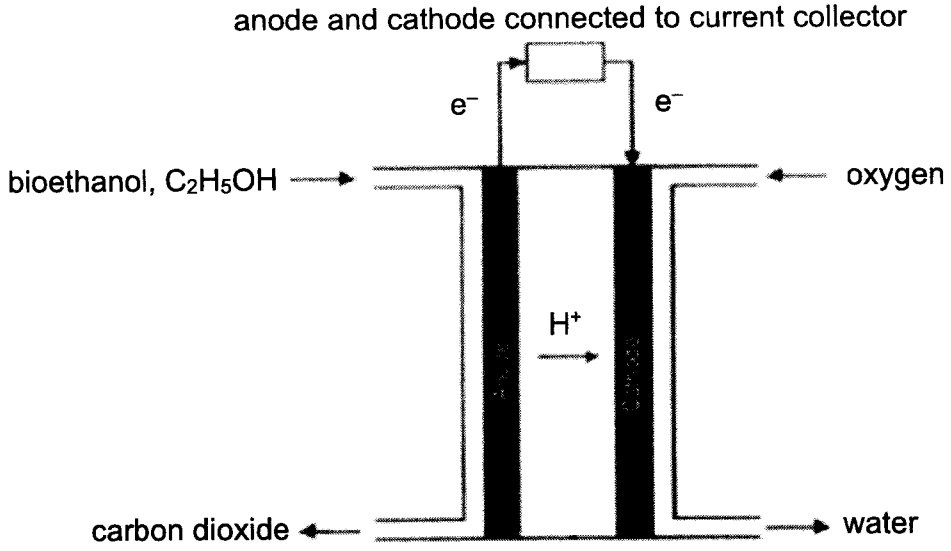
..... [5]

[Total: 10]

9 A diagram representing a bioethanol fuel cell is shown.



The reactions at the anode and cathode are given below.

Anode: $C_2H_5OH + 3H_2O \rightarrow 12H^+ + 12e^- + 2CO_2$

Cathode: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

(a) (i) In terms of electrons, explain how the operation of a fuel cell at the anode and cathode is a redox reaction.

.....

.....

.....

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..... [2]

(ii) Write an overall equation for the reaction of the fuel cell.

..... [1]

(b) Bioethanol is often compared to hydrogen and fossil fuels in terms of environmental effect. These may include issues like pollution and use of land space.

In terms of environmental effect, discuss:

- one advantage that bioethanol has compared to hydrogen and fossil fuels.
- one disadvantage that bioethanol has compared to hydrogen.
- one disadvantage that bioethanol has compared to fossil fuels.

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..... [3]

(c) The function of the current collector connecting the anode and cathode is to direct the electrons to an external circuit to power devices.

Graphite is commonly chosen as the material for the current collector due to its good electrical conductivity. However, graphite can be slippery.

Explain these properties of graphite in terms of structure and bonding.

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..... [4]

[Total: 10]

The Periodic Table of Elements

Group 1	Group 2											Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 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
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
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 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
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 –	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
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	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 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	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
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

YTSS 2025 Chem Prelim Marks Scheme

Paper 1

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

Paper 2

	Answers	**Remarks**
1(a)	^{12}C	1
(b)	^{56}Fe (accept ^{1}H)	1
(c)	^{65}Zn	1
(d)	^{56}Fe and ^{58}Ni	1
(e)	^{1}H and ^{18}O	1
(f)	^{12}C and ^{14}C	1
2(a)(i)	bubbles form **slowly** (with no flame)	1 (penalise if "with flame" written)
(a)(ii)	181, 98, 64, 39	1 (ignore units)
(b)(i)	T_1 °C is at a higher temperature. Gradient of the graph is higher / Slope of the graph is steeper, hence rate of reaction is higher.	(ignore units, no credit on its own, but required for the following credit) 1 1
(b)(ii)	(half the height and less steep than T_1, can either be above or below T_2)	1 (reject if any part of the graph overlap with T_1)
3(a)	$Mg(HCO_3)_2$	1, penalise name
(b)	number of mole of Ca^{2+} = (2.5/1000) x (100/1000) / 40 = 6.25×10^{-6} mol number of mole of PO_4^{3-} = (0.5/1000) x (100/1000) / 95 = 5.2632×10^{-7} mol mole ratio $Ca^{2+} : PO_4^{3-}$ = 3 : 2 = $6.25 \times 10^{-6} : 4.1667 \times 10^{-6}$ mol Hence, PO_4^{3-} is limiting. number of mole of $Ca_3(PO_4)_2$ formed = $5.2632 \times 10^{-7} / 2$ = 2.6316×10^{-7} mol maximum mass of $Ca_3(PO_4)_2$ formed = $2.6316 \times 10^{-7} \times 310$ = 8.16×10^{-5} g	1 for both moles 1 for LR explanation 1, ecf from mole of PO_4^{3-} 1, ecf from mole of $Ca_3(PO_4)$, M_r of Ca^{2+} and M_r of PO_4^{3-}

(c)(i)	To a sample of solution, add aqueous nitric acid and aqueous silver nitrate. If a white precipitate is seen, chloride is present.	1 (penalise sulfuric acid, hydrochloric acid, penalise ½ for missing "aqueous) 1
(c)(ii)	The concentration of chloride may be too low to be detected. OR Other precipitate may be obtained instead. (e.g. silver bromide or silver sulfate, hence the ppt may not prove the presence of chloride.)	1 (reject "impurities" alone with no explanation on what will impurities caused)
(d)	solid calcium oxide / solid or aqueous calcium hydroxide / solid calcium carbonate with aqueous hydrochloric acid	1 (penalise ½ for missing state) 1 (penalise ½ for missing state)
(e)	Ethanoic acid should only dissociate less than 1% in water, but the diagram shows a dissociation of about 10%. Particles arrangement in aqueous solution should be random / disorderly but the diagram shows an orderly arrangement.	1 (penalised "20%") 1
4(a)		1 for all bonding electrons and 1 for all non-bonding electrons
(b)(i)	Step 1: ~~SO_2~~ + KF → ~~KSO_2F~~ Step 2: ~~KSO_2F~~ + Cl_2 → ~~SO_2ClF~~ + KCl Step 3: ~~SO_2ClF~~ + KSO_2F → SO_2F_2 + KCl + ~~SO_2~~ Overall: KF + KSO_2F + Cl_2 → SO_2F_2 + 2KCl	(workings not required) 1
(b)(ii)	catalyst	
(b)(iii)	SO_2 dissolves in (rain)water to produce acid rain, which can corrode limestone (metal) structures / caused water bodies to be acidic killing marine lives / caused soil to be acidic and unsuitable for crops.	1 1
(c)(i)	Energy absorbed to break bond of reactant = 155 kJ/mol Energy released to form bonds of products = 2(265) = 530 kJ/mol Enthalpy change = 155 – 530 = –375 kJ/mol or kJ	 1 (penalise ½ for wrong statement, ignore units) 1 (with units)
(c)(ii)		1 for axes, ecf from (c)(i) 1 for exo graph 1 for labelled reactants, products and ΔH with values and units
(d)	$Na_2S_2O_7 \rightarrow Na_2SO_4 + SO_3$ Oxidation number of S (in $Na_2S_2O_7$ / or $S_2O_7^{2-}$, Na_2SO_4 / SO_4^{2-} and SO_3) remains unchanged as +6. Oxidation number of Na / Na^+ and O also remains unchanged at +1 and –2 respectively. Hence, this is not a redox reaction.	1 (not S^{6+}) 1 (not O^{2-}) (no marks awarded)

<table>
<tr><td>5(a)</td><td>$4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$
$Na_2CrO_4 + 2C \rightarrow Cr + Na_2O + CO + CO_2$

Number of mole of $FeCr_2O_4$ = 22.4 / 224 = 0.1 mol
Number of mole of CO_2 from Reaction 1 = 0.1 x 2 = 0.2 mol

Number of mole of $Na_2Cr_2O_4$ = 0.2 mol
Number of mole of CO_2 from Reaction 2 = 0.2 mol

Total number of mole of CO_2 = 0.4 mol

Total volume of CO_2 = 0.4 x 24 = 9.6 dm^3</td><td>

½

½

1, ecf

1, ecf</td></tr>
<tr><td>(b)</td><td>Steel has atoms of different sizes which disrupts regular arrangement of (layers of) atoms.
Hence, the LAYERS (of atoms) do not slide easily (when an external force is applied).</td><td>1

1</td></tr>
<tr><td>(c)(i)</td><td>Zinc requires a higher pressure.
Zing is less reactive than magnesium (and loses electrons less readily).</td><td>1
1 (or vice versa)</td></tr>
<tr><td>(c)(ii)</td><td>magnesium chloride</td><td>1</td></tr>
<tr><td>(d)</td><td>$Cr(CO)_6$ has a simple covalent molecular structure with weak intermolecular forces of attraction (between molecules)
which requires little / low (not less or lower) energy to break. Hence, it has a low melting point of 90 °C and low boiling points of 210 °C.
As simple covalent molecules, $Cr(CO)_6$ can dissolve in water / aqueous solution but not in organic solvent.</td><td>1 (structure and bonding)

1 (energy, mp, bp and quote <u>BOTH</u> data)

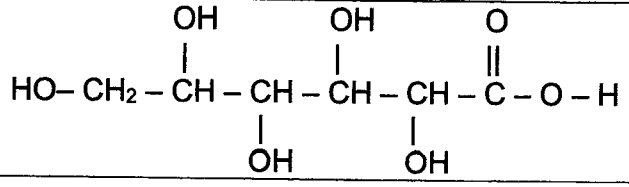
1 (solubility)</td></tr>
<tr><td>(e)(i)</td><td>$Cr(OH)_3$ (s) + $3HNO_3$ (aq) → $Cr(NO_3)_3$ (aq) + $3H_2O$ (l)</td><td>1 for balanced equation
1 for state symbols</td></tr>
<tr><td>(e)(ii)</td><td>amphoteric</td><td>1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>6(a)</td><td>“some, but not all (sucrose)”</td><td>1</td></tr>
<tr><td>(b)(i)</td><td>isomers</td><td>1 (accept isomerism)</td></tr>
<tr><td>(b)(ii)</td><td>dehydration / condensation / elimination</td><td>1 (ignore “polymerisation”)</td></tr>
<tr><td>(c)(i)</td><td>Assume 100 g of citric acid.

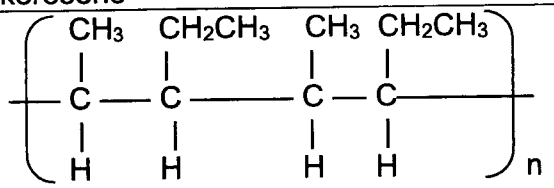
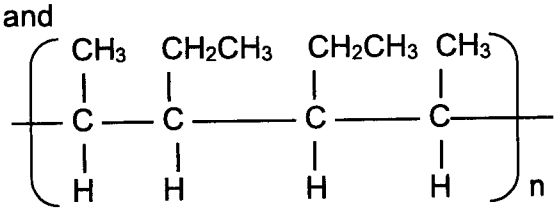
<table>
<tr><td>element</td><td>C</td><td>H</td><td>O</td></tr>
<tr><td>mass / g</td><td>37.5</td><td>4.2</td><td>58.3</td></tr>
<tr><td>amount / mol</td><td>37.5 / 12
= 3.125</td><td>4.2 / 1
= 4.2</td><td>58.3 / 16
= 3.6438</td></tr>
<tr><td>simplest ratio</td><td>3.125/3.125
= 1</td><td>4.2/3.125
= 1.344</td><td>3.6438/3.125
= 1.166</td></tr>
<tr><td>simplest whole number</td><td>1 x 6
= 6</td><td>1.344 x 6
= 8</td><td>1.166 x 6
= 7</td></tr>
</table>

Empirical and molecular formula = $C_6H_8O_7$</td><td>

1

1

1</td></tr>
<tr><td>(c)(ii)</td><td>  </td><td>1</td></tr>
</table>

(c)(iii)	sour	1
(d)(i)	$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$	1
(d)(ii)	Yeast / Enzyme is a catalyst which provides an alternative reaction pathway with lower activation energy. More glucose / reactant particles (has sufficient energy) to achieve / overcome the activation energy. Frequency of effective collisions increases and hence rate of reaction increases.	1 1 1 (frequency of collisions did not increase but ignore)
7(a)(i)	fractional distillation	1
(a)(ii)	compounds / substances that contain carbon and hydrogen ONLY	1
(a)(iii)	methane	1
(b)(i)	$C_{17}H_{36} \rightarrow C_4H_8 + H_2 + C_{13}H_{26}$	1
(b)(ii)	kerosene	1 (ecf)
(c)	 and 	1 for first structure showing 2 repeat units 1 for polymer with $( )_n$ 1 for second structure
8(a)	(short line on the left followed by long line on the right)	1
(b)	At the cathode, copper (II) ions is (preferentially) discharged / reduced / gains electrons (more easily than H^+) to become Cu. When copper is used at the anode, copper is (preferentially) oxidised / loses electrons more easily than OH^- and NO_3^-) to become Cu^{2+}. Hence, concentration of Cu^{2+} (in electrolyte) remains unchanged and blue colour remains. When graphite is used at the anode, OH^- is preferentially discharged / oxidised / loses electrons (more easily than NO_3^-) to become O_2 (gas and H_2O). Hence, concentration of Cu^{2+} (in electrolyte) decreases and blue colour fades / turns colourless.	1 ½ (penalise "discharge") ½ ½ ½ ½ ½
(c)	Graphite has a giant covalent (molecular layered) structure with strong (and extensive) covalent bonds between (carbon) atoms, which require (very) high energy to break. Hence, it has a (very) high melting point. Each (carbon) atom (in graphite has four valence electrons and) is bonded to three other (carbon) atoms (in a hexagonal structure). One valence electron (for each carbon atom) can be delocalised / free to move / is mobile (within the layer, but not across layers).	1 (structure and bonding) 1 (energy & mp) 1 1 ("valence" or "outermost" needs to be mentioned, can be in other sentences)

	Hence, graphite <u>can conduct electricity within each layer</u>.	1 ("within layer" needs to be mentioned, can be in other sentences)
9(a)(i)	Anode: $C_2H_5OH + 3H_2O \rightarrow 12H^+ + 12e^- + 2CO_2$ Cathode: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ At the anode, (each) ethanol loses (12) electrons / (each) carbon atom loses (6) electrons to become CO_2. At the cathode, (each) O_2 gains (4) electrons / (each) <u>oxygen atom gains (2) electrons</u> to become H_2O.	 1 1
(a)(ii)	$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$	1
(b)	<u>Advantage of bioethanol over hydrogen and fossil fuels</u> Bioethanol is **renewable / infinite** resource. Bioethanol is obtained from plant sources which can be quickly grown. Hydrogen and fossil fuels are non-renewable / finite since they are obtained from crude oil. **OR** Bioethanol is a **carbon neutral** fuel. CO_2 produced during burning of bioethanol is offset by that used during its growth. Hydrogen and fossil fuels is not carbon neutral since their production and burning produces CO_2. **OR** Bioethanol is **biodegradable** and will not harm the environment when spilled or leaked. Hydrogen and fossil fuels are not biodegradable. <u>Disadvantage of bioethanol over hydrogen</u> Bioethanol produces CO_2 which is a greenhouse gas during burning. H_2O produces only water which is non-pollutant during burning / combustion. <u>Disadvantage of bioethanol over fossil fuels</u> Bioethanol is obtained from crops which require large land area (which could otherwise be used for housing, conservation etc) **OR** large amount of water (which could be a scarce resource in some geographical areas). Production of fossil fuels uses less land area / less water.	1 1 1
(c)	Each (carbon) atom (in graphite has four valence electrons and) is bonded to three other (carbon) atoms (in a hexagonal structure). One <u>valence</u> electron (for each carbon atom) can be delocalised / free to move / is mobile (within the layer, but not across layers). Hence, graphite can conduct electricity <u>within each layer</u>. However, there is <u>weak</u> intermolecular forces of attraction <u>between layers</u>. Hence, it is slippery.	1 1 ("valence" or "outermost" needs to be mentioned, can be in other sentences) 1 ("within layer" needs to be mentioned, can be in other sentences) 1 ("between layers" is required)