Government of Western Australia
School Curriculum and Standards Authority

CHEMISTRY

Stage 3

WACE Examination 2013

Marking Key edit

Marking keys are an explicit statement about what the examiner expects of candidates when they respond to a question. They are essential to fair assessment because their proper construction underpins reliability and validity.

Section One: Multiple-choice **25% (25 Marks)**

Question No.	Answer
1	a
2	c
3	d
4	b
5	a
6	c
7	d
8	d
9	b
10	a
11	d
12	a
13	b
14	a
15	d
16	c
17	b
18	a
19	c
20	c
21	d
22	d
23	b
24	c
25	d

End of Section One

Section Two: Short answer 35% (70 Marks)

Question 26 (4 marks)

Carbon and silicon are Group 14 elements that form very different compounds with oxygen. Some of their properties are shown in the table below:

Explain why these oxides of carbon and silicon have such different properties.

Carbon dioxide is a non-polar molecule with weak dispersion forces between neighbouring CO_2 molecules. These weak forces result in low melting and boiling points for carbon dioxide.

Silicon dioxide is a network solid with strong covalent bonds between neighbouring silicon and oxygen atoms. This strong covalent bonding leads to high melting and boiling points.

Description	Marks
Recognition that the melting and boiling points for CO_2 are due to interactions between neighbouring molecules	1
Recognition that the melting and boiling points for silicon dioxide are due to covalent bonds between neighbouring atoms.	1
Recognition of dispersion forces between neighbouring CO_2 molecules.	1
Recognition of the relative strength of the forces/energies involved.	1
Total	**4**

Question 27 (5 marks)

(a) Explain the differences between a covalent bond (**intra**molecular force) and an intermolecular force. (2 marks)

A covalent bond is a shared attraction for electrons by the nuclei of adjacent (neighbouring) atoms.

An intermolecular force is the attraction between neighbouring molecules (or atoms for the group 18 elements) that arises due to an uneven distribution of electron density in the molecule.

Description	Marks
Recognition that a covalent bond is a shared attraction for electrons by the nuclei of adjacent atoms	1
Recognition that an intermolecular force is the attraction between neighbouring molecules (or atoms for the group 18 elements) due to an uneven distribution of electron density in the molecule/dipoles (temporary or permanent)	1
Total	**2**

(b) Mixtures of propan-2-ol and propanone can be separated by distillation due to their different boiling points. Explain why these compounds have such different boiling points even though they have very similar molar masses. (3 marks)

The main type of intermolecular force between neighbouring propan-2-ol molecules is hydrogen bonding.

The main type of intermolecular force between neighbouring propanone molecules is dipole-dipole forces.

As hydrogen bonding intermolecular forces are stronger than dipole-dipole attractions the boiling point of propan-2-ol is higher than that of propanone.

Description	Marks
Recognition that dispersion forces in the two substances are similar	1
Recognition that predominant IMF in propanone is dipole-dipole forces and in propan-2-ol is hydrogen bonding	1
Recognition that hydrogen bonding is stronger than dipole-dipole forces	1
Total	**3**

Question 28 **(4 marks)**

Explain, with reference to the type of bonding, why metals tend to be good electrical conductors and are usually malleable. Diagrams may be used to assist your explanation.

Metals exist as a 3-dimensional lattice of cations in a ‘sea’ of delocalised valence electrons.

Electrical conductivity results from the capacity of the delocalised valence electrons to move within the lattice of cations.

Malleability result from the non-directional nature of the electrostatic attractions between the cations and delocalised valence electrons. This allows one layer of cations to move relative to other layers.

Description	Marks
Recognition that metals exist as a (3-dimensional) lattice of cations in a ‘sea’ of delocalised valence electrons	1
Recognition that electrical conductivity results from the capacity of the delocalised valence electrons to move within the lattice of cations	1
Recognition that layers of cations can move relative to one another without disrupting the lattice (due to (non-directional) nature of the electrostatic attractions between the cations and delocalised electrons)	1-2
Total	**4**

N.B.: A suitably labelled diagram containing the above points should be awarded full marks.

Question 29 **(4 marks)**

Write the equation and the expression for the equilibrium constant for each of the equilibrium processes below.

Description	Marks
$H_2O(\ell) \rightleftharpoons H_2O(g)$ (state symbols required)	1
$K = [H_2O(g)]$ ((g) not required)	1
$A\ell_2(SO_4)_3(s) \rightleftharpoons 2\ A\ell^{3+}(aq) + 3\ SO_4^{2-}(aq)$	1
$K = [A\ell^{3+}(aq)]^2[SO_4^{2-}(aq)]^3$	1
Total	**4**

N.B.: State symbols not required for dissolution of aluminium sulfate

Question 30 **(8 marks)**

Consider the following system at equilibrium.

$$4\ NH_3(g) + 5\ O_2(g) \rightleftharpoons 4\ NO(g) + 6\ H_2O(g) + 920\ kJ$$

Indicate in the table below whether there would be an increase, decrease, or no change in the concentration of $NH_3(g)$ after the changes given in the table are imposed on the system and **equilibrium has been re-established**. Provide a brief explanation for the observation.

Change	**Change in concentration of $NH_3(g)$ (circle the correct response)**	**Brief explanation**
The volume of the reaction vessel is doubled	Decrease	Concentrations decrease and rate of forward reaction decreases less than rate of reverse reaction
The temperature of the reaction system is doubled	Increase	Increase in temperature causes the system to move in the direction that consumes heat. Reverse reaction is therefore favoured over forward reaction, increasing the concentration of ammonia.
$N_2(g)$ is injected into the reaction system while keeping the volume constant	No change	($N_2(g)$ is not involved in the equilibrium.) Relative partial pressures of all species remains the same, therefore reaction rates are unchanged.
Water vapour is injected into the reaction system while keeping the volume constant	Increase	Increase in concentration of water vapour increases the rate of reverse reaction relative to the forward reaction.

Description	Marks
1 mark for each correct change in $NH_3(g)$ concentration	1–4
1 mark for each correct explanation	1–4
Total	**8**

Question 31 **(7 marks)**

An aqueous solution is prepared that contains 0.1 mol L^{-1} Na^+ and 0.1 mol L^{-1} $HC_2O_4^-$.

(a) Write the **two** possible reactions for the hydrolysis of the $HC_2O_4^-$ ion. (3 marks)

One: $HC_2O_4^-(aq) + H_2O(\ell) \rightleftharpoons C_2O_4^{2-}(aq) + H_3O^+(aq)$

Two: $HC_2O_4^-(aq) + H_2O(\ell) \rightleftharpoons H_2C_2O_4(aq) + OH^-(aq)$

Description	Marks
$HC_2O_4^-(aq) + H_2O(\ell) \rightleftharpoons C_2O_4^{2-}(aq) + H_3O^+(aq)$	1
$HC_2O_4^-(aq) + H_2O(\ell) \rightleftharpoons H_2C_2O_4(aq) + OH^-(aq)$	1
Use of double arrows for equilibria	1
Total	**3**

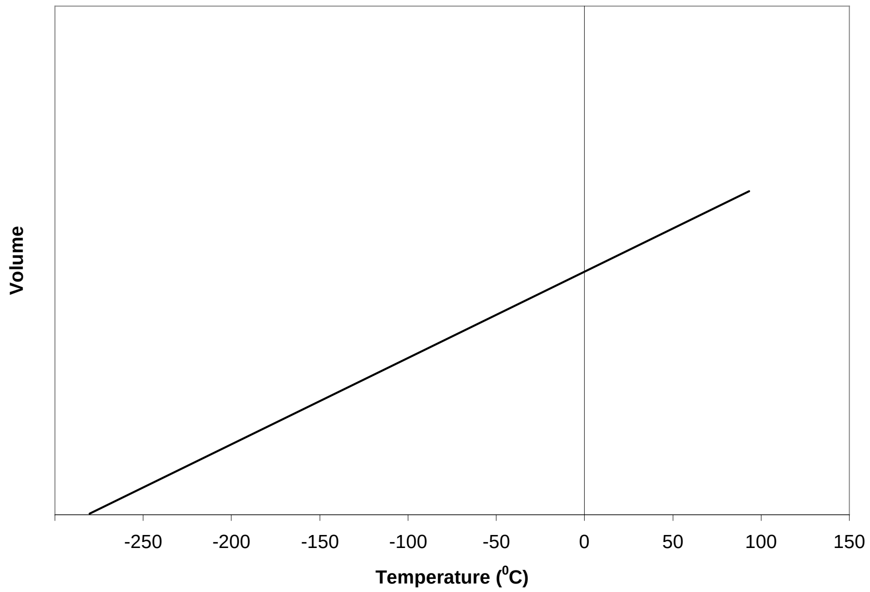
N.B. State symbols not required for full marks.
Award 1 mark if double arrows only used once.

(b) The pH of the solution was measured and found to be less than 7. Based on this observation, state which of the hydrolysis equations has the higher equilibrium constant. Use your understanding of equilibrium concepts to explain your choice fully. (4 marks)

Description	Marks
If solution has pH < 7, the concentration of $[H_3O^+] > [OH^-]$	1
K is ratio of products to reactants	1
H_3O^+ producing equation has the higher K value	1
Thus, H_3O^+ producing equation moves forward to a greater extent than the OH^- producing equation	1
Total	**4**

Question 32 **(8 marks)**

(a) Draw a line on the axis below to show how the volume of an ideal gas varies with the temperature. Show clearly where your line intersects each axis. Label your axes and show an approximate scale and unit on your temperature axis. (5 marks)



Description	Marks
Temperature axis labelled and with units on x-axis	1–2
Volume axis labelled on y-axis	1
Appropriate scale on temperature axis (at least three points on axis)	1
Linear plot intersecting	1
Total	**5**

N.B.: If temperature scale in kelvin no mark awarded for scale if negative values included.
No mark awarded for a linear plot going to negative volume.

(b) Label absolute zero on your plot above. (1 mark)

Description	Marks
Absolute zero labelled at -273 °C or 0K	1
Total	**1**

(c) Apply your understanding of Kinetic Theory to explain the concept of absolute zero. (2 marks)

Description	Marks
Temperature is a measure of the average kinetic energy of a substance	1
At absolute zero kinetic energy is zero or particle motion ceases **OR** At absolute zero the gas, theoretically, has no volume	1
Total	**2**

Question 33 **(9 marks)**

For each of the following pairs of substances, describe a chemical test that may be used to distinguish between them. Give the observation of the test for each of the substances. Assume the concentration of solutions is 0.1 mol L^{-1}.

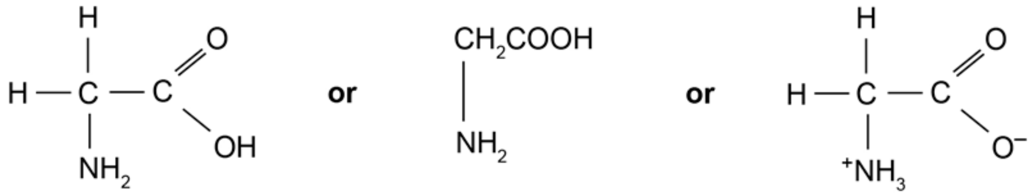
Substance 1	Silver nitrate solution	Magnesium chloride solution	Zinc sulfate solution
Substance 2	Lead(II) nitrate solution	Tin(II) chloride solution	Sodium sulfate solution
Chemical test	Add a solution of I^-(aq) to each of the solutions (may also use CO_3^{2-}(aq), S^{2-}(aq), Cu(s) for redox)	Place Zn metal in each solution (may also use Mg, Aℓ, Fe etc.)	Add a solution with OH^-(aq) (or CO_3^{2-}(aq)) to each of the solutions (may also use PO_4^{3-}(aq), S^{2-}(aq), Mg, Aℓ, Mn for redox)
Observation with Substance 1	Pale yellow precipitate forms	No observable change in solution	White precipitate forms
Observation with Substance 2	(Bright) yellow precipitate forms	Dark solid coats outside of zinc	No observable change in solution

Description	Marks
suitable chemical test	1–3
observation with substance 1	1–3
observation with substance 2	1–3
Total	**9**

N.B.: Accept any chemically correct test/s

Question 34 **(8 marks)**

(a) The chemical formula of the α-amino acid glycine is $C_2H_5NO_2$. Draw the structure of glycine, showing all atoms (1 mark)

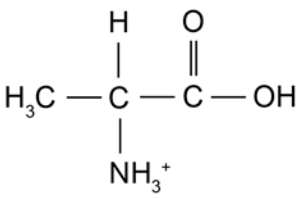


Description	Marks
Correct structure including all atoms. Condensed structure acceptable. No mark awarded if H atoms missing.	1
Total	**1**

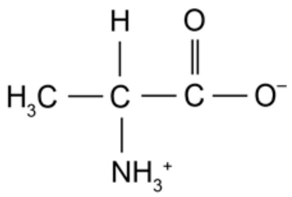
(b) The structure for the α-amino acid alanine is given below.

Give the structure for alanine under acidic, neutral and basic conditions by completing the table below. (3 marks)

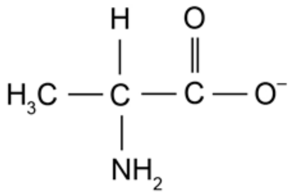
Acidic



Neutral



Basic



Description	Marks
1 mark for each correct structure at the corresponding pH	1–3
Total	**3**

(c) When crystallised from a neutral solution, alanine exists as a white crystalline solid. The solid has a melting point of 258 °C. This contrasts with a melting point of –47 °C for 2-methylpropanoic acid (molar mass 87 g mol^{-1}), a molecule of similar size to alanine. With reference to the appropriate structure in (b), explain why alanine has such a high melting point. (4 marks)

Description	Marks
Recognition that it exists as an ionic solid	1
Recognition that alanine exists as the zwitterion (neutral structure) or recognition of the ionic forms NH_3^+ and COO^-.	1
Recognition that strong (electrostatic) attractions exists between the oppositely charged regions	1
Recognition that significant energy required to overcome (electrostatic) attractions leads to a high melting point	1
Total	**4**

Question 35 **(7 marks)**

A white solid is analysed and found to have the empirical formula CHO and a molar mass of 116 g mol^{-1}.

(a) Determine the molecular formula of the compound. Justify your answer. (2 marks)

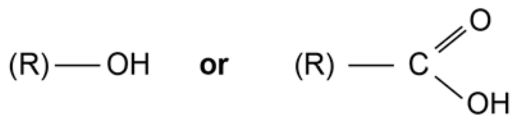
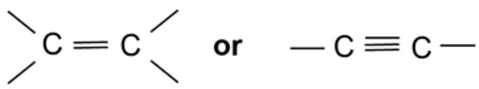
Empirical mass = 12.01 + 1.008 + 16.00 = 29.018 g

$$\frac{\text{Molar mass}}{\text{Empirical mass}} = \frac{116}{29.018} \cong 4$$

Thus molecular formula is $C_4H_4O_4$

Description	Marks
Ratio of molar mass to empirical mass	1
Molecular formula	1
Total	**2**

(b) Two tests were conducted on the solid, as shown in the table below. Complete the table by drawing a possible functional group that is consistent with the finding of each of the tests. (2 marks)

Test	Observation	Possible functional group
Water solubility	788 g L^{-1}	Diagram of alcohol or carboxylic acid 
Add to bromine water	Bromine water decolourises rapidly	Diagram of alkene or alkyne 

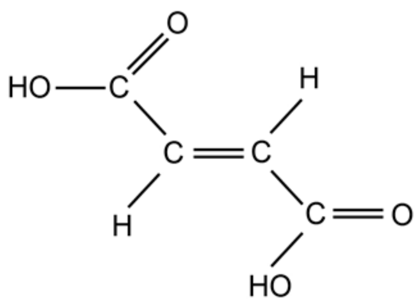
Description	Marks
1 for each functional group correctly drawn	1–2
Total	**2**

(c) A further 2.32 g sample of the white solid was analysed and shown to release 0.0400 mol of H^+ ions. Use this information and your answers to (a) and (b) to determine the structural formula of the white solid, and draw it in the box below. Show **all** atoms in your structure.

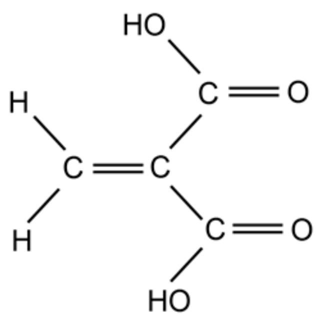
(3 marks)

$$n(X) = \frac{2.32}{116} = 0.0200 \text{ mol}$$

n(x) : n(H^+) = 1:2, thus the substance is a diprotic acid



cis or *trans* acceptable.



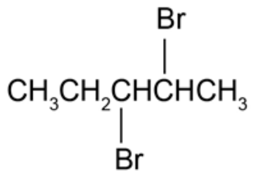
also acceptable

Description	Marks
moles of X = 0.0200 mol	1
Recognition that X is diprotic	1
Structure of X with all atoms shown	1
Total	**3**

Question 36 **(6 marks)**

Draw the structure in the box provided and name the organic product(s) for each of the following reactions. Include **all** H atoms in your drawings.

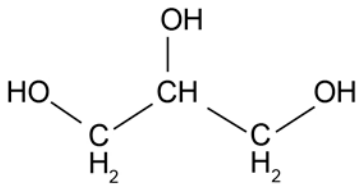
(a) (2 marks)



or $CH_3CH_2CHBrCHBrCH_3$

Name: 2, 3-dibromopentane

(b) (4 marks)



Name: glycerol

AND

$CH_3(CH_2)_{16}CO_2^-Na^+$

Name: sodium stearate or soap

Description	Marks
1 mark for each correct structure; condensed structures acceptable	1–3
1 mark for each correct name (accept soap)	1–3
Total	**6**

N.B.: If H atoms not shown, award 2 marks for otherwise correct structures.
Also accept 1, 2, 3-trihydroxypropane (instead of 'glycerol') or 1, 2, 3-propan triol or propan-1,2,3-triol
Stearate (with no Na^+) acceptable

End of Section Two

Section Three: Extended answer **40% (80 Marks)**

Question 37 **(8 marks)**

(a) What was being measured by the movement of the mercury bead? (1 mark)

Description	Marks
The volume of oxygen generated (or volume of gas)	1
Total	**1**

(b) What other quantity needed to be measured to determine the rate of decomposition? (1 mark)

Description	Marks
Time	1
Total	**1**

(c) List **three** variables that need to be controlled in this experiment. (3 marks)

Description	Marks
Volume of H_2O_2 used in each test (or amount of H_2O_2)	1
Concentration of H_2O_2 used in each test	1
Temperature of the system	1
Total	**3**

N.B.: Accept any chemically correct variables, pH
Accept mass for food; surface area

(d) In this experiment, the rate of reaction was measured by the rate of formation of oxygen. What other parameter in the system changes as the reaction proceeded? (1 mark)

Description	Marks
Concentration of H_2O_2 (or amount of H_2O_2)	1
Total	**1**

N.B.: Accept temperature

(e) State the role of a catalyst in a chemical reaction and explain how its effect is achieved. (2 marks)

Description	Marks
A catalyst speeds a reaction	1
A catalyst provides an alternative reaction pathway that has a lower activation energy than the uncatalysed pathway.	1
Total	**2**

Question 38 **(18 marks)**

(a) Given that the titanium remains in the +4 oxidation state throughout the reaction in Equation 2, identify the following. (2 marks)

Substance/s oxidised in Equation 2

Substance/s reduced in Equation 2

Description	Marks
(i) Fe^{2+} or $FeTiO_3$ C	1
(ii) $C\ell_2$ (or chlorine acceptable)	1
Total	**2**

(b) Determine the volume of chlorine gas at STP needed in Equation 2 to produce 1.00×10^3 kg of titanium dioxide in Equation 3. (4 marks)

Description	Marks
$n(TiO_2) = \frac{1.000 \times 10^6}{79.88} = 1.252 \times 10^4$ mol	1
$n(TiC\ell_4) = n(TiO_2) = 1.252 \times 10^4$ mol	1
Moles of Cl_2 required in step 2: $n_1(C\ell_2) = \frac{7}{2} \times 1.252 \times 10^4 = 4.3816 \times 10^4$ mol	1
At STP $V(C\ell_2)$ required = n × 22.71 = $4.3816 \times 10^4 \times 22.71 = 9.951 \times 10^5$ L	1
Total	4

(c) The chlorine gas produced in Equation 3 is recycled for use in Equation 2. If Equation 2 is 78% efficient, what **additional** volume of chlorine gas (at STP) needs to be supplied for Equation 2 for the production of 1.00×10^3 kg of titanium dioxide? Assume Equation 3 is 100% efficient. (4 marks)

Description	Marks
$n(Cl_2)$ produced in Equation 3 = $2 \times n(TiO_2)$ $= 2 \times 1.252 \times 10^4 = 2.5040 \times 10^4$ mol $C\ell_2$	1
mol $C\ell_2$ needed for Equation 2 is 78 % efficient $= \frac{4.382 \times 10^4}{0.78} = 5.6179 \times 10^4$ mol	1
mol to be supplied = mol (req'd) – mol (available) $= 5.6179 \times 10^4 - 2.5040 \times 10^4 = 3.1139 \times 10^4$ mol to be supplied	1
$\therefore V(C\ell_2)$ to be supplied at STP = $n \times 22.71 = 7.07 \times 10^5$ L	1
Total	**4**

(d) Write the balanced equation for the production of metallic titanium from the titanium tetrachloride. (2 marks)

Description	Marks
$TiCℓ_4 + 2\,Mg \rightarrow Ti + 2\,MgCℓ_2$	1–2
Total	**2**

N.B. Maximum 1 mark if equation incorrectly balanced

(e) When $TiCℓ_4$ reacts with H_2O one product is HCℓ(g). Write the balanced equation for the reaction between $TiCℓ_4$ and H_2O given that the oxidation state of Ti does not change. . (2 marks)

Description	Marks
$TiCℓ_4 + 2\,H_2O \rightarrow 4\,HCℓ + TiO_2$	1–2
Total	**2**

N.B. Maximum 1 mark if equation incorrectly balanced
Accept $TiCℓ_4 + 4\,H_2O \rightarrow Ti(OH)_4 + 4\,HCℓ$

(f) Use your understanding of atomic structure to compare and explain why argon and other Group 18 elements are generally unreactive, while sodium and other Group 1 elements are very reactive. (4 marks)

Description	Marks
Argon and other group 18 elements have a stable valence shell	1
Sodium and other group 1 elements have one electron in their outer shell	1
An element's reactivity is related to the acquisition of a stable valence shell	1
Sodium and group 1 elements react so that a stable outer shell is acquired. Argon and group 18 elements have a stable outer shell before reaction, and are therefore unreactive (i.e., inert)	1
Total	**4**

N.B. Expression of the ideas in stable terms of an octet should be accepted.
Maximum of three marks awarded if the term 'full' is used instead of stable

Question 39 **(11 marks)**

(a) Calculate the number of moles of ammonium ions formed from the treatment of the milk powder sample (Step 1). (4 marks)

Description	Marks
$n(H^+) = n(HCℓ) = C \times V = 0.752 \times 0.02578 = 1.9387 \times 10^{-2}$ mol	1
$n(NH_3) = n(B(OH)_3) = n(B(OH)_4^-) = n(H^+) = 1.9387 \times 10^{-2}$ mol	1
$n[(NH_4)_2SO_4] = 0.5 \times n(NH_3) = 9.6933 \times 10^{-3}$ mol	1
$n(NH_4^+) = 2 \times n[(NH_4)_2SO_4] = 1.94 \times 10^{-2}$ mol	1
Total	**4**

(b) What was the mass of nitrogen in the sample? Express your answer to **three** significant figures. (3 marks)

Description	Marks
n(N) = n(NH_4^+) = 1.9387 × 10^{-2} mol	1
m(N) = n × M = 1.9387 × 10^{-2} × 14.01 = 0.272 g	1
Correct sig. figs.	1
Total	**3**

(c) Calculate the mass of protein in the powdered milk product. (1 mark)

Description	Marks
Mass of protein = 0.272 × 6.38 = 1.74 g	1
Total	**1**

(d) Food labels usually give the protein content as the mass in a typical serving size. If the typical serving size for this product was 25 g, what mass of protein would be consumed in a single serving? (2 marks)

Description	Marks
1.74 g protein in 5.235 g of product *X* g of protein in 25 g of product	1
Mass of protein in serving = $\frac{25 \times 1.74}{5.235} = 8.31\text{g}$	1
Total	**2**

(e) Suggest what the chemist might do to increase the reliability of the value of the protein content he found for the milk product. (1 mark)

Description	Marks
The analysis should be repeated at least two times to obtain an average value	1
Total	**1**

N.B. Any measure that ensures the reliability of the analysis should be awarded one mark

Question 40 **(13 marks)**

(a) Determine which is the limiting reagent in the combustion reaction. Show your reasoning. (6 marks)

Description	Marks
$M(CH_3(NH)NH_2) = 46.078 \text{ g mol}^{-1}$	1
$n(CH_3(NH)NH_2) = \frac{10.1 \times 10^6}{46.078} = 2.1919 \times 10^5 \text{ mol}$	1
$M(N_2O_4) = 92.02 \text{ g mol}^{-1}$	1
$n(N_2O_4) = \frac{16 \times 10^6}{92.02} \times 0.979 = 1.702 \times 10^5 \text{ mol}$	1
4 mol ($CH_3(NH)NH_2$) requires 5 mol N_2O_4 2.1919×10^5 mol requires X $X = (5 \times 2.1919 \times 10^5)/4 = 2.7399 \times 10^5$ mol N_2O_4 required	1
$n(N_2O_4)$ available < $n(N_2O_4)$ required, therefore N_2O_4 is limiting	1
Total	**6**

(b) Determine the total volume of gas produced from the combustion of the entire propellant mixture when measured at STP. (3 marks)

Description	Marks
At STP, H_2O is not a gas, ∴ n(gas) produced from 5 mol N_2O_4 = 9 mol N_2 + 4 mol CO_2 = 13 mol gas	1
i.e., 5 mol N_2O_4 produces 13 mol gas 1.7022386×10^5 mol produces X $X = (13 \times 1.7022386 \times 10^5)/5 = 4.425 \times 10^5$ mol gas	1
At STP: $V = n \times 22.71 = 4.4258202 \times 10^5 \times 22.71 = 1.00 \times 10^7$ L	1
Total	**3**

N.B. Maximum 2 marks if candidate has included H_2O as a gas at STP

(c) The combustion chamber of Star Truck is at very high pressure and temperature to generate thrust and allow lift-off as the exhaust gases are expelled. At full thrust, the chamber is at a pressure of 2.03×10^4 kPa and temperature 3.30×10^3 °C. The chamber is designed to hold, at any one time, 0.05% by volume of the total gas produced. Determine the volume of the combustion chamber. (4 marks)

Description	Marks
Total gas produced **at high temp (H_2O is a gas):** 5 mol N_2O_4 produces 25 mol gas	1
i.e., 5 mol N_2O_4 produces 25 mol gas 1.702336×10^5 mol produces X $X = (25 \times 1.702336 \times 10^5)/5 = 8.511 \times 10^5$ mol gas (total) produced	1
Tank holds 0.05 % of total gas produced = $0.0005 \times 8.51168 \times 10^5$ = 425.58 mol gas	1
PV = nRT V = (nRT)/P = $\frac{425.584 \times 8.314 \times (3300 + 273.15)}{2.03 \times 10^4} = 622.77 = 623$ L	1
Total	**4**

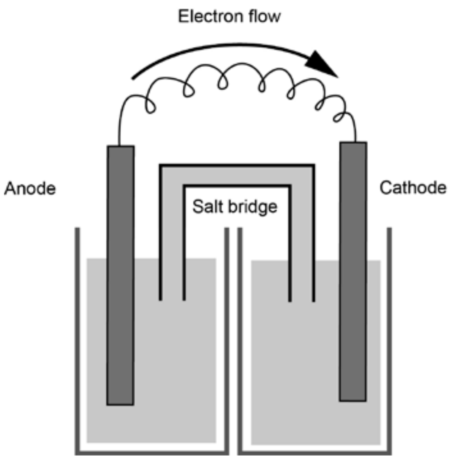
Question 41 **(18 marks)**

(a) The overall battery reaction during discharge is given below. Write and balance the anode and cathode reactions for the lead-acid storage battery. (2 marks)

Description	Marks
Anode: $Pb + SO_4^{2-} \rightarrow PbSO_4 + 2\ e^-$	1
Cathode: $PbO_2 + SO_4^{2-} + 4\ H^+ + 2\ e^- \rightarrow PbSO_4 + 2\ H_2O$	1
Total	**2**

NB: Maximum 1 mark if equations are reversed

(b) Draw a schematic diagram of the lead-acid battery showing the two half-cells. Label the anode, cathode and salt bridge, and indicate the direction of electron flow with an arrow. (4 marks)



Description	Marks
Anode	1
Cathode	1
Salt bridge	1
Direction of electron flow	1
Total	**4**

(c) (i) With reference to the 'electrical potential' of a galvanic cell, describe how the lead-acid storage battery produces current. (2 marks)

Description	Marks
In a galvanic cell there is a positive electrical potential/potential difference/spontaneous redox reaction which causes a flow of electrons (from anode to cathode)	1–2
Total	**2**

(ii) What determines the magnitude of the electrical potential of a cell? (1 mark)

Description	Marks
The magnitude of the difference between the E^o values or the concentration of reactants	1
Total	**1**

N.B. Also accept 'the chemicals used' or 'the half equations'; temperature

(d) (i) Determine the number of moles of $H^+(aq)$ in a lead-acid battery that contains 4.50 L of 3.55 mol L^{-1} sulfuric acid solution. (1 mark)

Description	Marks
$n(H^+) = 4.50 \times 3.55 \times 2 = 32.0$ mol ; accept $16 < n(H^+) \leq 32$ mol	1
Total	**1**

(ii) Use the overall battery equation to determine the number of moles of $H^+(aq)$ consumed when discharge of this battery forms 138.1 g of $PbSO_4(s)$. The molar mass of $PbSO_4$ is 303.26 g mol^{-1}. (2 marks)

Description	Marks
$n(PbSO_4) = 138.1/303.26 = 0.455$ mol	1
$n(H^+) = 2 \times 0.455 = 0.911$ mol	1
Total	**2**

(iii) Use your answers to (i) and (ii) to determine the concentration of $H^+(aq)$ in the electrolyte in the discharged battery. Assume that the electrolyte volume remains constant, and ignore any changes due to the formation of water.(2 marks)

Description	Marks
$n(H^+)$ remaining = 31.95 – 0.911 = 31.04 mol	1
$c(H^+) = 31.04/4.5 = 6.9$ mol L^{-1} or $3.35 < C(H^+) < 6.9$ mol L^{-1}	1
Total	**2**

(iv) Use your answers to (i) and (iii) to show that when this battery discharges as described above, the change in pH of the electrolyte solution is negligible. Note that in any acid solution whose $H^+(aq)$ concentration is greater than 1 mol L^{-1}, the pH is negative. (3 marks)

Description	Marks
pH original = –log(2 × 3.55) = –0.851 or pH = –log(3.356) = 0.551	1
pH final = –log(6.898) = –0.839 or pH = –log(3.35) = 0.525	1
∴ Very small (Difference = 0.012) or (difference = 0.026)	1
Total	**3**

(e) A flat (fully discharged) lead-acid battery can be ‘jump started’ by connecting it to a battery in a car whose engine is running. The current forced through the battery in this way causes the formation of a mixture of hydrogen and oxygen gas though the hydrolysis of water. State why the formation of the hydrogen and oxygen gas mixture may be dangerous. (1 mark)

Description	Marks
A mixture of hydrogen and oxygen can be explosive	1
Total	**1**

Question 42 **(12 marks)**

Using examples, describe 'condensation' and 'addition polymerisation'.

Your answer should include:

- an explanation of the term 'polymer'
- the structure and name of an example of each polymer type
- structures of starting materials for the production of each example of a polymer type
- polymerisation reactions.

Description	Marks
Recognition that a polymer is a very large molecule produced from the combination of many small molecules (the monomers)	1
Addition Polymers Name and structure of an example of an addition polymer such as PVC	1–2
Structure of monomer	1
Writes a reaction equation or series of equations	1–2
Condensation Polymers Correct structures of monomers Formula: $HOCH_2CH_2OH$ Formula $HOOC—C_6H_4$---COOH **(Accept HOOC—R—COOH)**	1–2
Correct repeating unit of polyester (or polyamide) dicarboxylic acid + diol $\rightarrow$ polyester + water n[$HOOC—C_6H_4$---COOH + $HOCH_2CH_2OH$] $\rightarrow$ n[—OC—C_6H_4—COO—$(CH_2)_2$—O--]$_n$-- + $2nH_2O$ Or n[HOOC—R--COOH + $HOCH_2CH_2OH$] $\rightarrow$ n[—OC—R—COO—$(CH_2)_2$—O—]$_n$-- + $2nH_2O$	1–2
Identified as polyester (or polyamide)	1
Inclusion of water as product in condensation equation	1
Total	**12**

NB: If dicarboxylic acid and diol are shown that do not match polyester example award one (of 2) marks.

End of questions

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