Government of **Western Australia**
School Curriculum and Standards Authority

WACE
Western Australian Certificate of Education

CHEMISTRY

Stage 2

WACE Examination 2013

Marking Key

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.

When examiners design an examination, they develop provisional marking keys that can be reviewed at a marking key ratification meeting and modified as necessary in the light of candidate responses.

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

1	b
2	c
3	a
4	d
5	a
6	b
7	c
8	d
9	c
10	a
11	d
12	c
13	d
14	a
15	b
16	b
17	c
18	a
19	b
20	b
21	d
22	d
23	c
24	a
25	c

End of Section One

Section Two: Short answer **40% (101 Marks)**

Question 26 **(5 marks)**

Interpreting the information contained in the symbol $^{34}_{16}S^{2-}$, answer the following questions.

The element represented is called
The ion shown has the following number of neutrons
The ion shown has the following number of electrons
The ion in this form has the following electron configuration
The ion has an electron configuration that is the same as the element called

Description	Marks
Sulfur	1
18	1
18	1
2,8,8	1
argon	1
Total	**5**

Question 27 **(6 marks)**

(a) Complete the table below by writing the formula of each of the substance listed. (3 marks)

Name	Formula
phosphoric acid	
magnesium oxide	
iron(II) sulfate	

Description	Marks
H_3PO_4	1
MgO	1
$FeSO_4$	1
Total	**3**

(b) Complete the table below by writing the name of each of the substance listed. (3 marks)

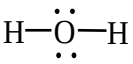
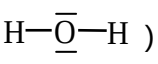
Formula	Name
$Fe(OH)_3$	
$H_2PO_4^-$	
CH_4	

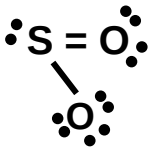
Description	Marks
iron(III) hydroxide	1
dihydrogen phosphate (ion)	1
methane	1
Total	**3**

Question 28 **(4 marks)**

For the species listed in the table below, draw electron dot diagrams.

All valence shell electron pairs should be represented either as **:** or as —

(for example, water  or  or )

Species	Electron dot diagram
Na_2S	
SO_2	

Description	Marks
Max 2 marks each	1–4
If non-bonding electrons are not shown in one or both answers, award a maximum of 3 out of 4 marks	
Resonance structures for SO_2 acceptable	
Total	**4**

Question 29 **(9 marks)**

(a) When solid zinc metal is dropped into a container of dilute hydrochloric acid it reacts. The solid dissolves and bubbles of a colourless gas are given off.

Write the balanced chemical equation for this reaction. Show only those species that take part in the reaction and use the appropriate state symbols. (3 marks)

$Zn(s) + 2\ H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

Description	Marks
Only correct formula / symbols of reacting species and products shown	1
All appropriate state symbols	1
Correctly balanced	1
Total	**3**

(b) When solid sodium carbonate is mixed with excess dilute sulfuric acid, a gas is produced according to the following equation.

$$H_2SO_4(aq) + Na_2CO_3(s) \rightarrow Na_2SO_4(aq) + CO_2(g) + H_2O(\ell)$$

(i) If 10.0 moles of solid sodium carbonate is reacted, how many moles of carbon dioxide gas will be produced? (1 mark)

(ii) What volume will this carbon dioxide gas occupy under standard conditions? (2 marks)

(iii) If 10.0 moles of hydrochloric acid react, what mass of water would be produced? (3 marks)

	Description	Marks
(i)	10.0 moles	1
(ii)	$V = 10.0 \times 22.71$ $= 227.1$ L	1 1
(iii)	$nH_2O = n\ H_2SO_4 = 10.0 = 10.0$ mol $mH_2O = n.M = 10.0 \times 18.016$ $= 180.16$ g	1 1 1
	Total	**6**

Question 30 **(9 marks)**

The energy profile diagram for a particular chemical reaction is given below. Use it to answer the following questions.

(a) State the heat of reaction with the correct unit. (2 marks)

(b) State the activation energy with the correct unit. (2 marks)

(c) Circle whether this reaction, as represented in the energy profile diagram, is exothermic, endothermic or neither. (1 mark)

exothermic endothermic neither

(d) During this reaction, the temperature of the mixture in the reaction vessel (1 mark)

increases decreases stays the same

(e) Circle whether in an exothermic reaction the amount of energy in the bond-breaking process is (1 mark)

greater than less than equal to

the amount of energy in the bond-forming process.

(f) On the energy profile diagram above, sketch what the graph would look like if a catalyst was introduced into the system. (2 marks)

	Description	Marks
(a)	Between 11 and 17	1
	Including kJ mol^{-1}	1
(b)	Between 37 and 44	1
	Including kJ mol^{-1}	1
(c)	Exothermic	1
(d)	Increase	1
(e)	<	1
(f)	Lower Ea peak Same shape and enthalpies (Reaches product enthalpy earlier)	1 1
	Total	**9**

Question 31 **(10 marks)**

(a) List **two** features of heterogeneous mixtures that make them different from homogeneous mixtures. (2 marks)

Description	Marks
Non uniform composition throughout the mixture	1
Non uniform properties throughout the mixture	1
Total	**2**

(b) Complete the table with one example of each category to illustrate the difference between elements, compounds and mixtures. (4 marks)

Element	Compound	Heterogeneous mixture	Solution

Description	Marks
One mark per category if every example per category is correct	1–4
Note: Air (a sample of air) is a solution; the air/the atmosphere is heterogeneous Salt water is a solution; the ocean is heterogeneous	
Total	**4**

(c) In terms of electron transfer, explain how the atoms of magnesium and bromine can react together to form the ionic salt, magnesium bromide. (4 marks)

Description	Marks
• Electrons are transferred from the magnesium atoms to the bromine atoms (as evident by a reaction)	1
• (In this process,) magnesium atoms lose electrons to become positively charged while	1
• bromine atoms gain electrons to become negatively charged ions	1
• (Because of the mutual) attraction of the positive and negative ions, the magnesium and bromine ions surround each other to form the (crystalline) lattice of the (ionic) salt	1
Total	**4**

Question 32 **(18 marks)**

The physical properties of substances are due to their bonding and structure.

(a) Complete the following table, outlining the differences in the physical properties of calcium fluoride and fluorine. (6 marks)

	calcium fluoride	fluorine
Type of bonding	**ionic**	**covalent**
Electrical conductivity as a solid (high, low, nil)	**nil**	**nil**
Electrical conductivity as an aqueous solution (high, low, nil)	**high**	**Nil or low**

Description	Marks
I mark per correct answer	1–6
Total	**6**

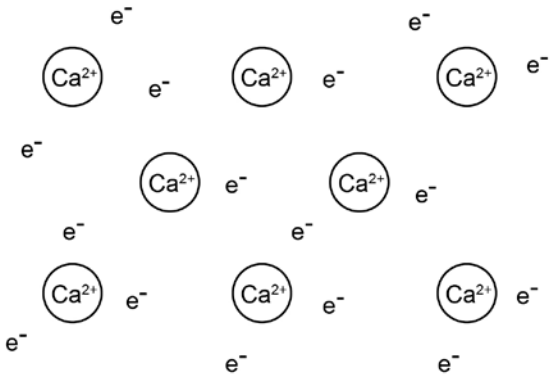
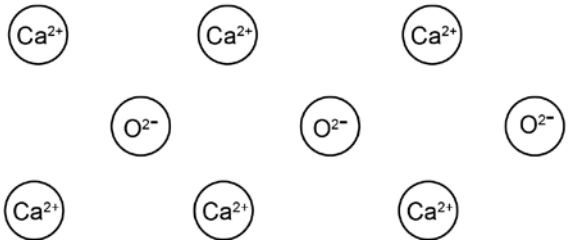
(b) (i) Does calcium fluoride or fluorine have the higher melting point? Circle your answer (1 mark)

calcium fluoride fluorine

(ii) By describing the bonding present in each substance, explain the difference in melting points. (5 marks)

	Description	Marks
(i)	calcium fluoride	1
(ii)	• calcium fluoride is held together in an ionic lattice by strong ionic bonding (each ion surrounded by and bonded strongly to several ions of opposite charge) • requiring large amounts of energy to overcome these attractive forces and so melt • fluorine molecules are only loosely held together by relatively weak dispersion forces that • require relatively low amounts of energy to overcome and so melt If not otherwise mentioned: • The stronger the forces of attraction holding the particles of the substance together, • the more energy is required to overcome these forces of attraction resulting in • the higher the temperature at which it melts	1 1 1 1 1
	Total	**6**

(c) (i) Use labelled diagrams to show the bonding structure of solid calcium and solid calcium oxide. (4 marks)

Description	Marks
Calcium  	1–2
Calcium oxide  	1–2
Total	**4**

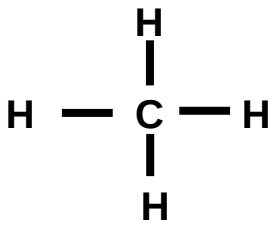
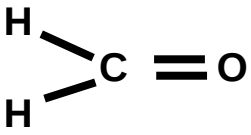
(ii) Describe how this bonding structure affects each substance's electrical conductivity. (2 marks)

Description	Marks
Calcium: Delocalised electrons able to transfer charge by moving around the metallic lattice.	1
Calcium oxide: No mobile charge carriers – valence electrons are localised on the ions.	1
Total	**2**

Question 33 **(6 marks)**

(a) Some atoms can form single covalent bonds with another atom, some can form double covalent bonds and some can form triple covalent bonds. Carbon can form combinations of single, double and triple bonds with atoms at the same time.

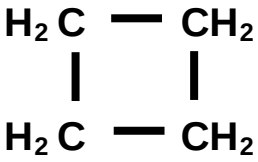
Draw structural formulae showing the bonds of the following **molecules.** (4 marks)

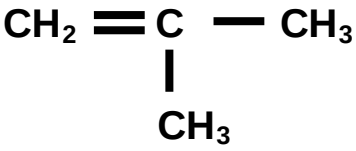
One carbon atom bonded only to hydrogen atoms	
One carbon atom bonded only to oxygen atoms	
One carbon atom bonded to only one oxygen and two hydrogen atoms	
One carbon atom bonded to one nitrogen and one hydrogen atom. (The nitrogen is only bonded to the carbon atom)	

Description	Marks
I mark per correct structure clearly showing the single, double or triple bonds	1–4
Total	**4**

(b) Draw two structural isomers of butene, C_4H_8. (2 marks)

Any two of





Description	Marks
I mark per correct structure	1–2
Total	**2**

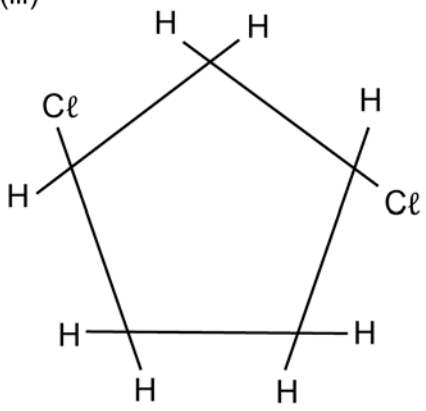
Question 34 **(7 marks)**

(a) State the IUPAC name for each of the following organic compounds. (5 marks)

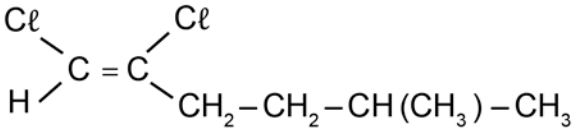
(i) $CH_3-CH_2-CH_2-CH_2-CH_2-CHBr-CH_3$

(ii) $CH_2=CH-CH_2-CH_2-CH_2-CH_2-CH_3$

(iii)



(iv)



Description	Marks
2-bromoheptane	1
hept-1-ene	1
1,3-dichlorocyclopentane	1
cis-1,2-dichloro-5-methyl-hex-1-ene (1 mark for *cis*)	1–2
Total	**5**

(b) Write the balanced equation for the combustion of methane gas (CH_4) in excess oxygen gas. (2 marks)

$$\mathbf{CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O}$$

Description	Marks
Correct formulae	1
Correctly balanced	1
Total	**2**

Question 35 **(12 marks)**

(a) Write the balanced chemical equation for the reaction, if any, that takes place when the following substances are mixed as described. Only include those species that take part in the reaction. If no reaction occurs, write 'no reaction'. (6 marks)

(i) Potassium carbonate solution is mixed with silver nitrate solution

$$2Ag^{+}(aq) + CO_3^{2-}(aq) \rightarrow Ag_2CO_3(s)$$

(ii) Carbon dioxide gas is bubbled through distilled water.

$$CO_2(g) + H_2O(\ell) \rightarrow H_2CO_3(aq) \text{ (or } 2\,H^{+}(aq) + CO_3^{2-}(aq) \text{)}$$

	Description	Marks
(i)	Correct formulae Correctly balanced No superfluous species	1 1 1
(ii)	Correct formulae Correctly balanced No superfluous species NB: (Cannot accept $2\,H^{+}(aq) + CO_3^{2-}(aq)$ without $H_2CO_3(aq)$)	1 1 1
	Total	**6**

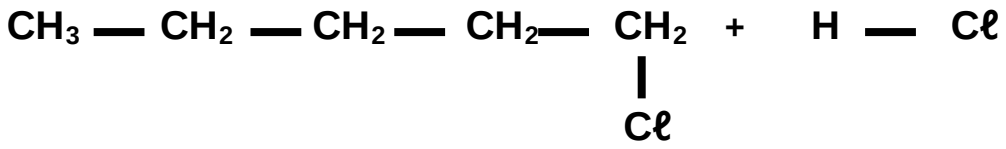
(b) Describe the predicted observations for the following reactions, if any, when each of the following substances is mixed as described. If no reaction occurs write, 'no observable change'. (6 marks)

(i) Nickel Ni(s) is added to a solution of silver nitrate, $AgNO_3(aq)$.
(ii) Copper(II) sulfate solution, $CuSO_4(aq)$, is added to potassium carbonate solution,$K_2CO_3(aq)$.
(iii) Ammonium nitrate solution $NH_4NO_3(aq)$ is mixed with concentrated sodium hydroxide solution NaOH(aq).

	Description	Marks
(i)	Shiny silvery crystals form, colourless solution turns green	1–2
(ii)	Blue solution decolourises (fades) and a green solid precipitates	1–2
(iii)	Pungent odour forms	1–2
	Total	**6**

Question 36 **(8 marks)**

(a) Write the structural formula for **one** organic product and any other products formed when pentane ($CH_3 - CH_2 - CH_2 - CH_2 - CH_3$) is mixed with chlorine gas ($C\ell_2$) in the presence of UV light and a catalyst. (3 marks)



Description	Marks
• Chlorine atom has been added to compound	1
• Correct structural formula	1
• Hydrogen chloride molecule ($C\ell$ can be added to any of the C atoms; more than one $C\ell$ atom can be substituted but there must have an equivalent number of $HC\ell$ molecules provided for full marks)	1
Total	**3**

(b) Write the structural formula for **one** organic product and any other products formed when pent-2-ene ($CH_3 - CH = CH - CH_2 - CH_3$) is mixed with hydrogen gas (H_2) in the presence of UV light and a catalyst. (2 marks)

Description	Marks
• Both H atoms added to compound	1
• Correct structural formula	1
Total	**2**

(c) Bromine water ($Br_2(aq)$) reacts differently with pentane and pent-2-ene. Describe the observations made when bromine water is added to samples of each and how this could be used to identify which sample was pentane and which sample was pent-2-ene. (3 marks)

Description	Marks
• Bromine water is decolourised when added to pent-2-ene (as it reacts to form 2,3-dibromopentane and is removed from the solution).	1
• No reaction occurs when bromine water is added to pentane (as no reaction occurs without UV light).	1
• The difference in observation can be used to distinguish the liquids. The liquid which decolourises when added to bromine water is pent-2-ene, the liquid in which no change occurs is pentane.	1
Total	**3**

Question 37 **(9 marks)**

Consider a 100.0 g sample of quartz (silicon dioxide, SiO_2) and a 100.0 g sample of carborundum (silicon carbide, SiC).

(a) Calculate the percentage of silicon contained in each sample. (4 marks)

Description	Marks
%Si in SiO_2 = [M(Si) / M(SiO_2)] × 100 = [28.09/28.09+(2 ×16.00)] × 100 = [28.09/60.09] × 100 = 46.747 = 46.7% %Si in SiC = [M(Si) / M(SiC)] × 100 = [28.09/(28.09+12.01)] × 100 = [28.09/40.1] × 100 = 70.0499 = 70.0%	1 1 1 1
Total	**4**

(b) Determine the number of moles of silicon in this quartz sample. (2 marks)

Description	Marks
n(Si) = n(SiO_2) = m(SiO_2) / M (SiO_2) = 100.0/60.09 = 1.66 mol	 1 1
Total	**2**

(c) Determine the number of atoms of silicon in this quartz sample. (2 marks)

Description	Marks
Number of atoms = n × 6.022 × 10^{23} = 1.66 × 6.022 × 10^{23} = 10.02 × 10^{23} = 1.00 × 10^{24}	 1 1
Total	**2**

(d) What mass of silicon is there in the 100.0g sample of this sample of carborundum? (1 mark)

Description	Marks
m(Si) = 70.0 g	1
Total	**1**

End of Section Two

Section Three: Extended answer **35% (86 Marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 65 minutes.

Question 38 **(29 marks)**

Some chemists decided to test the hypothesis that magnesium metal combines with oxygen in a 1 to 1 ratio, forming magnesium oxide with the formula MgO.

They used sandpaper to clean a strip of magnesium until it was smooth and shiny all over. They weighed a clean, dry crucible and its lid. Then they placed the strip of magnesium in the crucible, put on the lid and weighed it again.

To get the magnesium metal to react with the oxygen in the air, they heated it over a Bunsen burner flame as shown below. The chemists noticed that when they lifted the lid some white smoke appeared.

(a) State **two** potential safety hazards of this experiment. (2 marks)

(b) Outline **two** safety procedures which would minimise the risk to the experimenter. (2 marks)

(c) Explain why the magnesium strip was cleaned with sandpaper before it was weighed. (1 mark)

(d) Explain why the crucible and its contents was heated repeatedly and weighed rather than being heated and weighed just once. (1 mark)

(e) Give **one** reason why using a lid to cover the crucible while heating was a good idea. (1 mark)

(f) State **two** reasons for using the gauze mat in this experiment. (2 marks)

(g) Graph the results using the all 7 weighings of the magnesium strip. (4 marks)

(h) What was the mass of magnesium before it was heated? (1 mark)

(i) Calculate the total number of moles of magnesium metal before it was heated. (2 marks)

(j) What was the total number of moles of magnesium metal present after it was heated. (1 mark)

(k) Calculate the increase in mass of the crucible contents. (1 mark)

(l) Why did the mass of the crucible contents increase? (1 mark)

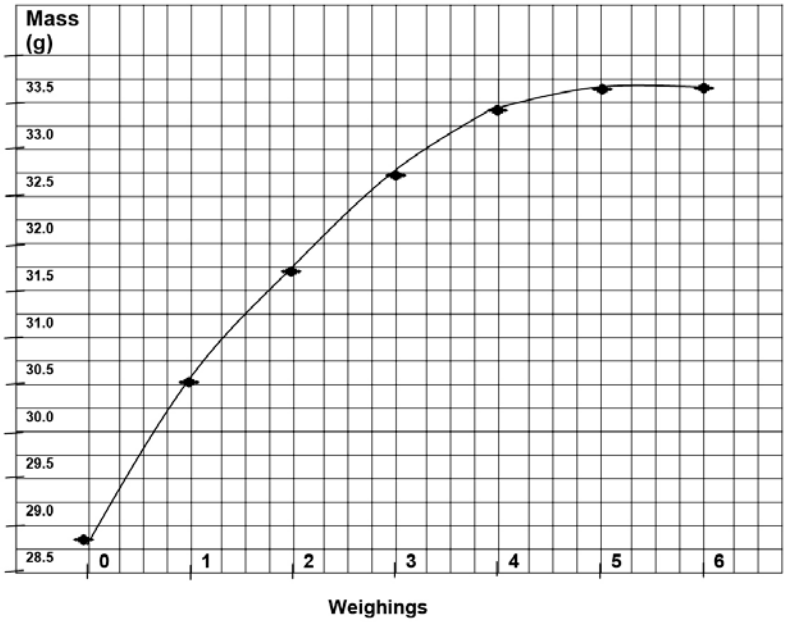
(m) Calculate the number of moles of oxygen in the magnesium oxide. (2 marks)

(n) What is the simplest calculated ratio between magnesium and oxygen once they have combined to form the compound magnesium oxide? (2 marks)

(o) Based on the experimental results, what conclusion should the experimenters have drawn about the formula of magnesium oxide? (2 marks)

(p) State **two** sources of error in this experiment. (2 marks)

(q) Write the balanced equation for the reaction of magnesium and oxygen, showing their states of matter. (2 marks)

	Description	Marks
(a)	One mark each for any two different reasonable hazards: eg • Burns from Bunsen burner • Burns from hot tripod, gauze mat, crucible or lid • Inhalation of white unknown fumes • Ignition of magnesium ribbon and subsequent eye damage	1–2
(b)	One mark each for any two different precautions: eg • Use of eye protection • Use of metal tongs to pick up crucible • Use of fireproof mat • Conduct inside a fume cupboard	1–2
(c)	To ensure that the magnesium strip was clean and pure, free from any corrosion (or magnesium oxide)	1
(d)	To ensure than any reaction that occurred had gone to completion.	1
(e)	To prevent any contamination into the reaction or to avoid any product escaping as white smoke Magnesium oxide in powder form easily lost	1
(f)	Any 2 of • Supports the crucible above the Bunsen burner flame • allows direct heating • stops it toppling over	1–2
(g)	One mark each for: • Labelled axes • Appropriate scale • Accuracy of points • Smooth curve (line) of best fit  	1–4
(h)	m(Mg) = 28.75 – 21.25 = 7.50 g	1
(i)	$n(Mg)_{initial}$ = 7.50 / 24.31 = 0.308515 = 0.309 mol	1 1
(j)	$n(Mg)_{final}$ = 0.309 mol (no atoms lost in the reaction)	1
(k)	Δm = 33.65 – 28.75 = 4.90 g	1
(l)	Oxygen had been added to the magnesium to form magnesium oxide	1
(m)	n(O) = 4.90 / 16.00	1

	= 0.30625 = 0.306 mol	 1
(n)	n(Mg) : n(O) 0.309 : 0.306 1 : 1	 1 1
(o)	MgO	1–2
(p)	1 mark each for any two reasonable sources given: eg • Loss of MgO when lifting crucible lid • Reaction not yet gone to completion • Not all corrosion / dirt removed from magnesium ribbon • Inaccuracy of measuring mass • Tolerance of mass balance • Rounding error	1–2
(q)	$2\ Mg(s) + O_2(g) \rightarrow 2\ MgO(s)$ I mark for correct formulas and balanced I mark for correct state symbols (Allow follow through marks from formula used in (o)	1–2
	Total	**29**

Question 39 **(17 marks)**

(a) A gaseous organic compound, consisting of carbon, hydrogen and oxygen, was analysed by burning it in excess oxygen. When a 0.870g sample of the compound was completely burnt, it had produced 1.98 g of carbon dioxide (CO_2) and 0.810 g of water (H_2O).

(i) Determine the number of moles and the mass of carbon in the sample. (3 marks)

Description	Marks
n(C) = n(CO_2) = 1.98/44.01 = 0.04499 mol	1
m(C) = 0.004499 × 12.01 = 0.5403 g	1
m(C) in 0.870 g sample = 0.5403 g	1
Total	**3**

(ii) Determine the number of moles and the mass of hydrogen in the sample.(3 marks)

Description	Marks
n(H) = 2 n(H_20) = 2 × 0.810 / 18.016 = 0.08992 mol	1
m(H) = 0.08992 × 1.008 = 0.09064 g	1
m(H) = in 0.870 g sample = 0.09064 g	1
Total	**3**

(iii) Determine the mass and the number of moles of oxygen in the sample. (2 marks)

Description	Marks
m(O) = 0.870 – (0.5403 + 0.09064) = 0.2391 g	1
n(O) = 0.2391 / 16.00 = 0.01494 mol	1
Total	**11**

(iv) Determine the mole ratios of carbon, hydrogen and oxygen in the compound. (2 marks)

Description				Marks
mole ratios	C	H	0	
	0.04499	0.08992	0.01494	1
Simplify (/0.1494)	3.01	6.02	1	
	3	6	1	1
Total				**2**

(v) Answer: Empirical formula (1 mark)

Description	Marks
Empirical Formula C_3H_6O	1
Total	**1**

(b) At STP 100.0 g of this compound occupied 39.7 L. What is the molecular formula of the organic compound? (6 marks)

Description	Marks
EFM = 3 × 12.01 + 6 x 1.008 + 1 × 16.00 = 58.078 g mol^{-1}	1
@ STP n = V/22.71 = 39.7/22.71 = 1.748 = 1.75 mol	1
FM = n × m = 1.75 × 100.0 = 175.0 g mol^{-1}	1
FM/EFM = 175 / 58.078 = 3.012 = 3.00	1
MF = 3 × C_3H_6O	1
Molecular Formula $C_9H_{18}O_3$	1
Total	**6**

Question 40 **(10 marks)**

(a) Describe briefly three **chemica**l tests that can be used to identify which label belongs with each of the four bottles. For every test, describe clearly the expected observations and how they are used to identify the unknown solution.

Description				**Marks**
One mark each for the test, observation and conclusion; each must match to be accepted. Eg:				
Test	**Describe the test**	**Expected observations**	**Unknown substance**	
1	Add a sample of each unknown solution to NaCℓ solution.	Three samples NR, one sample white precipitate.	The solution that produces a white precipitate is **silver nitrate**.	1–3
2	To a sample of the remaining three unknown solutions add some dilute hydrochloric acid.	One sample will evolve bubbles of a colourless, odourless gas.	That is **ammonium carbonate** solution.	1–3
3	Add some barium nitrate solution to each remaining solution.	One sample will remain unchanged, the other will produce a white precipitate.	The solution that produces a white precipitate is **sodium phosphate**.	1–3
4	The remaining unknown must be **sodium hydroxide.**			1
			Total	**10**

Note: There are several possible answer sequences. Any valid sequence is accepted.

Question 41 **(12 marks)**

(a) Ammonia is found in household ammonia solution. List **two** uses for this solution in and around the home. (2 marks)

Description	Marks
Up to 2 marks, I mark each for different use. eg • Cleaner Eg: Oven, oven racks, fireplace doors, carpets and upholstery, bathroom tiles, glassware, windows and crystal • Stain remover from clothing, concrete • Repel pests such as moths, rodents • Kills mildew • Eliminate paint odours • Clean gold and silver jewelry & remove tarnish from brass or silver • Remove grease and soap scum • Restore white shoes • Strip wax from resilient flooring • Fertiliser	1–2
Total	**2**

(b) Why is ammonia described as a weak base while sodium hydroxide is described as a strong base? Use chemical equations in your answer. (4 marks)

Description	Marks
Sodium hydroxide is described as a strong base because effectively all the NaOH that dissolves dissociates to form sodium and hydroxide ions.	1–2
$NaOH(s) \longrightarrow Na^+(aq) + OH^-(aq)$	
Ammonia is described as a weak base because only a relatively small proportion of it ionizes in water; most of it remains in the molecular form leaving relatively low concentration of hydroxide ions in solution.	1–2
$NH_3(aq) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$	
Total	**4**

(c) The label on a bottle that holds 2.50 kg of household ammonia solution states that it is a 5.00 % solution by mass of ammonia. Calculate the number of moles of ammonia that are in the bottle. Express your answer to **three** significant figures. (4 marks)

Description	Marks
$m(NH_3) = 5/100 \times 2.50 \times 10^3$ $= 125$ g	1
$n(NH_3) = 125.0/(14.01 + 3 \times 1.008)$ $= 7.338$ $= 7.34$ mol (3 significant figures)	1 1–2
Total	**4**

(d) If a 2.50kg bottle of household ammonia has a volume of 2.20L, express this concentration of ammonia in (2 marks)

(i) mol L^{-1}

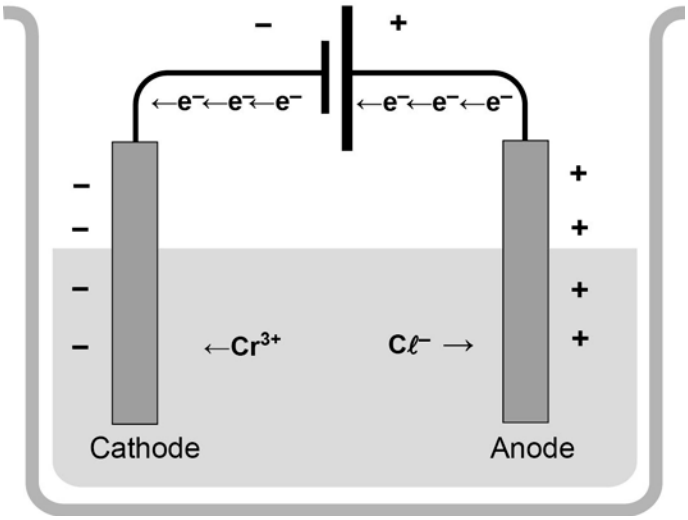
(ii) g L^{-1}

Description	Marks
$c = n/V$ $= 7.338/2.20$ $= 3.335$ $= 3.34$ mol L^{-1}	1
$c = m/V$ $= 125/2.20$ $= 56.82$ $= 56.8$ g L^{-1}	1
Total	**2**

Question 42 **(18 marks)**

(a) A quantity of pure chromium chloride ($CrC\ell_3$) is melted and placed in a heatproof vessel. Two inert electrodes are inserted as shown and a current flows through the molten liquid. Complete and label the diagram below, showing the:

- anode
- cathode
- direction of electron current
- ions present and the direction in which they are flowing (5 marks)



(a) Write the oxidation half equation. (2 marks)

(b) Write the reduction half equation. (2 marks)

(c) Write the overall redox equation. (1 marks)

(d) Indicate (by circling) which process occurs at the electrode on the left. (1 mark)

oxidation reduction redox

(e) What is acting as the oxidant in this reaction? (1 mark)

(f) What is produced at the anode? (1 mark)

(g) State the oxidation number of (4 marks)

(i) Cr in solid chromium chloride

(ii) Cℓ in molten chromium chloride

(iii) Cr in chromium metal

(iv) Cℓ in chlorine gas

	Description	Marks
(a)	1 mark each for clearly indicating on the diagram: • anode • cathode • direction of electron current • the ions present and • the direction in which they are flowing	1–5
(b)	$2\ C\ell^-(\ell) \rightarrow C\ell_2(g) + 2\ e^-$ 1 mark for correct formula 1 mark for correct balancing state symbols not required	1–2
(c)	$Cr^{3+}(\ell) + 3\ e^- \rightarrow Cr(\ell)$ 1 mark for correct formula 1 mark for correct balancing state symbols not required	1–2
(d)	$2\ Cr^{3+}(\ell) + 6\ C\ell^-(\ell) \rightarrow 2\ Cr(\ell) \rightarrow 3\ C\ell_2(g)$ 1 mark for correct formula 1 mark for correct balancing state symbols not required	1–2
(e)	Reduction	1
(f)	Chromium 3+ ion	1
(g)	Chlorine gas	1
(h)	1 mark each for each correct oxidation number. (i) +3 (ii) -1 (iii) 0 (iv) 0	1–4
	Total	**18**

End of questions

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