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

WACE
Western Australian Certificate of Education

CHEMISTRY

Stage 3

WACE Examination 2014

Marking Key

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

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

Question No.	Answer
1	B
2	D
3	D
4	B
5	D
6	D
7	C
8	A
9	C
10	C
11	A
12	B
13	D
14	C
15	D
16	D
17	A
18	C
19	C
20	B
21	B
22	C
23	B
24	A
25	A

End of Section One

Section Two: Short answer **35% (72 Marks)**

Question 26 **(4 marks)**

For the following reactions, describe fully the observed changes, including any

- colour changes
- odours
- precipitates (give the colour)
- gases evolved (give the colour or describe as colourless).

(a) Lead(II) nitrate solution is added to potassium iodide solution. (1 mark)

$$Pb^{2+}(aq) + 2\,I^-(aq) \rightarrow PbI_2(s)$$

(b) Solid copper(II) carbonate is added to dilute nitric acid solution. (3 marks)

$$CuCO_3(s) + 2\,H^+(aq) \rightarrow Cu^{2+}(aq) + CO_2(g) + H_2O(\ell)$$

Description	Marks
(a) Yellow precipitate formed	1
(b) Green solid dissolves to give blue solution and a colourless and (odourless) gas is evolved (1 for solid dissolving; 1 for colour change green to blue and 1 for colourless,(odourless) gas)	1–3
Incorrect	0
Total	**4**

Question 27 **(4 marks)**

Write balanced ionic equations to represent the reactions described below.

(a) Chlorine gas is bubbled through an aqueous solution of sodium bromide. (2 marks)

$$C\ell_2(g) + 2\,Br^-(aq) \rightarrow 2\,C\ell^-(aq) + Br_2(aq)$$

(b) Solid nickel oxide is added to dilute hydrochloric acid solution. (2 marks)

$$NiO(s) + 2\,H^+(aq) \rightarrow Ni^{2+}(aq) + H_2O(\ell)$$

Description	Marks
Correct formulae for reactants and products	1–2
Balanced equations	1–2
Incorrect	0
Total	**4**

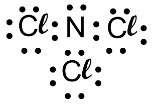
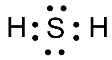
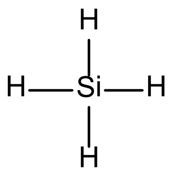
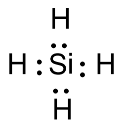
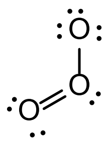
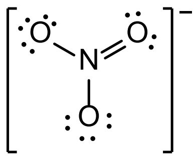
NB: State symbols not required.

Award 1 mark for correctly balanced molecular equation.

Question 28 **(8 marks)**

Complete the table below by **either** drawing the Lewis structures **or** naming the shape of the molecules. For Lewis structures, any lone pairs must be shown.

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

Molecule/Ion	Lewis structure	Name of shape
$NC\ell_3$		**(Trigonal) pyramidal**
H_2S		**Bent (V-shaped)**
SiH_4	 or 	tetrahedral
O_3		Bent (V-shaped)
NO_3^-		Trigonal planar

Description	Marks
Shapes correctly named	1–2
All Lewis structures correct including lone pairs	6
• Octet around central atom is correctly shown (i.e. bonds are correct) for all structures but lone pairs are missing; **or** • Lewis structures correct but square brackets and charge missing around NO_3^-	5
• Octet around central atom is correctly shown (i.e. bonds are correct) for all structures but lone pairs are missing; **and** • Lewis structures correct but square brackets and charge missing around NO_3^-	4
Award 3 marks if each structure has the correct number of valence electrons shown but not correctly distributed	3
Incorrect	0
Total	**8**

NB: Lewis structure does not need to represent the shape.

Question 29 **(9 marks)**

Ethanol C_2H_5OH, and hexane, C_6H_{14}, are two common industrial solvents.

(a) (i) Identify the polarity of molecules that are soluble in each of these solvents. (2 marks)

	Polarity of molecules/substances that are soluble in the solvent
Ethanol	(circle one only) $\boxed{\text{Polar}}$ Non-polar
Hexane	(circle one only) Polar $\boxed{\text{Non-polar}}$

Description	Marks
Recognition that ethanol will dissolve polar molecules	1
Recognition that hexane will dissolve non-polar molecules	1
Incorrect	0
Total	**2**

(ii) Explain the interactions between solute and solvent particles in solutions of these two solvents. (3 marks)

Description	Marks
Recognition that:	
solutions using ethanol is a result of dipole/dipole or hydrogen bond interactions between solute and solvent	1
solutions using hexane is a result of dispersion forces between solute and solvent	1
interactions between solute/solvent must be of similar strength to the solute/solute and solvent/solvent interactions	1
Incorrect	0
Total	**3**

Question 29 (continued)

(b) The ‘loss’ of 4 mL on mixing water with ethanol implies strong interactions between the water and ethanol molecules. Describe these interactions and explain the origin of their strength. (4 marks)

Description	Marks
Recognition that the interactions between water and ethanol are of similar strength to those in the individual liquids	1
Recognition that water and ethanol have hydrogen bonding	1
Explains hydrogen bonding in terms of: • oxygen being extremely electronegative leading to the high polarity of the O-H bond or • a big difference in electronegativity of O and H	1
Explains the strength of the H-bond (any one of the following) • highly polar • high charge density of H • low electron density • appropriate annotated diagram	1
Incorrect	0
Total	**4**

Question 30 **(9 marks)**

Hydrogen can be made by reacting methane (natural gas) with water (steam). The reaction can form the chemical equilibrium represented below.

$$CH_4(g) + H_2O(g) \rightleftharpoons 3\,H_2(g) + CO(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

State the conditions of temperature and pressure that would optimise the yield of hydrogen at a reasonable rate of reaction. Using collision theory and principles of chemical equilibrium, explain your choice of conditions.

	Optimum conditions	Explanation
Temperature	high temperature (1 mark)	High temperature increases the proportion of molecules colliding with energy above the E_a and so increasing the reaction rates for both the forward and reverse reactions but the (forward) endothermic direction will increase more so increasing yield of H_2. (3 marks)
Pressure	moderate pressure (1 mark)	High pressure increases frequency of collisions between molecules and increases rates for both the forward and reverse reactions but increases reverse reaction rate more (because there are fewer gas molecules on reactant side). Low pressure will increase yield of H_2 but the rate of the reaction will be too slow so a compromise moderate pressure is needed. (4 marks)

Description	Marks
Recognition of high temperature and moderate pressure	1–2
Recognition that high temperature increases the proportion of molecules colliding with energy above the E_a	1
Recognition that high temperature increases rates of forward (and reverse) reaction(s)	1
Recognition that high temperature increases the rate of forward reaction more than rate of reverse reaction **or** accept Le Chatelier's Principle explanation	1
Recognition that high pressure increases frequency of collisions between molecules	1
Recognition that high pressure increases rates of **both** forward and reverse reactions	1
Recognition that high pressure increases rate of reverse reaction more than forward	1
Recognition that low pressure will increase yield of H_2 but the rate of the reaction will be too slow. Compromise between yield and reaction rate	1
Incorrect	0
Total	**9**

NB: Where the student chooses the incorrect optimum conditions but their explanation matches the marking key, they may be awarded marks for the explanation.

Question 31 **(5 marks)**

(a) State the role of the standard hydrogen half-cell in determining the table of Standard Reduction Potentials. (2 marks)

Description	Marks
Recognition that the hydrogen half-cell:	
is the reference half-cell	1
against which the reduction potential of all other half-cells are measured	1
Incorrect	0
Total	**2**

(b) State **three** limitations of Standard Reduction Potential tables. (3 marks)

Description	Marks
Any three of: • The values of E^0 depend upon concentration. (1 mol L^{-1}) • Applies only to aqueous solutions • The emf of a cell can depend on temperatures • The values of E^0 give no indication of reaction rate/high activation energy • Predictive tool – reaction may not occur • All gases at 100kPa (standard pressure)	1–3
Incorrect	0
Total	**3**

Question 32 **(6 marks)**

Nitrogen gas from the atmosphere undergoes a series of redox reactions to transform it into nitrate ions that are absorbed by plants. The process can be simplified into the following three steps.

Step 1 – Nitrogen-fixing soil bacteria reduce nitrogen gas to ammonium ions.

Step 2 – Nitrifying bacteria then oxidise ammonium ions to nitrite ions.

Step 3 – Nitrifying bacteria then oxidise nitrite ions to nitrate ions.

Write the half-equations for each of these steps. Assume acidic conditions.

$$N_2 + 8\,H^+ + 6\,e^- \rightarrow 2\,NH_4^+$$

$$NH_4^+ + 2\,H_2O \rightarrow NO_2^- + 8\,H^+ + 6\,e^-$$

$$NO_2^- + H_2O \rightarrow NO_3^- + 2\,H^+ + 2\,e^-$$

Description	Marks
2 marks for a correct half-equation	0–6
Incorrect	0
Total	**6**

NB: For an incorrect half-equation, award 1 mark if reactants and products are correct but electrons or balancing incorrect; if atoms are consistently balanced for all the half-equations but electrons incorrect award 4 marks.

Question 33 **(9 marks)**

(a) Methanoic acid, HCOOH, may be produced by oxidation of an alcohol with acidified potassium permanganate, MnO_4^-, solution.

Write the oxidation and reduction half-equations and the final redox equation for this reaction. (5 marks)

Oxidation half-equation	$CH_3OH(\ell) + H_2O(\ell) \rightarrow HCOOH(\ell) + 4\ H^+(aq) + 4\ e^-$ (×5)
Reduction half-equation	$MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \rightarrow Mn^{2+}(aq) + 4\ H_2O(\ell)$ (×4)
Final redox equation	$5\ CH_3OH(\ell) + 4\ MnO_4^-(aq) + 12\ H^+(aq) \rightarrow 5\ HCOOH(\ell) + 4\ Mn^{2+}(aq) + 11\ H_2O(\ell)$

Description	Marks
Correct oxidation half-equation; for an incorrect oxidation half-equation, award 1 mark if reactants and products are correct but electrons or balancing incorrect	1–2
Correct reduction half-equation	1
Correct final redox equation; for an incorrect redox equation, award 1 mark if reactants and products are correct but balancing incorrect	1–2
Incorrect	0
Total	**5**

NB: State symbols not required.

If oxidation/reduction reversed award a maximum of 4 marks.

Balancing includes cancelling of H^+ and H_2O

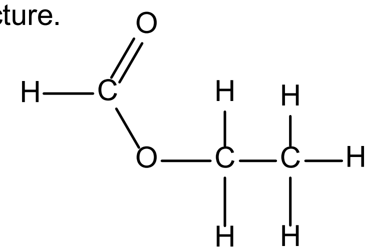
(b) Methanoic acid reacts with ethanol in the presence of sulfuric acid to produce a sweet smelling compound.

Write the balanced equation for the reaction of methanoic acid with ethanol. (2 marks)

$$HCOOH + CH_3CH_2OH \rightarrow HCOOCH_2CH_3 + H_2O$$

Description	Marks
Correct equation	2
Only 3 formulae correct or water missing	1
Incorrect	0
Total	**2**

(c) Draw the structural formula for the sweet smelling compound and give its IUPAC name. Show **all** H atoms in the structure. (2 marks)



Name: ethyl methanoate

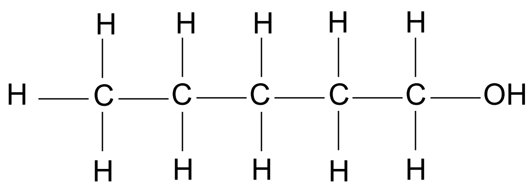
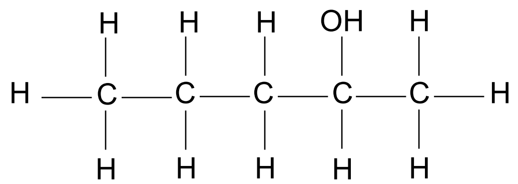
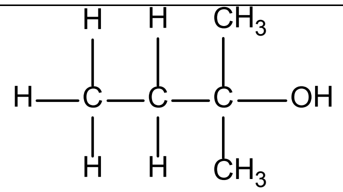
Description	Marks
Correct structure (condensed structure acceptable)	1
Correct name – ethyl methanoate	1
Incorrect	0
Total	**2**

Question 34 **(5 marks)**

Alcohols can be classified as primary, secondary or tertiary.

Complete the table below by drawing the structure for a primary alcohol, a secondary alcohol and a tertiary alcohol, each with the molecular formula $C_5H_{12}O$. Show **all** H atoms in your structures.

Give the IUPAC names for the primary and secondary alcohols you have drawn.

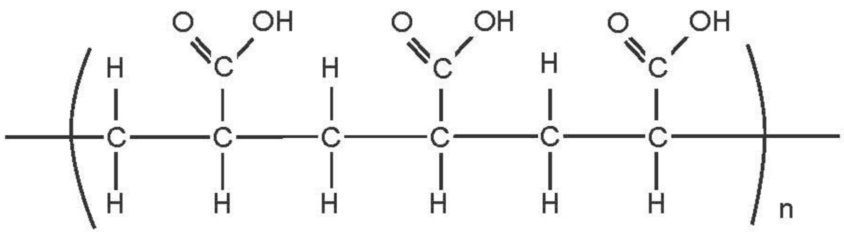
	Structure	Name
Primary alcohol		Pentan-1-ol 2-methylbutan-1-ol 2,2-dimethylpropan-1-ol
Secondary alcohol		Pentan-2-ol Pentan-3-ol 3-methylbutan-2-ol
Tertiary alcohol		Name not required.

Description	Marks
A correct primary alcohol structure with MF $C_5H_{12}O$ drawn	1
Name matches alcohol structure drawn	1
A correct secondary alcohol structure with MF $C_5H_{12}O$ drawn	1
Name matches alcohol structure drawn	1
Correct tertiary alcohol structure with MF $C_5H_{12}O$ drawn	1
Incorrect	0
Total	**5**

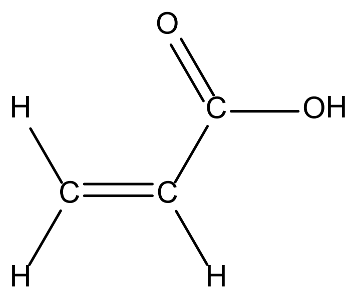
NB: Award 2 of the possible 3 marks for structures if all H atoms not shown; condensed structures acceptable.

Question 35 **(4 marks)**

(a) The structure below represents a segment of polyacrylic acid.



Draw the structure for the monomer of this addition polymer. (1 mark)



Description	Marks
Correct structure	1
Incorrect	0
Total	**1**

(b) (i) What is the name of the interactions occurring between water molecules and sodium ions to enable the removal of the latter from the polymer? (1 mark)

Description	Marks
The water molecules and sodium ions interact through ion-dipole attractions	1
Incorrect	0
Total	**1**

(ii) Explain how the polymer sodium polyacrylate can absorb large quantities of water. (2 marks)

Description	Marks
Recognition that water molecules form hydrogen bonds with the carboxylate groups (accept ion-dipole)	1
Recognition that there are a large number of carboxylate groups in the polymer so a large number of water molecules can hydrogen bond to the polymer	1
Incorrect	0
Total	**2**

Question 36 **(9 marks)**

(a) What is the independent variable in this investigation? (1 mark)

Description	Marks
Concentrations of solution (accept concentration of one of Cu^{2+} or Zn^{2+})	1
Incorrect	0
Total	**1**

(b) What is the dependent variable in this investigation? (1 mark)

Description	Marks
Electrical potential/voltage/volts	1
Incorrect	0
Total	**1**

(c) Why did the volumes and temperatures of solutions and surface areas of the electrodes need to be the same in each trial? (1 mark)

Description	Marks
To be confident that any changes in electrical potential are due to concentration changes only	1
Incorrect	0
Total	**1**

(d) Explain the increase in electrical potential as the concentration of Cu^{2+} ions increased and the decrease in electrical potential as the concentration of Zn^{2+} ions increased. (2 marks)

Description	Marks
The rate of forward reaction increases as concentration of Cu^{2+} ions increased (Accept forward reaction favoured)	1
The rate of reverse reaction increases as concentration of Zn^{2+} ions increased (Accept reverse reaction favoured)	1
Incorrect	0
Total	**2**

(e) The student also observed that as the cells were allowed to run for a while their electrical potential slowly decreased from its maximum value. Why did this happen? (2 marks)

Description	Marks
Recognition that as the cell operates the concentration of reactants decreases	1
Recognition that forward reaction rate decreases **or** system approaches equilibrium	1
Incorrect	0
Total	**2**

The student concluded:

‘As the concentration of the oxidant increases, so does the cell voltage (electrical potential).’

(f) List **two** ways to improve the investigation. (2 marks)

Description	Marks
Test other cells	1
Repeat trials	1
Incorrect	0
Total	**2**

Section Three: Extended answer **40% (82 Marks)**

Question 37 **(9 marks)**

Aqua regia is a mixture of concentrated hydrochloric acid and nitric acid that is able to dissolve gold. One of its uses is in the analysis of gold content in gold ore.

As part of quality control processes, a chemist in a gold analysis laboratory analysed aqua regia to ensure the required 3:1 mole ratio of hydrochloric acid to nitric acid. The chemist found that 20.0 mL of aqua regia needed 28.6 mL of 8.00 mol L^{-1} sodium hydroxide for complete neutralisation. The reaction for the neutralisation reaction between the sodium hydroxide and acid is represented by the equation below:

$$H^+(aq) \quad + \quad OH^-(aq) \quad \rightarrow \quad H_2O(\ell).$$

(a) Calculate the moles of hydrogen ions present in the 20.0 mL sample of aqua regia. (2 marks)

Description	Marks
n(NaOH) = 0.0286 × 8.00 = 0.2288 mol	1
$n(H^+) = n(OH^-)$ = 0.229 mol	1
Incorrect	0
Total	**2**

The chemist analysed the chloride content of the aqua regia by adding excess silver nitrate solution to a separate 20.0 mL sample of aqua regia. This resulted in the precipitation of 24.6 g of solid.

(b) Write the balanced ionic equation for precipitation of silver chloride from aqua regia. (1 mark)

$$Ag^+(aq) \quad + \quad C\ell^-(aq) \quad \rightarrow \quad AgC\ell(s)$$

Description	Marks
Correctly balanced equation	1
Incorrect	0
Total	**1**

NB: State symbols not required.

Question 37 (continued)

(c) Calculate the moles of hydrochloric acid in the 20.0 mL of aqua regia. (3 marks)

Description	Marks
M(AgCℓ) = 143.35 g mol^{-1}	1
n(AgCℓ) = $\dfrac{24.6}{143.35} = 0.1716$ mol	1
n(HCℓ) = n(Cℓ^-) = n(AgCℓ) = 0.172 mol	1
Incorrect	0
Total	**3**

(d) Determine whether the aqua regia had the required ratio of hydrochloric acid to nitric acid. State clearly whether the ratio was as required and support your answer with clear workings. (3 marks)

Description	Marks
n(HNO_3) = n(H^+)total – n(HCℓ) = 0.2288 – 0.1716 = 0.0572 mol	1
Ratio = $\dfrac{n(HC\ell)}{n(HNO_3)} = \dfrac{0.1716}{0.0572} = 3.00$	1
Yes the ratio of HCℓ to HNO_3 is 3:1	1
Incorrect	0
Total	**3**

Question 38 **(12 marks)**

(a) State and explain the trend in atomic radius across the Second Period. (3 marks)

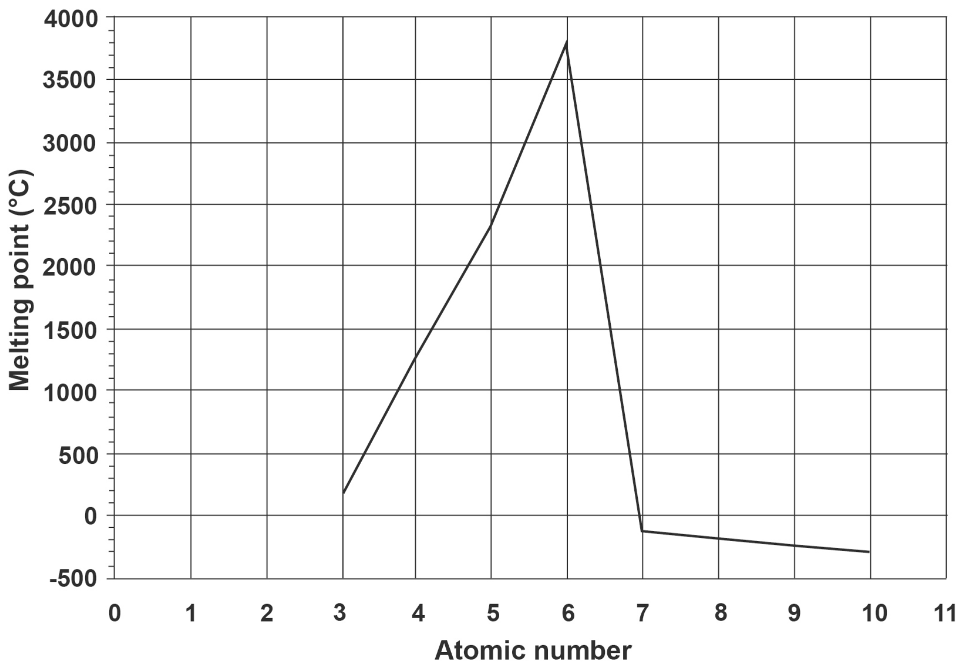
Description	Marks
Recognition that the atomic radius decreases across the period	1
Recognition that each successive electron is in the same valence shell	1
Recognition that increasing positive charge of the nucleus pulls the electrons closer to the nucleus	1
Incorrect	0
Total	**3**

(b) State and explain the trend in first ionisation energy across the Second Period. (4 marks)

Description	Marks
Recognition that the first ionisation energy increases across the period	1
Recognition that the valence shell is closer to nucleus (radius reduced) across the period	1
Recognition that the positive charge increases in nucleus.	1
Recognition that with increasing positive charge of the nucleus there is an increase in the force of attraction and more energy is needed to remove an electron	1
Incorrect	0
Total	**4**

(c) Plot a graph of atomic number against melting point for the Second Period elements. (2 marks)

Description	Marks
Accurate plotting of points	1
Straight line connecting points	1
Incorrect	0
Total	**2**



Question 38 (continued)

(d) Based on their bonding when solid, explain the difference in melting points of lithium, carbon and neon. (3 marks)

Description	Marks
Recognition that as a metal lithium has a moderately high melting point due to moderate forces of attraction between cations and delocalised electrons	1
Recognition that carbon's very high melting point can be explained by its strong covalent bonding between all carbon atoms in the network structure	1
Recognition that neon's low melting point can be explained by the weak dispersion forces between neighbouring neon atoms (so only small amounts of energy are needed to overcome these attractive forces)	1
Incorrect	0
Total	**3**

Question 39 **(14 marks)**

An organic compound that contains only carbon, hydrogen, oxygen and bromine, was analysed to determine its empirical formula. A combustion analysis of 1.50 g of the compound produced 1.58 g of carbon dioxide and 0.563 g water.

On treatment of 1.75 g of the compound to convert the bromine in the compound to bromide ions and further reaction with silver nitrate, 1.97 g of silver bromide was precipitated.

(a) Determine the empirical formula of the compound. (10 marks)

Description	Marks
m(C) = $1.58 \times \frac{12.01}{44.01} = 0.431$ g %(C) = $\frac{0.431}{1.50} \times 100 = 28.7\%$	1–2
m(H) = $0.563 \times \frac{2.016}{18.016} = 0.0630$ g %(H) = $\frac{0.0630}{1.50} \times 100 = 4.20\%$	1–2
m(Br) = $1.97 \times \frac{79.9}{79.9+107.9} = 0.838$ g %(Br) = $\frac{0.838}{1.75} \times 100\% = 47.9\%$	1–2
% O = 100 – 28.7 – 4.2 – 47.9 = 19.2	1
C H Br O Ratio by mass: 28.7, 4.20, 47.9, 19.2 Ratio by mol: $\frac{28.7}{12.01}$, $\frac{4.20}{1.008}$, $\frac{47.9}{79.9}$, $\frac{19.2}{16}$ 2.39, 4.17, 0.599, 1.20 Divide by smallest: $\frac{2.39}{0.599}$, $\frac{4.17}{0.599}$, $\frac{0.599}{0.599}$, $\frac{1.20}{0.599}$ 3.98, 6.96, 1, 2.00 Therefore empirical formula is $C_4H_7BrO_2$	1–3
Total	**10**

Question 39 (continued)

(b) 1.95 g of the compound was vaporised and was found to occupy 0.387 L at 95.0 kPa and 105 °C. Determine the molecular formula of the compound. (2 marks)

Description	Marks
$n = \dfrac{95 \times 0.387}{8.314 \times 378.15} = 0.0117 \text{ mol}$ $M = \dfrac{1.95}{0.0117} = 167$	1
$EFM(C_4H_7BrO_2) = (4 \times 12.01) + (7 \times 1.008) + 79.9 + (2 \times 16) = 166.996$ Since empirical mass = molecular mass, the molecular formula is $C_4H_7BrO_2$	1
Total	**2**

(c) Further analysis of the organic compound revealed that it had a carboxylic acid functional group. Draw a possible structural formula of the organic compound. (2 marks)

Description	Marks
$CH_2BrCH_2CH_2COOH$ or $CH_3CHBrCH_2COOH$ or $CH_3CH_2CHBrCOOH$	1–2
Total	**2**

NB: If molecule drawn with carboxylic acid shown with one minor error, 1 mark.

A correct structure is drawn for an incorrect molecular formula, if it represents a carboxylic acid, 2 marks.

Accept a correct bond-line structure, 2 marks

Question 40 **(15 marks)**

(a) Explain why sodium hydroxide is not suitable as a primary standard (2 marks)

Description	Marks
Any two of the following:	
• does not have high molar mass • absorbs moisture/is deliquescent/hygroscopic • reacts with CO_2 from the atmosphere • mass varies over time • cannot be obtained pure	1-2
Incorrect	0
Total	**2**

(b) Show that the concentration of the sodium hydroxide solution is 0.0916 mol L^{-1}. Show sufficient workings to justify your answer. (3 marks)

Description	Marks
n(HCℓ) = 0.01745 × 0.105 = 1.832 × 10^{-3} mol	1
n(NaOH) = n(HCℓ) = 1.832 × 10^{-3} mol	1
c(NaOH) = $\frac{n}{v} = \frac{1.832 \times 10^{-3}}{0.02} = 9.16 \times 10^{-2}$ molL^{-1}	1
Incorrect	0
Total	**3**

(c) Calculate the average titre volume to be used in the calculation of the citric acid content. (2 marks)

Description	Marks
Differences in initial and final readings = 21.80, 20.85, 20.90, 20.95	1
Titre volume = $\frac{20.85 + 20.90 + 20.95}{3}$ = 20.90 mL	1
Incorrect	0
Total	**2**

Question 40 (continued)

(d) Given that citric acid ($C_6H_8O_7$) is a weak triprotic acid, determine the percentage composition by mass of citric acid in the cleaner. The molar mass of citric acid is 192.124 g mol^{-1}. (6 marks)

Description	Marks
n(NaOH) = 0.02090 × 0.0916 = 1.914 × 10^{-3} mol	1
In 20 mL of dilute citric acid, n(citric) = $\frac{1.914 \times 10^{-3}}{3} = 6.381 \times 10^{-4}$ mol	1
n(citric) in 100 mL = 6.381 ×10^{-4} × 5 = 0.003191 mol	1
hence in 10 mL original = 0.003191 mol	1
m(citric) = n × M = 0.003191 × 192.124 = 0.613 g	1
Therefore % composition = $\frac{0.613}{10.4} \times 100 = 5.89\%$	1
Incorrect	0
Total	**6**

(e) Select a suitable indicator for this titration from the table below. Explain your choice. (2 marks)

Indicator	Colour change (low pH – high pH)	pH range
Methyl yellow	red-yellow	2.4 – 4.0
Litmus	red-blue	5.0 – 8.0
Bromothymol blue	yellow-blue	6.0 – 7.6
Thymol blue	Yellow-blue	8.0 – 9.6

Description	Marks
Thymol blue	1
The citrate ion hydrolyses to give hydroxide ions and so an equivalence point in the basic region or appropriate equation	1
Incorrect	0
Total	**2**

Question 41 **(24 marks)**

(a) Write the balanced equation for the hydrolysis of urea. (2 marks)

$$CO(NH_2)_2(aq) + H_2O(\ell) \rightarrow CO_2(aq) + 2\,NH_3(aq)$$

Description	Marks
Correct formulae for reactants and products	1
Balanced equation	1
Incorrect	0
Total	**2**

NB: States for reactants and products not required.

(b) Explain briefly why hydrolysis of urea causes an **increase** in pH. Include an appropriate balanced equation in your answer. (2 marks)

Description	Marks
Statement showing recognition that NH_3 hydrolyses to give OH^-	1
Balanced hydrolysis equation	1
Incorrect	0
Total	**2**

NB: States for reactants and products not required.

The pH increases because the ammonia produced by hydrolysis of urea in turn hydrolyses to produce hydroxide ions.

$$NH_3(aq) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

(c) Determine the concentration, in grams per litre, of the phosphorus in the urine. Express your answer to **three** significant figures. (Assume all phosphorus has been precipitated.) (9 marks)

Molar masses (in g mol^{-1}): struvite 245.418; calcium hydroxyapatite 1004.636.

Description	Marks
m($MgNH_4PO_4.6H_2O$) in the precipitate = 0.823 × 25.3 = 20.823 g	1
m($Ca_{10}(PO_4)_6(OH)_2$) in the precipitate = 25.3 - 20.823 = 4.478 g	1
n(P) in struvite = n($MgNH_4PO_4.6H_2O$) = $\frac{20.823}{245.418}$ = 8.484×10^{-2} mol	1
n($Ca_{10}(PO_4)_6(OH)_2$) = $\frac{4.478}{1004.636}$ = 4.457×10^{-3} mol	1
n(P) in calcium hydroxyapatite = $4.457 \times 10^{-3} \times 6 = 2.674 \times 10^{-2}$ mol	1
Total n(P) = $8.484 \times 10^{-2} + 2.674 \times 10^{-2} = 1.116 \times 10^{-1}$ mol	1
m(P) = $1.116 \times 10^{-1} \times 30.97 = 3.456$ g	1
Concentration = $\frac{3.456}{5.00}$ = 0.691 g L^{-1}	1
Answer expressed in **three** significant figures	1
Incorrect	0
Total	**9**

(d) Explain, using collision theory, why increasing the pH of the phosphorus-depleted urine converts the ammonium ions to ammonia. Support your answer with a balanced equation. (3 marks)

Description	Marks
Recognition that concentration of OH^- ions increases so the frequency of collisions between NH_4^+ and OH^- ions increases	1
Recognition that rate of the forward reaction in the equilibrium increases relative to the reverse reaction	1
Balanced equation	1
Incorrect	0
Total	**3**

NB: Increased pH increases concentration of OH^- so the frequency of collisions between NH_4^+ and OH^- ions increases and thus the rate of the forward reaction in the equilibrium below increases relative to the reverse reaction and so increases production of ammonia. (The increase in hydroxide ion concentration shifts the equilibrium below to the production of ammonia.)

$$NH_4^+(aq) \quad + \quad OH^-(aq) \quad \rightleftharpoons \quad NH_3(aq) \quad + \quad H_2O(\ell)$$

(e) State the purpose of heating the solution to 40 °C. (1 mark)

The solubility of NH_3 in water is reduced at high temperature.

Description	Marks
Statement showing recognition that solubility of NH_3 in water is reduced at high temperature; Accept $NH_3(aq) \rightarrow NH_3(g)$ is endothermic so increasing temperature favours the endothermic process and equilibrium shifts right producing more $NH_3(g)$	1
Incorrect	0
Total	**1**

(f) Write a balanced equation for the reaction in Step 3. (2 marks)

Accept any of the following:

$$NH_3(aq) \quad + \quad H^+(aq) \quad \rightarrow \quad NH_4^+(aq)$$

$$2\ NH_3(aq) \quad + \quad H_2SO_4(aq) \quad \rightarrow \quad 2\ NH_4^+(aq) \quad + \quad SO_4^{2-}(aq)$$

$$2\ NH_3(aq) \quad + \quad H_2SO_4(aq) \quad \rightarrow \quad (NH_4)_2SO_4(aq)$$

$$NH_3(aq) \quad + \quad HSO_4^-(aq) \quad \rightarrow \quad NH_4^+(aq) \quad + \quad SO_4^{2-}(aq)$$

Description	Marks
Correct formulae for reactants and products	1
Balanced equation	1
Incorrect	0
Total	**2**

Question 41 (continued)

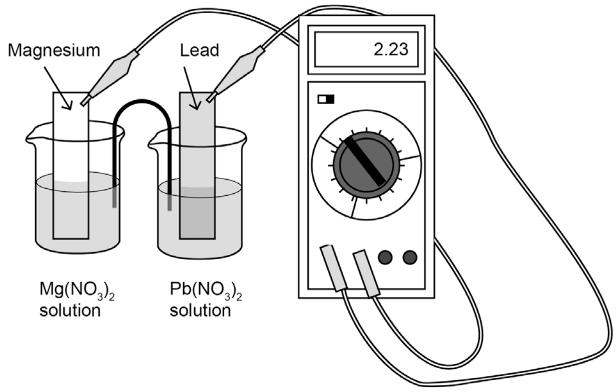
(g) The amount of ammonium sulfate recovered from the 5.00 L of urine in this experiment is 72.65 g. If the process is 78% efficient, what is the concentration of nitrogen, in grams per litre, in the phosphorus-depleted urine? (5 marks)

Description	Marks
$n((NH_4)_2SO_4) = \dfrac{72.65}{132.144} = 0.5498$ mol	1
$n(N) = 2 \times n((NH_4)_2SO_4) = 2 \times 0.5498 = 1.0996$ mol	1
For 78% efficient, $m(N) = 1.0996 \times 14.01 = 15.405$ g	1
For 100%, $m(N) = \dfrac{15.405}{0.78} = 19.75$ g	1
Concentration = $\dfrac{19.75}{5.00} = 3.95$ g L^{-1}	1
Incorrect	0
Total	**5**

Question 42 **(8 marks)**

Using the diagram below, explain the role of the following in the operation of an electrochemical (galvanic) cell:

- anode process
- cathode process
- lead(II) nitrate electrolyte
- salt bridge and ion migration
- electron flow in external circuit.



Description	**Marks**
Anode oxidation occurs	1
Mg loses electrons to form Mg ions or equation for reaction at the anode $Mg \rightarrow Mg^{2+} + 2e^-$	1
Cathode reduction occurs	1
Pb gains electrons to form Pb or equation for reaction at the cathode $Pb^{2+} + 2e^- \rightarrow Pb$	1
Lead(II) nitrate electrolyte is the source of Pb^{2+} ions	1
Salt bridge allows for the movement of ions between the two half-cells	1
Salt bridge allows electrical neutrality to be maintained or to complete the circuit	1
Electron follow provides energy to do work e.g. produces a reading on the meter	1
Total	**8**

ACKNOWLEDGEMENTS

Section Three

Question 42 Adapted from: Megna, R. *Electrochemical cell* [Image]. Retrieved June 23, 2014, from http://fphoto.photoshelter.com/search?I_DSC=45859901-2RM&_ACT=search

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